Release of *Sasajiscymnus tsugae*, *Scymnus sinuanodulus* (Coleoptera: Coccinellidae) And *Laricobius nigrinus* (Coleoptera: Derodontidae) On the Hemlock Woolly Adelgid, *Adelges tsugae* (Hemiptera: Adelgidae) in NJ

Annual Report 2017

Sasajiscymnus tsugae


Scymnus sinuanodulus ♀


Laricobius nigrinus


L. nigrinus larva

Prepared by:

Mark Mayer
Cynthia Detweiler-Hill
Marisa Grillo

NEW JERSEY
DEPARTMENT OF AGRICULTURE

Division of Plant Industry
Phillip Alampi Beneficial Insect Laboratory
Trenton, NJ 08625

ACKNOWLEDGEMENTS

The following individuals contributed greatly to the project and we thank them for all their help

New Jersey Department of Environmental Protection, Division of Parks and Forestry

Paul Stern, Superintendent,
Stokes State Forest
Blanca Chevrestt, Superintendent,
Swartswood State Park
Ernie Kabert, Superintendent,
Worthington State Forest
Jessica Krugel, Superintendent,
Wawayanda State Park

Connecticut Agricultural Experiment Station
Dr. Carole Cheah

USDA-Forest Service
Dr. Rusty Rhea
Dr. Richard Reardon
Bradley Onken (ret.)
Noel Schneeberger

United States Department of Interior - Delaware Water Gap NRA

Richard Evans
Jeffrey Shreiner

Virginia Polytechnic Institute and State University – for providing *Laricobius nigrinus*
Dr. Scott Salom
Carrie Jubb

Symbiont Biological Pest Management for Providing *L. nigrinus* and survey training
Dr. Richard McDonald

Pennsylvania Department of Conservation and Natural Resources
Brad Regester
Don Eggen
Houping Liu
Bill Laubshear
Tim Marasco

ABSTRACT

A total of 10,915 *L. nigrinus* have been released by the Phillip Alampi Beneficial Insect Laboratory since 2005. **In 2017, 108 *L. nigrinus* larvae and 19 adults were recovered which was an increase from 2016 season primarily due to the recovery of the hemlock woolly adelgid population.** We have confirmed dispersal of *L. nigrinus* over 33 miles from the Delaware Water Gap proper north to the NY State line, 34 miles west into Pennsylvania and 31 miles east into NJ. The area where *L. nigrinus* has been recovered is 35 by 64 miles or 2,240 square miles. If a NJ site had a hemlock woolly adelgid population staff could find larvae. Since 1998, a total of 288,675 *Sasajiscymnus tsugae* beetles were released into 64 New Jersey hemlock sites between 1998 and 2006. Overwintering recoveries of *S. tsugae* have been made at 12 sites since 1999. No *S. tsugae* have been recovered since 2008. A total of 10,355 *Scymnus sinuanodulus* have been released in NJ in nine sites between 2005 and 2007 but there have been no overwintering recoveries to date as the beetles are not a good climate match for NJ.

INTRODUCTION

In the spring of 1997, under a cooperative agreement with the United States Forest Service (USFS), the New Jersey Department of Agriculture's (NJDA) Phillip Alampi Beneficial Insect Laboratory (PABIL) received 100 *Sasajiscymnus tsugae* (Coleoptera: Coccinellidae) from Dr. Mark McClure and Dr. Carole Cheah of the Connecticut Agricultural Experiment Station (CAES) to serve as a back up to their colony. One of the goals of the PABIL was to try to further develop and refine the rearing procedures for *S. tsugae*. Beginning in 1998 and continuing through 2006, a total of 288,675 *S. tsugae* were released into NJ hemlock stands.

In 2004, the Laboratory undertook a new program rearing a Chinese ladybeetle, *Scymnus sinuanodulus* (Coleoptera: Coccinellidae), in conjunction with the US Forest Service and Dr. Cheah of the CAES. The aim of the project was to develop a mass rearing procedure for the new species and then release the species after sufficient numbers have been produced. A total of 10,355 *S. sinuanodulus* were released in New Jersey distributed among nine sites through 2007.

In 2005, Virginia Polytechnic Institute and State University (VPI) shipped 300 *Laricobius nigrinus* to the PABIL for release in northern New Jersey. VPI shipped an additional 3,300 beetles to New Jersey during 2007-2009, and 4,000 in 2010. The lab also received 1,119 field collected beetles from 2007-2009 as well as 1,743 in 2010 collected by Dr. Richard McDonald from Seattle, WA. A total of 10,915 *L. nigrinus* have been released in New Jersey distributed among twelve hemlock stands. 414 *L. nigrinus* were released in 2013, 299 from the rearing colony with the remainder from field collections in the Delaware Water Gap NRA.

OVERVIEW

Hemlock Woolly Adelgid (HWA) is a common, but insignificant insect on ornamental and forest hemlock and spruce in Japan and China. It does not attain high densities on hemlock in Asia except for trees growing on very poor sites. There is no significant injury to the Asian hemlocks due to host resistance and the presence of native predators that regulate HWA populations.

The first infestation in the eastern US was discovered on the east coast in Virginia in the 1950's. This infestation has been confirmed to be an accidental introduction from Japan (Havill, et. al. 2009). Havill also discovered that the hemlock woolly adelgid in the Pacific Northwest is native to that area. Eastern hemlocks are the successional climax trees in Northern NJ forests and although hemlock is not a valuable timber tree, the wood is used for barns, sheds, pulpwood, and landscaping and it is ecologically important providing cover for deer, turkey, ruffed grouse, and other wildlife. About 90 species of birds use hemlock as a nesting site, roost site or winter shelter. Northern goshawk, solitary vireo, and the black-throated warbler require habitats provided by a hemlock forest and would be stressed should the hemlock stands be

reduced for any reason (Hennessey 1995). Hemlock is also an important component of some of the more popular recreational areas in NJ, due to the dense canopy, cooler temperatures in summer, and the stands provide a much-needed respite from the heat for those who visit them. The species is also an important component of the large watersheds in Northern NJ. In NJ, all hemlock stands have had some level of HWA infestation with the healthiest stands located in northern Passaic and Sussex Counties**.** In the NJDA Study Plots, the long-term mortality due to the HWA as of 2010, when the monitoring program ceased, averaged 60.7%.

HWA populations are virtually unmanageable in hemlock forests using traditional control measures although some select trees can be treated using injections or soil treatments. Application of chemical insecticides is impractical on a widespread basis due to the inaccessibility of most stands, proximity to water, and poor coverage of aerial spraying and/or excessive cost.

BIOLOGICAL CONTROL

In 1992, Dr. Mark McClure of the CAES initiated a trip to Japan to attempt to find and collect potential HWA predators. He collected a Coccinellid, *S. tsugae*, which showed promise and the USDA granted a permit for its release in 1995. Dr. Mike Montgomery (ret.) of the USDA-FS has worked with *Scymnus* spp. from China and Dr. Scott Salom of Virginia Tech is working with a native Derodontid beetle, *Laricobius nigrinus* and two Japanese *Laricobius* spp., one of which, *L. osakensis*, has been approved for release. Recently, the USFS has sponsored searches in China and Japan for some additional predators. *L. nigrinus* is also being collected in the Pacific Northwest and has been established and is being collected in North Carolina by Dr. Richard McDonald of Symbiont Biological Pest Management. He is also conducting research on a ladybeetle predator, native to the Pacific Northwest, *S. coniferarum.* The Phillip Alampi Beneficial Insect Laboratory has reared and released *L. nigrinus* into the hemlock stands in New Jersey.

MATERIALS AND METHODS

All *S. tsugae*, *S. sinuanodulus* and *L. nigrinus* release sites were monitored using the VPI monitoring protocols (Mausel et. al. 2007).

Monitoring for the presence of the beneficial ladybeetles was conducted at each site from the spring through late fall if sufficient hemlock woolly adelgid populations were present. If the stand at the site was in poor health or if the HWA population was low, the site was not surveyed. No coccinellid monitoring was done in 2014 due to staffing shortages. Surveys were conducted in the fall and in early spring at all *L. nigrinus* release sites within the state and any potential dispersal sites. The original sampling methodology consisted of a one meter square beating sheet placed beneath several branches and the branches were struck ten times with a plastic whiffle ball bat (Figure 1). Any life stages of the beetles recovered on the beating sheet were recorded.

Figure 1. *Sasajiscymnus tsugae* Sampling and Recovery

Photo by L. Bronhard

In 2011, a change was made in the monitoring methodology after a training session with Dr. Richard McDonald of Symbiont Pest Management. Previously, staff had used one meter square beating sheets as described above and had tapped the branches down over the beating sheets. Dr. McDonald's methodology was subtly different in that he used an upside down umbrella and gently tapped up on the branches and then down to recover *L. nigrinus* adults and larvae. Also, only the sunny sides of the trees that had hemlock woolly adelgid populations were sampled resulting in the recovery of more *L. nigrinus* beetles and larvae. The *L. nigrinus* larvae are gray but are often covered with hemlock woolly adelgid wool and were much easier to see on the contrasting color umbrellas than on the white beating sheets. The umbrellas are more convenient to use in the forest as they are more easily transportable as well as being less susceptible to winds than the beating sheets.

When *S. tsugae* and *S. sinuanodulus* beetles were in production by the Phillip Alampi Beneficial Insect Laboratory they were transported to the new release sites in either Sweetheart®, 165 oz., stock number 10T1 paper buckets covered with Sweetheart® 10V19S paper lids or Sweetheart® Flexstyle 10 oz. food cups fitted with nylon screen at the ends. There were 2,500-5,000 beetles per bucket and up to 500 beetles per cup. The cups and the buckets were filled with excelsior providing increased surface area for the beetles. At the release site the lid is removed and the containers and lids are placed into the branches of the tree. After five minutes, any stragglers in the buckets are gently brushed out onto the infested branches using a soft, 1-inch paintbrush. The release trees were at least moderately infested with HWA.

L. nigrinus was shipped to PABIL in plastic vials from VPI, 50 beetles per vial and were released following the protocol in Mausel, *et. al* 2007. The PABIL also received field-collected *L. nigrinus* in the fall from Dr. McDonald who collected wild *L. nigrinus* in Seattle. The *L. nigrinus* releases from PABIL stock were made using the methodology in the paragraph above. Field collected *L. nigrinus* from the Delaware Water Gap NRA were aspirated into a Bioquip® 9 dram aspirator and then transferred into Sweetheart® Flexstyle 10 oz. food cups, combined with lab reared *L. nigrinus* and transported to the new release sites. The last release of *L. nigrinus* in NJ was made in November 2013.

RESULTS AND DISCUSSION

The PABIL released the coccinellid predators *S. tsugae* from 1998 through 2006 and *S. sinuanodulus* from 2005 through 2007. In January 2007 the PABIL received a new predator, *L. nigrinus*, so all rearing efforts have been directed toward the new species with the Coccinellids dropped from the laboratory cultures. *S. tsugae* is established in New Jersey and it is no longer necessary to rear it in the laboratory. Surveys will continue for *S. sinuanodulus*. Table 1 summarizes the releases and recoveries of all three predators 1997 through 2013. Some release sites received augmentative releases. With *Laricobius*, if the releases were in the same hemlock stand, then the stand was considered one release site. Figure 2 also shows the release and recovery sites for *S. tsugae* over the course of the project.

Recovering overwintering beetles to prove establishment has been a tedious and challenging process. No *S. tsugae* and no *S. sinuanodulus* were recovered in NJ in 2014, although *L. nigrinus* continue to be recovered at new dispersal sites.

Sasajiscymnus tsugae

There are several factors that may account for the low recovery rate for *S. tsugae*: First, HWA populations have been relatively low throughout New Jersey. In 1999 and 2000, the last years of high hemlock woolly adelgid populations in New Jersey, was when the most *S. tsugae* beetles were recovered. Not surprisingly, the recovery of *S. tsugae* would seem to be dependent on the amount of host material. Second, collecting becomes more difficult due to HWA caused branch dieback of the lower limbs; it

becomes increasingly more difficult to find branches that could be sampled using the beating sheet technique. In New Jersey, the average crown ratio for the hemlock forest is 26% (Figure 4), but crown ratios of 85-100% are needed to sample for the predators. The beetles may not be a perfect climate match as well. Lastly, the *S. tsugae* beetles may have dispersed to the higher branches, (Scudder, et. al. 2001, Cheah et. al. 2005) which are unreachable by the survey personnel.

Table 1. *S. tsugae, S. sinuanodulus* and *L. nigrinus* Releases and Recoveries in NJ 1997 – 2015

	Sasajiscymnus tsugae			***Scymnus sinuanodulus***			***Laricobius nigrinus***			
Year	No. Released in NJ	No. of Release Sites	No. of Sites with Recoveries	No. Released in NJ	No. of Release Sites	No. of Sites with Recoveries	No. Released in NJ	No. of Release Sites	No. of Sites with Recoveries	Number *L. nigrinus* Recovered
1997	0	0		-	-		-	-		
1998	75,500	15		-	-		-	-		
1999	65,000	13	6	-	-		-	-		
2000	50,000	13	3	-	-		-	-		
2001	30,500	6	2	-	-		-	-		
2002	40,260	9	2	-	-		-	-		
2003	175,001	5	1	-	-		-	-		
2004	150,001	2	1	-	-		-	-		
2005	230	1	1	1,530	3	0	300	1		
2006	2,185	1	1	1,500	2	0	-	-	1	2A
2007	0	0	1	6,305	4	0	1,390	3	2	3A
2008	0	0	1	0	0	0	2,033		3	5A
2009	0	0	0	0	0	0	1,071	2	2	2A
2010	0	0	0	0	0	0	5,743	2	6	1L, 52A
2011	0	0	0	0	0	0	30	1	4	155 L, 17A
2012	0	0	0	0	0	0	0	0	10	468L, 21A
2013	0	0	0	0	0	0	348	3	111	848L, 335A
2014	0	0	0	0	0	0	0	0	42	168L, 45A
2015	0	0	0	0	0	0	0	0	7	23L, 15A
2016	0	0	0	0	0	0	0	0	13	67L, 66A
2017	0	0	0	0	0	0	0	0	20	108L, 19A
Totals	**288,675**	**65**	**19**	**10,335**	**0**	**0**	**10,915**	**12**		

*A = adults, L= larvae

Figure 3 illustrates the HWA sistens population and the number of *S. tsugae* recovery sites by year up through 2010 when the Permanent Study Plots were dropped. The most *S. tsugae* recoveries were made in 1999 which was also the year that the highest HWA population levels were observed. The beetles may not show up until the HWA population increases, although the HWA population did increase in 2008 but there was no subsequent recovery of *S. tsugae.* That may have been more due to a lack of survey personnel due to retirements and budget cuts. There also have been no summer staff personnel since 2010. The majority of the recoveries were along the Kittatinny Ridge in the Skylands section of NJ.

Dr. Jerome Grant of the University of Tennessee (personal communication) is recovering *S. tsugae* from older sites in the Great Smokies and in the southern Appalachians and stated that it may take longer than we expect to get high numbers of that species. Overall, *S. tsugae* has successfully established in NJ but its effect on the hemlock woolly adelgid population remains to be determined.

Figure 2. Hemlock Stands and *S. tsugae* Release/Recovery Sites in New Jersey Through 2008 (the last year of recovery).

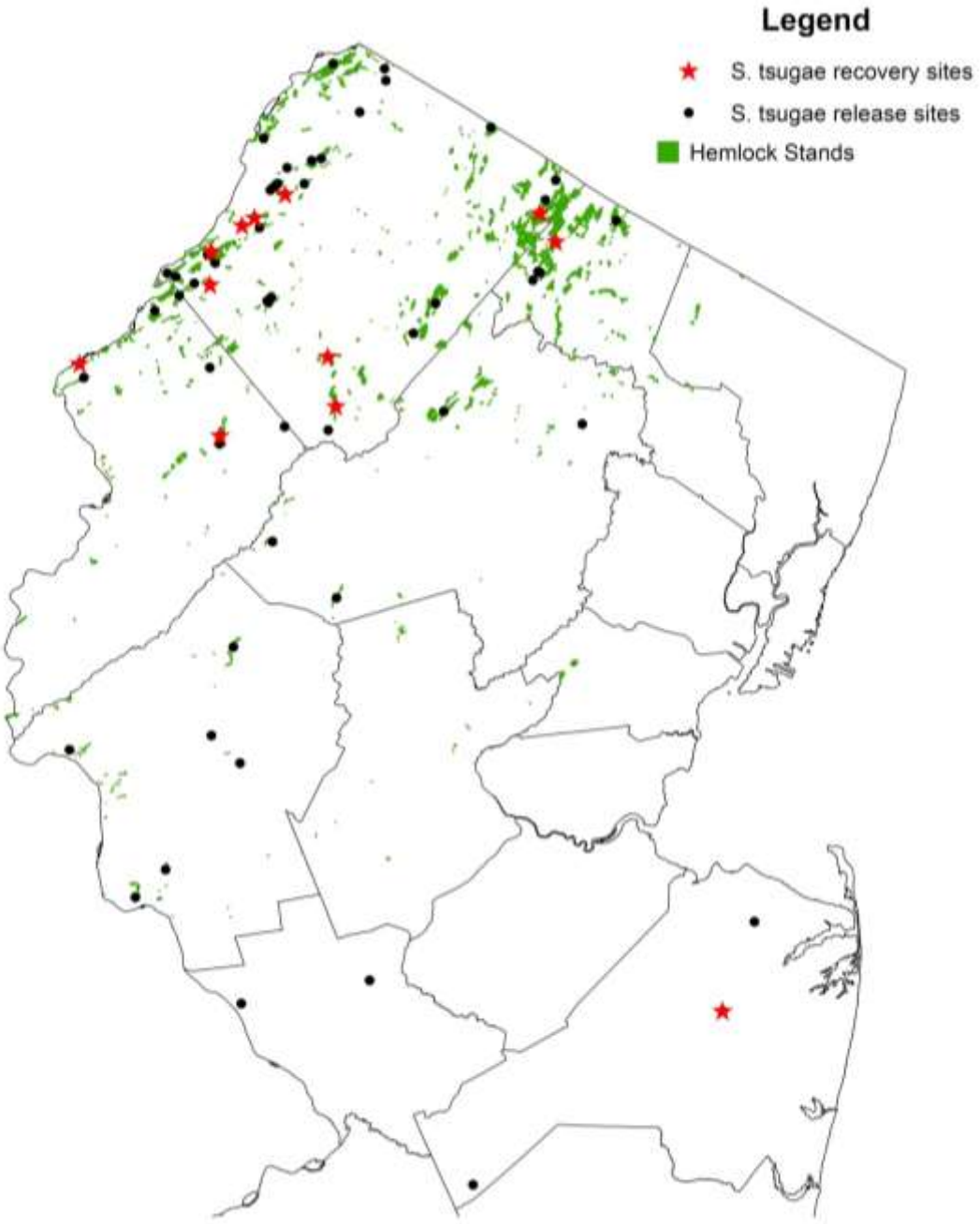
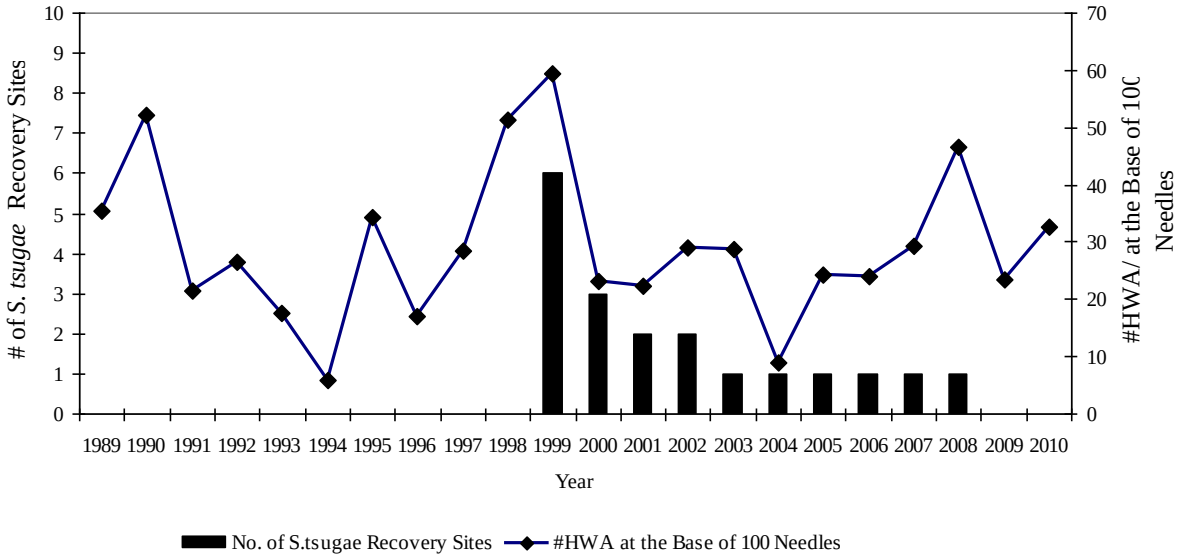


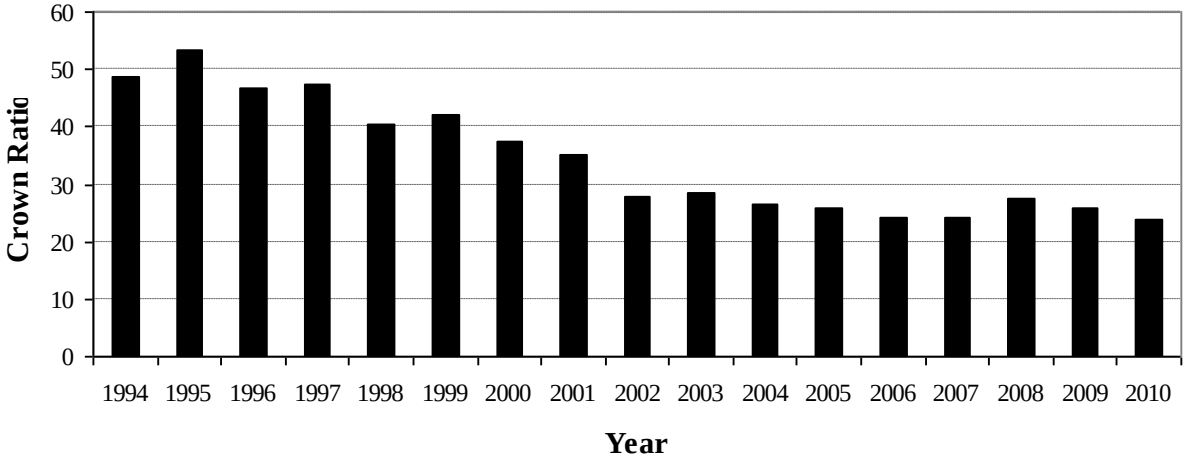
Figure 3. HWA Sistens Population and *S. tsugae* Recovery Sites in NJ 1989-2010



Cheah et. al. 2005, found that the trees in the Skylands region were healthier overall than the trees in the Highlands region of New Jersey, most likely because they were infested later. The temperatures in the Skylands are also slightly colder due to the higher elevations which could result in higher hemlock woolly adelgid mortality during the winter. Releasing 10,000 beetles into the middle of a forest sounds like a large quantity, however, when one considers the number of trees, the number of beetles released would be hard pressed to even have an impact on an individual tree.

Figure 4

Average Crown Ratio of Hemlock Trees in NJ 1994-2010



Scymnus sinuanodulus

In 2005 *S. sinuanodulus* was released for the first time in New Jersey at three sites and into two additional sites in 2006. The beetles were readily found at the 2006 release sites until the middle of summer during the same season but disappeared after consuming all of the hemlock woolly adelgid. A total of 10,355 *S. sinuanodulus* have been released in NJ. No overwintering beetles have been recovered. Dr. Mike Montgomery (personal communication) of the USFS (ret.) is of the opinion that the beetles may be a better ecological fit to the Southern Appalachians where they have been recovered. *S. sinuanodulus* then, may not overwinter in NJ.

Laricobius nigrinus

L. nigrinus is a Derodontid beetle native to the Pacific Northwest that is predacious on the hemlock woolly adelgid. The beetles are active from fall until spring whenever the temperatures exceed 0^{o} C. *L. nigrinus* beetles, from a colony at Virginia Tech, were released for the first time in 2005 in Worthington State Forest and recoveries were made in all succeeding years from release and non-release trees at that site. Since 2005 the total number of *L. nigrinus* released in New Jersey by the Phillip Alampi Beneficial Insect Laboratory is 10,537 with beetles provided by Virginia Tech and Dr. Richard McDonald of Symbiont Biological Pest Management. The vast majority of the beetles were released in the Delaware Water Gap NRA (DEWA) for two reasons 1) that is where the highest hemlock woolly adelgid populations were and 2) *L. nigrinus* will get into the log phase of their population cycle more rapidly in an area where they are concentrated. Staff from the National Park Service has released 3,147 *L. nigrinus* from 2007-2009 in the Upper Van Campens Watershed and in the Camp Ken-etiwa-pec/Skyline Drive area (Richard Evans and Jeff Shreiner, personal communication).

Table 1 shows the number of beetles recovered by year with increasing numbers of both adults and larvae recovered each year, until 2014 when the polar vortex came in and caused high hemlock woolly adelgid mortality of over 90% (McAvoy 2014). This resulted in the recovery of fewer beetles into 2017 although there was a slight increase in 2017 due to the increase in the HWA population. Until 2014, the increasing recovery of *L. nigrinus* was highly encouraging as the beetles were dispersing very well. In 2014 and 2015, we expected to recover fewer *L. nigrinus* as a result of the high hemlock woolly adelgid mortality but to the surprise of the authors, the beetles not only were still present but had dispersed further than they had ever been before (Figure 6). The decline in recoveries in Table 5 from 2013 through 2017 represents the lingering effect of the polar vortexes but the good news was that the *L. nigrinus* were found in additional sites and were far more widely dispersed than they were in previous years. There was an increase in LN *L. nigrinus* recoveries in 2017.

Figure 6 shows the location of the release sites and the dispersal of the *L. nigrinus* from 2005 to the present. The first releases were made in 2005 and 2006 (Figure 6a). The vast majority of the releases were made into the Van Campens drainage of the Delaware Water Gap National Recreation Area (Figure 6b). A total of 7,800 beetles were released from 2007 through 2009 in the Van Campen's Drainage through the combined efforts of the Phillip Alampi Beneficial Insect Laboratory and the National Park Service. In 2010 a series of releases totaling 5,457 beetles was made above Buttermilk Falls (Figure 6c) so a little over 13,000 *L. nigrinus* were released within 3.5 miles of each other between 2007 and 2010. There was no real dispersal from the release sites until 2012 (Figure 6d. No recoveries were made at Buttermilk Falls until 2012 but at that time beetles reached the log phase of their population cycle and began to

disperse to non-release hemlock trees. By 2013 the *L. nigrinus* beetles had dispersed over 17 miles in the Delaware Water Gap (Figure 6e. By 2014, the beetles had dispersed 33 miles throughout the Delaware Water Gap on both sides of the Delaware River wherever there was hemlock woolly adelgid (Figure 6f). Figure 6g shows the dispersal of the beetles 33 miles into Pennsylvania with the blue dots showing the recoveries made by Dr. Richard McDonald. It is likely that the beetles have dispersed further into Eastern Pennsylvania and into Upstate NY. Essentially the *L. nigrinus* were found everywhere there was hemlock woolly adelgid present along the Kittatinny Ridge. Figure 6h shows the recoveries in 2015 and Figure 6i

Dr. McDonald also stated that that he believes that we are "locked on" and if the NJ sites follow the same progression as the sites in NC, we should see improvements in tree health in the coming years. The *L. nigrinus* recoveries are very promising considering the small quantity of beetles released.

At the Worthington State Forest *L. nigrinus* release site in 2013 we observed a collapse of the hemlock woolly adelgid population without an attendant increase in twig dieback or rise in

Figure 6. *L. nigrinus* Release and Dispersal Sites

.

Stars = release sites; Orange dots = *L. nigrinus* dispersal sites,; Blue dots s= L. *nigrinus* dispersal sites found by Dr. Dick McDonald of Symbiont Biological Pest Management; Green = Hemlock Stands

Figure 6a. 1st Releases of *L. nigrinus* in NJ (2005) and DEWA in PA (2006)

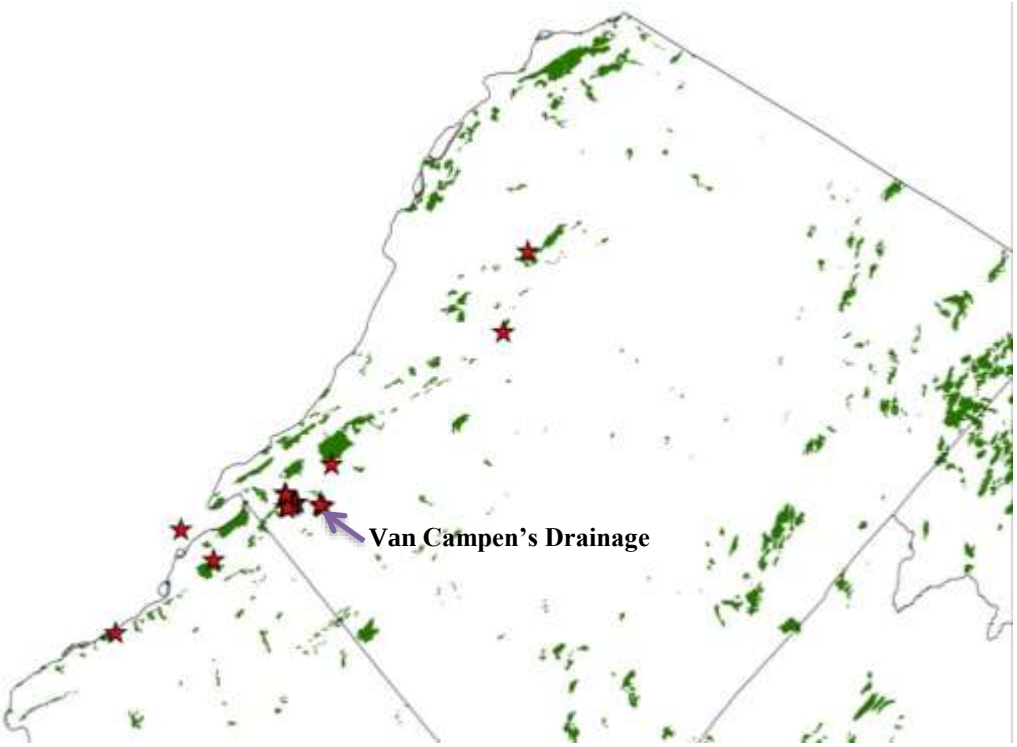


Figure 6b. 2007 to 2009 Releases, a total of 7,800 beetles between NPS and NJDA

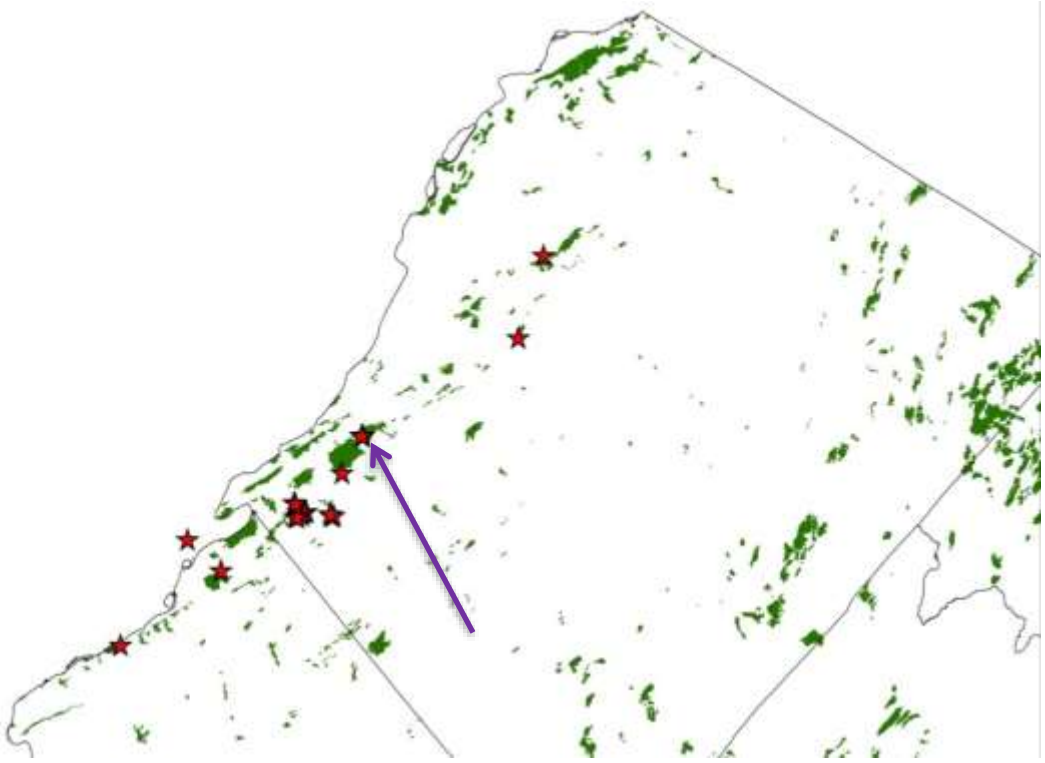


Figure 6c. 2010 Release of 5,457 *L. nigrinus* Beetles at Buttermilk Falls

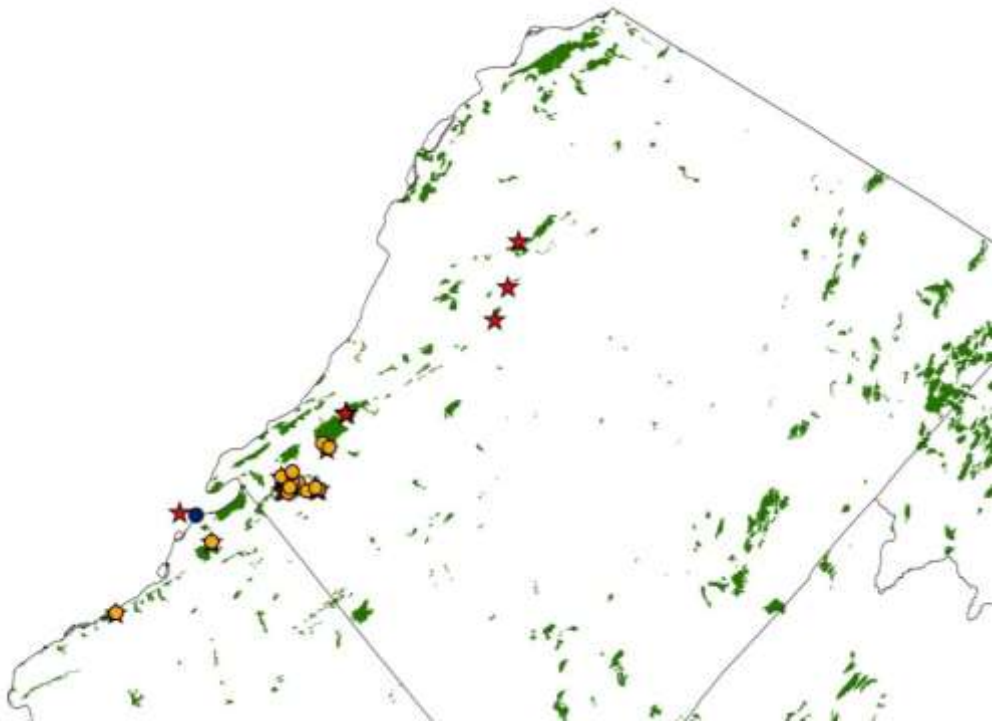


Figure 6d. *L. nigrinus* dispersal and Recovery through 2012; gold circles are recovery sites.

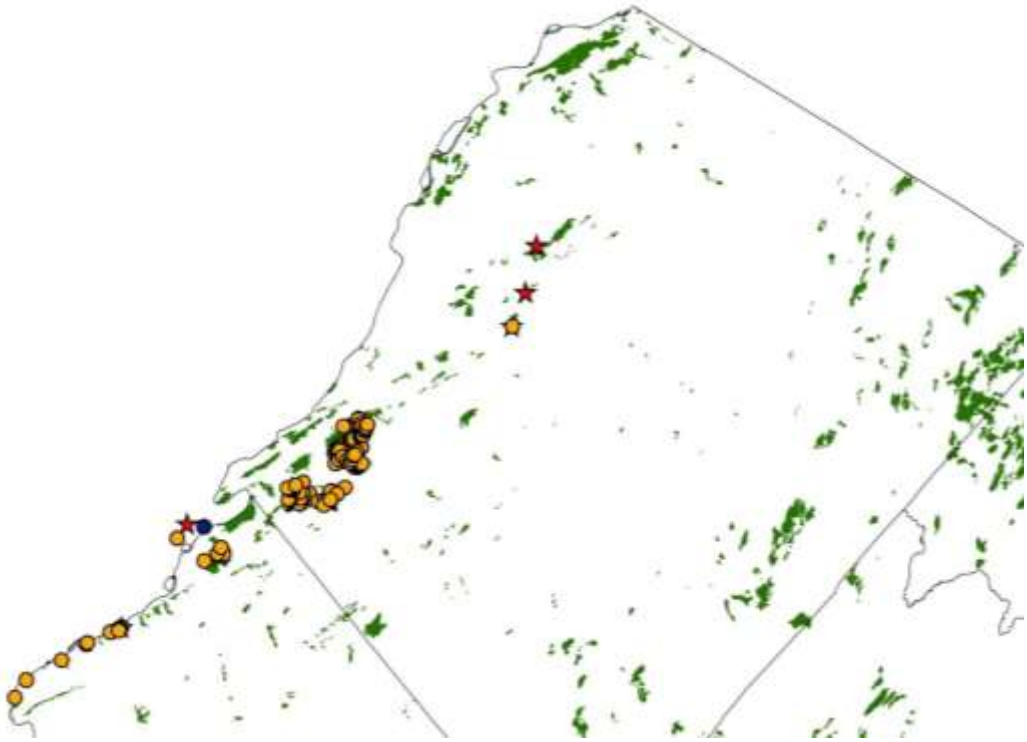


Figure 6e. *L. nigrinus* dispersal and Recovery through 2013; gold circles are recovery sites.

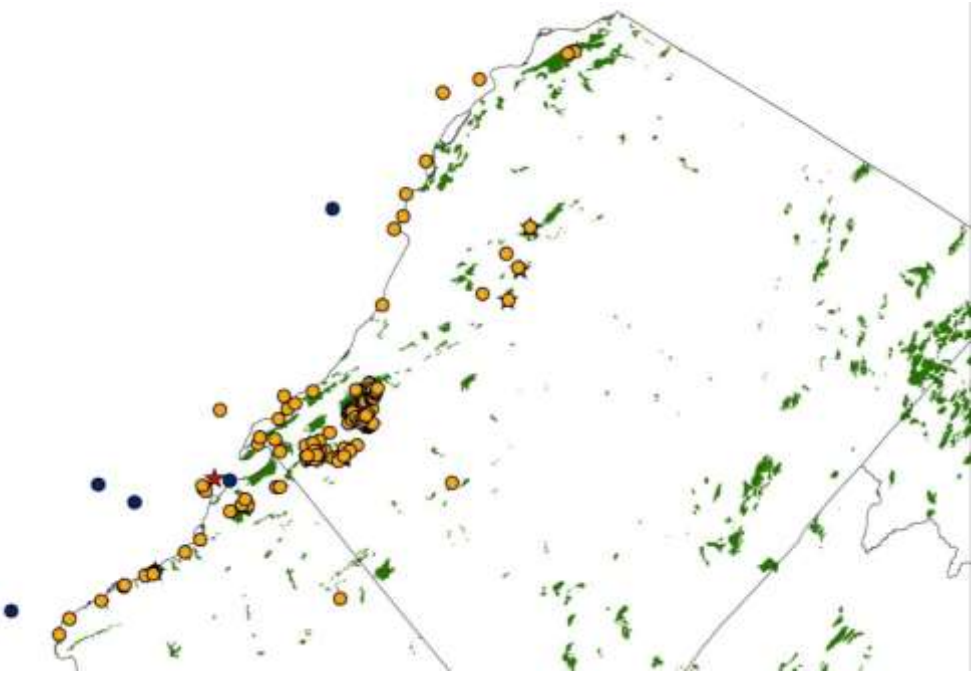


Figure 6f. *L. nigrinus* dispersal and Recovery through 2014; gold circles are recovery sites.

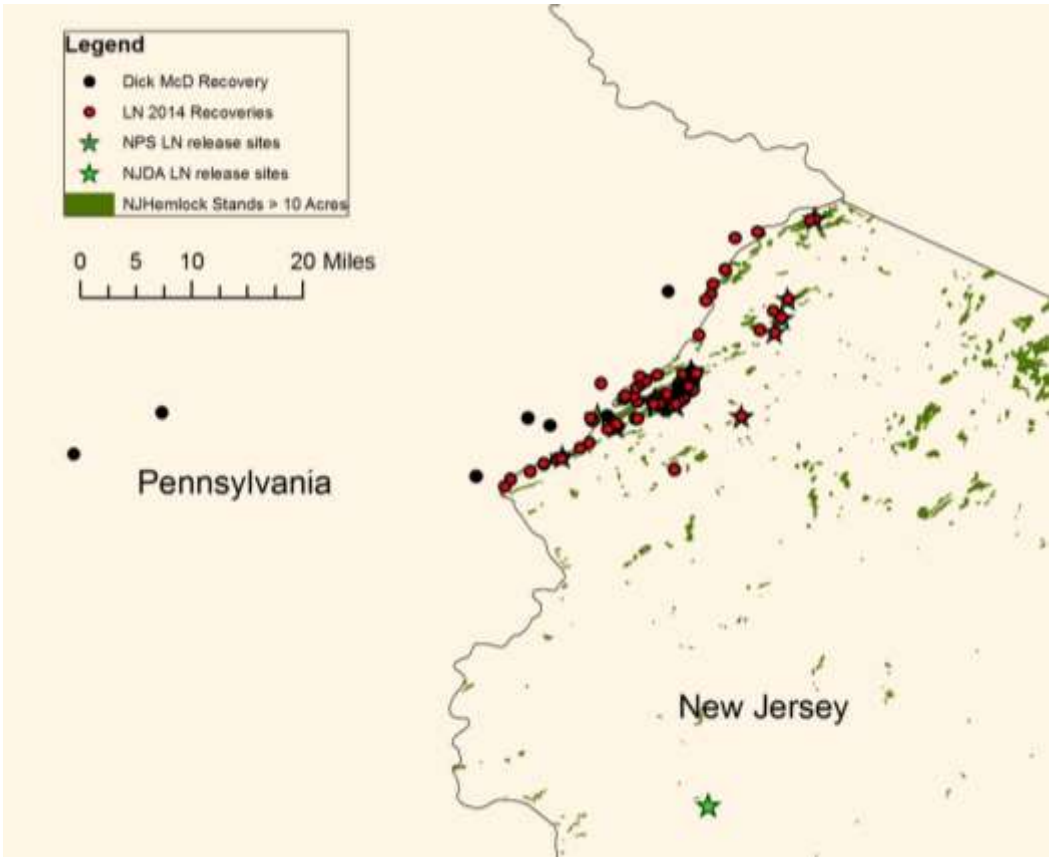


Figure 6g. Release and 2014 Recovery Sites (red circles) of *L. nigrinus* in NE Pennsylvania and Northwestern NJ

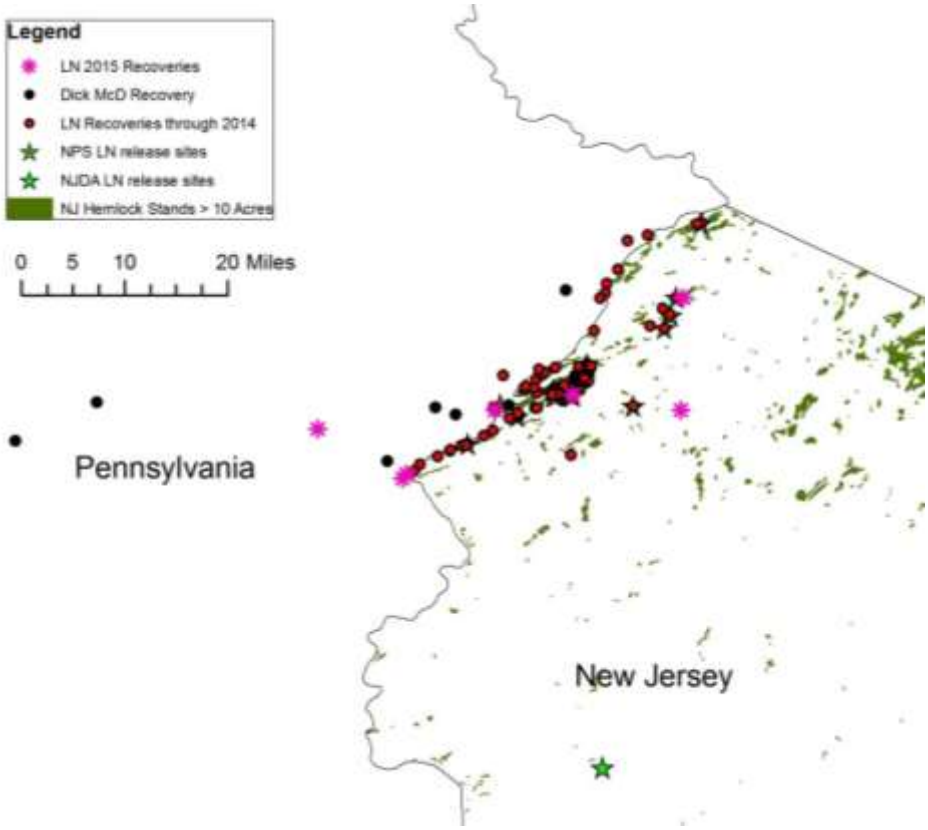


Figure 6h. Release and Recovery Sites (pink asterisks) of 2015 *L. nigrinus* in NE Pennsylvania and Northwestern NJ

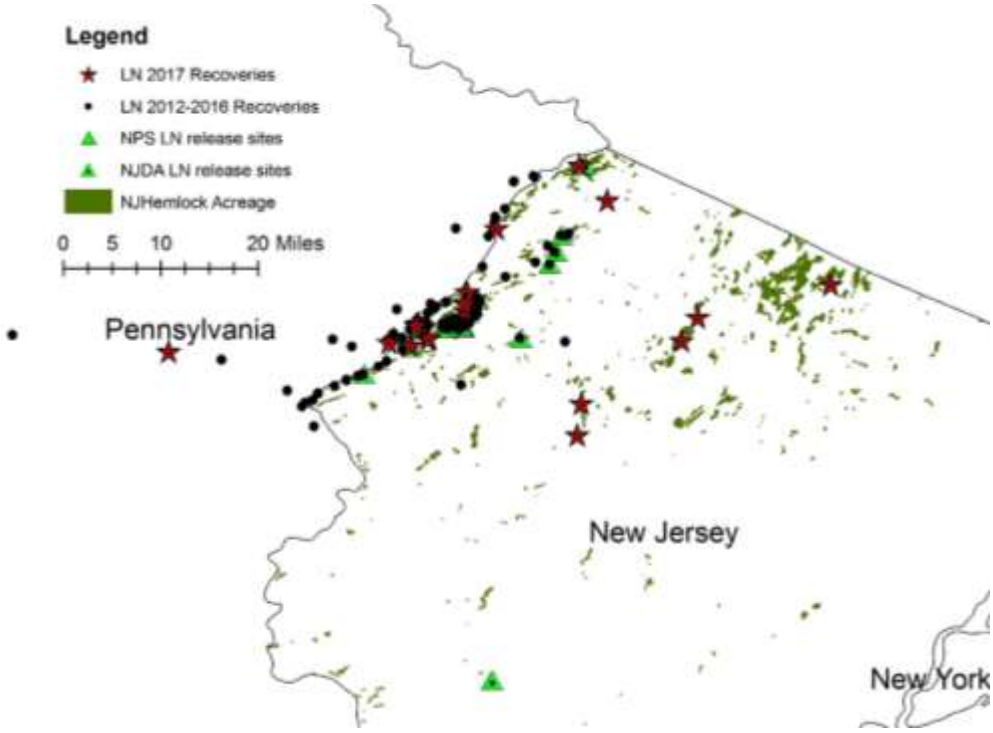


Figure 6i. Release and 2017 Recovery Sites (red stars) of *L. nigrinus* in NE Pennsylvania and Northwestern NJ

crown transparency. Usually the hemlock woolly adelgid causes a decline in new growth

accompanied by twig dieback, which is evident after the peak hemlock woolly adelgid population collapses. The hemlock woolly adelgid suppresses new growth and then loses it food source due to overpopulation; the population then collapses causing tree stress and mortality. This is the first time that we have seen a decrease in the hemlock woolly adelgid population at a site without a subsequent decline in tree health. Absent other evidence, anecdotally it appears that the *L. nigrinus* may be helping to improve the tree health at the Worthington State Forest release site. Table 2 shows the results of a quick survey of selected hemlock stands in the state of NJ over the last three years. The number of sites has varied but the numbers have been consistent over the past three years with the only real decline being in the crown ratio.

Table 2. Crown Ratings and Tree Health in Hemlock Stands in NJ 2015-2017

# sites	Year	Ratio	Transparency	HWA density[1]	Health[2]
17 sites	2017	70.43	53.00	1.78	2.14
5 sites	2016	60.40	63.68	1.80	1.80
15 sites	2015	58.28	62.96	1.90	1.90

The lower the transparency the healthier the tree, HWA density is based on the Virginial Tech and USFS protocols with High = 3, Medium = 2 and Low = 1[1]. Tree health is 1= poor, 2= fair and 3 = good[2].

Overall, the crown ratio has gotten worse but the crown transparency is improved as is the tree health, although slightly, but there are no real significant differences in the overall crown ratings of the trees. Transparency and crown ration are (+/-) ten percent so little can be concluded from the surveys using those measures.

L. nigrinus is firmly established in NJ and is impacting the hemlock woolly adelgid population.

With the decline in hemlock woolly adelgid populations due to the Polar vortex of 2014 and 2015 there is the possibility that the *L. nigrinus* populations may not be sufficiently high enough to collect releasable numbers of beetles as yet. Field staff will continue to look for beetles and record the GPS coordinates of the recoveries.

L. nigrinus and *L. rubidus* hybrids?

Havill, et. al. 2012 reported that *L. nigrinus* and *L. rubidus* hybridize and produce fertile progeny. *L. rubidus* is native to the eastern U.S. and feeds primarily on pine bark adelgid, *Pineus strobi* (Hartig) but has been found on hemlock woolly adelgid. *L. nigrinus* and *L. rubidus* may be different biotypes of the same species. *L. rubidus* is reddish with black stripes along the edge of the elytra while *L. nigrinus* is black. The hybrid is reddish but with bold black stripes on the edge of the elytra. Figure 7 below shows a photo of a possible hybrid compared with a *L. nigrinus*.

Fisher et. al. 2015 reported on the frequency of occurrence of *L. nigrinus* and *L. rubidus* in the hemlock forest. The authors found that *L. nigrinus* and the hybrids are primarily found on hemlock with *L. rubidus* primarily found on Eastern White Pine. We have recovered reddish

beetles (six beetles total in three years) with black stripes on the borders of the elytra and they are possibly hybrids or *L. rubidus*. The greatest number of *Laricobius* spp. beetles recovered in NJ has been the black *L. nigrinus*.

Figure 7. *L. rubidus/L. nigrinus* hybrid? and *L. nigrinus*

2018 Plans

In 2018, the PABIL intends to continue to survey for HWA predators in areas where there are HWA populations and to collect and release (*L. nigrinus*) in the northwestern corner of the state as they are available. The goal is to release as many beetles as can be provided in high value public forested areas in northern NJ to boost their chances of establishment. Provide on ground support to Dr. J. Elkinton of UMass for the L. nigrinus efficacy evaluation in the Delaware Water Gap NRA. Provide support to Cornell University and Dr. M. Whitmore in setting up outdoor insectaries and distribution of *L. nigrinus*. Identification of candidate insectary sites in Southern NY State.

The releases will be made according to a priority list as follows:

1. State and Federal lands, with a minimum of a moderate hemlock woolly adelgid population, including natural lands that are located in areas in close proximity to other hemlock stands where the beetles can redistribute themselves.

2. County and municipal lands with a moderate hemlock woolly adelgid population located in areas in close proximity to other stands where the beetles can redistribute themselves readily.

3. Private lands with a moderate hemlock woolly adelgid population in hemlock stand (excluding landscapes).

There are no heavily infested hemlock stands with sufficiently healthy trees in New Jersey which are suitable for collecting sufficient rearing material.

The primary goal of the field staff will continue to look for beetles and record the GPS coordinates of any recoveries in order to document the dispersal of the beetles.

CONCLUSION

The *S. tsugae* program has been successful in that the beetles have become established in the state as evidenced by the recoveries of adults and/or larvae at 12 of 64 sites. It is probable that *S. tsugae* is established at more sites, but the dieback of the lower branches in many sites and lack of personnel limits our field search and survey capabilities. The *S. tsugae* population is still present and their actual impact may not be fully known for some years. The Chinese ladybeetle *S. sinuanodulus* has been released but not recovered. *L. nigrinus* has been released, has established, and is increasing in population in NJ with the highest number of beetles ever recovered in 2013. We have confirmed dispersal of *L. nigrinus* over 33 miles from the Delaware Water Gap proper north to **the NY State line**, 3**4** miles west into Pennsylvania and 31 miles east into NJ. The area where *L. nigrinus* has been recovered is 3**5** by 64 miles or 2,**240** square miles. If a **NJ** site had a hemlock woolly adelgid population staff **could** find larvae. The *L. nigrinus* beetles have dispersed 34 miles into Pennsylvania, throughout the Delaware Water Gap NRA and as far east as Greenwood Lake, NJ.

REFERENCES

Cheah, C., M. Mayer, D. Palmer, T. Scudder, and R. Chianese. **2005.** Assessments of biological control of hemlock woolly adelgid with *Sasajiscymnus* (*Pseudoscymnus*) *tsugae* in Connecticut and New Jersey in Onken, B. and R. Reardon Third Symposium on hemlock Woolly Adelgid in the Eastern United States. Asheville, North Carolina, February 1-3, 2005. http://na.fs.fed.us/fhp/hwa/pub/2005_proceedings/cheah.pdf

Evans, R. 2005. Ecologist, Delaware Water Gap National Recreation Area.

Fischer, Melissa J., Nathan P. Havill, Carlyle C. Brewster, Gina A. Davis, Scott M. Salom and Loke T. Kok. **2015**. Field assessment of hybridization between *Laricobius nigrinus* and *L. rubidus*, predators of Adelgidae. Biological Control Volume 82, pp. 1-6.

Havill, Nathan P.; Montgomery, Michael; Shiyake, Shigehiko; Lamb, Ashley; Keena, Melody A.; Caccone, Adalgisa. 2009. Hemlock woolly adelgid population genetics In: McManus, Katherine A; Gottschalk, Kurt W., eds. Proceedings. 20th U.S. Department of Agriculture interagency research forum on invasive species 2009; 2009 January 13-16; Annapolis, MD. Gen. Tech. Rep. NRS-P-51. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 75.

Havill, Nathan P.; Gina Davis, David Mausel, Joanne Kline, Richard McDonald, Cera Jones, Melissa Fischer, Scott Salom, Adalgisa Caccone. 2012. Hybridization between a native and introduced predator of Adelgidae: An unintended result of classical biological control. Biological Control, Volume 63, Issue 3, pp. 359-369.

Hennessey, R. 1995. Field Release of a Nonindigenous Lady Beetle, *Pseudoscymnus* sp. (Coleoptera: Coccinellidae), for Biological Control of Hemlock Woolly Adelgid, *Adelges tsugae* (Homoptera: Adelgidae). Environmental Assessment. USDA-APHIS Riverdale, MD.

Hodek, I. 1973. Biology of Coccinellidae. Dr. W. Junk N.V., The Hague.

Mausel, David L., Theresa A. Dellinger, Ashley B. Lamb, Scott M. Salom, and Loke T. Kok. 2007. Field Instructions for Release of *Laricobius nigrinus*, a Biological Control Agent for the Hemlock Woolly Adelgid in the Eastern U.S. Department of Entomology, Virginia Tech, Blacksburg, VA.

Mayer, M., T. Scudder, C. Burdel, F. Golz, and T. Dorsey. 2007. Unpublished Annual Report. The Effect of the Hemlock Woolly Adelgid *Adelges tsugae* (Homoptera: Adelgidae) in New Jersey Hemlock Stands. Phillip Alampi Beneficial Insect Laboratory, Division of Plant Industry, New Jersey Department of Agriculture.
http://www.state.nj.us/agriculture/plant/biolab.htm

McAvoy, T. J., E. A. Roberts, N. G. Johnson, T. McCoy, N. F. Schneeberger and S. M. Salom. 2014. Hemlock Woolly Adelgid Sistens Mortality During the Winter of 2013 - 2014 and Progrediens Recovery; Report for hemlock woolly adelgid researchers and managers in the eastern U. S. Department of Entomology, Virginia Tech, Blacksburg, VA; Dept. of Biology, Colorado State University, Fort Collins, CO; USDA Forest Service, Forest Health Protection, Newtown Square, PA

Millers, I., R. Anderson., W. Burkman, W. Hoffard. 1992. Crown Condition Rating Guide. USDA-FS Technical Report.