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Short Communication

Sargassum muticum (Yendo) Fensholt (Fucales, Phaeophyta) in Morocco, an invasive marine species new to the Atlantic coast of Africa

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Abstract

The Japanese brown seaweed *Sargassum muticum* (Yendo) Fensholt (Fucales, Phaeophyta) is reported for the first time in Atlantic Morocco, along the shoreline of Doukkala (S of Casablanca). This record, the first in the African continent, represents a remarkable range expansion of this invasive marine species. Indeed, it is the southern-most occurrence of the species in the Atlantic. Preliminary phenological and ecological data of this non-native species were provided from the Doukkala coast. The major effects on benthic structure and composition of this invasive brown macroalga were also evaluated from published data. Oyster transfers from the French coast were the most likely primary introduction vector, but maritime vectors linked to shipping and navigation cannot be ruled out. Guidelines for prevention of further expansion of this highly invasive marine species along the Moroccan coasts are described.

Key words: early detection; Japanese brown seaweed; Africa; oyster transfers; shipping; prevention

Introduction

The invasion of habitats by Nonindigenous Invasive Species (NIS) is a global phenomenon with serious consequences for ecological, economic, and social systems (Carlton 2000; IUCN 2009). Species invasions are considered one of the greatest threats to native biodiversity and resource values of the world's oceans (Rilov and Crooks 2004; Molnar et al. 2008). Several marine species, such as the brown macroalga *Sargassum muticum* (Yendo) Fensholt, are known to be highly successful alien seaweeds, with many of the intrinsic traits of an invasive species, including very high growth rates of 2-4 cm per day, high fecundity, monoecious individuals with a perennial life history (Norton 1977; Norton and Deysher 1989; Williams and Smith 2007), and multiple-range dispersal mechanisms including germling settlement and drifting fertile thalli (Engelen and Santos 2009). This Japanese seaweed was accidentally introduced to Pacific North America in the 1940s and then to European coasts in the early 1970s, in both cases associated with the intentional transfer of the Pacific oyster *Crassostrea gigas* (Thunberg, 1793) (Haroun and Izquierdo 1991; Wonham and Carlton 2005). The species was first recorded as drift on the Belgian coasts in 1972 (Coppejans et al. 1980) and established populations were observed on the Isle of Wight, southern England, in 1973 (Farnham et al. 1973). It was subsequently observed in numerous locations around the Channel region, and spread during the next 30 years along European shores, reaching Scandinavia and Portugal (Rueness 1989; Karlsson and Loo 1999; Engelen and Santos 2009). It was also introduced into Mediterranean coastal lagoons: Thau (France) and Venice (Italy) (Curiel et al. 1999).

A population of *Sargassum* different from native species of the genus was detected during a field trip along the shoreline of Doukkala (Atlantic coast of Morocco, Northwest Africa) in the winter of 2011-2012. We report here the

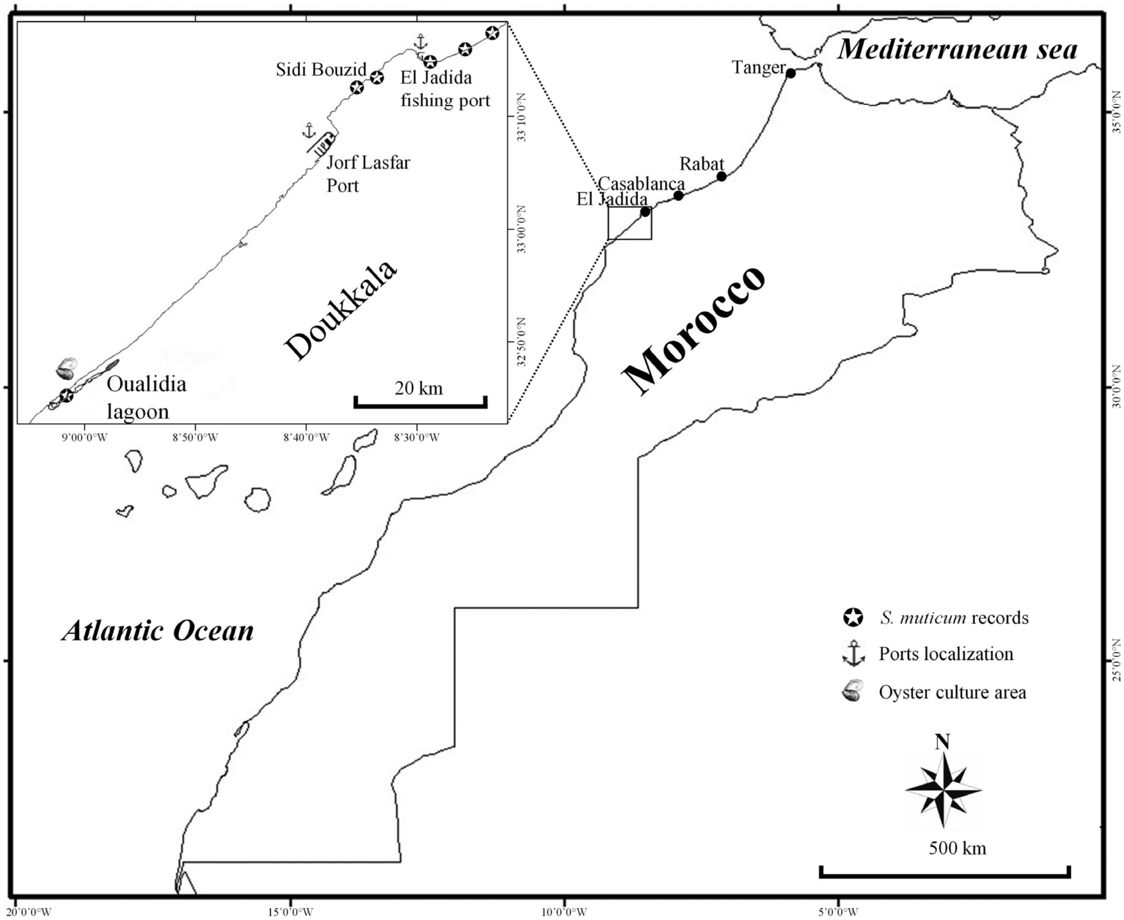

Figure 1. Distribution of *Sargassum muticum* populations in El Jadida coasts (Morocco).

discovery of *S. muticum* on the Moroccan Atlantic coast (South of Casablanca), which greatly extends the geographical range of this highly invasive species at latitudes below the Iberian Peninsula. It is the most southern record of this species in the Atlantic, and the first on the African continent.

Moroccan *Sargassum muticum* description and habitat preferences

Until now, the genus *Sargassum* was represented in the Moroccan coasts by six species: *S. acinarium* (Linnaeus) Setchell, *S. desfontainesii* (Turner) C. Agardh, *S. flavifolium* Kützing, *S. hornschuchii* C. Agardh, *S. natans* (Linnaeus) Gaillon and *S. vulgare* C. Agardh (Benhissoune et al. 2002).

The Moroccan specimens of *S. muticum* were first discovered during an annual phycology field course conducted by the Faculty of Sciences (Chouaib Doukkali University) in January 2012 in Sidi Bouzid, a tourist locality on the Atlantic coast of Morocco (Figure 1). Other *S. muticum* populations have been subsequently detected all along the coast of El Jadida city. At low tide *S. muticum* wraps in thick mats across intertidal rocks whereas at high tide it floats upright (Figure 2). The thalli, arising from a small discoid holdfast, may reach up to 5 m total length, with few primary lateral branches. Basal leaves are generally 1-5 cm long, 0.5-1 cm wide, lanceolate and serrated. Pear shaped aerocysts 2-5 mm in diameter are borne on branchlets amid the leaves. Fertile receptacles (Figures 3 and 4) were observed in the axils of tertiary lateral branches in late March.

Figure 2. *Sargassum muticum* populations in Deauville beach of El Jadida (a) and in tide pools at Sidi Bouzid site (b). Photographs by Abdeltif Reani.

The Moroccan samples were deposited in the herbarium and were positively identified using preserved material of *Sargassum muticum* held at the BCM Herbarium (Fac. of Marine Sciences, University of Las Palmas de Gran Canaria, Canary Islands, Spain). The Herbarium material used were**:** BCM 2442 (St. Catalina Island, California, USA; November 07, 1991); BCM 6213 (Portaferry, Down County, N Ireland; May 07, 2003); BCM 6531 (Nabeta Bay, Shimoda, Japan; May 15, 1987); BCM 7601 (Sidi Bouzid tide pools, El Jadida, Morocco; February 13, 2012).

The first *Sargassum muticum* populations were detected during the winter months of 2011-2012 in two different habitats: a) sheltered, well-illuminated and shallow, subtidal, rocky substrate along the coastline of El Jadida city (i.e., in Deauville beach) (Figure 2a) and b) inside rocky intertidal pools of 1- 5 m depth in the Sidi Bouzid coastal area (Fig 2b). The ecological data gathered from surveys, and in situ observations in nearby coastal areas along the Doukklala coastline, indicates that this invasive macroalga occupies rocky bottoms between 1 to 5 m deep in protected intertidal pools and shallow, sheltered embayments. Specimens of *S. muticum* that had been washed ashore were identified inside the Oualidia lagoon in June 2012. *Sargassum muticum* populations were not observed in exposed coastal areas.

Discussion

Potential vectors of introduction

Alien or introduced seaweeds can be transported by various means: in ship ballast water (transport of embryos), by attaching to hulls, as 'hitch-hikers' entangled on ship propeller, clinging to scuba gear, by packaging, as consignments of live organisms traded to provide live bait or gourmet food, etc. (Critchley et al. 1990; Molnar et al. 2008; Mineur et al. 2008; IUCN 2009). The most common method of introducing non-native marine algae has been unintentional, associated with deliberate commercial shellfish introductions (such as the Pacific oyster *C. gigas*) (Farnham et al. 1973; Wonham and Carlton 2005; Mineur et al. 2007; Williams and Smith 2007).

The vector of introduction of *Sargassum muticum* to the Atlantic coast of Morocco is unknown but its discovery in the El Jadida and Sidi Bouzid coastal areas suggests shellfish transfer as primary vector because oyster culture areas are found nearby (inside Oualidia lagoon, 70 Km S of El Jadida city). Although shellfish transfers seems to be the most likely introduction vector, we cannot rule out maritime traffic as a potential vector (e.g. hull fouling). In this context, two potential entry ports could be

Figure 3. Morphology of juvenile *Sargassum muticum* (Sidi Bouzid, March 2012). Photographs by Brahim Sabour.

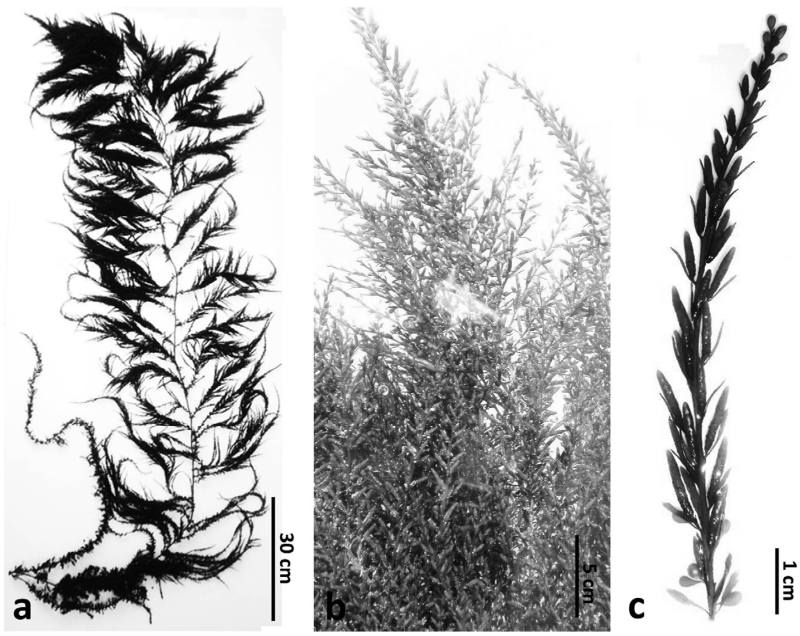

Figure 4. Mature *Sargassum muticum* (a) with receptacles arising in the axils of lanceolate lamina of a tertiary branchlet (b, c), (Deauville Beach of El Jadida, May 2012). Photographs by Brahim Sabour.

identified: the nearby international harbor of Jorf Lasfar, (the largest port in Africa for phosphate export, with more than 1000 bulk ships per year from around the world), and the small fishing port of El Jadida. Nevertheless, hull fouling of large seaweeds on cargo ships is not very likely, but fouling on mobile submerged structures, or entangled on propellers of sailing and smaller recreational boats is quite possible (Mineur et al. 2008).

Shellfish transfers have been identified as the most common introduction vector for the arrival and quick expansion of *Sargassum muticum* along the Northeast Pacific where it spread a distance of over 5,000 km (i.e., Sea Otter Sound – Alaska to Baja California – Mexico) in less than 30 years (Druelh 1973; Pedroche et al. 2008). Similarly, it spread more than 2,000 km along Northeast Atlantic coast (Sweden to Iberian Peninsula) also in a very short period of time (Critchley 1983; Rueness 1989; Engelen and Santos 2009). Now *S. muticum* has jumped to the Moroccan coastline in the African continent, demonstrating the high capabilities of this marine species to disperse and colonize new shallow coastal habitats outside its natural range.

Ecological effects

Seminal works in British *Sargassum muticum* populations showed that the growth of embryos and floating/detached lateral branches is faster than that of native seaweeds at both high (25ºC) temperature and relatively low (15ºC) temperatures (Norton 1977; Critchley 1983). Nienhuis (1982) reported a wide range of salinity tolerance without metabolic damage. More recently, Engelen and Santos (2009) demonstrated that the invasiveness of *S. muticum* relies on K- rather than r-selected traits and without drastic changes in life-history strategy between phases of invasion. Unfortunately, knowledge of socio-economic impacts of invasive seaweeds is poor, and there is little information on the impacts of introduced species on ecosystem function (Schaffelke and Hewitt 2007). In this specific case, Andrew and Viejo (1998) and Sánchez et al. (2005) in NE Atlantic, as well as Britton-Simmons (2004) in NW Pacific reported modifications in native seaweed assemblages, with lower recruitment and survival of local species after invasion by *S. muticum*. Moreover, the associated native marine biota is negatively affected, as demonstrated by Viejo (1999) in the Cantabric Sea, with drastic changes in epifauna abundance and size, and in epiflora biomass. Also, in Northern Spain, Sánchez and Fernández (2006) found that nutrient enrichment enhances the growth of *Sargassum muticum* and, thus, eutrophication processes could promote its further spread towards nearby coastal areas.

Future actions

Bio-invasions can be enormously costly, both in terms of economic and ecological damages as well as costs associated with management (Carlton 2000; Schaffelke and Hewitt 2007; Rilov and Crooks 2009). Because of the scale of the problem, NIS should be tackled at the international and regional level as well as at the national and local level. As already stated by IUCN (2009), prevention of marine invasion is by far the best option to avoid damaging ecological and economical effects.

International shipping, which is considered as the principal anthropogenic vector of introduction for NIS - including seaweeds - on a global scale (Williams and Smith 2007; Molnar et al. 2008), facilitates NIS transport and raised concern about their impact on marine communities (IUCN 2009). Aside from hull bio-fouling, transports or transfers on recreational boats, submerged materials, and shellfish for culture production within the same country may also cause problems (Mineur et al. 2008). Therefore, moving a small boat, fishing tackle/net, scuba gear or oyster spat from one island/coastal area to another without any preventive action (such as cleaning, brine or heat shock) could further facilitate the spreading of invasive species. Mineur et al. (2007) suggested relatively simple changes to the transfer practices, such as short treatments with hot water (especially effective with oyster transfers). This seems to be an appropriated tool to be applied with oyster spats and reduce the risk of NIS introductions, such as *Sargassum muticum*, in the Doukkala's coast.

Further studies will be needed to identify the major factors driving the spread of *Sargassum muticum* along the Moroccan coasts as well as the interactions with native marine vegetation. Future surveys along the Atlantic Moroccan shoreline will be conducted in order to understand the ecological implications and the eventual spread of this invasive species, as well as to evaluate the potential impacts on the native benthic assemblages.

Conclusions

This contribution is the first report documenting populations of *Sargassum muticum* in an initial phase of development for Morocco and, thus, for the Atlantic coast of Africa.

A likely vector of introduction was oyster transfer with epibiontic seaweeds for shellfish farming from European sources (French commercial supplies).

This highly invasive species could spread further on and affect the structure and composition of native marine vegetation along the coast of Morocco and down the Atlantic coast of Africa, including nearby archipelagos. Several measures and actions are needed to avoid further spread of this NIS along the Moroccan coasts.

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