



NOTE

Mass deposition of hemlock woolly adelgid sexuparae on New England beaches

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On June 7, 2021, staff at the Maine Department of Agriculture, Conservation and Forestry (DACF), received reports of a black substance deposited on Wells Beach in Maine that was staining the bare feet of beachgoers over the previous two days (Edward Smith, personal communication, 2021). Similar reports also came from York, Kennebunk, and Ogunquit Beaches in Maine, Great Island Common beach in New Hampshire, and an unspecified beach in Gloucester, Massachusetts (Figure 1). Numerous news outlets reported on this phenomenon and on the concern from beachgoers about whether this substance could be hazardous (e.g., Mannino and Wlodkowski 2021; Murphy 2021; Russell 2021; Sweeny 2021). Based on photographs submitted by members of the public (Linda Stathoplos and John Lilibridge, personal communication, 2021; Figure 2), and a follow-up site visit, DACF staff quickly concluded that the substance on Wells Beach consisted of countless dead winged insects deposited on the shore by waves as the tide receded.

In a concurrent and related incident, a boater travelling between Misery Island and Danvers River near Beverly, Massachusetts on 5–6 June 2021 reported “thousands of tiny dead bugs [that] kept falling out of the sky and littered [my] boat all day long. There was no keeping up with it,” and, “the surface of the water was covered with the dead bugs. There must have been trillions.” (Adam Frasca, personal communication, 2021; Figure 3).

To identify the insects, a sample consisting of thousands of individuals was collected from a tidal pool on Wells Beach in southern Maine on 8 June 2021. Twenty individuals were slide-mounted and identified as belonging to the adelgid genus *Adelges* (Hemiptera: Adelgidae) (Figure 4). Identification to species was not possible using morphology, because comprehensive keys to the winged forms of adelgids in eastern North America are not available. However, the presence of knobbed setae on the end of the abdomens of the specimens suggested that they could be hemlock woolly adelgid, *Adelges tsugae* Annand (Figure 5). Although this character is not known for the winged forms of this species, it is diagnostic for the wingless forms (Annand 1924). We sought to confirm this identification by producing a DNA barcode sequence from specimens collected on Wells Beach. DNA was extracted non-destructively from a pooled group of 20 insects using the MagMAX DNA Multi-Sample Ultra Kit (Thermo Fisher) on a KingFisher Flex automated instrument (Thermo Fisher), using the manufacturer's protocols. The insect bodies were removed after the proteinase K digestion step and slide mounted as a voucher. All slide-mounted insects were deposited at the Yale Peabody Museum (accessions ENT996109 to ENT996134). The cytochrome c oxidase I (COI) DNA barcoding region was amplified with primers LepF1 and LepR1 (Hebert et al., 2004). Sequencing was performed at the Yale University Keck DNA Sequencing Facility

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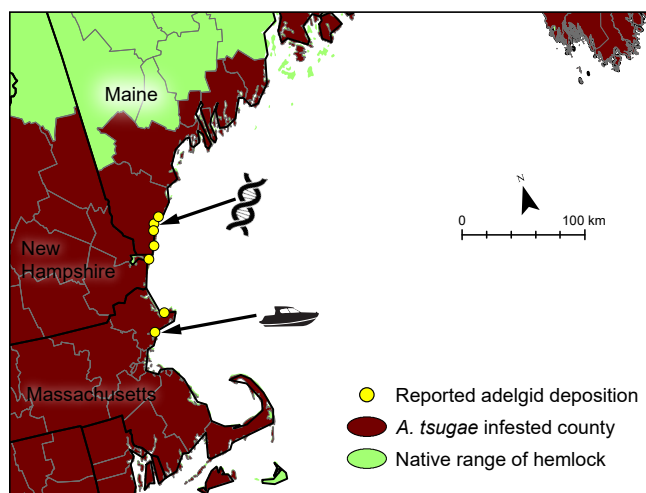
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Figure 1. Map showing counties reporting hemlock woolly adelgid in the region, and locations where mass insect deposition was reported. The double helix icon shows Wells Beach, Maine where we collected a sample for DNA barcoding, and the boat icon shows Misery Island, Massachusetts near where a boater documented mass deposition of insects on the water surface. Map provided by USDA Forest Service, Eastern Region S&PF, Forest Health Protection.



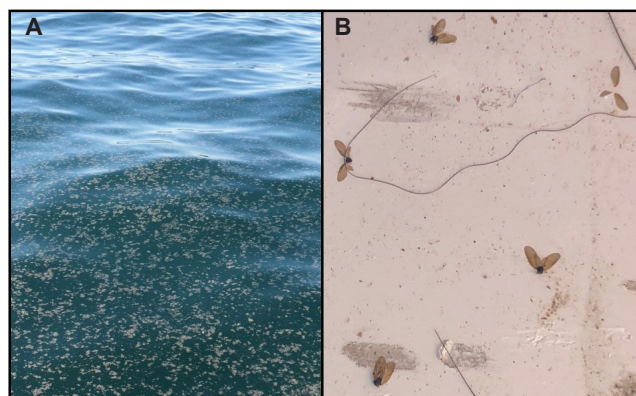
on an Applied Biosystems 3730xL DNA Analyzer. Forward and reverse chromatograms were aligned and edited using Geneious Prime 2021.2.2 (<https://www.geneious.com>). The resulting sequence was deposited in GenBank (accession OM654047). The sequence was identical to the *A. tsugae* haplotype present in eastern North America that originated in southern Japan (Havill et al. 2016), confirming identification of these insects as this species.

Since its introduction from Japan, *Adelges tsugae* has become a serious pest of eastern hemlock trees from Nova Scotia in the North, to Georgia in the South (Limbu et al. 2018). In New England it has been killing trees since the 1980's (McClure 1987). It has two parthenogenetic generations per year in eastern North America (Limbu et al. 2018). A proportion of the individuals that mature in early summer become winged individuals called sexuparae, which in their native range migrate from hemlock to tigertail spruce, *Picea torano* (Siebold ex K. Koch) Koehne, where winged gallicolae later emerge from galls (Havill et al. 2016). In the introduced range, the gallicolae do not occur because *A. tsugae* cannot survive on native spruce species (McClure 1989). The proportion of individuals that develop into winged sexuparae increases as adelgid population density increases (McClure 1991), and since these forms cannot continue the life cycle, their death constitutes a significant source of population regulation

Figure 2. Dead hemlock woolly adelgid sexuparae deposited on the sand at Wells Beach, Maine. Photo by John Lillibridge, retired NOAA Oceanographer.



Figure 3. Dead hemlock woolly adelgid sexuparae accumulating on the surface of the ocean (A) and on the hull of a boat (B) near Beverly, Massachusetts in early June 2021. Photo by Adam Frasca.



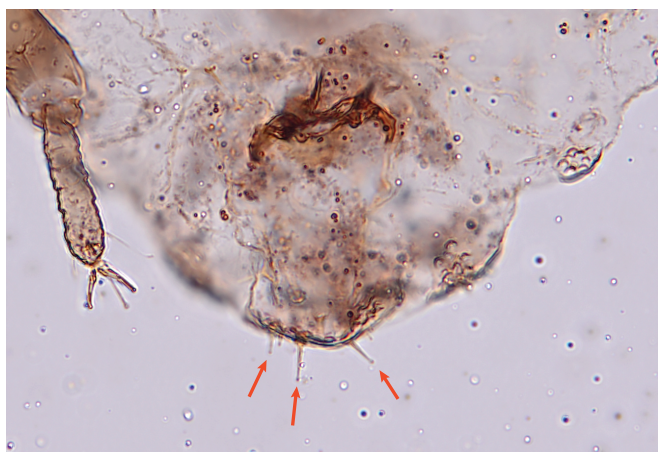
(Sussky and Elkinton 2014). In 2021, in the region where the beach deposition was observed, *A. tsugae* density was high after a couple of years of relatively warm winters, and a higher than usual number of alate sexuparae was observed on hemlock trees (Jennifer Weimer, unpublished data).

DNA barcode and morphological evidence (Figure 5) confirmed that hemlock woolly adelgid was the insect species that constituted the black substance on Wells Beach, and the similar description and timing of the reports on the other beaches in the region lead us to believe it was responsible there as well (Figure 1). Other adelgid

Figure 4. Slide-mounted hemlock woolly adelgid sexupara collected from Wells Beach, Maine.



Figure 5. Knobbed setae on the tip of the abdomen of a hemlock woolly adelgid sexupara collected from Wells Beach, Maine. Setae are indicated by red arrows.



species in the region are not likely to have contributed to this phenomenon because they rarely produce sexuparae (e.g., *Adelges piceae* Ratzeburg and *Pineus strobi* Hartig), or despite having synchronized flight of sexuparae and/or gallicolae, are much less abundant than hemlock woolly adelgid [e.g., *Adelges abietis* L., *Adelges lariciatus* (Patch), and *Pineus pinifoliae* (Fitch)]. We conclude that the high *A. tsugae* population density in southern New England in the Spring and Summer of 2021 led to an extraordinary number of sexuparae being produced in early June. These insects were likely blown out to sea where they died, and were washed ashore by a sea breeze, creating the mass deposition on beaches reported throughout the region. We are not aware of any previous reports of mass beach deposition of adelgid sexuparae, but it is possible that this will be a recurring phenomenon in years with mild winters as long

as hemlock remains abundant in coastal New England.

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