

European Science Foundation
Standing Committee for Life, Earth and Environmental Sciences (LESC)

ESF LESC EXPLORATORY WORKSHOP

**Invasion of European Shores by
Sargassum Muticum: Research Integration
towards the Future**

Scientific Report



Faro, Portugal, 8 - 12 November 2006

Convened by:

Aschwin Hillebrand Engelen and Rui Santos

Center of Marine Sciences (CCMAR), Universidade do Algarve, Faro, Portugal

Co-sponsored by:

FCT Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA E DO ENSINO SUPERIOR



ESF/LESC Exploratory Workshop:

Invasion of European Shores by *Sargassum Muticum*: Research Integration towards the Future

Faro, Portugal, 8 - 12 November 2006

1. Executive summary

The ESF Exploratory Workshop on “Invasions of European Shores by *Sargassum Muticum*: Research Integration towards the Future” was hosted by the Center of Marine Sciences, University of the Algarve and held at the Hotel Vila Galé Albacora, Tavira, Portugal, during November 8-12, 2006.

The aim of this workshop was to assemble researchers that are working in various disciplines of marine sciences and that have an interest in *Sargassum muticum* invasions, in order to update and integrate all knowledge on the subject, to identify data gaps, to improve management strategies and to stimulate future collaborative research.

After a welcome dinner on Thursday evening, the workshop was officially opened on Friday morning. The workshop started with a presentation of the European Science Foundation (ESF). Prof. Hefin Jones presented an overview of the ESF, detailing the various organs of the foundation, its overall structure and membership, the various functions it performs and highlighted the most probable options for future collaborations among the participants of the workshop. This was followed by a quick round in which each participant introduced him- or herself. Each workshop day was divided in sessions covering specific aspects of *Sargassum muticum* ecology. Each session gave the presenter ample time both for his or her presentation and for debate with the other participants. As well, there was the possibility for other participants to present unpublished scientific data that were not available to the presenter.

Additional sponsoring by the Portuguese Science Foundation (FCT), together with the ESF funds, allowed complementing the group of European researchers with two key scientists, one from the USA and one from China. All invited participants (including the convenors) presented results in their field of expertise during at least one of the sessions.

The first day of the workshop started with the review of both the little biological knowledge that is available on *Sargassum muticum* in its native range and the taxonomic uncertainty within the *Sargassum* genus. This was followed by presentations on the history of *Sargassum muticum* invasions on the Pacific coast of the USA and on the Atlantic coast of Europe unveiling the most probably dispersal vectors involved. The session on demography showed that although there is a long list of life history traits that presumably play a role in the invasive character of the species, few of them have been tested and that, locally, less invasive characters may be of importance. The first day ended with a presentation on the competition with local seaweed species and showed that most studies have been providing rather circumstantial evidence rather than experimental proof of displacement of natives by the invader. During lunch and dinner there were several enthusiastic discussions about the presented results, implications and future research possibilities. The second day started with a presentation on the factors involved in the invasibility of communities to *S. muticum* invasions followed by the impact of the invader on organisms associated to the native seaweed communities. The last presentation of the morning stressed the importance of invasion genetics as tools for not only tracing the origin of invasions but also for studying evolutionary processes throughout invasions. The afternoon was used to present the contributions from the invitees that were not able to attend the workshop (Henning Steen and Jose Rico). After a long coffee break when the conclusions of the workshop were summarized, the participants discussed the possibilities of future collaborations and established the individual tasks for a joint review paper on *Sargassum muticum* invasions.



All 12 participants from 8 countries experienced the workshop as a very positive and stimulating experience. Although the total number of participants was relative low, this enabled the participants to share their experiences and points of view more effectively and allowed the presentations to be long with plenty of time for discussion. These turned out to be very usefull and clearly identified the current state of knowledge and the directions of future research. The outstanding surroundings of the Hotal Albacora and the good atmosphere provided ample excellent opportunities for informal interactions among the participants.

During the workshop it has become clear that the current state of knowlege on *Sargassum muticum* invasions needs to be reviewed and that the species should be used as a model species to address marine invasion research questions. There was general agreement among the participants that 1) most studies have been performed on a too small scale, but that some of these could be used for meta-analysis studies, 2) although there is huge amount of literature available on *Sargassum muticum* there are still data gaps that need to be addressed, 3) there is a need and much room for fruitfull collaborations which will enable to test invasive theories on larger scales.

2. Scientific content of the event

The impact of invasive species on native species, communities, and ecosystems has been widely recognized for decades. Besides severe economic impacts, invasive species have strong negative consequences for biodiversity. Numerous terrestrial studies have summarized the impacts of invasive species on native species and community structure. Allmost all invasive theories are based on terrestrial invasions and relative little is known about marine invasions.

S. muticum (Yendo) Fensholt is a monoecious brown seaweed originating from the coasts of Japan, China and Korea and one of the best known invasive seaweeds. After its introduction and spread along the Pacific coast of North America it was recorded in Europe in 1971 and rapidly spread from the British Isles (Critchley *et al.* 1983, Rueness 1989). As of today it can be found throughout Europe from Norway to Portugal as well as in the Mediterranean (Critchley *et al.* 1990). Clearly, *S. muticum* is an aggressive invader, exhibiting a combination of opportunistic features. In its introduced areas *Sargassum muticum* has caused displacement of native species through over-growing and shading underlying species. *S. muticum* can change the ecology of the coastal community by allowing certain species to dominate over others that are associated with native seaweeds (Giver 1999). This species is a pest, a fouling organism which is reported to interfere with recreational use of waterways, particularly when it becomes detached from hold fasts and floats off forming large masses. Although hundreds of papers have been published on *S. muticum*, they have never been summarized, beyond analysis for single locations or regional scales. Moreover, the complexities and potential biases of these data, and inferences than can be drawn from the data, have not been evaluated critically. As an outcome of this workshop, we want to provide a synthesis for *Sargassum muticum* invasions of European and American shores and to evaluate emergent spatial and temporal patterns, underlying mechanisms, management strategies and future directions for research. In addition, we want to initiate large scale studies involving collaboration of several research groups throughout Europe and to involve scientists that study *Sargassum* on other continents.



During the introductory presentation by Put Ang (Hong Kong) it became clear that there is hardly any information available on *Sargassum muticum* in its native range. The only thing known is that the species is wide spread from Hong Kong to northern Japan, but uncommon. It mostly grows together with other species of *Sargassum*. It is also extremely clear that the taxonomy of the genus *Sargassum* is far from certain. Many species are described on uncomplete specimen and identification characters are very plastic. For this reason the taxonomic status of *S. muticum* and other species of the genus is uncertain. A few genetic studies on the phylogeny of the genus *Sargassum* have been published, but they have been dealing with a very limited number of species and most of the time they have included only a single sample of each species. There is a clear need for studies on *Sargassum muticum* in the native range.

The introduction of *S. muticum* on the East Pacific coast is uncertain since for an unknown period the species has been confused with a native brown seaweed. However, spread has been quite quickly and the species has established itself from Alaska to Mexico. It mainly affects kelps and associated organisms. Its effects on the fauna, particularly on fishes have almost never been assessed and these assessments are needed especially in subtidal areas.

The species seems to have been introduced with oysters although direct evidence is not available. In Europe, the rate of spread approximates 50 km/year. This spread can be attributed to natural spread through drift material and relocation of oysters and transport of plant material entangled to vessels, but the relative contribution of each factor is unknown. Experimental studies have shown that oysters can be treated relatively easy to prevent the spread of algae by use of a heat bath of 85 °C. Since oysters are still relocated throughout Europe these preventive baths should be required before relocation.

Life history traits important for invasive species like *S. muticum* have been theoretically pointed out, but traits have seldomly been tested. Demographic matrix models suggest that common traits of late succession species, like persistence of adults, are important. However, the important traits are probably very depending on the habitat characteristics encountered. This certainly calls for demographic studies that cover a wide range of habitats and latitudes.

Sargassum muticum competes with a wide range of different native macrophytes throughout its introduced range. Most of them seem to be other brown seaweeds with a perennial rather than a pseudo-perennial life cycle like the invader. The invader and the native macrophytes compete for light, nutrients and space. The competition for light has been investigated and it shown to be very important. In general, *Sargassum muticum* is a better competitor for light than native seaweeds. However, competition is dependent on the developmental stage, recruits compete for different resources than adults. Although adult *S. muticum* seem to be superior competitors, recruits have a harder time competing with locals and may depend more on the amount of available space.

It is difficult to identify factors involved in the invasibility of communities. Studies on the biotic resistance to *Sargassum muticum* invasion highlight the role of particular functional groups or species in mediating invasion. Native functional groups with different resource use strategies affect differently the biotic resistance of the community during the pre- and post-settlement invader phases. Functional groups that utilize primary space obstruct the recruitment of *Sargassum* propagules, while functional groups preempting light inhibit post-



settlement growth. Similarly, Arenas (unpublished) found that the establishment of *Sargassum* in tidepools was strongly inhibited by native algae with the exception of encrusting species, which promoted invasion by providing a suitable substratum for the recruits.

The displacement of local macrophytes by *S. muticum* causes a change in habitat impacting many organisms. The impact on the composition and abundances of seaweed associated fauna, however, seem to be relative small. This is most probably because marine herbivores in general are not strongly specialistic in host and food, in contrast to terrestrial herbivores. The Enemy Release Hypothesis (ERH) tries to explain why exotic species can be invasive by stating that introduced plant species will have a competitive advantage to native plants due to the fact that native specialist herbivores will not recognize them as food. Only two studies have tested this hypothesis and both of them conclude that the ERH hypothesis does not apply to *S. muticum*. The ERH was first postulated for terrestrial habitats where specialist herbivores are common. However, specialist herbivores are rare in the marine environment where seaweed-herbivore interactions are commonly dominated by generalist herbivores, and therefore the ERH may not apply to marine habitats.

Invasion genetics provide important insights in the evolutionary processes related to invasion and provide tools to trace back sources of invasion as it has been demonstrated for the invasive brown seaweed *Undaria pinnatifida*. Unfortunately, no population genetic studies have been performed on *Sargassum muticum*. A further step, in marine non-native species, is to depict and understand the rates of change in the genetics of non-native species and associated life-history traits, the importance of natural selection in shaping the genetic architecture of genetically impoverished populations, the degree of hybridisation between native and non-native species, and thus the role played by exotic species in modifying the genetic architecture of native species and the long-term ecological and evolutionary changes due to introduced species. Until recently, most of the work and much of the literature on invasion have dealt with ecology and population dynamics studies. Only recently, the evolutionary impact and the genetics of alien species have been emphasized. Marine introduced algae, although among the most invasive species (e.g. *Caulerpa taxifolia*), have been only rarely studied through genetic approaches. The rarity of genetic studies is even worse when considering brown algae with only two published studies (*Fucus evanescens* and *Undaria pinnatifida*) and surprisingly, there is no published study on the introduced populations of *Sargassum muticum* although the species is a major invader. Such approaches are nevertheless pivotal: the use of genetic approaches is not only important for tracing back the introduction processes but also to provide an eco-evolutionary scenario of the introduction process.

Temperature and salinity are often considered as two of the most important distributional regulators for marine algae, and tolerance to these factors will often vary between different life-stages. Experiments have shown that adult plants of *S. muticum* tolerate temperatures between -1 °C and 30 °C, and survive at salinities below 10 ‰. Although adult *S. muticum* plants have a wide physiological tolerance to several environmental variables, multifactorial experiments have shown that fertilization and post-fertilization development in this species are reduced at low temperatures and salinities. Fertilization in *S. muticum* is not possible at salinities of 15 ‰ or lower, and growth of germlings is strongly reduced at temperatures below 10 °C. Moreover, plants of *S. muticum* require at least 4 months of temperatures above 8 °C, to mature and reach fertility. This suggests that colonization into the Baltic will most



probably not progress in contrast to spread further north and especially south in Europe and North Africa.

Failure to prevent invasions can have a profound socio-economic impact, but the integrated approach between economy and ecology is relatively novel. There are, however, methods available that would allow the calculation of the economic costs associated with the presence of successful seaweed invaders. These costs can be calculated directly, by the economic costs incurred into when removing the invader, as was done with *Sargassum* in the United Kingdom, or indirectly, by estimating the value given by users to pristine coastal areas as compared to those which have been invaded. Contingent valuation methods have the significant problem that the general public have a low awareness and poor understanding on the environmental good under investigation, but they account for the value given by end users and give policy makers and environmental managers which aspects are more valued by taxpayers. Direct estimates of *S. muticum* removal from European coasts can only be based on a single recent study in Northern Spain, which estimated the cost of 11-15 €/per m of shore per year to remove *Sargassum muticum* from colonized areas. A very crude estimation of the management cost of *Sargassum* in European coasts will be as follows: assuming 1% of Atlantic coast affected (that is, 1 km every 100 km of coast) and disregarding the Mediterranean, less affected, nearly 400 km of coast would be the subject of such control measures. This is equivalent to 4.4 -6.0 million €/per year.

3. Assessment of the Results

Our understanding of marine invasions is constrained by the limited general use of the studies conducted. Most studies have been descriptive and focused on local processes. However, there is much potential for testing general invasive theories using *Sargassum muticum* as a model organism since it has invaded different continents and habitats covering large latitudinal scales, but this will require stronger collaborations between research groups.

All participants of the workshop agreed that it was a very positive experience, resulting in a greater understanding of what is known and which issues need to be addressed in the future. This meeting has provided a strong stimulus for collaboration between research groups and researchers from different fields of expertise. Looking towards the future, it is envisaged that marine invasion research will need to move to larger and more inter-disciplinary investigations and thinking ahead to avoid the lag that has always existed between terrestrial and marine invasion research. There was general agreement that there is much room for fruitful collaborations among the workshop participants and beyond, and in the closing discussion the potential for European projects and networks to evolve from this workshop was pointed out. It was decided that the first step towards the future should be the writing of a joint review on the available knowledge on *Sargassum muticum* invasions by all participants, which will constitute the basis for the development of both a European network and research projects on marine invasions using this as a model species.



4. Final Programme

Thursday 9 November 2006

Arrival and dinner

Friday 10 November 2006

- 10:00 **Workshop introduction**
Rui Santos (Center for Marine Sciences, Universidade do Algarve)
- 10:15 **Presentation of the European Science Foundation (ESF)**
Hefin Jones (Standing Committee for Life, Earth and Environmental Sciences)
- 10:30 **Informal presentation of all participants** (*5 min power point
presentation by each*)
- 11:30 *Coffee break*
- 11:45 **Sargassum muticum in its native region**
Ang Put
- 13:00 *Lunch*
- 14:30 **Sargassum muticum on the East Pacific coast**
Kevin Britton-Simmons
- 15:30 *Coffee break*
- 16:00 **Introductions and introduction vectors of spread in Europe**
Frédéric Mineur
- 17:00 **Demography**
Aschwin Engelen
- 18:00 **Competition with local species**
Morten Pedersen
- 20:00 *Dinner*

Saturday 11 November 2006

- 10:00 **Factors involved in the invasibility of communities**
Francisco Arenas & Concelación Fernández
- 11:00 *Coffee break*
- 11:15 **Seaweed-animal interactions**
Robin Svenson, Henrik Pavia & Gunilla Toth
- 12:15 **Population genetics: Lessons to be learned from the population
genetics of other brown seaweeds**
Frederique Viard
- 13:15 *Lunch*



14:30	Economical and social impacts: extrapolating the work of ALIENS to European scale – not coming
15:00	Coffee break draft of conclusions (Rui +Aschwin)
16:00	Conclusions and management strategies (Rui +Aschwin)
17:00	Discussion of future collaborative research interests and possibilities (FP7)
18:00	Establishment of individual tasks for a joint paper on Sargassum muticum invasions
20:00	<i>Dinner</i>

Sunday 12 November 2006

Departure

5. Final List of Participants

This final list of participants differs from the preliminary list because Dr. Henning Steen (Norway) and Prof. Jose Rico (Spain) as well as Deniz Haydar (her presentation was covered by Frederic Mineur) unfortunately were not able to attend the workshop.

Convenors

Rui Santos

Center for Marine Sciences, University of Algarve, FCMA, Campus de Gambelas, 8005-139 Faro, Portugal
Tel. : 00531 965352842
Rosantos@ualg.pt

Aschwin Engelen

Center for Marine Sciences, University of Algarve, FCMA, Campus de Gambelas, 8005-139 Faro, Portugal
Tel. : 00531 934977238
Aengelen@ualg.pt

Invited participants

Gunilla Toth

Department of Marine Botany, Tjärnö Marine Biological Laboratory, SE 452 96 Strömstad, Sweden
Gunilla.toth@tmbl.gu.se

Henrik Pavia

Department of Marine Botany, Tjärnö Marine Biological Laboratory, SE 452 96 Strömstad, Sweden
Henrik.pavia@tmbl.gu.se

Robin Svensson

Department of Marine Botany, Tjärnö Marine Biological Laboratory, SE 452 96 Strömstad, Sweden
Robin.svensson@tmbl.gu.se



Morten Pedersen

Roskilde University, Department of Life Sciences and Chemistry, 18-1, Universitetsvej 1,
P.O.Box 260, DK-4000 Roskilde, Denmark
mfp@ruc.dk

Frédéric Mineur

Queen's University Belfast, School of Biology and Biochemistry, Medical Biology Centre, 97
Lisburn Road, Belfast BT9 7BL, Northern Ireland
f.mineur@qub.ac.uk

Frédérique Viard

UMR 7127, Stn Biol Roscoff, CNRS, Pl Georges Teissier, BP 74, F-29682 Roscoff, France
viard@sb-roscoff.fr

Consolación Fernández

Departamento de Biología de Organismos y Sistemas, Universidad de Oviedo. c/ Catedrático
Rodrigo Uría s/n. E-33071 Oviedo, Spain
chely@uniovi.es

Francisco Arenas

CIMAR, University of Porto, R do Campo Alegre 823, 4150-180 Porto, Portugal
Farenas@ciimar.up.pt

Kevin Britton-Simmons

University of Washington, Friday Harbor Laboratories, 620 University Road, Friday Harbor,
Washington 98250, USA
Aquaman@u.washington.edu

Put Ang

Marine Science Laboratory, Dept of Biology, The Chinese University of Hong Kong, Shatin,
N.T., HKSAR, China
put-ang@cuhk.edu.hk

6. Statistical Information on Participants

The country of origin of the participants:

<u>Country</u>	<u>Number of participants</u>
Sweden	3
Denmark	1
N-Ireland	1
France	1
Spain	1
Portugal	3
USA	1
China	1

There were 3 female and 9 male participants. Unfortunately Henning Steen from Norway and Jose Rico were unable to attend the workshop, but they did send a presentation. The youngest participants were Ph. D students in their twenties and the oldest experienced Professors in their early fifties.