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Rapid Communication

The brown macroalga *Colpomenia peregrina* (Sauvageau, 1927) reaches Rhode Island, USA

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Abstract

Introduced, or nonnative, marine species are a threat to local biodiversity, disrupt marine industries, and can have negative effects on coastal communities. *Colpomenia peregrina* (Sauvageau, 1927) is one of the most successful brown algal invaders in the world. Originating from the Northwest Pacific, *Colpomenia peregrina* was first collected in the Northwest Atlantic in Nova Scotia, Canada in the 1960s. Since then populations of *C. peregrina* have been discovered at 57 sites ranging from Grand Barachois Lagoon, Saint Pierre and Miquelon to South Wellfleet, MA, USA. The spread of *Colpomenia peregrina* can be attributed to its broad tolerance to environmental conditions, buoyant morphology that aids dispersal, and generalist epiphytic biology. Here we report the occurrence of *Colpomenia peregrina* at five sites in Rhode Island, USA for the first time, representing the crossing of a major biogeographic boundary by this species. The spread of *C. peregrina* will likely continue, warranting research on its impact on native communities and host algae.

Key words: sea potato, range expansion, macroalga, epiphyte, biogeographical regions

Introduction

Introduced, or nonnative, marine species are a threat to local biodiversity, disrupt marine industries including fishing and recreation, and can have negative effects on coastal communities through habitat alteration (Carlton 1999; Bax et al. 2003; Thomsen et al. 2016). Worldwide, there are 346 seaweeds that are either nonnative or have unknown origins (Thomsen et al. 2016). Seaweeds are most commonly transported by ship hulls, through ballast water, or aquaculture (Mathieson et al. 2016; Thomsen et al. 2016) and can have dramatic consequences for native communities. Nonnative seaweeds can negatively impact the native flora through competition, epiphytism, or habitat alteration. However, some nonnative species can provide positive ecosystem services through the creation of new habitats. For example, the introduced red alga *Dasysiphonia japonica* (Yendo) H.-S. Kim, 2012 has replaced native kelp beds in the Gulf of Maine, USA, resulting in a significant change in canopy height and complexity that has increased the biodiversity of associated faunal communities (Dijkstra et al. 2017).

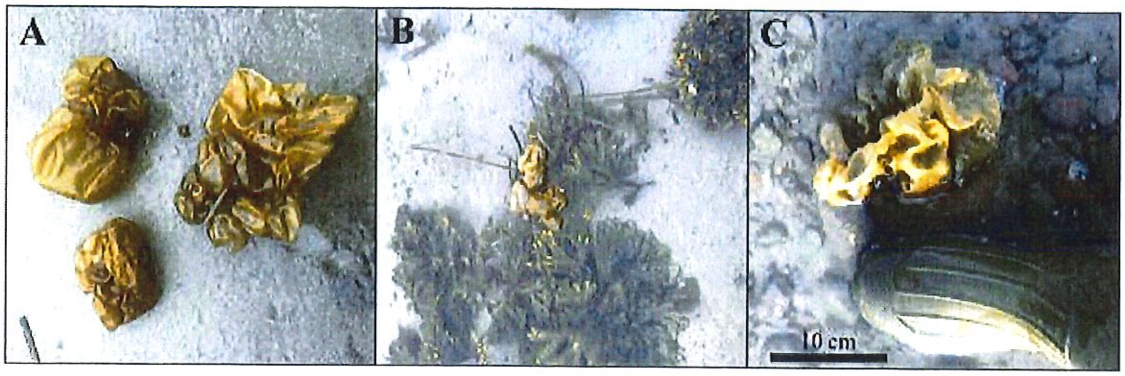

Figure 1. Representative samples of *Colpomenia peregrina* collected in Rhode Island. *Colpomenia peregrina* in drift (A) and attached to *Fucus* spp. (B) in February 2018 (Photos courtesy of Emma Ferrante). Large *Colpomenia peregrina* specimen in drift in March 2018. (C) (Photo by Lindsay Green-Gavrielidis). Scale bar for 1C only.

Colpomenia peregrina Sauvageau, 1927 (Figure 1), commonly referred to as the sea potato due to its saccate morphology, is one of the most successful brown algal invaders in the world (Lee et al. 2014). According to recent genetic analysis by Lee et al. (2014), the center of genetic diversity of *C. peregrina* and thus its origin is in the Northwest Pacific, likely in Korea. However, *C. peregrina* is also found in Russia, Japan, and China in the Northwest Pacific (Cho et al. 2005); Australia and New Zealand in the Southwest Pacific (Clayton 1979; Parsons 1982); from Alaska to Baja California and Mexico in the Northeast Pacific (Abbott and Hollenberg 1976; Pedroche et al. 2008); from Norway to Portugal in the Northeast Atlantic (Brattegard and Holthe 2001; Araújo et al. 2009; Bunker et al. 2017); in the Mediterranean (Blackler 1967); from Morocco to Liberia in Western Africa (John et al. 2004); Tanzania (Oliveira et al. 2005); and from Saint Pierre and Miquelon to the Gulf of Maine in the Northwest Atlantic (Blackler 1964; Mathieson et al. 2016).

The first collection of *Colpomenia peregrina* in the Northwest Atlantic was in Nova Scotia, Canada in the 1960s (Blackler 1964), which was likely introduced from the nonnative population in Europe (Lee et al. 2014). In 2011, extensive populations of *C. peregrina* were discovered in the Gulf of Maine, USA; in total *C. peregrina* has been documented at 57 sites in the Northwest Atlantic spanning from Grand Barachois Lagoon, Saint Pierre and Miquelon to South Wellfleet, MA, USA (Mathieson et al. 2016). Importantly, *C. peregrina* was observed in close proximity (< 1 km) to the Cape Cod Canal (Sandwich, MA, USA) in 2012 (Green et al. 2012). The Cape Cod Canal connects the Gulf of Maine to Buzzards Bay in southern New England, which represent two distinct biogeographical regions: the Acadian Province which extends from Nova Scotia, Canada to the north shore of Cape Cod, MA, USA and the Virginian Province which extends from the south shore of Cape Cod to Cape Hatteras, NC, USA (Humm 1969; Van den Hoek 1975). Cape Cod, therefore, serves as a major biogeographical barrier, with the cool Labrador Current dominating in the northern Acadian Province and the warm Gulf Stream dominating in the southern Virginian Province.

Previous studies in the Northwest Atlantic have indicated that *C. peregrina* occurs in drift, due to its buoyant saccate morphology, and either epilithically or epiphytically in the intertidal and subtidal (Green et al. 2012; Mathieson et al. 2016). Seaweeds that colonize the intertidal environment are subject to a wide range of physical conditions and are generally more tolerant of physical stressors such as desiccation than seaweeds that are restricted to the subtidal. Previous studies have shown that *C. peregrina* has a broad tolerance to desiccation (Oates 1985), temperature, and salinity (Vandermeulen 1986); this broad tolerance likely explains its continued expansion worldwide and in the Northwest Atlantic. Here, we report on the expansion of *C. peregrina* south of Cape Cod and provide the first records of its presence in Rhode Island.

Materials and methods

After the initial discovery of *Colpomenia peregrina* in Rhode Island in drift at Mackerel Cove (Jamestown, RI) in the fall of 2017, thirteen sites (Supplementary material Table S1, Figure 2) were surveyed to determine the extent of the range expansion of *C. peregrina* in the Northwest Atlantic. At each site, seaweed wrack and the shallow subtidal were surveyed for the presence of *C. peregrina*. All collected samples were placed on ice and transported to the laboratory where they were examined and identified using microscopy and preserved either as herbarium vouchers or in silica gel for future research. Specimens of *C. peregrina* collected in Rhode Island were microscopically similar to those previously collected in the Gulf of Maine that were identified through DNA barcoding (Green et al. 2012). *Colpomenia peregrina* can be distinguished from *C. sinuosa* and *C. bulbosa* due to the lack of cuticle on reproductive tissue and plurilocular cell characteristics, respectively (Vandermeulen et al. 1984).

At two sites (Charlestown Breachway and Mackerel Cove, Figure 2), surveys were conducted in June 2018 to determine the abundance and biomass of the introduced saccate alga *C. peregrina* and the native saccate alga *Leathesia marina* (Lyngbye) Decaisne, 1842 in the seaweed wrack. *Colpomenia peregrina* and *L. marina* have superficially similar morphologies, but can be distinguished using microscopy (Mathieson et al. 2016). At each site, a 100 m transect was laid in the seaweed wrack line parallel to the water 1–2 hours before low tide. At every 10 m, a quadrat (0.25 m by 0.25 m) was placed alternatively above or below the transect line. All clumps of saccate algae (including *L. marina* and *C. peregrina*) within each quadrat were collected and transported to the laboratory where the number of clumps of each alga was counted and the blotted dry fresh mass was determined. Both *L. marina* and *C. peregrina* can form clumps with multiple

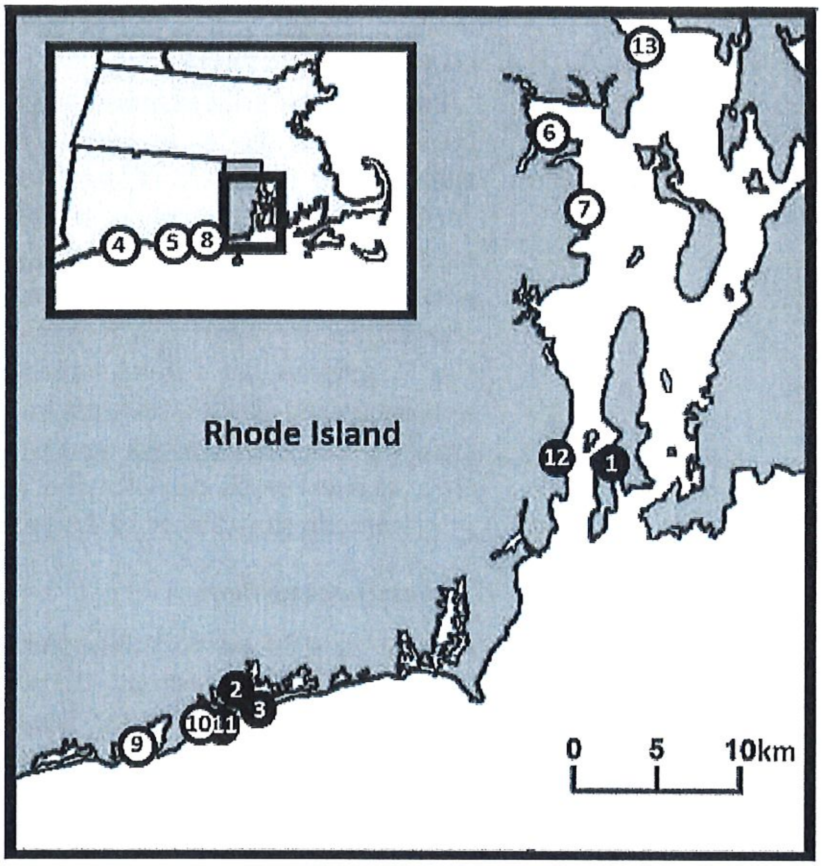

Figure 2. Sites in southern New England, USA that were surveyed for *Colpomenia peregrina*. Inset shows Cape Cod, MA, USA, which serves as a major biogeographic barrier separating the Acadian and Virginian Biogeographical Provinces. Sites where *C. peregrina* was found are represented by closed circles, while sites lacking *C. peregrina* are represented with open circles. Site numbers correspond with site names and coordinates in Table S1.

individuals, and it can be difficult to accurately determine the number of individuals in a clump; therefore, we counted clumps rather than individuals. All measurements were then standardized for the number and biomass of each alga per m^2. Additionally, if the algae were epiphytic on another alga, we identified and recorded the host whenever practical.

Results

The initial collection of *C. peregrina* (Figure 1) in Rhode Island occurred on October 19, 2017, where it was collected in the drift at Mackerel Cove in Jamestown (Figure 2, Table S1). Subsequently, *C. peregrina* was collected from the coasts of Narragansett and Charlestown and at two sites within Ninigret Pond (Ninigret National Wildlife Refuge and Charlestown Breachway, Table S1). *Colpomenia peregrina* was found during each visit to Charlestown Breachway during February, March, April, and June 2018.

At Charlestown Breachway, a mean of 3.56 clumps of *Colpomenia peregrina* per m^2 was found, with no *Leathesia marina* (Table 1). However,

Table 1. Mean (± 1 Standard Error) number of clumps and biomass of *Colpomenia peregrina* and *Leathesia marina* collected during transect surveys conducted at Charlestown Breachway and Mackerel Cove in June 2018.

Site	*Colpomenia peregrina*		*Leathesia marina*	
	No. per m^2	Biomass (g/m^2)	No. per m^2	Biomass (g/m^2)
Charlestown Breachway	3.56 ± 2.35	0.03 ± 0.02	0 ± 0	0 ± 0
Mackerel Cove	4.36 ± 2.25	1.51 ± 0.81	21.82 ±12.06	16.34 ± 10.73

both species were present at Mackerel Cove where a mean of 4.36 and 21.82 clumps per m^2 of *C. peregrina* and *L. marina* were collected, respectively (Table 1). Epiphytic *Leathesia marina* was most commonly attached to *Chondrus crispus* Stackhouse, 1797 (n = 7 clumps) although it was also found attached to *Corallina officinalis* Linnaeus, 1758 (n = 1) and *Ceramium* spp. Roth, 1797 (n = 1). A single collected *Colpomenia peregrina* was epiphytic on *Corallina officinalis*; no host could be identified from the other drift specimens of *C. peregrina*.

Discussion

We report the presence of the sea potato, *Colpomenia peregrina*, in Rhode Island for the first time. We collected *C. peregrina* at five different sites in Jamestown, Narragansett, and Charlestown, Rhode Island including two sites within Ninigret Pond; all collections were in drift except at Charlestown Breachway where *C. peregrina* was growing on attached *Fucus* spp. in the shallow subtidal. Inspection of digitized herbarium specimens showed that *C. peregrina* was collected in 2012 from Wing's Neck in Buzzards Bay by H. Traggis (Macroalgal Herbarium Portal 2018), suggesting that *C. peregrina* had traveled through the Cape Cod Canal at that time although it was not collected in Rhode Island until 2017.

The continued southern expansion of *C. peregrina* contrasts with the typical expansion of temperate seaweed species poleward due to warming waters as a result of climate change. For example, Jueterbock et al. (2013) predicted that poleward migration of three temperate rockweed species: *Fucus serratus* Linnaeus, 1753, *Fucus vesiculosus* Linnaeus, 1753, and *Ascophyllum nodosum* (Linnaeus) Le Jolis, 1863 as a result of ocean warming. The range expansion of *C. peregrina* also contrasts with the rapid northward expansion of the introduced green alga *Codium fragile* ssp. *fragile* (Suringar) Hariot, 1889 (Mathieson et al. 2003) and *Grateloupia turuturu* Yamada, 1941 (Mathieson et al. 2008). Importantly, *Codium fragile* ssp. *fragile* appears to have been independently introduced at multiple sites in the Northwest Atlantic, while *C. peregrina* and *G. turuturu* likely have single points of introduction (Blackler 1964; Villalard-Bohnsack and Harlin 1997; Mathieson et al. 2008; Mathieson 2016).

Physiological studies of *C. peregrina* have reported that growth rates slowed at temperatures of 5 °C compared to rates at 13 °C and 20 °C

(Vandermeulen 1986), which may partially explain the successful migration of the species southward. Although *C. peregrina* did not appear to be present in the Gulf of Maine prior to 2010, it is possible that the species existed in the subtidal in crustose form. The initial spread of *Colpomenia peregrina* from Nova Scotia to the Gulf of Maine could also have been limited by its tolerance to overwintering in Nova Scotia where average winter sea surface temperatures are below 5 °C from January through May (Petrie and Jordan 1993). *Colpomenia peregrina* has a heteromorphic life history with an alternation between the saccate gametophyte and a cryptic crustose sporophyte that could go unnoticed (Clayton 1979). The hollow morphology of *Colpomenia* makes it positively buoyant, and this characteristic has likely contributed to its rapid dispersal (38 km yr^{-1} in Europe; Mineur et al. 2010), aided by the hydrodynamic characteristics of the Gulf of Maine (Xue et al. 2000), along with its broad tolerance to desiccation (Oates 1985), salinity, and temperature ranges (Vandermeulen 1986). Similarly, the successful nonnative *Codium fragile* ssp. *fragile* also has buoyant fragments that aid in long distance dispersal and has allowed the alga to spread rapidly within its invaded range (Gagnon et al. 2011). Further research should be conducted to determine and contrast the rate of spread of *C. peregrina* across its invaded range.

Colpomenia peregrina continues to expand its range in the Northwest Atlantic and worldwide. It is typically an epiphyte and can be found in densities ranging from 0.09 cm^{-1} to 0.43 cm^{-1} on rockweeds in its introduced range (Mathieson et al. 2016). Epiphytes have many negative impacts on their hosts through competition for light and nutrients that result in lower growth rates and reproductive output of the hosts (D'Antonio 1985). For example, epiphyte load was negatively correlated with performance of *Fucus distichus* Linnaeus, 1767 (Hart 2014). Epiphytes can also increase physical drag on the host and result in increased risk of breakage or dislodgment (D'Antonio 1985; Wahl 1996). The metabolic cost of defense against epiphytism acts as a strong selection pressure on populations and recent evidence suggests that different genotypes of *Fucus vesiculosus* have different levels of resistance to epiphytism (Jormalainen et al. 2008). *Colpomenia peregrina* has been recorded as a common epiphyte on 33 different seaweed species in the Northwest Atlantic (Mathieson et al. 2016) and it may potentially have negative effects on the individual hosts and their populations.

Nonnative marine species are a global threat to biodiversity, with some estimates suggesting that only 16% of marine ecosystems have no reported nonnative species (Bax et al. 2003; Molnar et al. 2008). At the same time that global travel and transportation of species have increased, so have local (e.g. eutrophication) and global stressors (e.g. climate change; Rabalais et al. 2009). Complex stressors act as disturbances in the marine environment and may provide space and opportunity for introduced species to become established (Andreakis and Schaffelke 2012). The arrival of *C. peregrina* in Rhode Island will have consequences for native seaweed communities, especially those that serve as hosts. Continued monitoring of introduced species and detailed studies on their impacts are required in order to understand and mitigate the spread of nonnative species.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Sites surveyed for the presence of *Colpomenia peregrina*, in chronological order of first visit.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2019/Supplements/BIR_2019_Green-Gavrielidis_etal_Table_S1.xlsx