Insertion Site Selection & Feeding of the Hemlock Woolly Adelgid:

Implications for Host-Plant Resistance

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The Hemlock Woolly Adelgid

Adelges tsugae

- Small, sucking insect

- Native to Asia, PNW
  - 1951: Richmond, VA
  - So. Japanese origin

- Kills susceptible trees in 4+ yrs

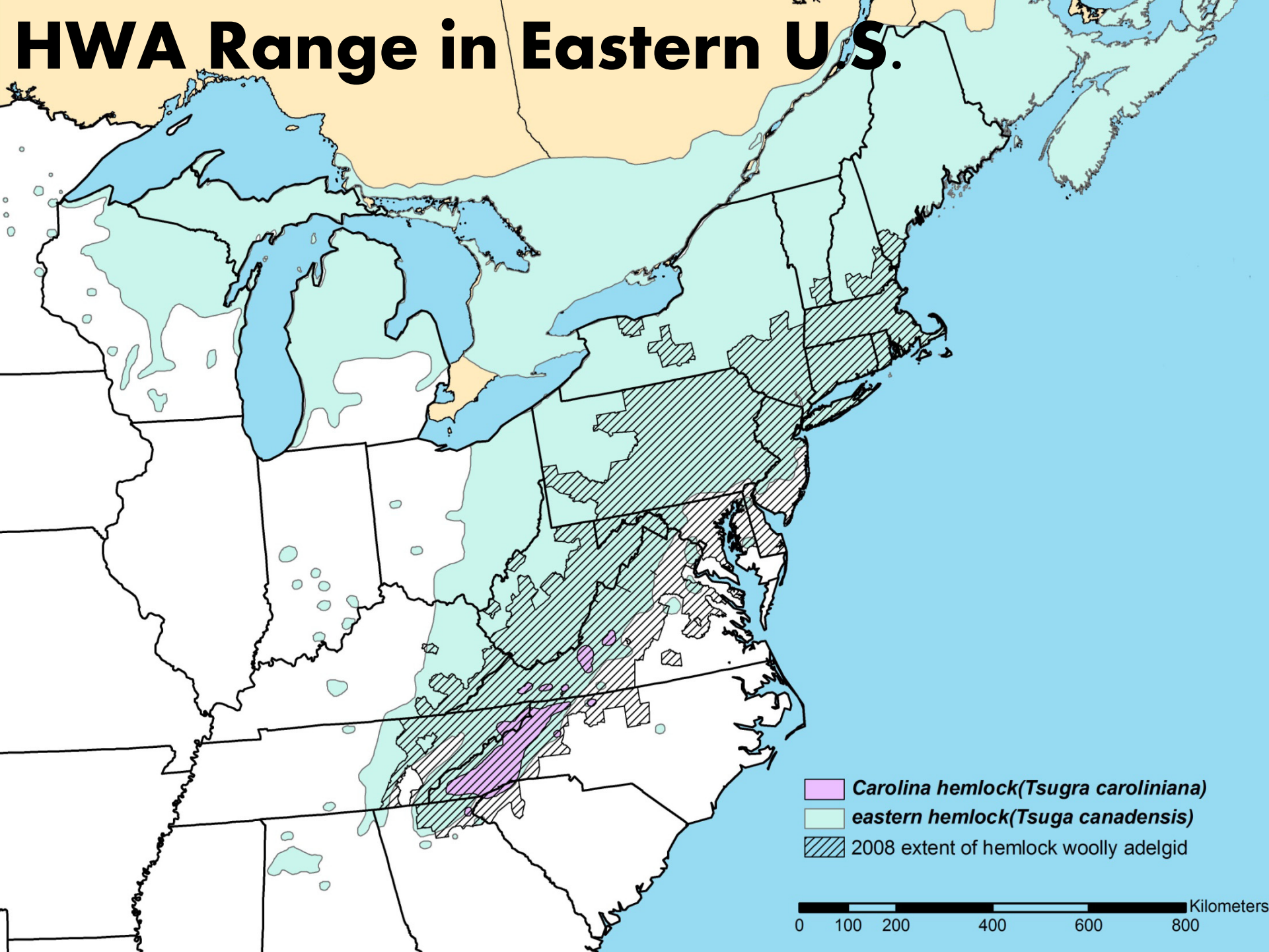
Newly infested hemlock in Durham, NC

Dead hemlock at Linville Falls, NC

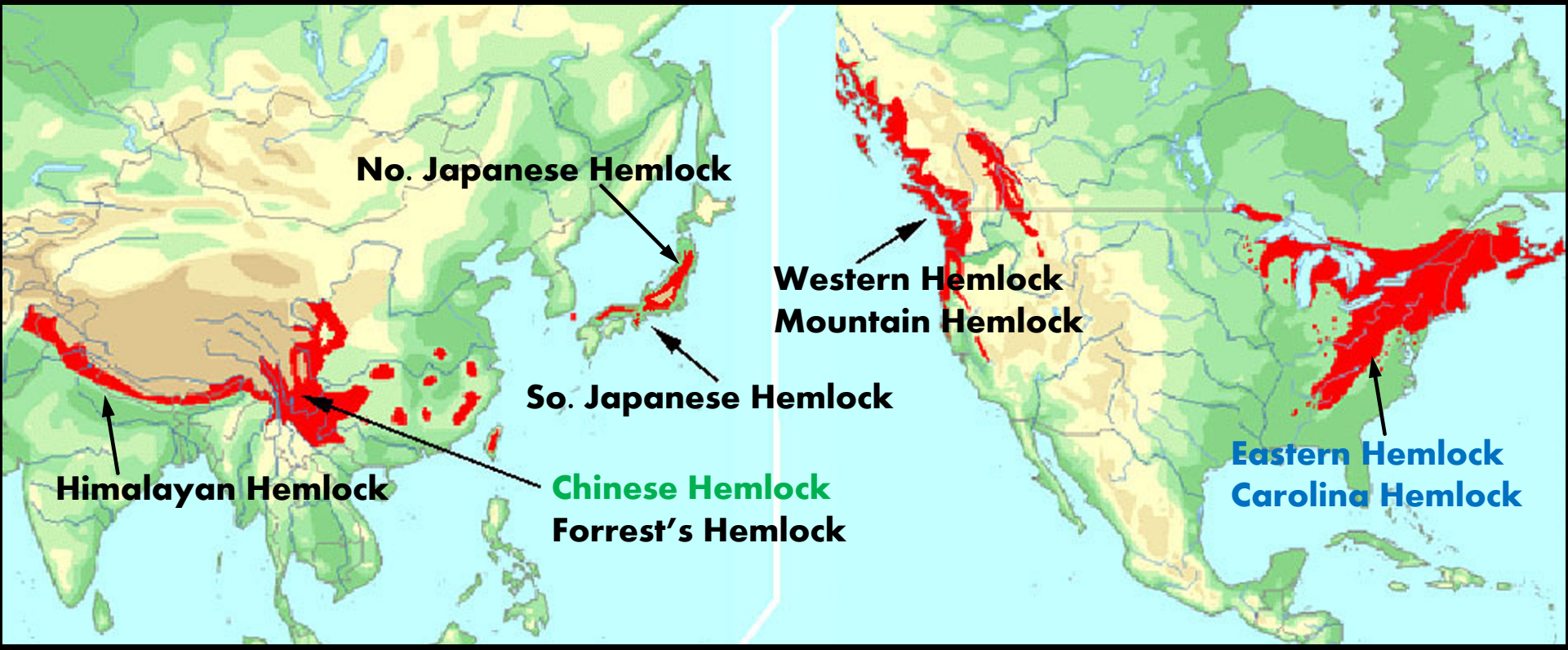
Shenandoah National Park

Great Smoky Mountains National Park

HWA Range in Eastern U.S.



Hemlocks of the World



Inter and intra-specific variation in resistance...

Putative Resistance

Eastern & Carolina Hemlock

- Anecdotal
- Research supported
  - Carolina hemlock more resistant[1, 2]
  - Intraspecific variation[3]
- Identification
  - URI: 4 sites
  - ASTF: currently exploring

[1] Jetton et al. 2008, [2] Oten unpubl. res., [3] Kaur 2009

Why is it important to understand resistance mechanisms?

- Selection of individuals among natural populations
- Screening within a breeding program

How does HWA select its feeding site?

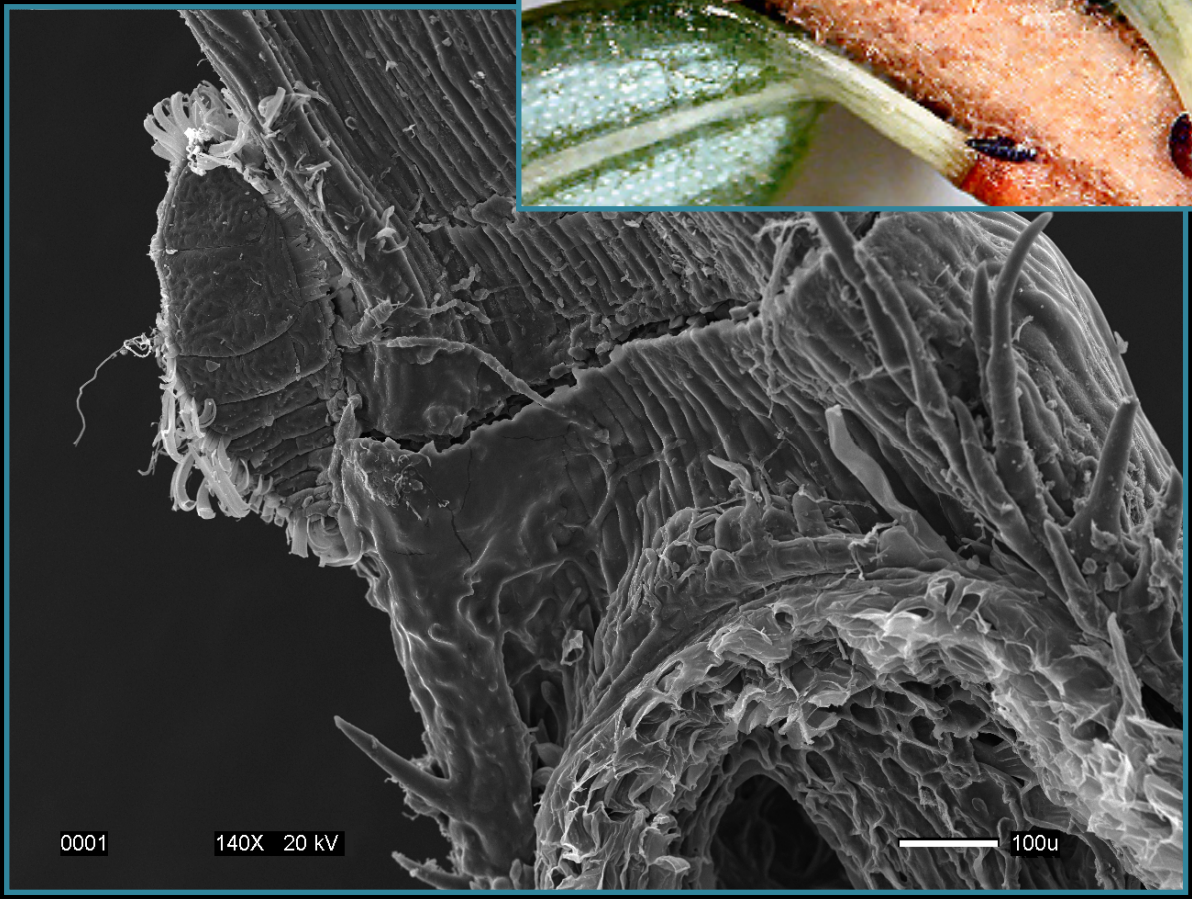
Sequence of steps in host selection[1]:

1)Habitat location

2)Host location

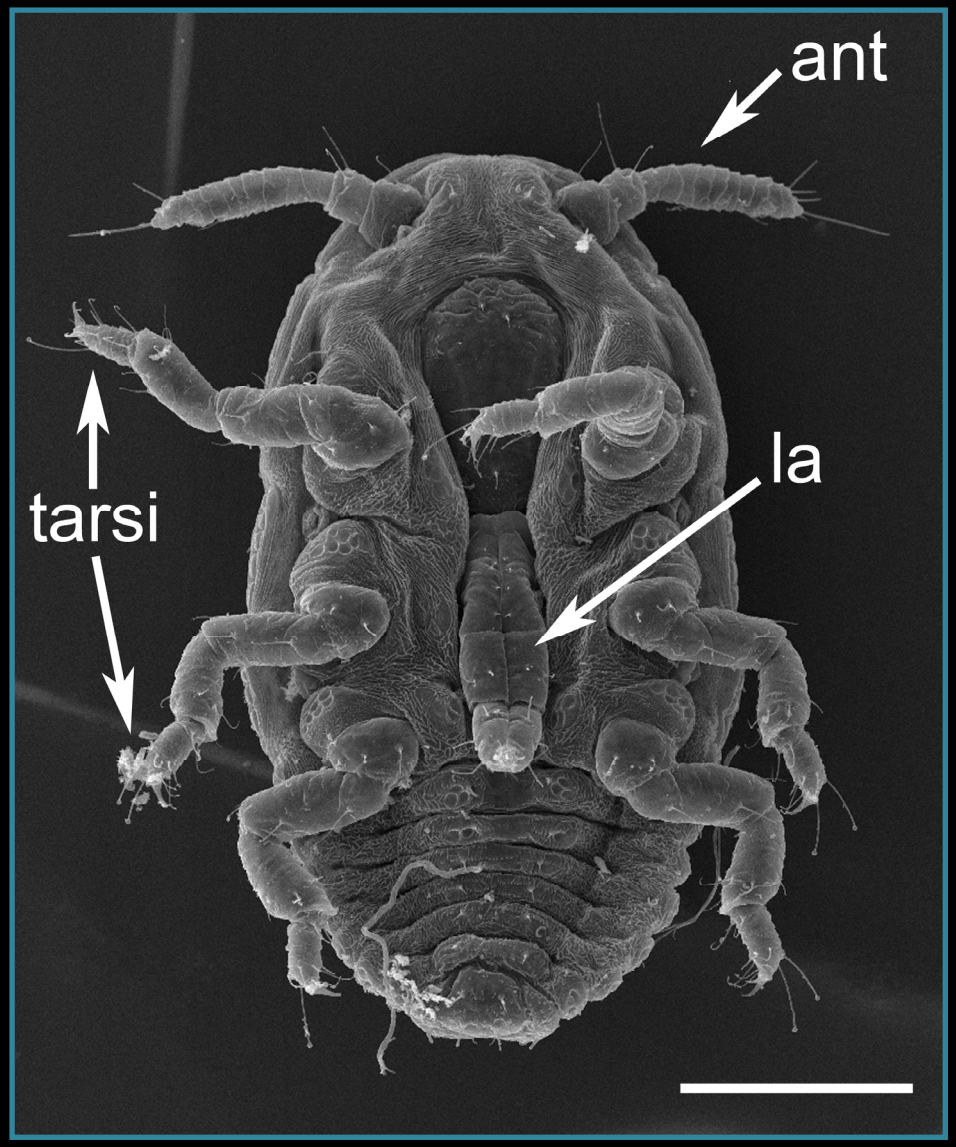
3)Host acceptance

4)Host use

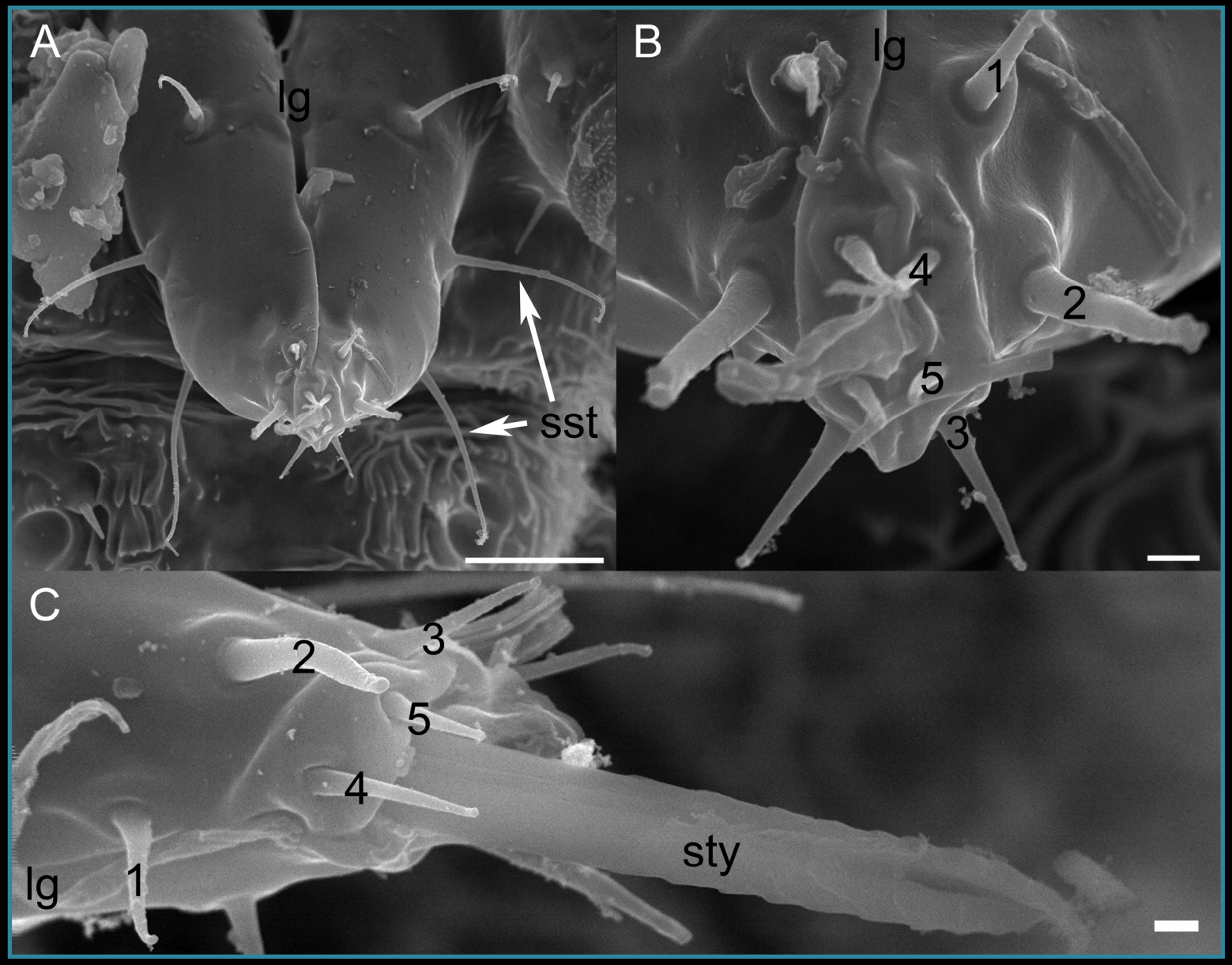


[1] Bernays & Chapman 1994

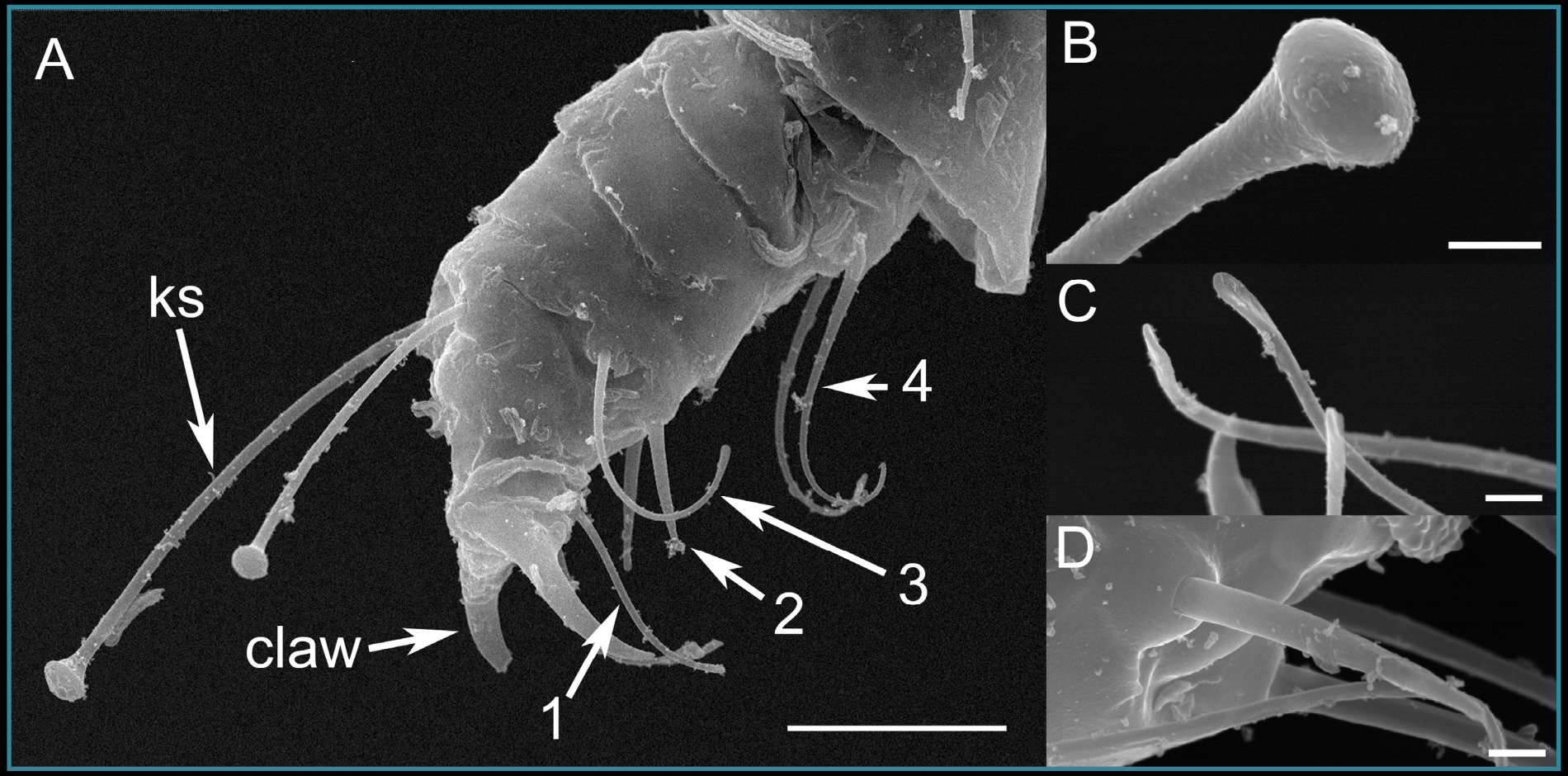
HWA sensilla



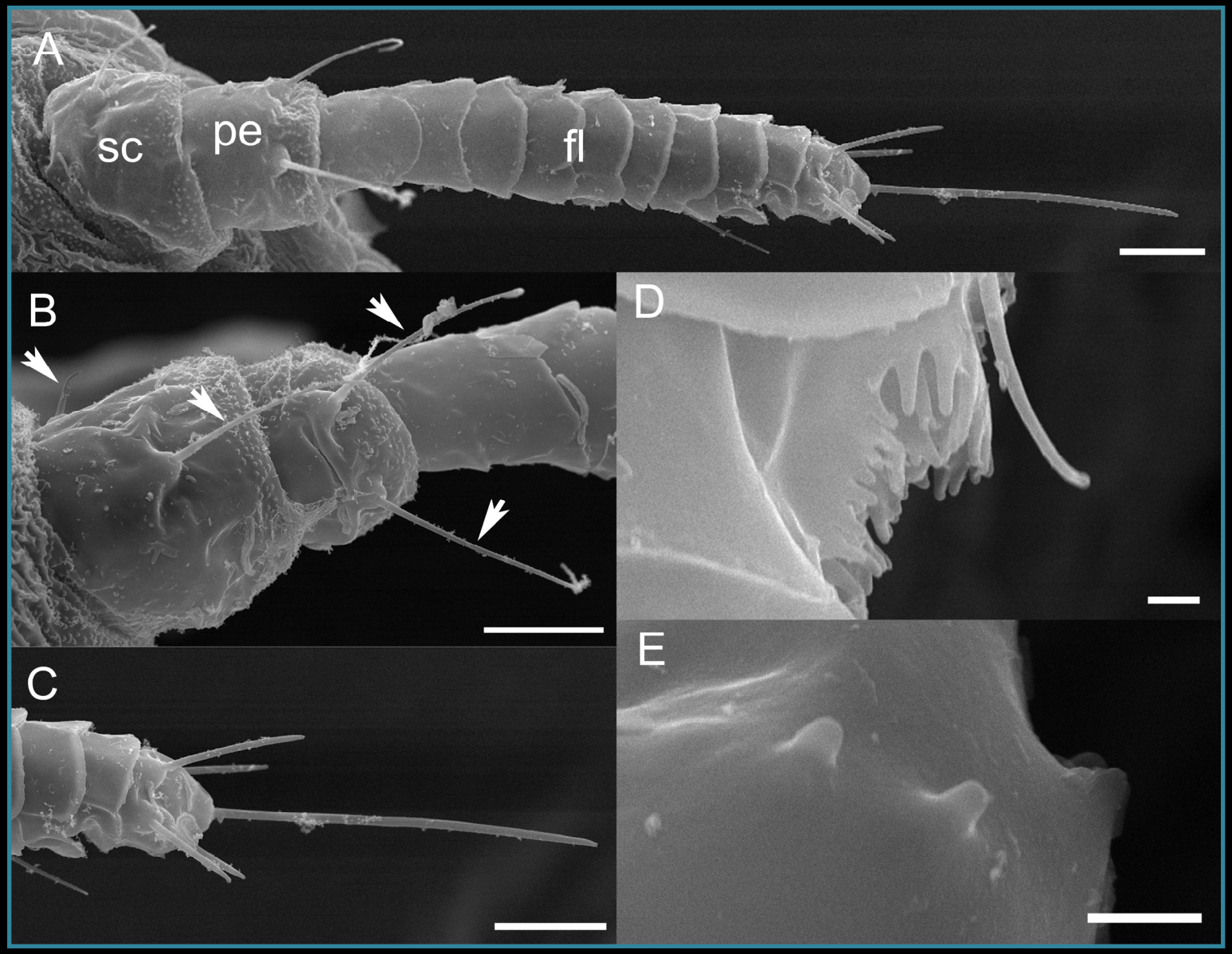
Labial tip



Tarsi



Antennae



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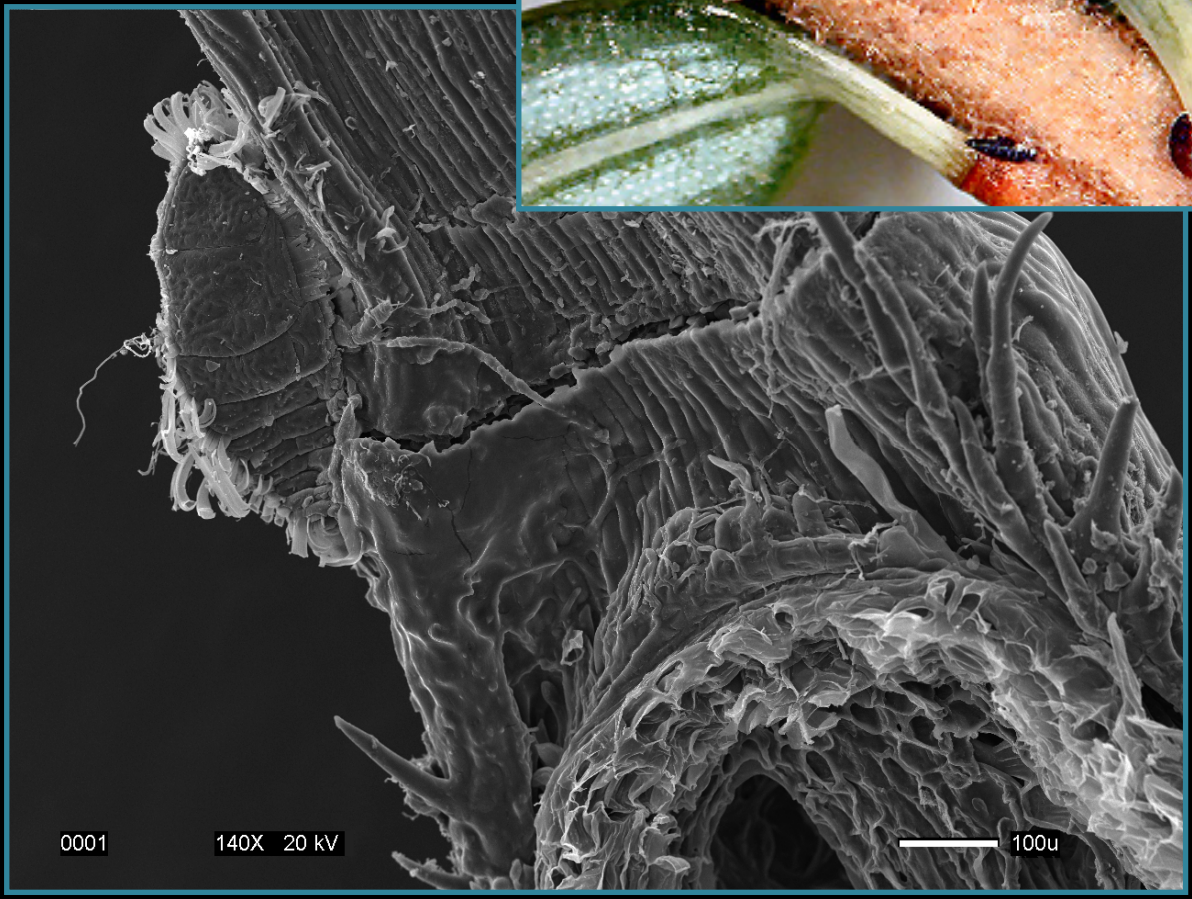
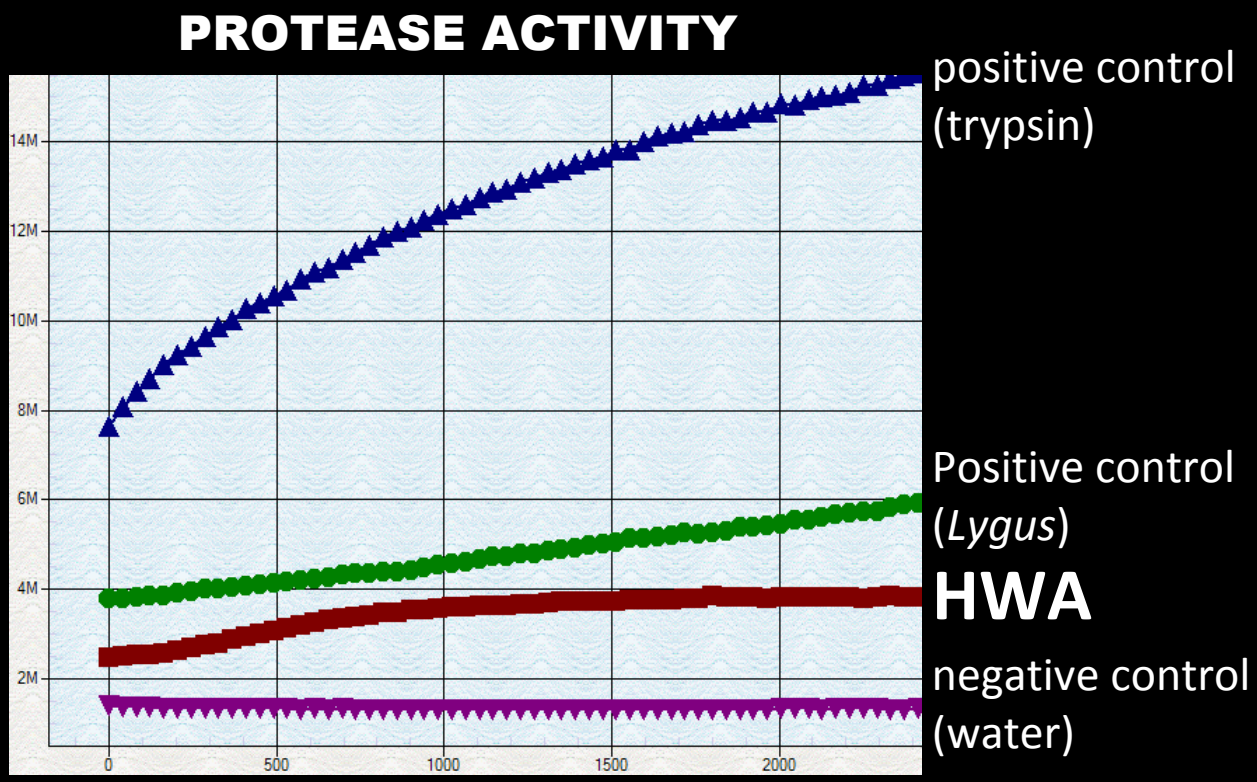


[1] Bernays & Chapman 1994

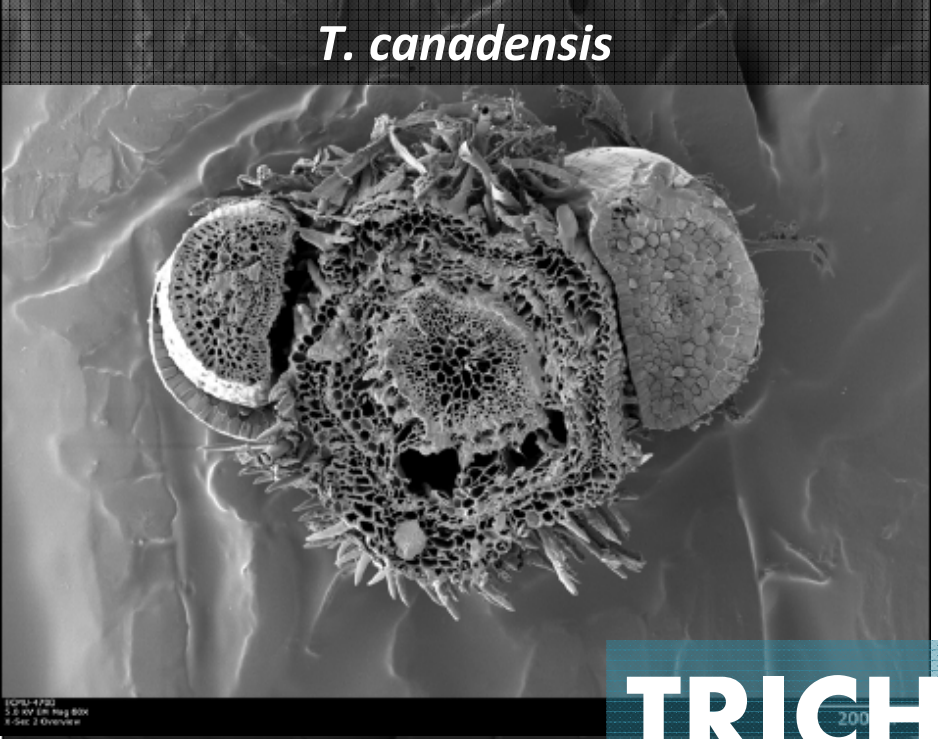
HWA Digestive Enzymes

- Protease 👍
- Amylase 👎?
- Peroxidase
- Polyphenyloxidase
- Pectinase

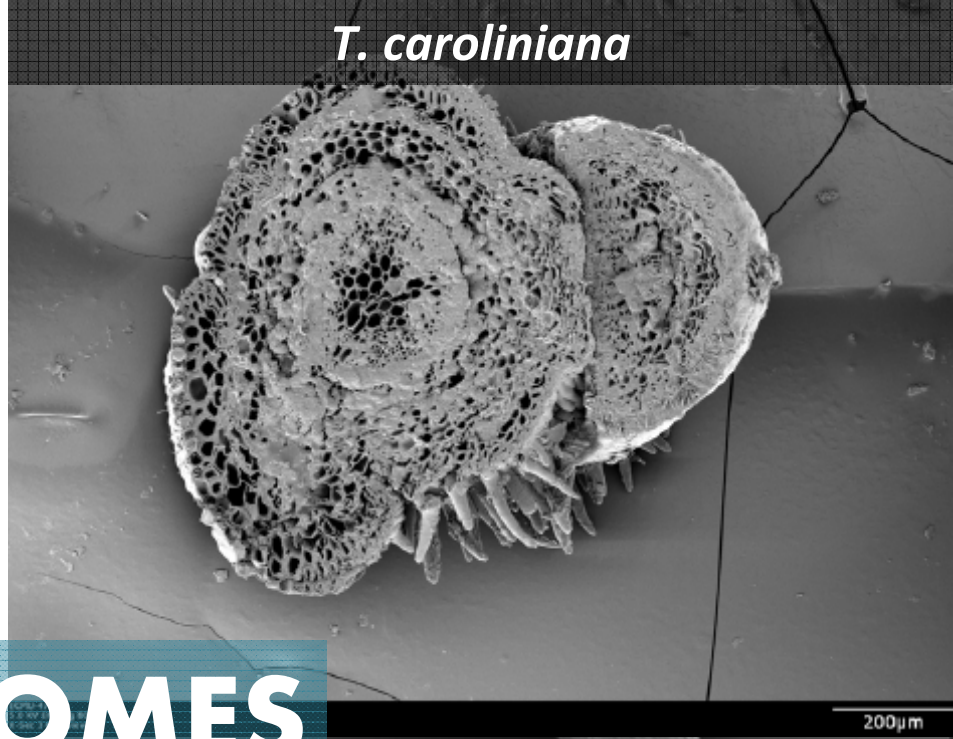


Defensive mechanisms of the hemlock

TRICHOMES

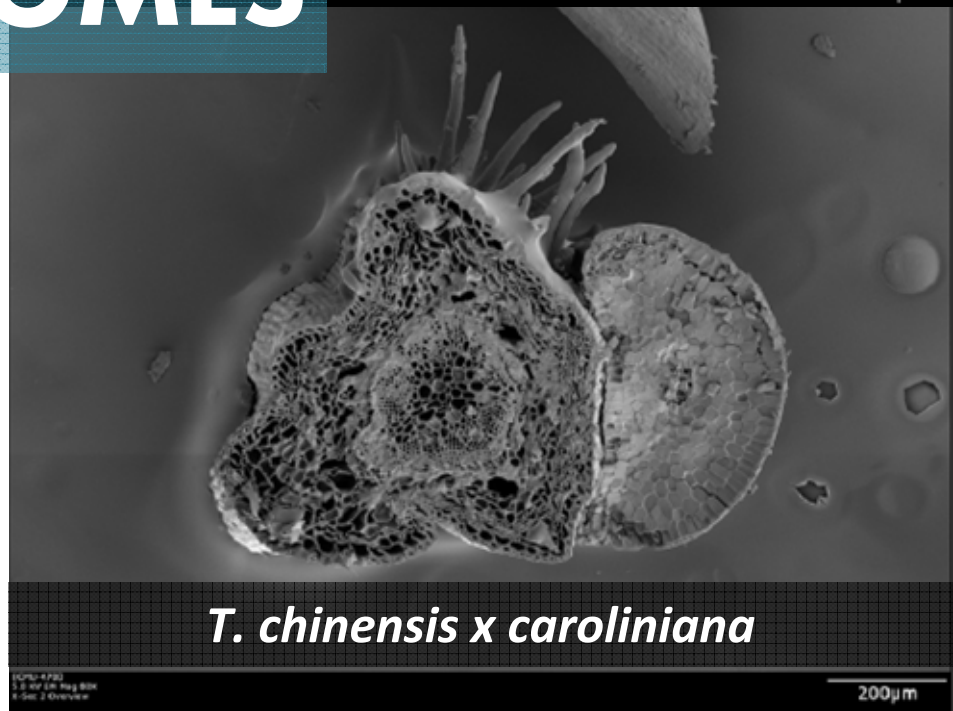


T. canadensis



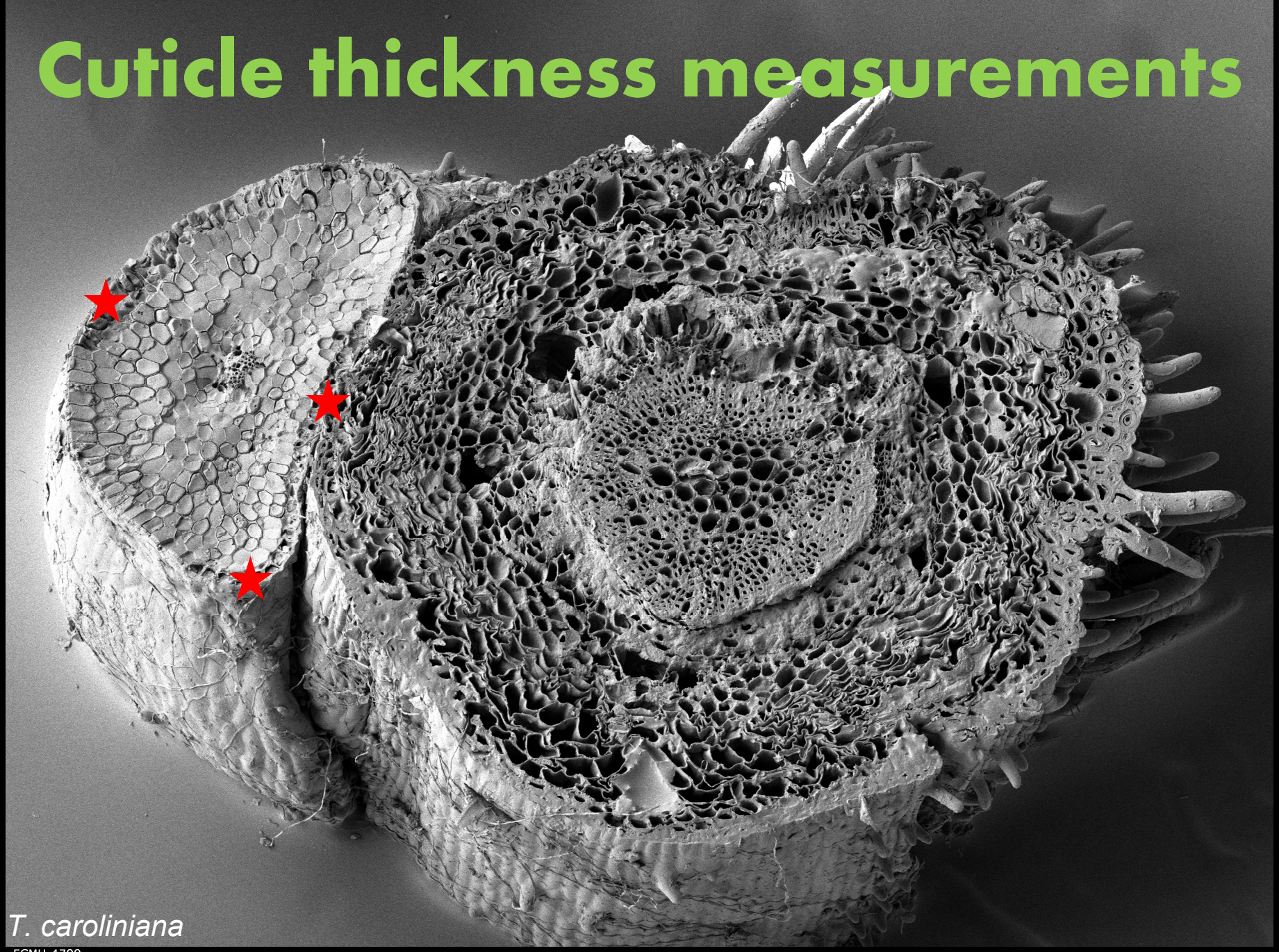
T. caroliniana

T. sieboldii

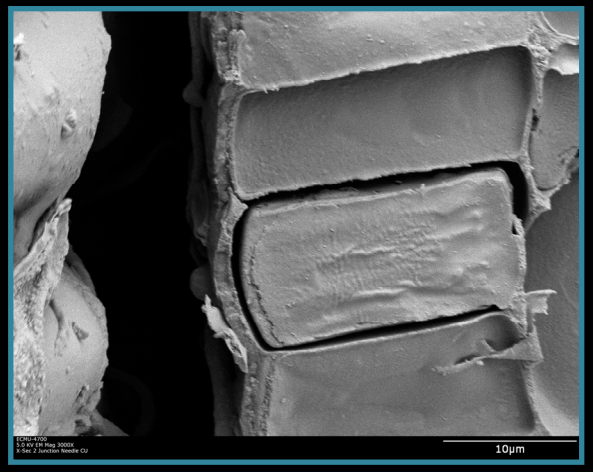


T. chinensis x caroliniana

Cuticle thickness measurements



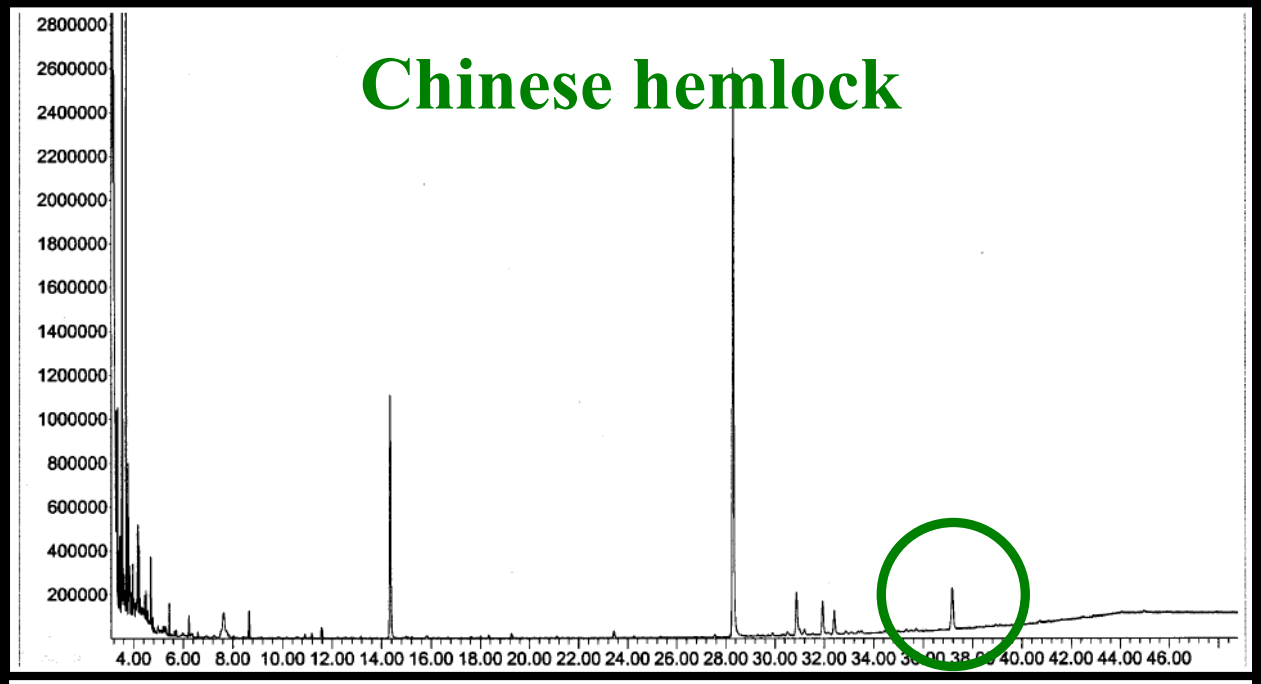
Cuticle thickness (µm)

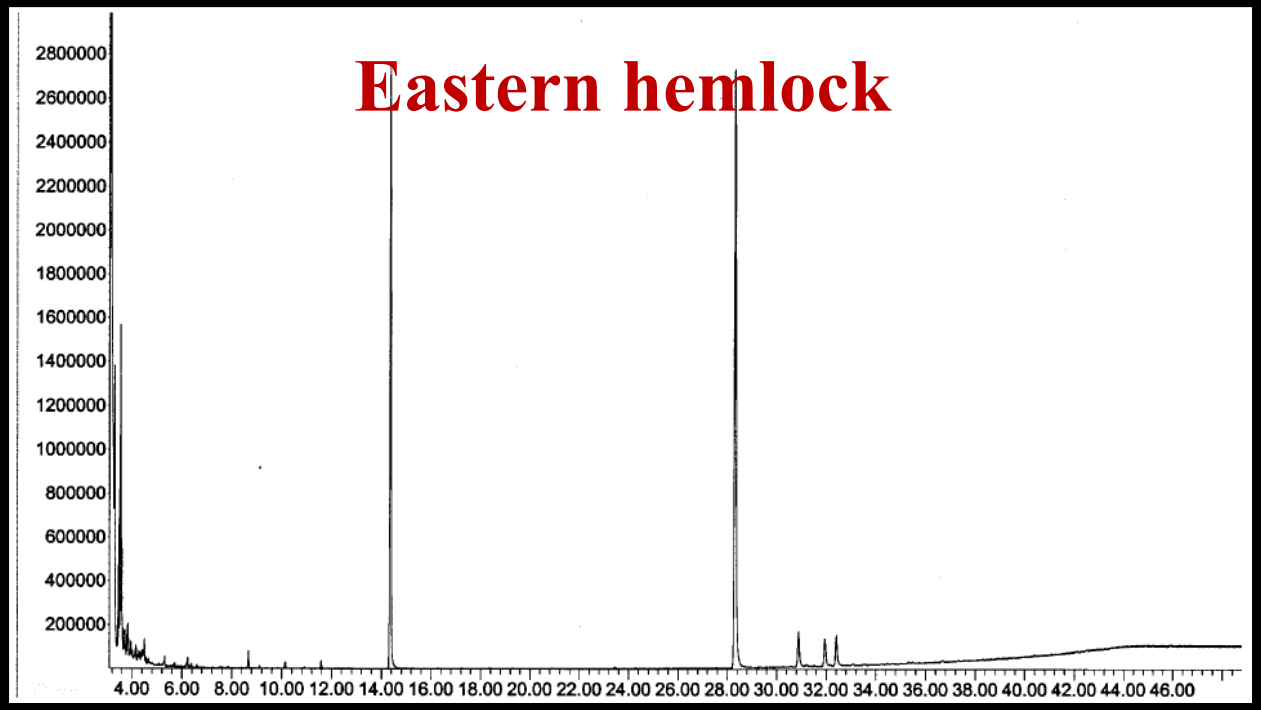


Hemlock species	Insertion Point	Needle Side	Needle Outside
Chinese	2.46 ± 0.86 n=6	2.79 ± 1.84 n=4	2.55 ± 0.71 n=3
Eastern	1.21 ±0.81 n=3	--	--
Carolina	1.74 ± 0.77 n=3	5.62 ± 0.60 n=3	--
Southern Japanese	2.28 ± 1.17 n=2	--	--
Northern Japanese	2.13 ± 0.53 n=2	3.94 ± 0.64 n=3	4.12 ± 0.27 n=2

Waxes: GC/MS

WASTE
HEXA
CH2C

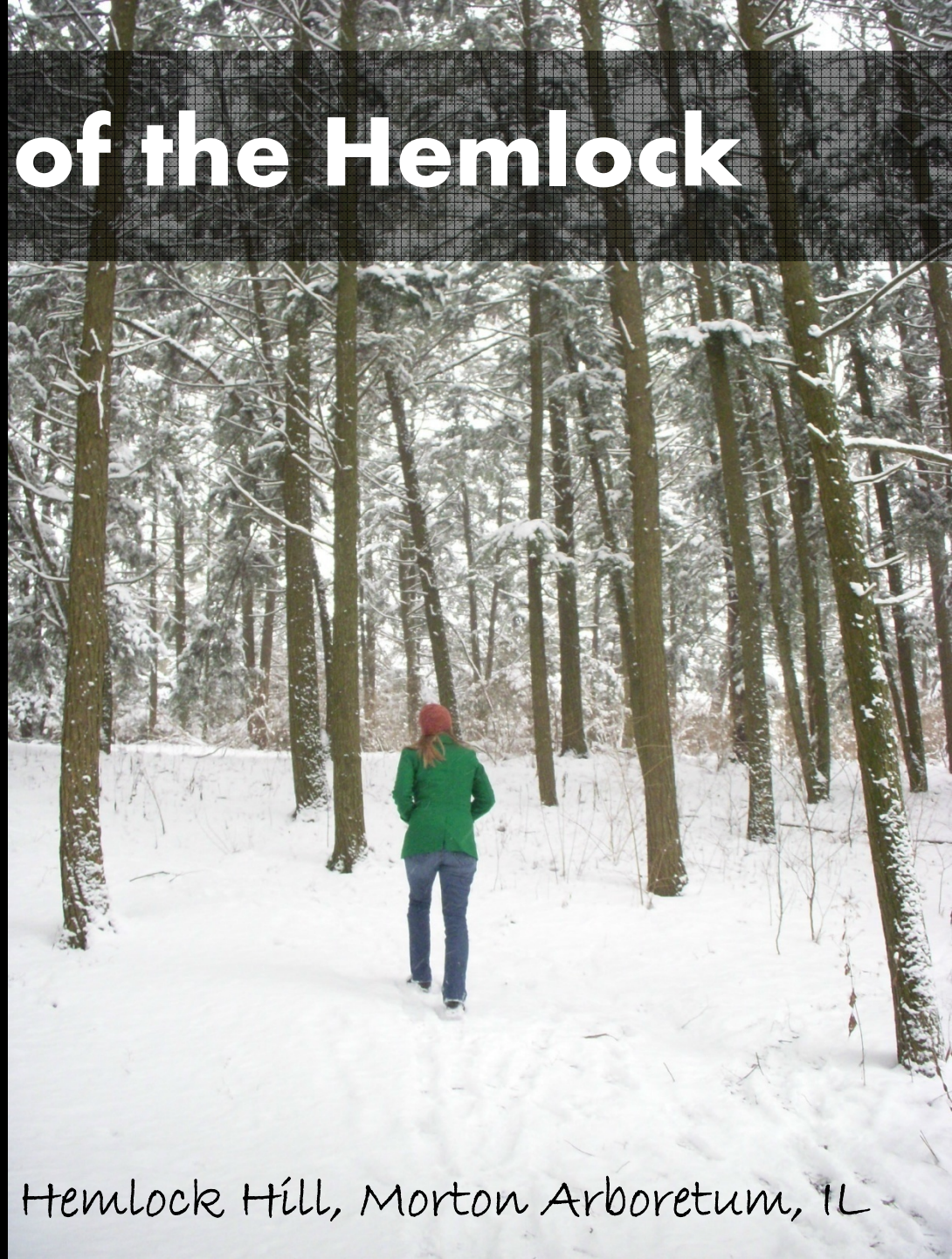

Chinese hemlock
2800000
2600000
2400000
2200000
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 24.00 26.00 28.00 30.00 32.00 34.00 40.00 42.00 44.00 46.00


Eastern hemlock
2800000
2600000
2400000
2200000
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 24.00 26.00 28.00 30.00 32.00 34.00 36.00 38.00 40.00 42.00 44.00 46.00

The Future of the Hemlock

Host plant resistance should be part of an IPM program to control HWA.

- **Breeding programs**
  - **Restoration**



Hemlock Hill, Morton Arboretum, IL

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Contributors:

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Gary Bauchan, USDA (LT-SEM)
Valerie Knowlton (SEM lab)
NCSU Veterinary Entomology Lab

Hemlock samples:

NC State Parks
Morton Arboretum, Lisle, IL
National Arboretum, Beltsville, MD
Glenn Kohler (Washington state)

Mountain hemlock
Crater Lake National Park