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The Red Bark Phenomenon

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Eastern White Pine

Eastern Hemlock

In Connecticut and Massachusetts, there have been many recent observations of a novel condition which causes intense reddish orange coloration of tree bark, termed here for the first time as the red bark phenomenon (RBP). Preliminary surveys, annual assessments of long-term hemlock plots, and annual Forest Health Monitoring plot surveys in Connecticut (Fengler pers. comm.) all indicated that this is a condition that has only recently been detected to any noticeable degree in New England during 2008-2010. Many conifer and hardwood tree species (over 20 species), were found to be affected in a survey conducted in Connecticut in 2009-2010, with the condition being most prevalent on white pine, eastern hemlock, red oak and American beech. RBP has also been noticed to a greater extent in Maine, New Hampshire and Vermont and RBP has now been observed throughout New England (personal observations Cheah 2008-2016 Connecticut; Massachusetts, Gooch; Maine, Ostrofsky, Donahue; New Hampshire, Lombard, Vermont, Winiarski). The tree species affected are of particular concern as many are of important economic value: oaks form the dominant forest species type in Connecticut, while in Massachusetts, pine and oaks are the dominant species. Maples, dominant in New Hampshire and Vermont, are also affected. In Maine, maple and pine are also important forest species after spruce and balsam fir. Eastern hemlock is also a major species affected in all the states and is already under stress from exotic infestations of hemlock woolly adelgid and elongate hemlock scale in New England. The causal agent(s) of RBP are unknown but current trends in climate change in the northeast, in particular warming seasonal temperatures, increased precipitation punctuated by droughts, and more turbulent weather may be related to the increasing prevalence of RBP across the region.

There are no accounts in the literature referencing the ecological and forest health implications of this bark condition. The following is a description of the red bark phenomenon (RBP) as observed in Connecticut from 2008-2010.

Description and Distribution

The phenomenon appears as a distinctive reddish-orange crust or film which coats bark plates, fissures and ridges or smooth trunk surfaces and has been observed on both individual or small groups of diverse trees (Fig. 1a-f) and in whole tree stands (Fig. 2a & b). While initial observations of this bark condition occurring on eastern hemlock were noted 6 years ago in northwestern Connecticut at Great Mountain Forest, Norfolk (Bronson, pers. comm.), recent Connecticut tree health surveys in 2009 and 2010 have also documented the arrival and increasing abundance of this bark condition in annually monitored plots. Long term annual crown health assessments of twenty-three Connecticut hemlock stands have been maintained for 5-10 years (Cheah 2008). These eastern hemlock plots span a wide range of habitats, topography, elevations and soil types throughout Connecticut and include assessments of biological control releases, insect pests such as the hemlock woolly adelgid and elongate hemlock scale, and/or diseases. In 2009 crown health assessments, RBP was recorded for the first time in 26% of these Connecticut sites (Cheah unpublished data). In the winter and spring of 2009-2010, extensive road and state forest and park surveys in Connecticut also detected the widespread occurrence of RBP affecting many diverse conifer and hardwood species (Fig. 3a & b). Other affected trees in Connecticut include apple, green ash, white, yellow and sweet birches, black cherry, American elm, pignut and shagbark hickories, European larch, Norway, red and sugar maples, chestnut, black, scarlet and white oaks, red pine, and Norway spruce. Red bark has also been observed more recently in increasing intensity and abundance in 2011, especially in Massachusetts (hemlock and white pine; Gooch, pers. comm.), Maine (white pine and hemlock; Ostrofsky, Donahue, pers. comm.), New Hampshire (hemlock, hickories and oaks; Lombard, Weimer, pers. comm.) and Vermont (white pine; Winiarski, pers. comm.).

Affected trees appear to be of varying age classes, and are often, but not exclusively, observed near bodies of water, such as swamps and rivers. Aspects of the tree trunk affected with this coloration ranges from the north to west and occasionally on the southwest aspects, usually on one side of the tree. Observations of affected trees in Connecticut were more abundant at all elevations in the northern half of the state but, also in scattered locations nearer the coast. A detailed survey of the literature finds no mention of this phenomenon in North America. Microscopic examination of tape lift samples from various affected tree bark in the winter of spring of 2010 indicated that the organism(s) in question were not fungi, protozoa nor bacteria, but, microscopic green algae (*Chlorophyta*) characterized by branching mats of filamentous series of single cells (10-20 µm in diameter) with thick cell walls. The cytoplasma of the cells from different tree species were all filled with bright orange red pigment (Fig. 4a-d), and the algae were tentatively identified as belonging to the genus *Trentepohlia.* The algae can be cultured in petri dishes under laboratory conditions, using Alga-Gro© (Carolina Biological Supply Company) (Fig. 4e,f).

Literature

Trentepohlia, the postulated causal agent(s) of the red bark of woody plant hosts found in New England, belongs to the Trentepohliaceae, Trentepohliates (Ulvophyceae, Chlorophyta) (Rindi et al. 2008). It is a filamentous green alga. However, the presence of large quantities of carotenoid (β-carotene and lutein etc.) and haematochrome in its cytoplasma results in the strong orange-red color of the algal thalli (Noble 2008), which masks the green of the chlorophyll and as a consequence, turns the bark of host trees to red or orange-red. Among the 149 epithets published in the genus, 51 species of *Trentepohlia* Martius are recognized (Guiry & Guiry 2016). The species of *Trentepohlia* are subaerial and free-living algae and occur widely on living and nonliving terrestrial substrates: rocks, stone works, moist soil surfaces, wood, moist concrete structures, building structures, tree trunks, and leaves (Chapman 1984, Rindi and Guiry 2002, Thompson and Wujek 1992, Wakefield et al. 1996, Rindi et al. 2008). They also develop associations with fungal hyphae, and are widespread photobionts in lichens (Rindi et al. 2005, (Mukherjee et al. 2010). However, *Trentepohlia* were also found to be pathogenic to plants (Brooks 2004, Brooks et al. 2015). The majority of *Trentepohlia* species occur in subtropical and tropical areas (Chapman and Good 1983, Thompson and Wujek 1992) but, some species are also found in temperate regions with humid climates (Hoffman 1989). In temperate regions, *Trentepohlia* species can only occur where there is adequate moisture or high relative humidity and favorable light conditions and are thus sensitive to environmental change (Hoffman 1989). Collins (1928) reported seven species of *Trentepohlia* from North America over 80 years ago. At present, only eight species are currently described and distributed in the US (Guiry & Guiry 2016). Reported species in New England are *T. abietina* (Flotow) Hansgirg (=*Trentepohlia aurea* var. *corticola* Wolle) from New Hampshire and Vermont; *T. iolithus* (Linnaeus) Wallroth from Maine, Massachusetts, New Hampshire; and, *T. odorata* from Maine, Massachusetts (Collins 1928). Three species of *Trentepohlia* were reported in Connecticut: *T. jolithus* (Linnaeus) Wallroth (as *T. iolithus*) (on rock, misted with lichen), *T. effusa* (Krempelhüber) Hariot (=*Printzina effusa* (Krempelhuber) R.H. Thompson & D.E.Wujek) (on tree bark and stone work) and *T. aurea* (Linnaeus) C.F.P. Martius (on limestone rocks) (Hylander 1928), but, our preliminary morphological observations showed that the samples of *Trentepohlia* collected in 2010 from tree boles did not fit the descriptions of any of these native species. It is unknown at this time if this is a *Trentepohlia* species new to science and if the same species occurs on diverse tree hosts.

Reasons for the noticeable expansion of RBP over such a diversity of tree hosts are not known at this time. Observations and preliminary studies over the past year in Connecticut point to the rapid local expansions of this condition (within 2-3 months) during the winter and early spring of 2010. This expansion may be related to environmental changes in winter conditions (e.g. the carotenoid contents of *T. aurea* and *T. cucullata* increased several fold in winter in India; Mukherjee et al. 2010). Airborne algal spores, cysts and vegetative sections (Schlichting 1969) are known to be dispersed by air currents and deposited in rain, and climatic changes are known to affect spatial distribution and biogeography of airborne algae (Sharma et al. 2007). However, airborne *Trentepohlia* spores were not detected from June through August 2010 during a preliminary aerobiological study at a forest research site in Connecticut, a period marked by extreme heat and drought conditions. Algal growth and reproduction are dependent on physical factors such as temperature, water (moisture or relative humidity), light, pH, nutrients and a host of other factors (Agrawal 2009). Projections of climate change in the Northeast include rises in seasonal and annual temperatures, reflected in warming winter temperature trends (Cheah 2016 under review) which would result in heavier and wetter snowfall but, less snow cover overall; higher annual precipitation including an increase in extreme precipitation events; more frequent short-term droughts; changes in the timing of the seasons e.g. the accelerated arrival of spring and expanded growing seasons; and increases in the ocean temperatures and projected rises in sea-levels (NECIA 2006).

Trentepohlialean algae have long been recognized as biodeteriogens of buildings (Wee and Lee 1980, López-Bautista et al. 2002, Gaylarde et al. 2006), inflicting progressive mechanical degradation and decay of stone structures (Noguerol-Seoane and Rifon-Lastra 1997). The potential for red bark alga(e) to degrade the outer bark, the tree's first line of defense against insect and pathogen attack, has not been investigated.

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Fig.1. Red bark conditions on a) eastern hemlock b) white pine c) red oak d) American beech e) shagbark hickory f) black cherry (pictures by Carole Cheah)

(a) Eastern hemlock

(b) White pine

(c) Red Oak

(d) American Beech

(e) Shagbark hickory

(f) Black Cherry

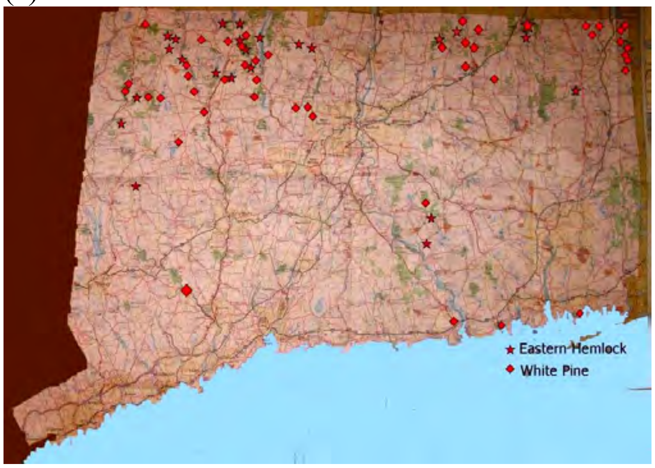
Fig. 2. Red bark phenomenon in (a) white pine and (b) eastern hemlock stands in Connecticut (Photos by Carole Cheah)

(a) White pine (Southwestern CT)

(b) Eastern hemlock (Northeastern CT)

Fig. 3. 2009-2010 Connecticut surveys for RBP on a) white pine and eastern hemlock and b) red oak and American beech (maps by Carole Cheah)

(a)



(b)

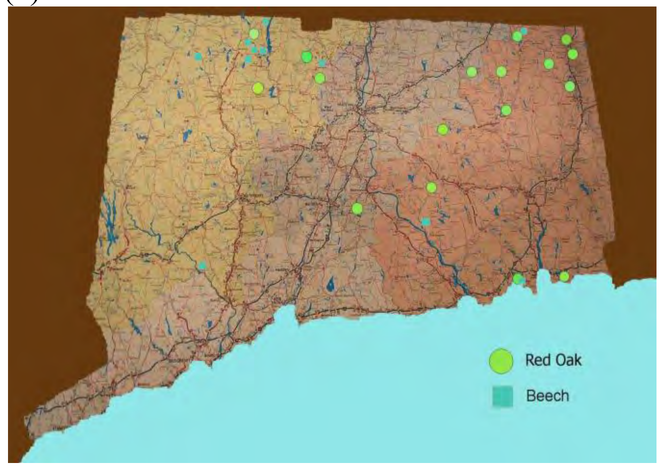
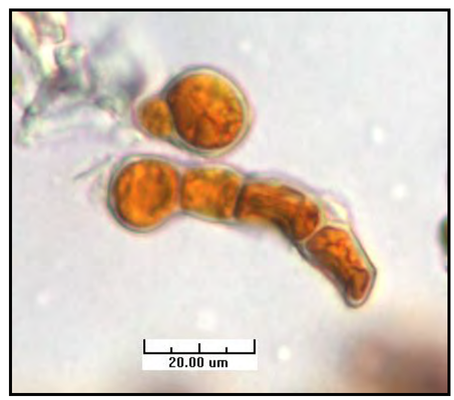


Fig. 4. Cells of the red bark alga(e) *Trentepohlia* collected from Connecticut trees in 2010 indicating the range in cell size (a-d); pictures by De Wei Li; in laboratory culture (e-f) pictures by Carole Cheah)

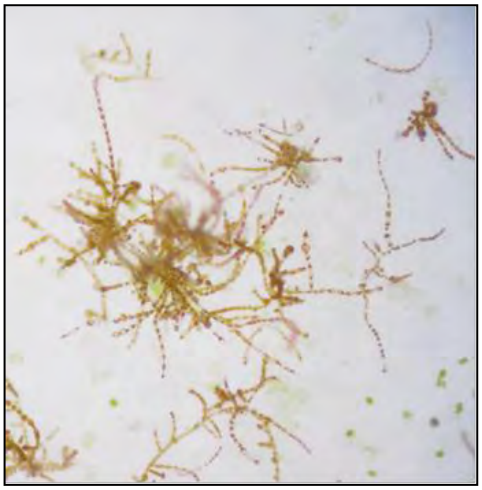
(a) Hemlock

(b) White pine



(c) American beech

(d) Red oak


(e) Red oak samples


(f) Shagbark hickory samples