

Establishment of the hemlock woolly adelgid predator, *Laricobius nigrinus* (Coleoptera: Derodontidae), in the Eastern U.S.

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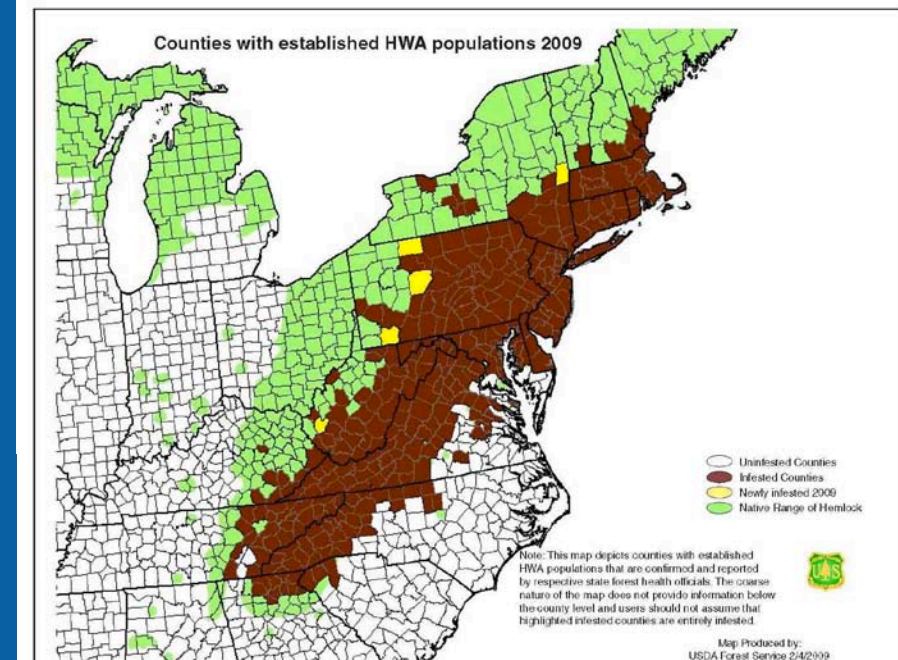
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Northampton, Massachusetts

HWA, *Adelges tsugae* (Hem: Adelgidae)

- Native to the Pacific Northwest and Asia
- Introduced accidentally to Virginia from Japan (Havill & Montgomery 2006, *Annals Entomol. Soc. Am.*)
- First considered an invasive pest in the 1960's (VA Dept. Agric. and Consumer Services, unpub. report)
- The most important hemlock pest
- Extensive areas of moribund hemlock and mortality



Hemlock forests are forests at risk

Mt. Toby Experimental Forest, UMASS

- Few stand and landscape variables affect hemlock susceptibility and mortality in CT (Orwig et al. 2002, *J. Biogeography*)
 - Trees regardless of age or health can succumb
 - Trees succumb quicker on xeric sites
 - Duration of infestation primary factor that explains damage patterns



Foreign exploration for safe natural enemies

- China, Japan, Taiwan, Pacific Northwest of North America
- Predators under quarantine evaluation with releases likely coming soon
 1. *Laricobius osakensis* (Japan)
 2. *Leucopis* spp. (PNW)
- One derodontid beetle released
 1. *Laricobius nigrinus* (PNW)
- Three coccinellid beetles released
 1. *Sasajiscymnus tsugae* (Japan)
 2. *Scymnus sinuanodulus* (China)
 3. *Scymnus ningshanensis* (China)



Laricobius nigrinus (Col.: Derodontidae)



Dr. Leland Humble: Research Scientist, Entomology, Canadian Forest Service, Victoria, British Columbia

Laricobius nigrinus (Col.: Derodontidae)

- Native to PNW
 - Highly co-adapted with HWA
 - Narrow host-range (Zilahi-Balogh et al. 2002, *Biological Control*)
 - Synchronized with HWA
 - Oviposits in sistens ovisacs
 - Feeds on progrediens & sistens at base of needles
 - Fall, winter, spring active
- Voracious larvae
- Cold hardy
- First release in 2003 (Lamb et al. *CJFR* 2006)



To increase the supply of *L. nigrinus*

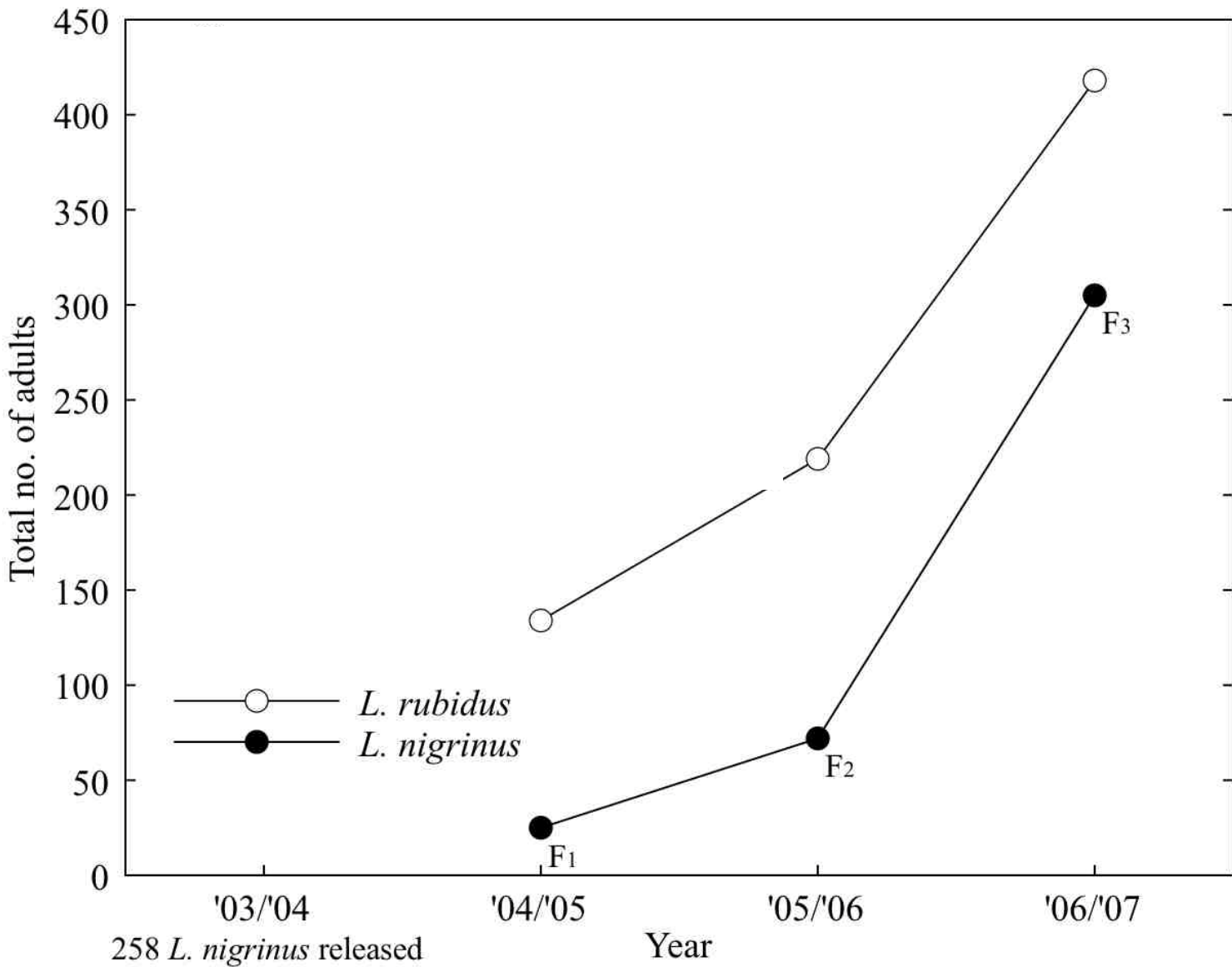
- **Objective:** Produce beetles at “field insectaries” in the East to supplement rearing operations
- Field Insectary in Virginia
 - Planted 300 trees in 2001
 - Infested with HWA in 2002 - 2003
 - Released 258 *L. nigrinus* in 2004
 - Collection and redistribution in 2007



Eastern hemlock field insectaries



L. nigrinus pop. growth at Kentland Farm



(Mausel et al. 2008, *Env. Entomol.*)

Exploratory release study

- Objective 1: Determine establishment rates
- Objective 2: Expand release guidelines
- Lab-reared beetles from Victoria, British Columbia, Canada
- Mixed release strategy
 - Location: 22 sites in eight states
 - Numbers: 75, 150, 300, 600, 1,200 beetles / site
 - Timing: Fall, winter, spring, sequential
- Establishment
 - Standardized adult and larval sampling
 - For 3 yr (up to F_3 generation)



Release summary

(Site, State)	Release variables							
	Site			Total no. <i>Ln</i>	Season			
	Min. Temp. ^a	Hard. Zone ^b	<i>A. tsugae</i> Den. ^c		Date(s)	Fall	Win.	Spr.
Mt. Tom, MA	-25.5	5b	40.0	150	19 Nov 04	150	--	--
Rothrock, PA	-18.3	6a	19.5	600	4 Dec 03	--	300	--
					20 Apr 04	--	--	300
Bear Run, PA	-18.3	6a	16.9	300	24 Mar 05	--	--	300
Finzel, MD	-21.7	6a	42.3	300	18 Dec 03	--	300	--
Rocky, MD	-16.7	6b	38.4	1,200	23 Nov 04	1,200	--	--
Frederick, MD	-18.9	6b	18.2	75	23 Nov 04	75	--	--
Seneca, WV	-22.8	5a	18.8	600	28 Nov 03	300	--	--
					10 Mar 04	--	--	300
Watoga, WV	-22.8	5a	18.9	300	28 Nov 03	300	--	--
Mon, WV	-22.8	5a	19.0	300	10 Mar 04	--	--	300
North, VA	-23.3	5b	43.1	600	8 Dec 03	--	300	--
					28 Mar 04	--	--	300
Big Stony, VA	-23.3	5b	23.7	300	8 Dec 03	--	300	--
Lick, VA	-21.1	5b	34.6	150	4 Nov 04	150	--	--
Highland, VA	-18.3	6a	58.0	1,200	4 Nov 04	1,200	--	--
Hurricane, VA	-18.3	6a	41.7	300	30 Mar 03	--	--	300
Dickey, VA	-16.1	6a	61.8	75	8 Feb 05	--	75	--
Hem Hill, NC	-16.7	6a	35.6	300	31 Dec 03	--	300	--
Holloway, NC	-16.7	6a	32.9	150	27 Oct 04	150	--	--
Ivy, NC	-13.9	6b	58.1	1,200	14 Mar 05	--	--	1,200
Locust, NC	-15.5	6b	39.9	75	12 Jan 05	--	75	--
Middle, NC	-15.5	6b	48.2	600	12 Jan 05	--	300	--
					13 Mar 05	--	--	300
Laurel, TN	-14.4	6b	23.6	300	17 Feb 04	--	--	300
Overflow, GA	-12.2	7a	41.1	150	26 Oct 04	150	--	--

(Mausel et al. 2010, *Env. Entomol.*)



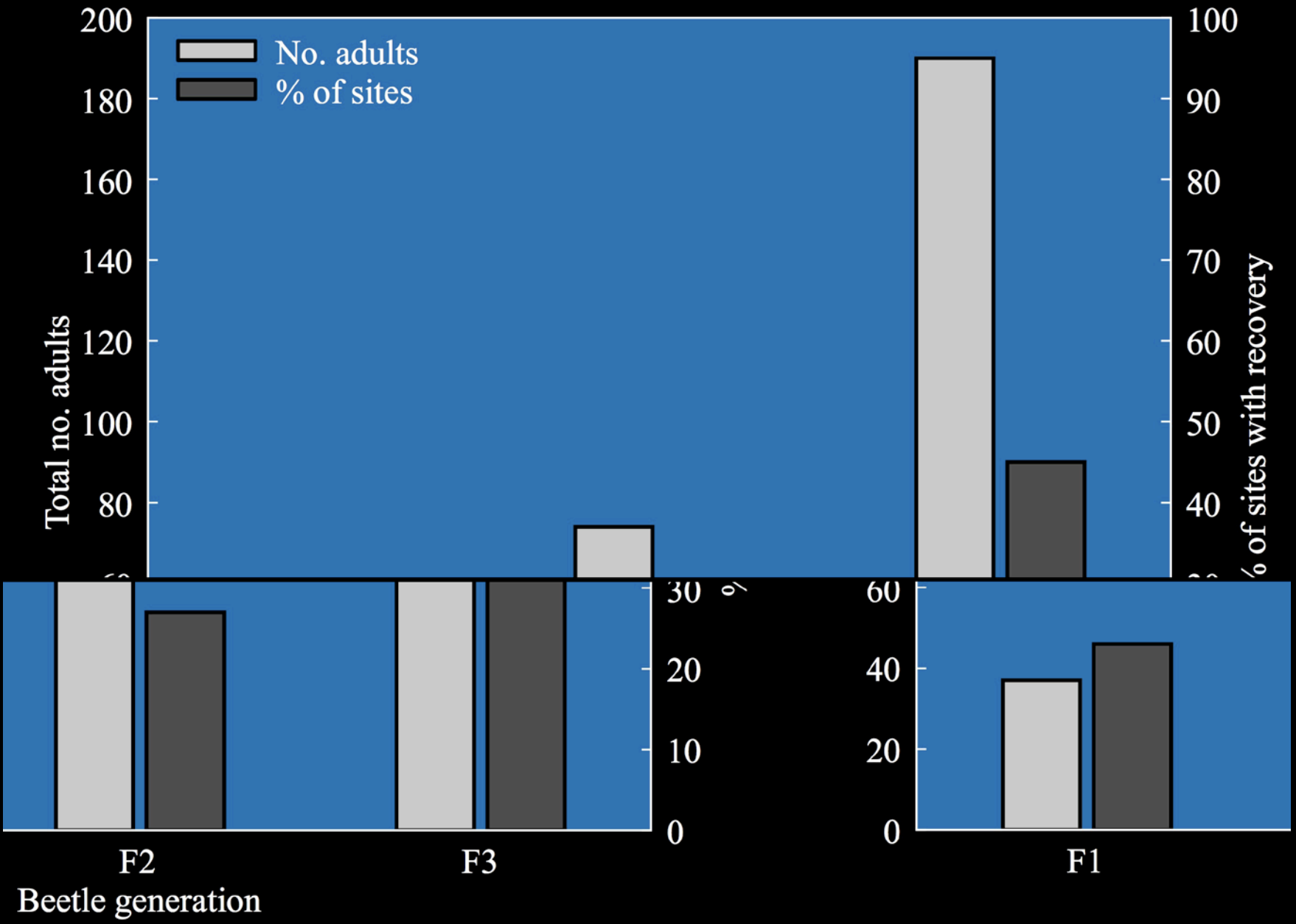


L. nigrinus established (i.e., F₃ recoveries)

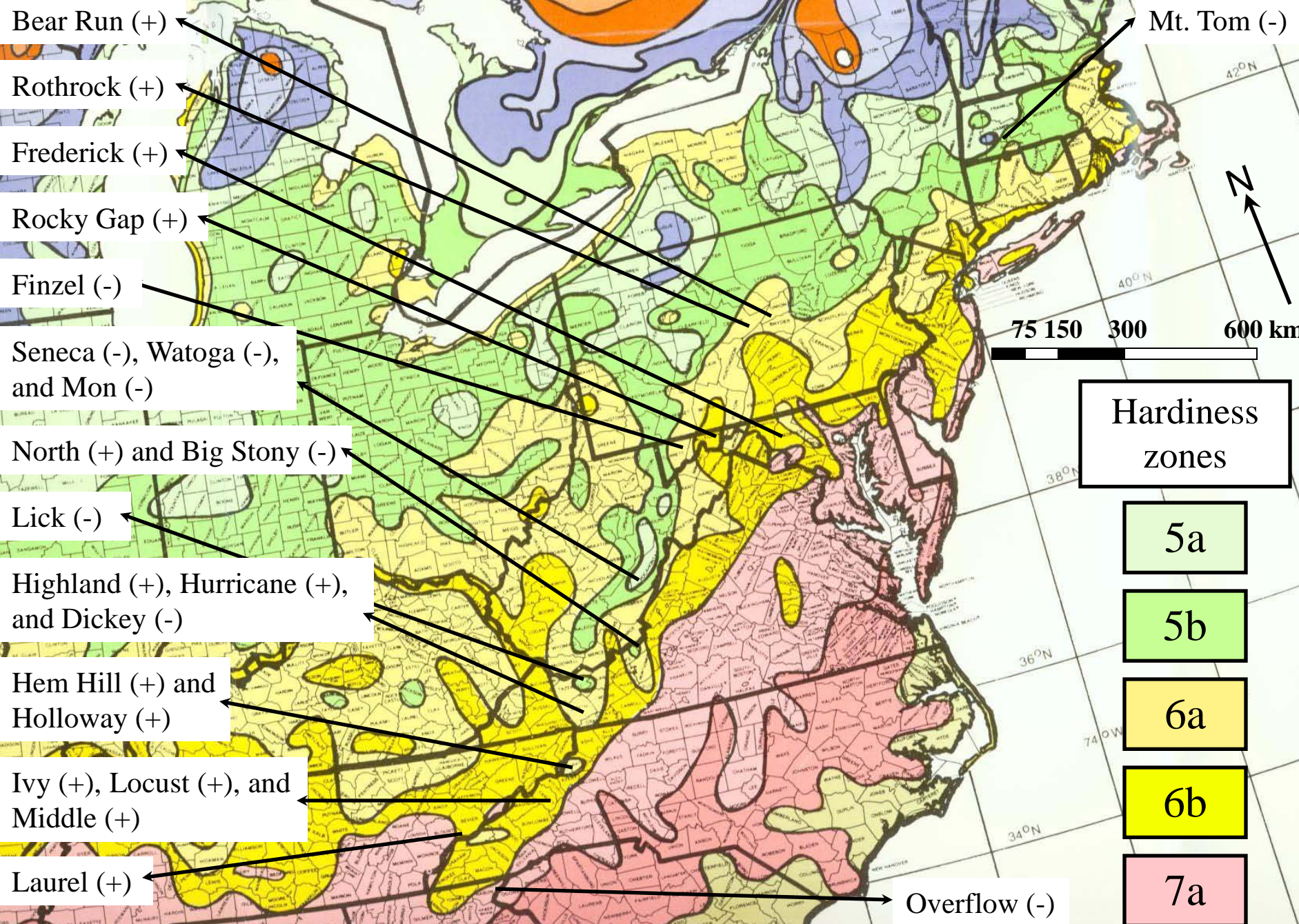
(Site, State)	Post-release recoveries							<i>Ln</i> result
	No. Adults			No. Larvae				
	<i>Ln</i>			<i>Ln</i>		<i>Lr</i>		
	F ₁	F ₂	F ₃	F ₂	F ₃	Yr 1	Yr 2	
Mt. Tom, MA	0	0	0	0	0	0	0	Not established
Rothrock, PA	0	0	8	30	343	7	61	Established
Bear Run, PA	0	1	18	125	311	9	23	Established
Finzel, MD	0	0	0	0	0	0	0	Not established
Rocky, MD	31	49	37	517	440	64	54	Established
Frederick, MD	0	1	15	1	14	1	5	Established
Seneca, WV	0	0	0	0	0	10	158	Not established
Watoga, WV	0	0	0	0	0	16	114	Not established
Mon, WV	0	0	0	0	0	0	7	Not established
North, VA	0	0	0	23	32	5	7	Established
Big Stony, VA	0	0	0	0	0	2	44	Not established
Lick, VA	1	0	0	5	0	5	0	Not established
Highland, VA	0	0	9	0	62	6	0	Established
Hurricane, VA	1	0	1	19	1	14	0	Established
Dickey, VA	0	0	0	0	0	52	27	Not established
Hem Hill, NC	3	13	93	10	314	0	0	Established
Holloway, NC	1	9	9	2	2	24	20	Established
Ivy, NC	0	1	0	42	868	0	0	Established
Locust, NC	0	0	3	42	109	42	109	Established
Middle, NC	0	0	8	180	1,163	12	74	Established
Laurel, TN	0	0	0	118	31	31	67	Established
Overflow, GA	0	0	0	0	0	0	0	Not established

(Mausel et al. 2010, *Env. Entomol.*)

L. nigrinus increasing in abundance



(Mausel et al. 2010, *Env. Entomol.*)



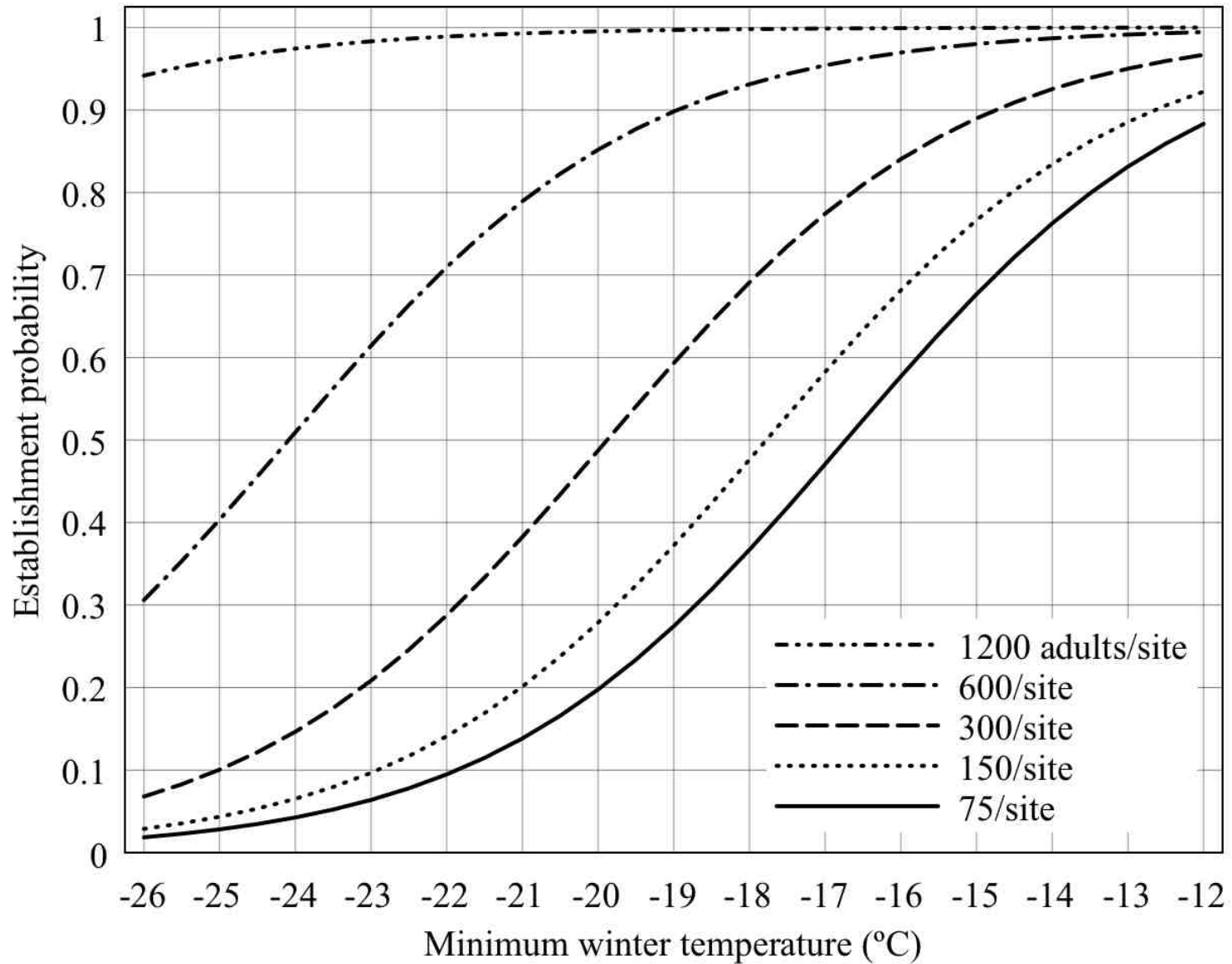
Results: Establishment

- At the end of 3 yr, *L. nigrinus* established at 13 of 22 sites (59 %)
- Establishment probability was positively related to minimum winter temperature and release size

$$P = \frac{1}{1 + e^{-[6.709 + (0.428)(\text{Minimum temp.}) + (0.006)(\text{Release size})]}}$$

- HWA density and release season had no influence on establishment

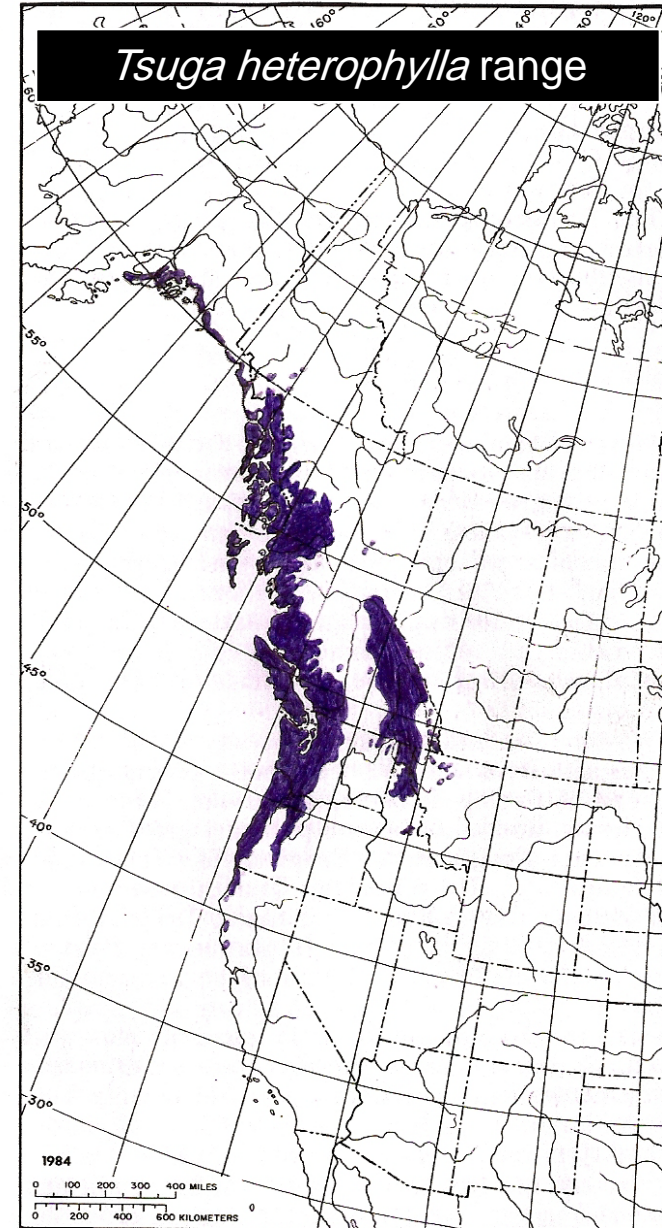
Establishment and temp. and release size



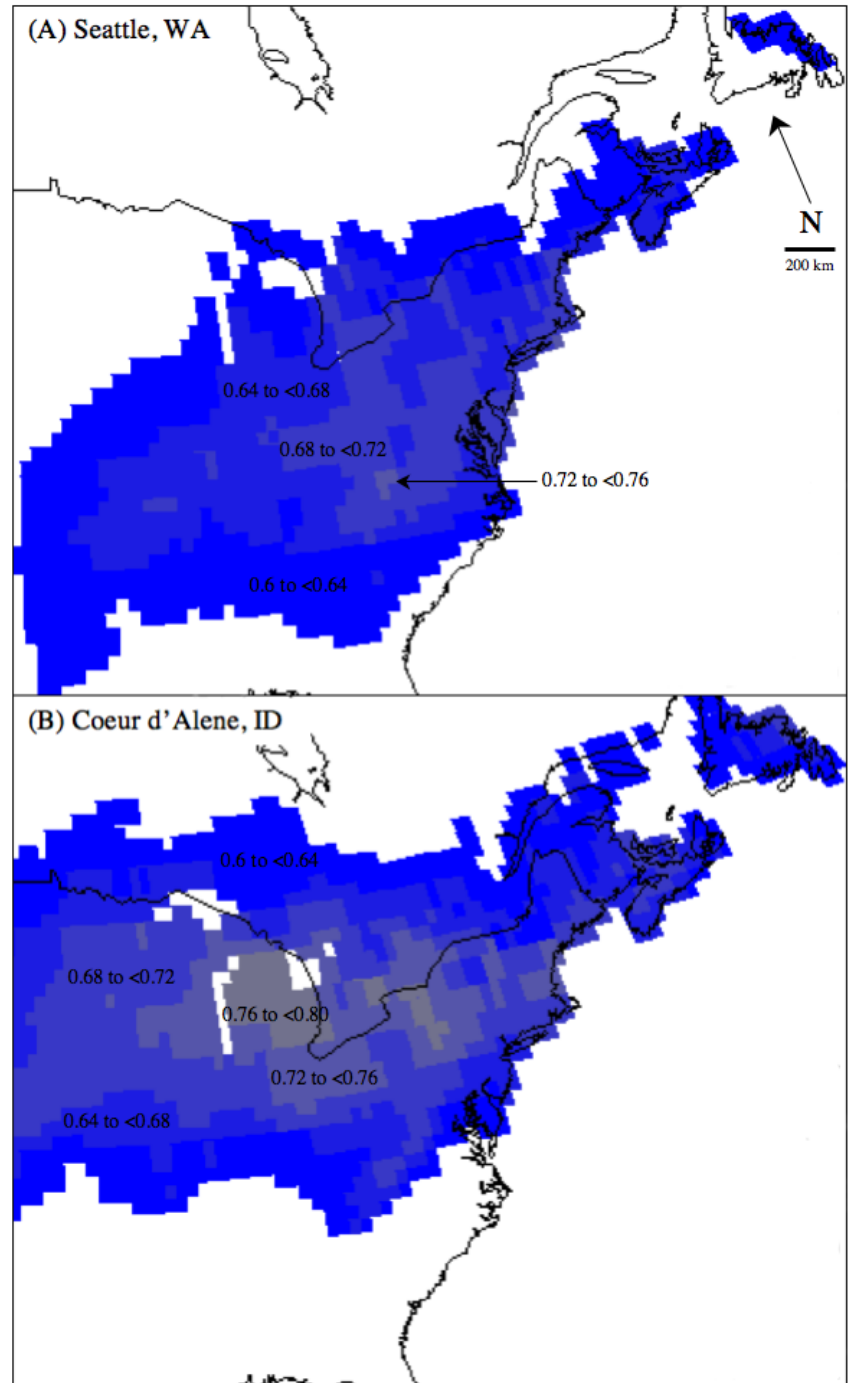
(Mausel et al. 2010, *Env. Entomol.*)

L. nigrinus geographic races?

- *L. nigrinus* specimen from Creston B.C. in the Fender collection (Fender 1945, Pan-Pac. Entomol.)
- Same species?
 - Morphologically identical to coastal population
 - mtDNA (CO1 gene) suggests coastal and inland populations are the same species (0.5% sequence divergence)
 - Not evaluated or released for *A. tsugae* bio-control.
 - ~3,000 adults collected in Idaho and Montana from 2007-2010 for evaluation and release



Climate matching (CLIMEX v.2)



Pacific maritime forest, western Washington

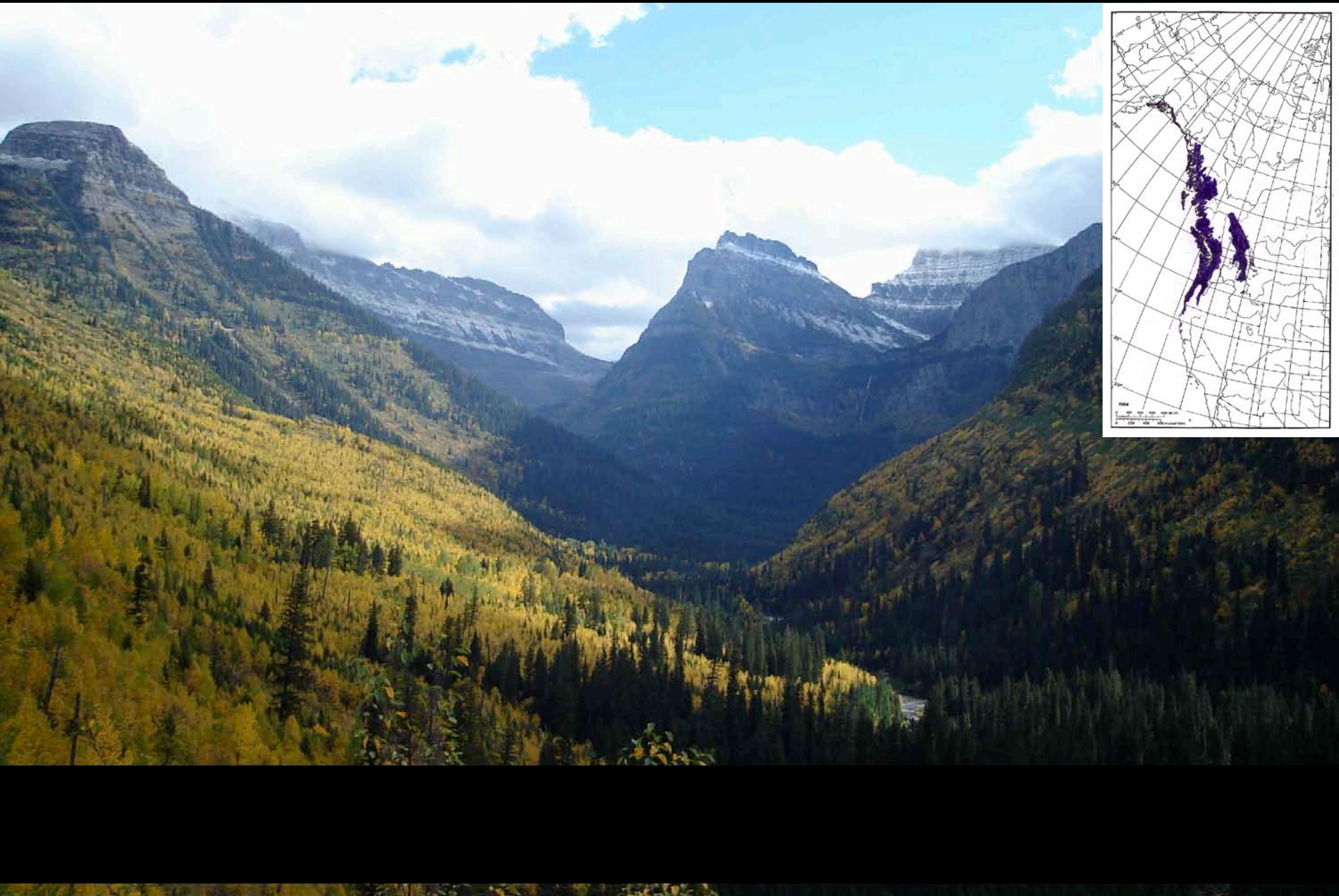


Columbia plateau, eastern Washington



OCT 11 2008

Rocky Mountains, northwest Montana



Rocky mountains, northern Idaho

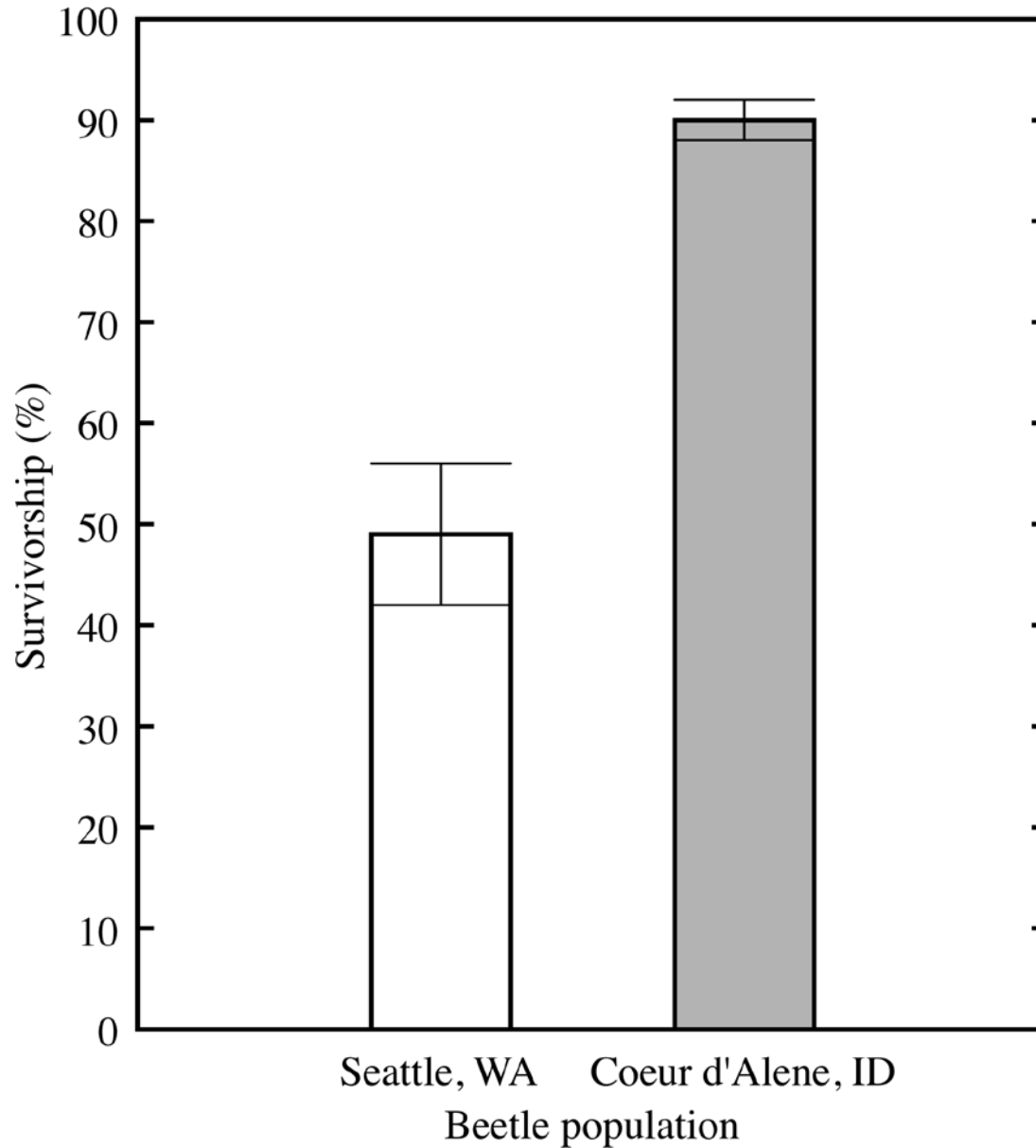


Inland *L. nigrinus* host-range

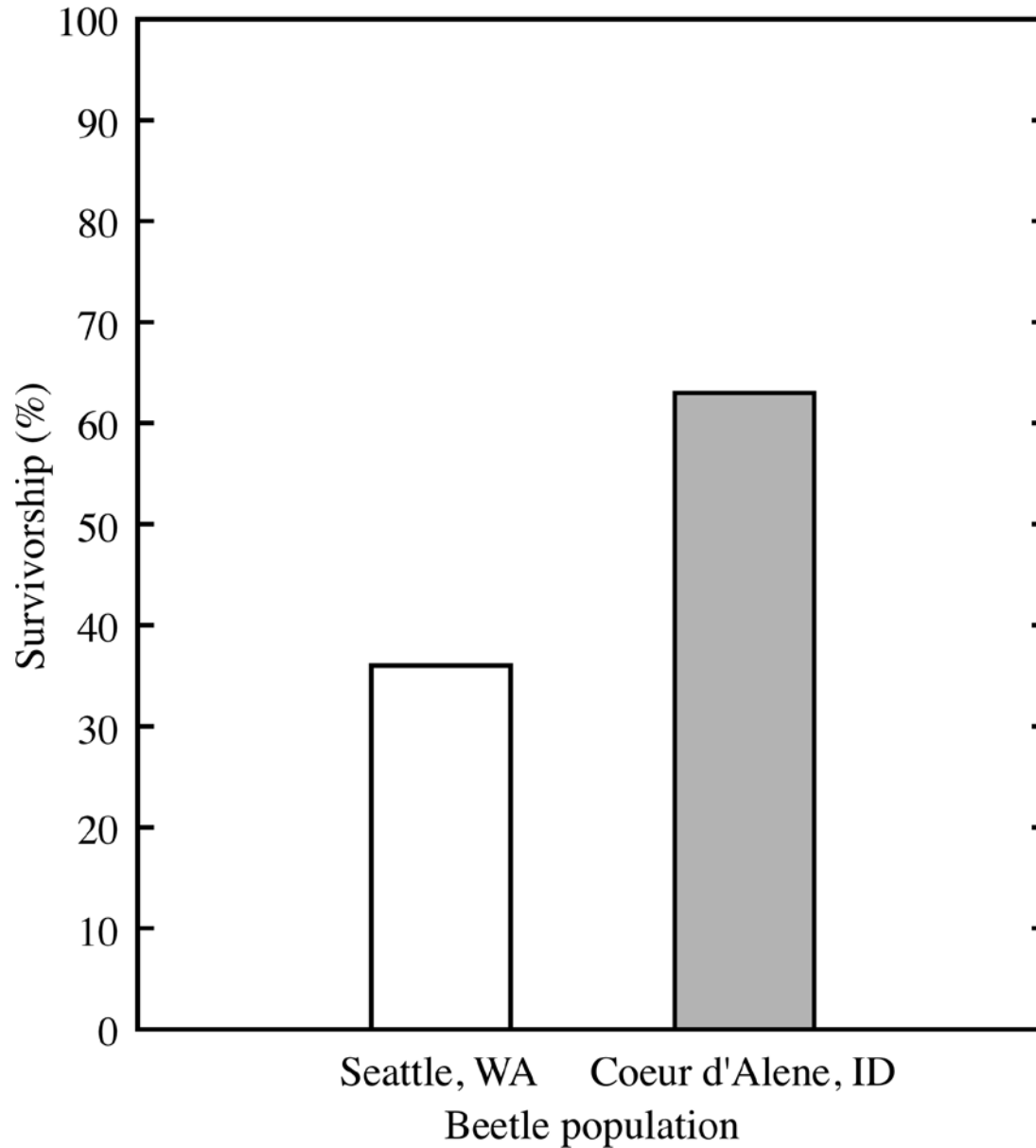
	Test prey	
	<i>A. tsugae</i>	<i>Pineus strobi</i>
Coastal Population (Seattle, WA)		
Feeding	Yes	Yes
Oviposition	Yes	Yes
Development	Yes	No
Inland Population (Coeur d'Alene, ID)		
Feeding	Yes	Yes
Oviposition	Yes	Yes
Development	Yes	No

- Results as in Zilahi-Balogh et al. (2002): narrow host range

Survival in field cages



Survival at -15°C for 18 hours



Long-term research plots in New England

1. Objective: Evaluate *L. nigrinus* impact on...
 1. Hemlock woolly adelgid
 2. Hemlock stand health
 3. Stand structure and vegetation
2. Location: Hemlock dominated forests in the northeast U.S. (Zone 5a and 5b)
3. Year plots established: 2008-2010
4. Completion date: expected to continue
5. Probability of relocating plots: 100%
3. Sampling frequency: 2 yr

Long-term research plots

- Experimental treatments ($n = 14$):
 1. Coastal beetle releases
 2. Inland beetle releases
 3. No release control sites
- Sampling methods:
 - Modified USFS-FIA phase 3 plots = Forest structure and vegetation, site cond.
 - Hemispherical photography = Hemlock canopy health
 - Canopy sampling = HWA and EHS densities, *L. nigrinus* and *L. rubidus* larval numbers, and hemlock shoot growth
 - Beatsheet sampling = *L. nigrinus* and *L. rubidus* adult numbers

Holyoke range experimental block, w. Mass.

Bare Mtn.
Control site

Mt. Norwottuck
150 inland adults
24 Mar + 2 Nov 2008

Long Mtn.
150 coastal adults
23 Mar + 4 Nov 2008



N

1 mile

4896 ft

Image U.S. Geological Survey
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image MassGIS, Commonwealth of Massachusetts EOE
Image Town of Amherst

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Conclusion: Established, no obvious impact



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