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EXOTIC MARINE MACROALGAE ON THE BRAZILIAN COAST: A REVISION

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ABSTRACT

The introduction of exotic marine species is a recent concern in Brazil, and seaweeds are the least studied group. The first publications deal with intentional introduction of species for aquaculture. Recent papers focus on putative accidental introductions. In this review we summarize the existing knowledge about the presence of non-indigenous seaweeds on the Brazilian coast. Nevertheless, the labeling of a species as an exotic one can be a complex issue. *Kappaphycus alvarezii* and *K. striatum* were the only authorized and well documented intentional introductions in Brazil, aiming to carrageenan production. *Caulerpa scalpelliformis*, known from a large stretch of the northeast and east Brazilian coast, seems to have spread to Rio de Janeiro state and can be considered as the only invasive species in Brazil so far. Available data indicate that this species is impacting benthic communities on Ilha Grande Bay. In this same region, *Laurencia caduciramulosa* populations appeared in 2001 and begun to spread. Other introductions are mere suspicions: *Anotrichium yagii* and *Dasya brasiliensis* are suspected to be exotic for being conspicuous species not reported previously to well studied areas. *Cladophora corallicola, Laurencia venusta, Pedobesia ryukyuensis, Porphyra leucosticta, Porphyra rizzinii* and *Porphyra suborbiculata*, all reported on recent surveys and suspected to be newcomers, should rather be considered as cryptogenic because they may have been overlooked or misidentified on previous surveys.

Keywords: Seaweed introduction; aquaculture; invasive species; cryptogenic species.

RESUMO

MACROALGAS MARINHAS EXÓTICAS NA COSTA BRASILEIRA: UMA REVISÃO. A preocupação com a introdução de organismos exóticos é recente no país, especialmente no que diz respeito às algas. As primeiras publicações a tratarem de algas exóticas no Brasil tiveram como foco a introdução de espécies de interesse comercial, visando à maricultura, enquanto que publicações mais recentes abordaram introduções involuntárias. Nosso trabalho resume o que se sabe sobre a presença de espécies de macroalgas não-nativas na costa brasileira, enfatizando as dificuldades inerentes ao processo de reconhecer uma espécie como tal. *Kappaphycus alvarezii* e *K. striatum* são as únicas espécies introduzidas oficialmente no país visando a produção de matéria prima para obtenção de carragenanas. *Caulerpa scalpelliformis*, uma espécie que está presente em larga faixa da costa nordeste do país, parece ter chegado recentemente na Ilha Grande (RJ), onde vem se comportando como espécie invasora, a única que poderia ser catalogada nesta categoria até o momento. Outra espécie que parece ter chegado recentemente na mesma região é *Laurencia caduciramulosa*, registrada pela primeira vez em 2001. Além destas existem algumas evidências de que *Anotrichium yagii* e *Dasya brasiliensis*, atualmente conspícuas e comuns, mas não registradas em trabalhos pretéritos, tenham chegado ao Brasil nas últimas décadas. Casos semelhantes são os de *Cladophora corallicola, Laurencia venusta, Pedobesia ryukyuensis, Porphyra leucosticta, Porphyra rizzinii* e *Porphyra suborbiculata*, todas registradas há pouco tempo mas não necessariamente exóticas, pelo fato de serem inconspícuas e de difícil determinação.

Palavras-chave: Introdução de algas; aquicultura; espécies invasoras; espécies criptogênicas.

RESUMEN

MACROALGAS MARINAS EXÓTICAS EN LA COSTA DE BRASIL: UNA REVISIÓN. La introducción de especies exóticas marinas es un evento reciente en Brasil, en donde las algas son el grupo menos estudiado. Las primeras publicaciones trataron sobre la introducción intencional de especies para su uso en acuicultura, mientras que las más recientes versan sobre introducciones involuntarias. En este trabajo se revisa el conocimiento actual sobre la presencia de macroalgas no nativas en la costa de Brasil, teniendo en cuenta las dificultades propias al proceso de establecer a una especie como tal. *Kappaphycus alvarezii* y *K. striatum* son las únicas especies introducidas oficialmente al Brasil para la producción de carragenanos. *Caulerpa scalpelliformis* una especie presente a lo largo de la costa noreste del país, parece haber llegado recientemente al estado de Río de Janeiro, en donde se comportaría como una especie invasora, siendo la única que podría ser catalogada como tal en la actualidad. Otra especie que parece haber llegado recientemente a la misma región, es *Laurencia caduciramulosa*, que fue registrada por primera vez el año 2001. Además de estas especies hay algunas evidencias de que *Anotrichium yagii* y *Dasya brasiliensis*, actualmente conspicuas y comunes, pero no reportadas en trabajos anteriores, habrían llegado al Brasil en las últimas décadas. Otros casos son los de *Cladophora corallicola*, *Laurencia venusta*, *Pedobesia ryukyuensis*, *Porphyra leucosticta*, *Porphyra rizzinii* y *Porphyra suborbiculata* que han sido registradas recientemente, pero que no necesariamente serían especies exóticas pues son inconspicuas y de difícil determinación.

Palabras clave: introducción de algas; acuicultura; especies invasoras; especies criptogénicas.

INTRODUCTION

Along with pollution and habitat degradation, the introduction of exotic species (alien, non-indigenous) has been considered among the major treats to algae biodiversity with reflections to the food webs (Walker & Kendrick 1998). It is estimated that at least 277 seaweed species have been introduced on different places around the world (Williams & Smith 2007) impacting ecosystems at different levels, including species displacement, communities and productive systems, and even human health (e.g. Mack *et al*. 2000). Studies on the establishment of non-indigenous marine species were intensified during the last decades, dealing with causes, vectors, biogeographic issues, as well as prevention, control and eradication strategies. Nevertheless we are far from understanding the mechanisms behind the establishment of non-indigenous marine species.

The introduction of exotic marine species is a very recent concern in Brazil. In spite of playing important roles as structurers and sustainers of benthic communities, marine algae are one of the least studied groups on what concerns species introduction.

The aim of this review is to summarize the existing knowledge about the presence of non-indigenous seaweeds on the Brazilian coast, their possible ecological harm and management procedures, where applicable.

HISTORICAL REVIEW

The first paper to consider the issue of exotic marine macroalgae in Brazil focused on species introduced for aquaculture purposes (Oliveira 1984). The author discusses the necessity of introducing alien species for commercial utilization and made a plea to governmental agencies and public stakeholders to define guidelines and responsibilities on this subject. Later on, Bellorín & Oliveira (2001) dealt with the situation of exotic seaweeds in Latin America for maricultural purposes. Their study was motivated by suggestion made by Oliveira (1990) to introduce in Brazil species of *Gracilaria* from Chile or Argentina, for agar production, as well as species of *Eucheuma* (or *Kappaphycus*) from the Indo-Pacific for carrageenan production (see also Oliveira 1995). The issue of *Kappaphycus alvarezii* (Doty) Doty ex Silva introduction in Brazil, which occurred in October 1995 (Paula *et al*. 1998) was utilized as a case study by Oliveira & Paula (2003).

Following the trend of an international concern on accidental invasive species, in addition to those studies focused on intentional introductions of commercial species of seaweeds, other publications (e.g. Horta & Oliveira 2000, Paula & Oliveira 2004, Falcão & Széchy 2005, Cassano *et al*. 2006) suggested that some species reported to the Brazilian coast may have been introduced involuntarily.

A database of exotic marine species in Brazil was possible after a network organized by the Brazilian environment agency (IBAMA) and the Global Invasive Species Program (GISP) (Ferreira *et al*. 2009), as the result of a national effort to gather information on exotic species. This initial survey, the INFORME/Probio project, detected 66 marine and estuarine non-indigenous species on the Brazilian coast, 10 of these being seaweeds (MMA 2006). A full report detailing the information on these marine species was recently published (Lopes 2009). The present article reviews and updates the informations presented by Oliveira *et al*. (2009) about macroalgae included in the former report.

CATEGORIES OF NON-INDIGENOUS ORGANISMS

To recognize a non-indigenous species that was introduced on purpose is an obvious matter. However, with rare exceptions, to recognize a species that was introduced involuntarily may become very complex.

Besides purposeful introductions, usually due to the commercial value of the organism, there are other routes through which a non-indigenous species can reach a new place outside its natural area of occurrence. One is the involuntary introduction by man as a contaminant in, or on, an introduced organism - this happens when the introduced organism was not subjected to an efficient quarantine program. Other routes are the introduction via ballast water, or as fouling agents on boats or other floating devices, including oil platforms (Ferreira *et al*. 2004) and plastic rift material (Souza *et al.* 2009). In this case they are usually spotted due to their recent detection and a disjunctive distribution. However, certain organisms also can spread naturally without the interference of man. How to distinguish them from the ones transported by anthropic activities is the question. In this case the key issue is time, i. e., the organism was non-indigenous before a certain date. But, how far, in time, this date can go back? The answer is to the oldest biodiversity study available for a given locality. Even so, the doubt still remains because communities are dynamic and the assemblages of species change in time. This problem is even more critic for rare and inconspicuous organisms, which may have been present but not detected in previous studies. The situation gets even more complicated for organisms whose identification requires great expertnesses of the surveyor.

CONFIRMED INTRODUCTIONS

INTENTIONAL

1. *Kappaphycus alvarezii* (Doty) Doty ex P.C. Silva

The success of *Kappaphycus alvarezii* cultivation in the Philippines in the 1970's, for the production of carrageenan, motivated its introduction on many tropical localities worldwide (Ask *et al.* 2003). Some of the introductions succeeded and became commercial, while others were abandoned and failed to get established, or became a nuisance, such as in Hawaii (Rodgers & Cox 1999). *K. alvarezii* was introduced in Brazil in 1995 at Ubatuba, São Paulo state, to evaluate its commercial viability (Paula *et al.* 1998, Oliveira *et al.* 2009). This is the only documented seaweed intentionally introduced in the country, although there are anecdotic reports of other, non-successful attempts to introduce commercial seaweeds in Brazil (Oliveira 1984).

The introduction of *K. alvarezii* at Ubatuba is well documented and was approved by the Brazilian federal environmental agency (IBAMA 2008). The inoculum, a branch of 2.5 g, taken from a culture kept by M. Ohno in Japan, was brought to São Paulo by E.J. Paula. The plants kept in Japan came from a commercial farm in the Philippines. The inoculum was propagated in vitro, in the algal laboratory of the University of São Paulo, in São Paulo, for ten months before its introduction in the sea under the supervision of E.J. Paula and R.T.L. Pereira. It took over a decade of studies and paper work until the IBAMA authorized its distribution for commercial cultivation on a limited area of the southeastern Brazilian coast (Figure 1). The official authorization was formally published on July 23, 2008. During this period several studies, including non-published dissertations, were made with the plants kept continuously on a raft (ca. 30 m^2) at Ubatuba (e.g. Paula *et al.* 1998, Paula & Pereira 1998**,** Paula *et al*. 1999, Paula *et al*. 2001, 2002, Paula & Pereira 2003, Oliveira & Paula 2003, Paula & Oliveira 2004, Bulboa & Paula 2005, Bulboa *et al*. 2007, Hayashi *et al.* 2007, 2008, Reis *et al.* 2007, Bulboa *et al.* 2008).

Meanwhile, unauthorized introductions originated from a clone brought from Venezuela (probably imported from The Philippines) were made, first in the state of Santa Catarina, and latter on at Ilha Grande, south of Rio de Janeiro state. The first introduction failed and was discontinued, but the one in Rio de Janeiro, at Sepetiba Bay, became commercial and its production led to the establishment of a plant for carrageenan production (Sete Ondas Biomar - http://www.seteondasbiomar.com.br). Samples from Ilha Grande were transplanted and introduced illegally on the northeastern coast of Brazil, in the states of Ceará, Paraíba, Pernambuco and possibly Bahia, where they are maintained at a pilot stage. Studies on the impact of the commercial farm at Sepetiba Bay was published by Castelar et al. (2009a, 2009b). These authors concluded that the cultivated plants did not produce spores and that cuttings escaping from the farms did not attach and die, if not eaten by herbivores. Therefore, their conclusion was that "the invasive potential of *K. alvarezii* was considered remote". Nevertheless they recommended "the use of environmental protocols for cultivation activities to prevent environmental impacts, mainly in tropical regions".

More recently, explants from the original material kept in the laboratory in São Paulo since 1995 were introduced in Santa Catarina, in February 2008, by L. Hayashi (Pesquisa Fapesp 2009) and is going on as a pilot experiment with the IBAMA authorization.

So far there are no evidences of ecological problems derived from the introduction of *K. alvarezii* in Brazil. However, there are no enough efforts on evaluating introductions-originated impacts on the entire coast, specially Northeastern. Moreover, considering other countries where *K. alvarezii* was introduced, ecological problems have been reported for Hawaii, where the population is increasing (Concklin & Smith 2005), and India where it is invading coral reefs (Chandrasekaran *et al*. 2008). So, there is a consensus among local phycologists that the species should not be introduced in, or close to reef areas. There are also reports of associated species which were accidentally introduced along with *Eucheuma denticulatum* (N.L. Burman) F.S. Collins & Hervey and *Kappaphycus striatum* (Schmitz) Doty transplanting in Christmas Island, Kiribati (Russel 1982). These examples illustrate the need of apropriated measures as quarantine programmes and rigorous management protocols when introducing non-indigenous seaweeds.

A document dealing with the situation of *K. alvarezii* in Brazil prepared by Oliveira (2005) under the request of the actual Ministry of Fisheries, was circulated through the web among experts of the Brazilian phycological community and discussed on public meetings. The overall conclusion of this document is that the species cannot survive outside the farm, held back by local herbivores and suboptimal conditions for growth such as low temperature and high turbidity. Consequently, the author considers that ecological risk of farming *K. alvarezii* on the coasts of Rio de Janeiro and São Paulo is small. However, he recommends more cautions to introduce the species towards the north of Rio de Janeiro where the conditions for its growth are more favorable.

Ghilardi *et al*. (2008) emphasize the requirement of previous knowledge about structure and functioning of the local natural communities, suggesting an expedite method (Physiognomic Assessment of Hard Bottom Benthic Community) for monitoring the cultivation of *K. alvarezii* in Brazil.

2. *Kappaphycus striatum* (Schmitz) Doty ex P.C. Silva

Kappaphycus striatum was introduced in Brazil on the year 2000, also by E. J. Paula, following a similar protocol as described for *K. alvarezii* (Bulboa 2001, Bulboa & Paula 2005). However, its performance, in terms of productivity, was not as favorable as *K. alvarezii*. The specimens were taken out of the water and the experiments interrupted because this species produced viable tetraspores in the pilot farm (Bulboa & Paula 2005). Since then the species was not found in the region.

ACCIDENTAL

1. *Caulerpa scalpelliformis* (R. Brown ex Turner) C. Agardh

Common on a large extent of the Brazilian coast, from Piauí to Espírito Santo states, this species was considered absent in Rio de Janeiro state until recently when it was reported for Ilha Grande Bay

by Falcão & Széchy (2005). The authors registered dense and fast growing populations of *Caulerpa scalpelliformis* which are changing dramatically the physiognomy of the benthic community in the region. This species seems to be displacing the dominant stands of the native *Sargassum vulgare* C. Agardh on rocky outcrops, spreading as well to sandy bottoms, in Ilha Grande and nearby islands (M.T.M. Széchy personal communication).

The origin of these populations is uncertain. They could just have overcame climatic barriers (temperature?) migrating from northern populations. Another possibility is a recent introduction through marine traffic. Ilha Grande contains many harbors and has experienced a growing traffic of tourist and commercial boats in their way to Rio de Janeiro metropolis (Falcão & Széchy 2005). Its introduction via aquariophily is also considered. This species has been spotted in many aquaria shops in São Paulo and is popular among seawater aquaria lovers due to it's beauty and easy propagation along with other *Caulerpa*, as *C. racemosa* (Forsskål) J. Agardh and *C. sertularioides* (S.G. Gmelin) M.A. Howe. *Caulerpa scalpelliformis* has already been reported as an invader on Australian waters where it has shown a rapid increase in its cover, high values of biomass per area, similar to those found for *C. taxifolia* (M. Vahl) C. Agardh in the Mediterranean, and fast spreading capacity, including the formation of new populations from vegetative fragmentation (Davis *et al*. 1997). Other species of *Caulerpa* are well known for their invasive potential all over the world. Among these *C. taxifolia* had the most severe effects since its introduction in 1984 in Monaco. The history of the "catastrophic" invasion of *C. taxifolia* in the Mediterranean is well documented and there is no need to repeat it here (e.g. Meinesz & Hesse 1991, Meinesz *et al*. 2001).

C. scalpelliformis is probably the only species of seaweed that could be considered as invasive on the Brazilian coast so far.

2. Laurencia caduciramulosa Madusa & Kawaguchi

Described initially for Vietnam, this species has been reported recently for Ilha Grande Bay, RJ (Cassano et al. 2006). In 2001, when first spotted, it was represented by scarce individuals. However, more recent surveys indicate that the species is spreading to other areas, being found in nearby areas (Parati and Angra dos Reis, RJ) by Cassano (2009). The species bears abundant deciduous branchlets at the tips of the erect axes which are able to attach to the substratum. This seems to be the way this species propagates once no sexual reproduction has been found so far. It is supposed to be a newly introduced species because it was not referred to in past surveys made in the region and it was found at sites close to potential introduction zones such as harbors. The high traffic of ships in the region suggests that it may have arrived as fouling or in ballast water. However, the primary point of introduction may be elsewhere, on less studied regions.

SUSPECTED ACIDENTAL INTRODUCTIONS

This section is based largely on a recent study by Oliveira *et al*. (2009).

CONSPICUOUS SPECIES

1. *Dasya brasiliensis* E.C. Oliveira & Braga

This species was described for a narrow stretch of the Brazilian coast, with occurrence between Cabo Frio (23° S) and São Sebastião (24° S). Although collected by A.B.Joly in 1962, a perusal of herbarium material shows that it was confused with *Heterosiphonia gibbesii* (Harvey) Falkenberg (Joly 1965). Oliveira & Braga (1971) remarked that this species was getting more frequent and abundant in the region, indicating an expansion of the population. Later on (Paula & Oliveira 2004), launched the hypothesis that a species so conspicuous as this one could not have been overlooked by the careful surveys that Joly and his co-authors made in the region since the 1950s. They considered that this was an indication that the species was a newcomer to the area, probably linked to the maritime traffic of the São Sebastião (SP) or Rio de Janeiro harbors.

Although the species is common on the north coast of São Paulo state, its biomass is not relevant and it is not spreading geographically, so it cannot be considered as invasive.

2. *Anotrichium yagii* (Okamura) Baldock

The same introduction process referred for *Dasya brasiliensis* may have brought *Anotrichium yagii*

to Brazilian waters. It was never recorded from the Atlantic Ocean until 1997 and 1998, when it was detected in Santa Catarina, São Paulo and Rio de Janeiro states during a survey of the infralitoral around islands of the SE-S coast of Brazil (Horta 2000, Horta & Oliveira 2000). Although these populations are not showing invasive behavior in Brazil, they seem to be increasing its cover area (E.C. Oliveira, unpublished data). A con-generic species, *A. furcellatum* (J. Agardh) Baldock, has been found as an exotic invader in Europe (Maggs & Stegenga 1999) and is under suspicion of becoming invasive in Argentina (Zaixso & Akselman 2005).

CRYPTOGENIC SPECIES

Taxa listed below could have arrived recently to the Brazilian coast. They are included here because they were reported only on recent surveys. As they are inconspicuous and difficult to identify we prefer to refer to them as cryptogenic until further studies may clear their origin.

1. *Cladophora corallicola* Børgesen

Referred to Bermuda and the Virgin Islands (Taylor 1960), this species was first recorded to Brazil in 1981 by Yoneshigue (1985), initially at Armação de Búzios and Arraial do Cabo (RJ). Recent surveys from 1986 and 2003 registered *C. corallicola* for other localities in the state of Rio de Janeiro as well as in Espírito Santo and Santa Catarina (Gestinari 2004). The identification of *Cladophora* species is very difficult because of high morphological plasticity (van den Hoek 1961). Therefore, the presence of this species may have been overlooked in previous surveys.

2. *Laurencia venusta* Yamada

Referred to the Indian and Pacific oceans this species was collected only once in the Espírito Santo state in 2003 (Fujii *et al*. 2005). Fujii *et al*. (2005) believe that this could be an introduced species because it was found in the vicinity of a busy harbor, have a fragile thallus, that break away easily and disperse the species, and have not been spotted on previous surveys in the region.

3. *Pedobesia ryukyuensis* (Yamada & Tanaka) Kobara & Chihara

This species was described for Japan and latter on referred to South Africa, Australia, New Zealand and the Micronesia (Guiry & Guiry 2009). It was first recorded for São Sebastião (SP) in 1983 (Paula & West 1986) and in 1987 at Arraial do Cabo (RJ) by Yoneshigue & Figueiredo (1987). It is possible that this tiny species was not recorded before because it is very inconspicuous. It may have been introduced with the Pacific oyster, *Crassostrea gigas*, which was introduced at Arraial do Cabo decades ago.

4. *Porphyra leucosticta* Thuret in Le Jolis

Described from the Mediterranean and latter on referred to various places outside Europe. Reported for Cabo Frio (Yoneshigue 1985) it may be a newcomer to Brazil if the identification is confirmed, since it was not found in a previous survey by Oliveira & Coll (1975). This may have been introduced in Cabo Frio along with the Pacific oyster or as fouling on marine vessels.

5. *Porphyra rizzinii* J. Coll & E.C. Oliveira

Similarly as *P. leucosticta* this species was registered for Cabo Frio (Yoneshigue 1985) and was not registered in the survey of Oliveira & Coll (1975). Considered endemic to Uruguay, *P. rizzinii* may have migrated northward along the coast if its identity is confirmed.

6. *Porphyra suborbiculata* Kjellman

This cosmopolitan species (Broom *et al*. 2002) may have been introduced in Brazil with the Pacific oyster. It may, as well, have arrived as a conchocelis phase within barnacle or mollusk shells encrusting transoceanic vessels. This is a small species that can easily be confounded with juvenile phase of other local species. Its identification was only possible when molecular biology methods were utilized to study some populations of small individuals of *Porphyra* from São Sebastião and Arraial do Cabo (Milstein & Oliveira 2005). This species will probably be found elsewhere on the coast

because phycologists usually collect mainly larger specimens. We hypothesized that the specimens identified by Yoneshigue (1985) as *P. pujalsiae* J. Coll & E.C. Oliveira, also a very small species described from Uruguay (Coll & Oliveira 1976) may also be *P. suborbiculata* (Milstein 2006).

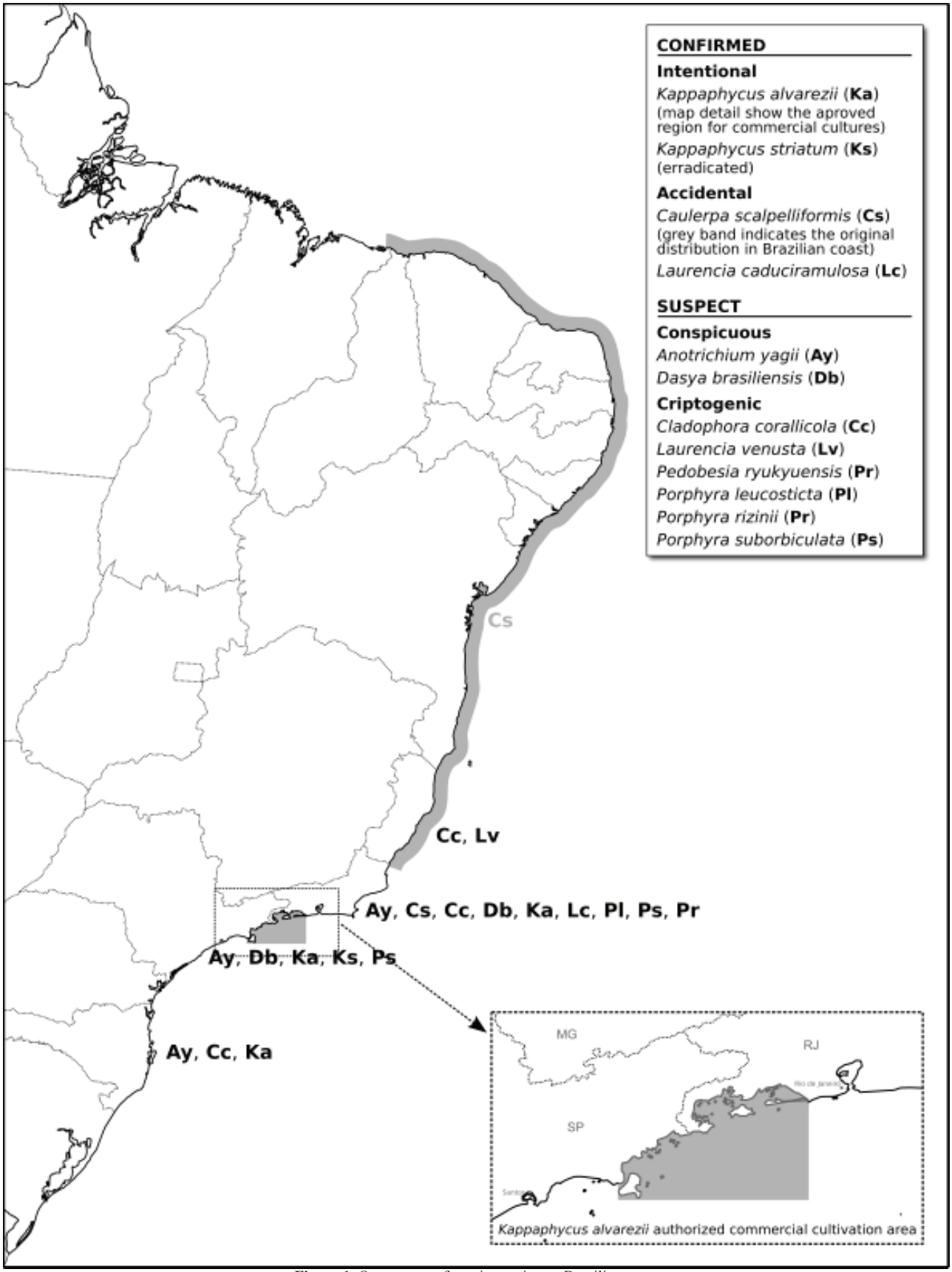

Figure 1. Occurrence of exotic species on Brazilian coast.

DISCUSSION

All cases discussed herein are summarized on Table I and on Figure 1.

With the exception of *Kappaphycus alvarezii*, all the other putative introductions of seaweeds on the Brazilian coast are just hypothesis to be tested. The available data indicate that so far *K. alvarezii* has not been able to survive autonomously, i.e., outside of the farming sites. However, its cultivation in reef areas should not be allowed considering the risk of impacting the coral beds. Its introductions in the northeast coast should also be carefully monitored.

From the species dealt with in this paper, only *Caulerpa scalpelliformis,* on Ilha Grande Bay, encompass the features attributable to an invasive species based on the evidences available so far. The actual populations should be monitored and a program of eradication should be considered if the species presents an aggressive behavior displacing local species and altering communities. A program of manual eradication of *C. scalpelliformis* already took place at Piraquara de Fora in Ilha Grande Bay (M.T.M. Széchy personal communication).

The identification of *Porphyra suborbiculata* was supported by molecular markers, while for *Laurencia caduciramulosa*, morphological and anatomical approaches seem to be well-suited (Cassano 2009). *Porphyra suborbiculata* is inconspicuous and can be considered as a cryptic species and, therefore, its distribution on the coast can be extended pending on future studies based on molecular biology (Milstein & Oliveira 2005). On the other side, conspicuous species such as *Dasya brasiliensis* and *Anotrichium yagii*, are well characterized morphologically, although the correct identification of *D. brasiliensis* is not well ascertained yet in our opinion.

Of course a big problem is to define introduced species in a country with an extensive coastline as Brazil and where phycological surveys and base line data are so recent. In view of that, one should realize that it makes more sense to consider most species as cryptogenic, i. e., of uncertain origin. Other obstacles in the categorization of a taxon as introduced are the case of rare and inconspicuous species and taxonomic misidentification.

In Mediterranean and in north-western Atlantic, policies concerning the introduction of non-native species are more advanced (Williams & Smith 2007). However, in Brazil, strategies for prevention and control of exotic species are still on debate (Ziller *et al.* 2007, Machado *et al.* 2009). Williams & Smith (2007) made a global review on introduced seaweed concluding that hull fouling and aquaculture (direct or indirectly) are responsible for 85% of the known vectors of introduction. Ballast water, fishing gear and the aquarium industry follow with 10%, 3% and 1% of the cases where the vectors were identified.

The control of a non-native species when it reaches the status of invasiveness is almost impossible. Mechanical, chemical and even biological approaches have been applied on diverse cases, like in Anderson

Table I. Attempt to summarize the status of the seaweeds that may be of recent introduction in Brazil. *Kappaphycus striatum* is not listed since it is considered eradicated.

			Detected	Established	Invader	Contained
Confirmed	**Intentional**	*Kappaphycus alvarezii*				x
	Accidental	*Caulerpa scalpelliformis*			x	
		Laurencia caduciramulosa		x		
Suspected	**Conspicuous**	*Anotrichium yagii*		x		
		Dasya brasiliensis		x		
	Cryptogenic	*Cladophora corallicola*	x			
		Laurencia venusta	x			
		Pedobesia ryukyuensis	x			
		Porphyra leucosticta	x			
		Porphyra rizinii	x			
		Porphyra suborbiculata		x		

(2007) which has made a revision on control strategies for invasive seaweeds, and many others (e.g. Boudouresque & Verlaque 2002, Ask *et al.* 2003). But, there is not a protocol to be followed when a newly invader is detected, and thus each episode shall be treated as a specific case. For all cases of suspected introduction some basic steps must be taken such as: monitoring activities; previous biological and ecological knowledge about the non-native species in other areas; previous data on geographical, biological, social and political characteristics of the area; previous knowledge on invasion processes in other areas, including interaction between invaders and the native biota, apart from the social impacts of that introduction, and strategies of eradication. All that implies on research and funding investments, and on effective communication with different institutions (Mack *et al.* 2000, Schaffelke *et al.* 2006, Anderson 2007).

Although Brazil is already committed to this and other environmental concerns after joining the 1992 Rio Earth Summit, obligation should be shared by plural, private and government agencies. Machado & Oliveira (2009) recommend the foundation of an integrated national system to deal with the problem of species introduction.

It is suggested that scientific and private sectors make mutual efforts on monitoring marine structures (as ships and diving and fishing gears) and processes (as deballasting, touristic activities and aquaculture introductions) to prevent further problems (Ferreira *et al.* 2009). The participation of the whole society is also essential to reach more effective results, including discussion along with other ecological topics on schools and popular media (Machado & Oliveira 2009, Souza *et al.* 2009).

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