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Invasion note

The first known invasion of a free-living marine flatworm

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Much attention has been devoted to the introduction of larger organisms into marine communities worldwide, such as macroalgae (Farnham et al. 1973; Carlton and Scanlon 1985; Russell and Balazs 1994), vascular plants (Harrison and Bigley 1982) and invertebrates (Carlton 1989; Berman et al. 1992; Petersen et al. 1992; Cohen et al. 1995; Geller 1999). Although invasions by microscopic marine organisms have occurred (for examples see Carlton 1985; Subba Rao et al. 1994; Pierce et al. 1997), reports of these are less common. We report here the first case to our knowledge of an invasion by a small free-living marine flatworm (Platyhelminthes, 'Turbellaria', Acoela). The European flatworm *Convoluta convoluta* (Abildgaard 1806) has invaded the Western North Atlantic Ocean and now occurs there in very large numbers. *Convoluta convoluta* is well known from the European Arctic and Atlantic coasts, Canary Islands, Mediterranean Sea, Black Sea and Baltic Sea (Dörjes 1968; Karling 1974; Bush 1981). It is dark green to yellowish-brown in color due to endosymbiotic algae and is rather large for an acoel, typically 2–4 mm in length but reaching 9 mm (Dörjes 1968; Karling 1974). In Europe, it is known to prey on diatoms, small molluscs and copepods (Apelt 1969; Mamkaev and Seravin 1963).

Convoluta convoluta was first discovered in the western North Atlantic Ocean in the fall of 1995 on the introduced green alga *Codium fragile tomentosoides* near Halifax, Nova Scotia (A. Chapman, personal communication). In the summer of 1996 we observed it at the Isles of Shoals (600 km SW of Halifax, and 10 km off the coast of the Maine–New Hampshire border in the Gulf of Maine). Dense populations were observed on macroalgae at 3–8 m depths. It is unlikely that *C. convoluta* was present at the Isles of Shoals in large numbers prior to 1996, for it was never observed during extensive diving by two of us (B.R.R. and J.C.) each summer between 1982 and 1995. In the fall of 1996 *C. convoluta* was observed 70 km south of the Isles of Shoals at Nahant, Massachusetts (N. Riser, personal communication). We do not interpret this north-to-south chronology of discovery, however, as necessarily indicating a southern spread of this species over time from Canada.

The identity of the worms was confirmed by examination of the external and internal morphology and of symbionts in mature specimens collected at Nahant and the Isles of Shoals. Features characteristic of *C. convoluta* include a C-shaped cross-section by virtue of downward-rolled lateral sides of the body, 2–3 pairs of prostatoids, a muscular and strongly ciliated and glandular penis invaginated into the seminal vesicle, a large bursa seminalis with strongly developed bursa nozzle, and paired testes and ovaries reaching into the anterior quarter of the body. Zooxanthellae also were present; these endosymbiotic algae are reported in *C. convoluta* from Europe but are not known to be present in any native Gulf of Maine flatworms. Lacking or indistinguishable in the Gulf of Maine specimens of *C. convoluta*, however, were the reddish eyespots that

flank the statocyst in European specimens. The worms collected in Nova Scotia in late fall 1997 were immature but showed the same body shape and presence of zooxanthellae.

Specimens of *C. convoluta* were found on a variety of subtidal algal substrates and reached high densities (see cover photo). Image analysis of underwater macrophotographs taken in 1998 revealed worm densities up to 19 cm^{-2} on the kelp *Laminaria* sp. and on crustose algae-covered rocks in sea urchin (*Strongylocentrotus droebachiensis*) barrens at the Isles of Shoals, and 12 cm^{-2} in urchin barrens off York Beach, Maine, 18 km to the north. Additional observations at these two locations during the summer of 1999 indicated that *C. convoluta* were more abundant and reached densities as high as or higher than those recorded in 1998. Additionally, this species recently has appeared sporadically in sand samples collected in shallow subtidal sites near alga-covered rocks in southern Maine (by ST) and New Hampshire (R. Hochberg, personal communication).

We consider *C. convoluta* to be a new arrival in North America. It could not have been overlooked by Verrill (1893), Graff (1911) nor Bush (1981), all of whom were familiar with this species, nor by several generations of 20th century invertebrate zoologists intimately familiar with the common marine biota of the New England shores. How *C. convoluta* was introduced is not clear, but transport by ballast water or fouled ships are possibilities (see review by Carlton 1989). An ongoing study of population dynamics and diet will further our knowledge of the ecological impact of this small but abundant predator.

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