THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

Recent *Sargassum* Inundation Events in the Caribbean

Shipboard Observations Reveal Dominance of a Previously Rare Form

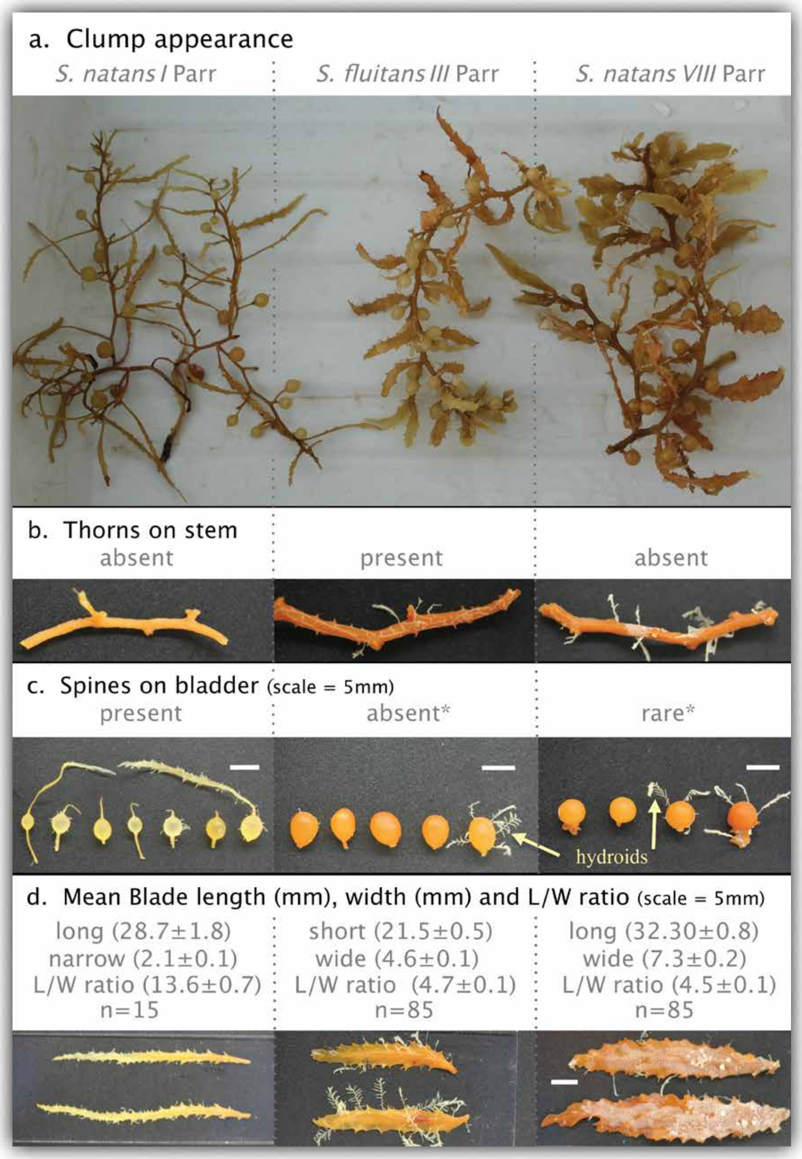

FIGURE 1. Characteristics of three pelagic *Sargassum* forms (left to right: *S. natans I* Parr, *S. fluitans III* Parr, and *S. natans VIII* Parr) collected during the 2014/2015 Caribbean inundation event. (a) Fronds showing arrangement of stem, blades, and bladders. (b) Section of stem highlighting presence/absence of thorns. Bladders and blades removed. (c) Bladders highlighting presence/absence of spines. Bladder stalk is directed downward in each photo. (d) Mean and standard error for length (mm), width (mm), and length/width ratio of blades. *Hydroid colonies are often present on *Sargassum* and can be mistaken for spines or thorns.

By Jeffrey M. Schell, Deborah S. Goodwin, and Amy N.S. Siuda

During June 2011, pelagic *Sargassum* began washing ashore along Caribbean, Gulf of Mexico, West African, and Brazilian coastlines in unprecedented quantities. Tourist beaches were covered by more than a meter of seaweed. Economic impacts of this Atlantic basin-scale inundation event drew international media attention (Higgins, 2011). By summer 2012, our shipboard observations suggested the Caribbean portion of the event had run its course. However, another similarly extensive *Sargassum* inundation was underway by April 2014, persisting through 2015 (MercoPress, 2015).

Did the invading pelagic *Sargassum* drift out of the Sargasso Sea, a vast region bounded by the currents of the North Atlantic gyre (Smetacek and Zingone, 2013)? Alternatively, is its source the North Equatorial Recirculation Region (NERR), as suggested by satellite-derived observations of *Sargassum* mats (Gower et al., 2013) and hindcast models of *Sargassum* landfalls (Johnson et al., 2013)? Our recent net sampling indicates that the invading *Sargassum* did not come from the Sargasso Sea.

In late November 2014, Sea Education Association's (SEA's) SSV *Corwith Cramer* departed the Canary Islands. We sailed across the eastern Sargasso Sea without a sighting, but on day 15, after heading south into the tropics, we were surrounded by *Sargassum*. For the next three weeks, twice-daily surface net tows contained more *Sargassum* than ever recorded by SEA voyages. We noticed the seaweed looked different from the *Sargassum fluitans* or *S. natans* with which we were familiar from 20 years of sailing in the Sargasso Sea, the Caribbean, and Florida Straits (Figure 1a).

Most resources assert pelagic *Sargassum* is composed of two species, *S. fluitans* and *S. natans*. However, each species exhibits a diversity of morphological forms, originally described by Winge (1923) and refined by Parr (1939) but which are absent from contemporary field guides. Parr (1939) recognizes two forms of *S. fluitans* (III, X) and four forms of *S. natans* (I, II, VIII, IX). Presence or absence of thorns on the stem, especially on the distal portion, distinguishes between *Sargassum* species: all *S. fluitans* have thorns, whereas all *S. natans* have smooth stems (Figure 1b; Parr, 1939). Bladder and blade attributes differ widely among forms (Figure 1c,d).

Within the North Atlantic, Caribbean Sea, and Gulf of Mexico, Winge (1923), Parr (1939), and SEA's shipboard sampling over the past several decades (unpublished) indicate that *S. natans I* Parr and *S. fluitans III* Parr were most common while other morphological forms were rare. We provisionally identified the predominant form of *Sargassum* inundating the Caribbean during 2014/2015 as *S. natans VIII* Parr based on its consistent smooth stem, broad blades, and rare bladder spines across the entire range of this study. While future genetic analyses may resolve subspecies taxonomy, in practice, field observations rely on morphological identification to distinguish between forms. At first glance, *S. natans VIII* is easily mistaken for *S. fluitans*, although the latter has significantly smaller blades (Figure 1d). These and other differences in physical structure may influence the ecological role of each form.

Here, we present recent distribution and abundance data for three morphologically distinct pelagic *Sargassum* forms. Sampling occurred November 2014 to May 2015 aboard SSV *Corwith Cramer*. Cruises began in the Canary Islands, traversed the Sargasso Sea and western tropical Atlantic to the Lesser Antilles, and then sailed to the eastern Caribbean before heading to New England. Fifty-four surface neuston tows (net 1.0 m wide × 0.5 m high, 333 µm mesh) sampled 102,919 m^2. *Sargassum* was collected in 92.6% of tows, sorted by morphological form, and wet weighed (g). Stations were sorted into four oceanographic regions; *Sargassum* was absent east of 44°W and rarely encountered north of 34°N.

Composition of *Sargassum* forms differed starkly by region (Figure 2). *S. natans VIII* dominated the western tropical Atlantic (87.3% wet weight), eastern Caribbean (95.3% wet weight), and Antilles Current (92.0% wet weight). In contrast, *S. natans I* dominated the South Sargasso Sea (87.5% wet weight). Observed *S. natans VIII* proliferation throughout three of these regions is significant given its historic low abundance and rare occurrence limited to the western Caribbean (Parr, 1939).

The 2014/2015 *Sargassum* inundation event is exceptional, particularly in the western tropical Atlantic (Figure 2, inset). In autumn 2014, the mean concentration of all *Sargassum* forms combined (0.84 g m^{-2}, n = 8 tows, SE = 0.4) was 10 times greater than that during the 2011/2012 event (0.07 g m^{-2}, n = 13, SE = 0.05) and 300 times greater than that of any other autumn over the last two decades (0.0027 g m^{-2}, n = 270, SE = 9.16 × 10^{-5}; ANOVA, p <0.0001). In fact, during 16 of the 21 non-event years, autumn SEA cruises in the western tropical Atlantic encountered no *Sargassum*. In the South Sargasso Sea (Figure 2, inset), mean springtime concentrations during event years 2011/2012 (0.25 g m^{-2}, SE = 0.07, n = 20) and 2014/2015 (0.23 g m^{-2}, SE = 0.08, n = 15) and all non-event years (0.17 g m^{-2}, SE = 0.07, n = 163) were not different from each other (ANOVA, p = 0.89). On the basis of both *Sargassum* composition and abundance, the Sargasso Sea exhibited no connection to the Caribbean events.

SEA's decades-long shipboard records establish an invaluable baseline and are the only quantitative assessment of *Sargassum* abundance prior to and during the Caribbean inundations; therefore, this data set enables recognition of a recent change in biodiversity and provides important context for future monitoring. With proper field identification of the distinct *S. natans VIII* morphological form, the source region and geographic extent of *Sargassum* inundation events can be tracked at finer spatial resolutions than permitted by remote sensing

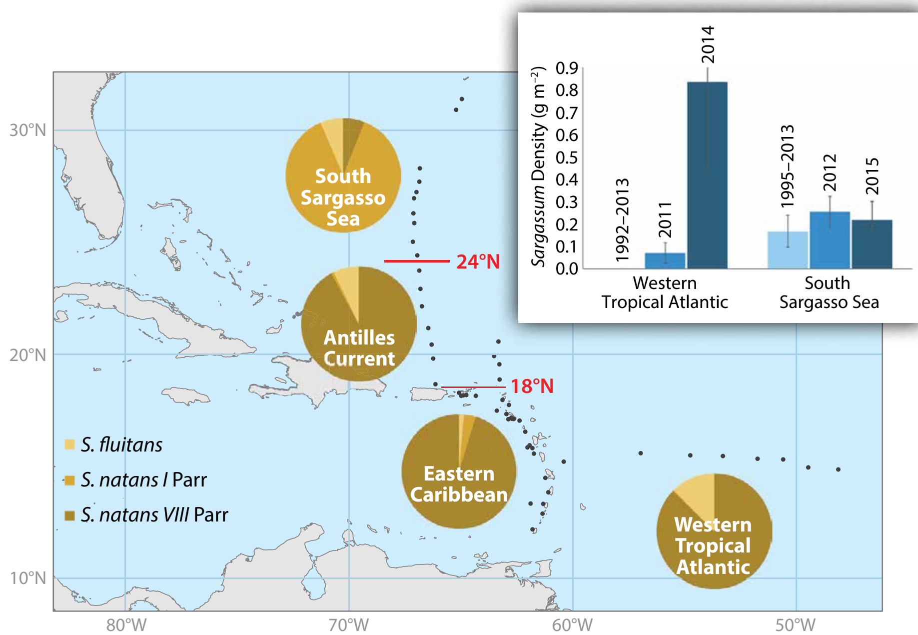

FIGURE 2. Map panel: Proportion of each *Sargassum* form (*S. fluitans*, *S. natans I* Parr, and *S. natans VIII* Parr) observed in four western North Atlantic regions. Regional boundaries are indicated by horizontal lines. Inset: Total density (g m^{-2}) and standard error of *Sargassum* collected in the western tropical Atlantic and the South Sargasso Sea over Sea Education Association's historical survey period and the two recent inundation events.

and modeling techniques. Furthermore, the occurrence and dominance of a previously rare pelagic *Sargassum* form has significant ecological consequences. Preliminary observations comparing resident fauna on *S. natans VIII* reveal lower species richness and abundance. Accordingly, compared to other pelagic *Sargassum* forms, we predict a lower value of *S. natans VIII* as foraging and nursery habitat for known macrofaunal associates, including fishes, turtles (Coston-Clements et al., 1991), and seabirds (Moser and Lee, 2012); indeed, few such organisms were present near the *S. natans VIII*-dominated mats encountered during our 2014/2015 cruises. While modeling and remote-sensing efforts continue to offer insights into basin-scale circulation processes influencing *Sargassum* distribution and transport, field observations are essential for evaluating and interpreting ecological impacts of future *Sargassum* inundation events.

REFERENCES

Coston-Clements, L., L. Settle, D. Hoss, and F. Cross. 1991. *Utilization of the* Sargassum *Habitat by Marine Invertebrates and Vertebrates: A Review.* Technical Memorandum NMFS-SEFSC-296, National Marine Fisheries Service, NOAA, Beaufort, NC, 32 pp.

Gower, J., E. Young, and S. King. 2013. Satellite images suggest a new *Sargassum* source region in 2011. *Remote Sensing Letters* 4:764–773, http://dx.doi.org/10.1080/2150704X.2013.796433.

Higgins, M. 2011. *Where's the Beach? Under the Seaweed*. http://www.nytimes.com/2011/10/16/travel/caribbean-beaches-dig-out-from-massive-seaweed-invasion.html.

Johnson, D., D. Ko, J. Franks, P. Moreno, and G. Sanchez-Rubio. 2013. The *Sargassum* invasion of the eastern Caribbean and dynamics of the equatorial North Atlantic. Pp. 102–103 in *Proceedings of the 65th Annual Gulf and Caribbean Fisheries Institute Conference,* November 5–9, 2012. Gulf and Caribbean Fisheries Institute, Santa Marta, Columbia.

MercoPress. 2015. Sargassum *Bloom are Ruining Caribbean Beaches and Tourism Season*. http://en.mercopress.com/2015/08/12/sargassum-bloom-are-ruining-caribbean-beaches-and-tourism-season.

Moser, M., and D. Lee. 2012. Foraging over *Sargassum* by western North Atlantic seabirds. *The Wilson Journal of Ornithology* 124:66–72, http://dx.doi.org/10.1676/11-067.1.

Parr, A. 1939. *Quantitative Observations on the Pelagic* Sargassum *Vegetation of the Western North Atlantic*. Bulletin of the Bingham Oceanographic Collection, vol. VI, part 7. Peabody Museum of Natural History, Yale University, New Haven, CT, 93 pp.

Smetacek, V., and A. Zingone. 2013. Green and golden seaweed tides on the rise. *Nature* 504:84–88, http://dx.doi.org/10.1038/nature12860.

Winge, O. 1923. *The Sargasso Sea, Its Boundaries and Vegetation*. Report on the Danish Oceanographical Expeditions 1908-10 to the Mediterranean and Adjacent Seas, Volume III: Miscellaneous Papers. Carlsberg Physiological Laboratory, Copenhagen, Denmark, 33 pp.

ACKNOWLEDGMENTS

This research was funded by Sea Education Association. We thank students and crew of SEA Semester cruises C256, C257, and C259 for help with *Sargassum* collection. This manuscript benefited from valuable comments from two anonymous reviewers and S. Moret, as well as taxonomic consultation with phycologists A. Mathieson, C. Schneider, and another.

AUTHORS

Jeffrey M. Schell (jschell@sea.edu) is Associate Professor, **Deborah S. Goodwin** is Assistant Professor, and **Amy N.S. Siuda** is Associate Professor, all at Sea Education Association, Woods Hole, MA, USA.

ARTICLE CITATION

Schell, J.M., D.S. Goodwin, and A.N.S. Siuda. 2015. Recent *Sargassum* inundation events in the Caribbean: Shipboard observations reveal dominance of a previously rare form. *Oceanography* 28(3):8–10, http://dx.doi.org/10.5670/oceanog.2015.70.

Update on Coordination of International Ocean Color Remote Sensing

Contributed by the International Ocean Color Coordinating Group

The International Ocean Color Coordinating Group (IOCCG; http://www.ioccg.org) is an organization of experts from both the satellite data provider (space agencies) and user communities (scientists, managers) operating in the field of satellite ocean color. It provides a critical forum for sharing, coordinating, and disseminating information related to the measurement of ocean color radiometry from space. The IOCCG hosted the second International Ocean Color Science meeting in San Francisco, CA from June 15–18, 2015. The primary focus of the meeting was to build and strengthen the international ocean color community by providing a forum to collectively address common issues and goals, and to foster exchange between the research community and space agency representatives. Representatives from ocean and satellite agencies from the United States, Canada, Europe, South Korea, China, India, Japan, and Brazil briefed the participants on current and future plans for ocean color sensors from their respective agencies. The IOCCG supports all efforts to make the calibrated, geo-located radiances from all international sensors freely available to the global research community. Such data are important for development and validation of new ocean color products including methods to better estimate phytoplankton functional types across the world ocean. Further information on IOCS meeting can be found on the TOS website at http://www.tos.org/pdfs/IOCCG_TOS_7.20.15.pdf.