Predator Beetles at Work:

Evidence-based Assessments of

Private Sasajiscymnus tsugae Release Sites

in Western North Carolina

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Developing and Assessing Cost-Effective Biological Control Strategies for HWA

The test site for the initial release was a 150 acre headwaters property on the Blue Ridge Escarpment in western North Carolina. The property contained about 9000 feet of waterways, including a 1.5 acre pond and several streams and tributaries. Heavy HWA infestations were noted in 2003, when several large hemlocks were topped by wind gusts associated with a hurricane. Hemlock populations were mapped in late 2005 and in April 2006 a release of 3000 *Sasajiscymnus tsugae* beetles (purchased from Conservation Concepts) was completed.

The primary purpose of this effort was to save a large number of heavily defoliated eastern hemlocks (*Tsuga Canadensis*) located mostly along waterways on the property. However, lacking a suitable protocol for low-density HWA predator beetle releases, the owner/author drew on his background in behavioral/epidemiological research in planning a release design, which included several dose-response test elements (varying release quantities to assess effects). Data from field and research reports on beetle reproduction and movement from Connecticut (McClure & Cheah 2002) were used to motivate a low-density release design that included from 30 to 100 beetles per site and from 100 to 300 beetles per multi-site colony.

Because there were no expectations for short-term results, no baseline observations of the trees were recorded prior to predator beetle releases. Careful observations of hemlock foliage changes were begun in mid-June 2006, in response to dramatic production of new foliage on large trees around the pond. By mid-July, new crown foliage production was visible on crowns of larger trees in the vicinity of beetle release areas. After leaf-fall in mid-October, most of the larger trees along the waterways were observed to have produced visible amounts of new crown foliage. (This new-crown-growth phenomenon was not observed in comparable size trees along the waterways on other properties in the immediate area – where no beetles had been released.) And production of new crown growth did not appear to be limited to the large trees in the immediate area of predator beetle releases, extending in one instance over 1000’ along a waterway onto an adjacent property.

These photos illustrate 3 different patterns of hemlock re-foliation that were observed following the 2006 release. The photo on right shows new foliage in mid-June on most of the branches of a ~50’ hemlock in full sun on which ~100 beetles were released. Note the unaffected branches on the lower right, representing a “before” perspective. The photo below shows a view, from 90˚ to the left, of the new foliage on this same tree in mid-June, 10 weeks after beetle release.

The photo on right, also from mid-June shows new foliage on some lower branches and on the crown of a 100’ hemlock on which about 30 beetles were released. This tree had 180˚ sun exposure and this mixed, bottom/top re-foliation pattern was unusual, although it does clearly illustrate the difference between “before” and “after” components.

The photo on the right, taken in October 2006, shows the new crown growth pattern that is characteristic of larger trees in the area of a beetle release area. For this ~100' tree, located about 500' from the nearest release, the lower branches are gray, with little or no new foliage while the crown branches have significant new growth. The extent of new crown growth will vary depending on the health of the tree, the exposure to sunlight and the distance from the nearest beetle release.

However, this pattern of significant new crown growth with little or no growth on lower branches appeared to be reflective of beetle activity. This pattern was <u>not</u> found on hemlock waterways on an adjacent property, where no beetles had been released. Smaller trees and the middle and lower branches of most of the larger trees (with the exception of some release area trees with full sunlight exposure) typically produced little or no new foliage in this first year, while crowns of larger trees in the same area showed substantial new growth. It was hypothesized that this new growth was made possible by reductions in adelgid density due to predation by adult beetles and larvae (McClure & Cheah 2003, Evans 2004). To test this hypothesis, sample twigs collected from these new growth areas in October/November 2006 were examined for HWA crawlers and very low crawler densities were observed. (New growth twigs collected from adjoining areas had very high crawler densities.)

<u>Low-Density Release Plan</u>: A dose-response component was included in the release design, utilizing systematic variations in the number of beetles released at different sites, as well as in the number of beetles per hemlock acre. The per-tree densities evaluated here ranged from 30 to 100 per release site. And the release densities (per hemlock acre) ranged from 100 to 300 per acre. (It should also be noted that all the trees in these release areas were well above the 50% defoliation level that is often cited as the upper limit for effective (biological or chemical) treatment.) The dose-response results indicate that even small releases of 30-50 beetles per tree and 100 per hemlock acre appeared to be effective at initiating the biological control process over a substantial area. And while some positive correlation was noted between release density and quantity of new foliage production, the relationship was not strong. Other situational issues such as tree health, sunlight and stage of infestation appear to be more important determinants of foliage response than beetle quantities.

These results supported the efficacy of a colony-based release design utilizing multiple sites located within 100' of one another to define a self-sufficient predator beetle colony for reproduction and growth. Utilizing 30-50 beetles per site (depending on tree size) to create a ~100 beetle colony allows flexibility and provides short-term coverage. And such colonies can then be spaced on a property as local conditions and resources dictate.

Beetle Activity Indicators: Three important indicator types are needed to monitor *Sasajiscymnus tsugae* beetle activity after release. The first are the hemlock foliage indicators discussed here and below. The second are adelgid density indicators, including Spring ovisac densities, Fall crawler emergence densities and Winter ovisac densities and predation. The third set of indicators are the recovery of beetle adults and larvae. During the first season after release, the foliage indicators will be most important for summer monitoring purposes, with adelgid density comparisons becoming more useful in the Fall. While the importance of both indicators continues in the 2nd season after release, predator beetle recovery will then become a useful indicator as well.

If we presume that observed foliage changes are a result of predator beetle behavior, then we can use these foliage changes as "indicators" to indirectly observe and track the movement of the beetles during the first season after release. Use of this method suggests that after release, the beetles tend to move to the tops of the largest hemlocks in the area to feed and lay eggs. Then they move to adjacent tall trees, repeating the process, sometimes over considerable distances. Why were the beetles' early activities apparently concentrated at the crowns of the larger hemlocks? Perhaps on defoliated trees, the crown holds the largest adelgid (food) population. Perhaps the beetles are attracted to either the height or light conditions at such locations. Or perhaps those light conditions facilitated growth buds that could be released by the beetles' predation.

<u>Second year observations</u> indicate that new growth appears in crown areas as well as on middle and lower branches and on smaller trees in release areas, indicating continuing beetle activity. Adelgid concentrations remain low on the previous year's new growth and both adult predator beetles and signs of beetle predation on adelgids are found following the re-emergence of adelgid crawlers in the Fall. These beetle recovery densities are not high, but they represent an important confirmation of the information provided by other indicators. <u>No</u> substantial reinfestation of prior or current year's new growth was observed at any second year sites.

Measuring Changes in Hemlock Crown Density

The magnitude of short-term changes observed in hemlock foliage in 2006 motivated a search for an objective measurement strategy for hemlock foliage change. The standard USDA crown density measurement strategy, using multiple trained raters with crown density-foliage transparency cards (e.g., Cheah et al 2005), was not readily applicable to private sites where no professional raters were available. An alternative digital strategy, requiring no human judgment, seemed preferable for such private applications. The foliage changes that were so obvious to the human eye should also be detectable in photographic images. But how could information on hemlock crown density (HCD) be extracted from such digital images?

My approach to defining the problem was to focus on a special type of photograph, one that silhouettes the hemlock crown against an open sky. (While such trees are not "representative" of trees in hemlock areas, the hope was that they could be useful for comparisons over time and across similarly situated trees in different areas.) In such a photograph, the hemlock trunk, branches and foliage (density) are represented by darker pixels, while the background (transparency) is represented by lighter pixels. The digital analysis procedure was suggested by several experienced graphic/photographic professionals (Christine von Lersner and Rita & Steve Buchanan). The first operation utilizes the Histogram procedure in Photoshop to represent the dark/light composition in a digital photo by charting the percentage distribution of the pixels from darkest to lightest. The second operation uses the histogram to calculate the cumulative density at a darkness level representing hemlock foliage. This density level can then be compared with corresponding foliage density measurements for other photos to measure change in one tree or to make numerical comparisons between different trees.

The photos and data here illustrate the application of this measurement strategy to a set of 2007 Sasjiscymnus tsugae release sites on defoliated hemlocks near the Horsepasture River in Sapphire, NC. These photos were taken in mid-April and mid-July, after a mid-March release of 50 Sassie beetles at each site. On the right are the "before" and "after" photos which have been cropped in order to focus the measurement procedure on the same crown areas for comparison.

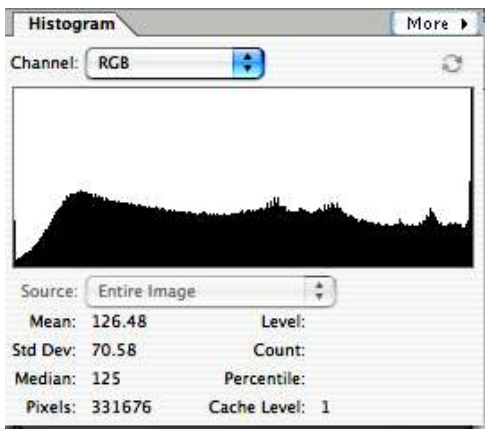
Mid-April

Mid-July

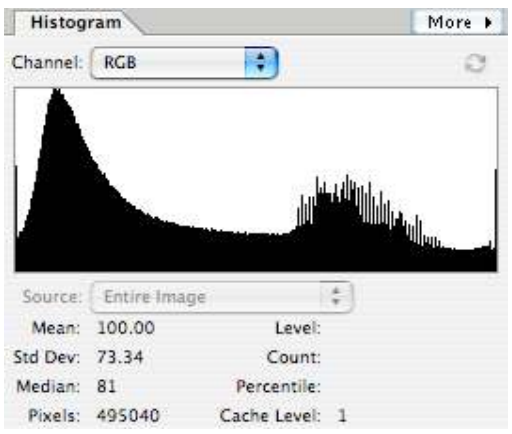
These photos indicate the presence of more foliage on the trees in mid-July than mid-April. But the histogram will allow us to quantify these density differences in terms of the distribution percentage of pixels in the darker color range. The histogram is a plot representing pixel darkness on the horizontal axis and pixel frequency/percentile on the vertical axis – from darkest on left to lightest on right. It also provides cumulative percentile information - from dark to light - at any specified level that can be used to obtain quantitative measures of HCD.

The corresponding histograms for these two photos illustrate even more clearly the extent of foliage growth on the hemlocks in the two pictures. The histogram for the April photo shows a relatively uniform density distribution moving horizontally from dark (left) to light (right) - with a spike at the far right for the white clouds. The histogram for the July photo shows a definite peak for darker pixels in the early 20% of the distribution, representing new foliage.

Mid-April



Mid-July



Utilization of Digital Measurement Procedure:

The difference between these two charts can be used to measure the change hemlock crown densities by calculating the percentile of darker pixels in a photograph. The proposal here is to use cumulative percentile numbers derived from a photograph's histogram to represent the crown density in the pictured tree(s), as well as to measure changes in that density over time. However, this will require selecting a darkness level benchmark that best captures hemlock foliage growth.

The histograms illustrate that changes due to new foliage growth appear well down into the darker end of the spectrum. So this will help us to identify the "best" point in the spectrum for measuring these foliage changes. Table 1 below contains percentile readings for 3 different darkness levels – darkest half, darkest third, and darkest quarter. A review of histograms for such photos, suggests that differences due to foliage changes are concentrated in the darkest 20% of the spectrum. And the results in Table 1 below indicate that either the 25%

or 33% benchmarks would have considerable sensitivity to the 3-month foliage changes represented here. Specifically, the benchmark representing the darkest 25% of the pixel color spectrum, indicates a 19.04% increase (due to new foliage growth) while the benchmark representing the darkest 33% of the pixel color levels, indicates a 16.55% increase (due to new foliage growth).

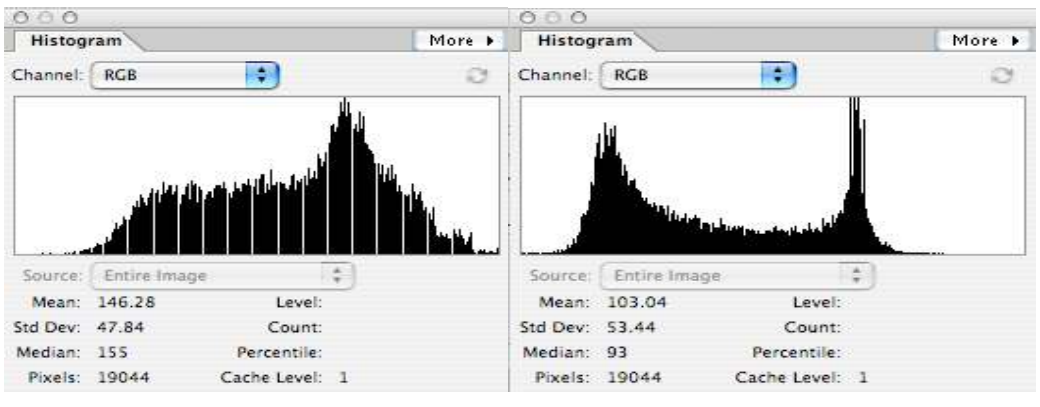
Table 1: Comparisons of Hemlock Crown Density Measurement Benchmarks

	Darkest 1/2	Darkest 1/3	Darkest 1/4
mid-April	51.12%	34.75%	25.35%
mid-July	61.99%	51.30%	44.39%
3 Month Change	10.87%	16.55%	19.04%

Variability in light conditions is always a concern for the use of photographic comparisons, and field comparisons will often exhibit such variability. However it appears that the proposed use of the histogram adequately separates the variability in backlight levels from that of hemlock foliage density. Background light is represented on the right side of the distribution – note the spike for white clouds for the April photograph. But the proposed hemlock crown density measure is derived from the darkest spectrum of the histogram, and does not appear to be unduly influenced by the relative lightness or darkness of the background.

In an experiment to evaluate the "background light" issue, photographer Jack Anthony cropped samples from the above photographs and converted them to black & white with a more equalized background, producing the images below. The corresponding histograms maintain the growth spike noted in comparing the original pictures above. The 25% density percentiles were 4.86% for April and 36.44% for July, producing a change measure of 31.58. (This is higher than the change measures reported above, because this cropping reduced the area of background included and increased emphasis on the hemlock foliage area.)

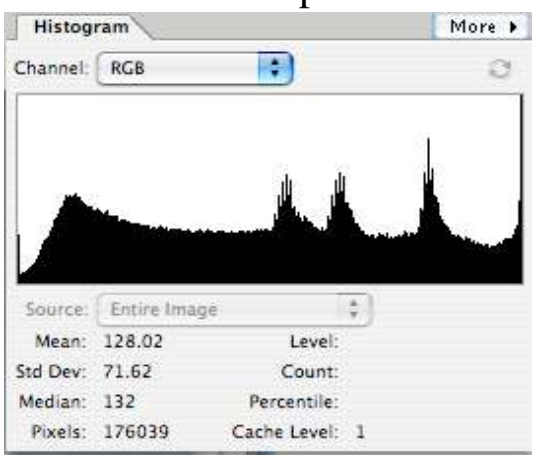
mid-April mid-July mid-April mid-July

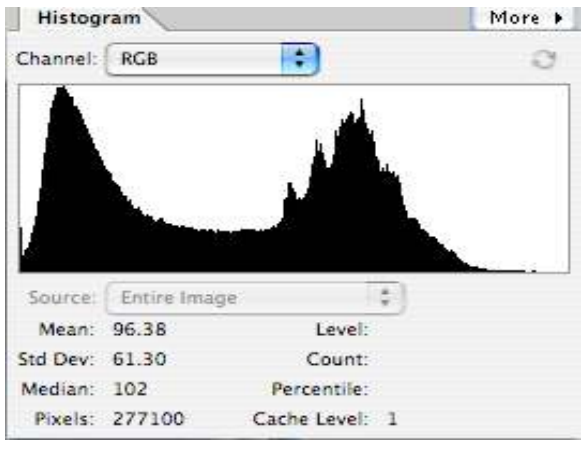


Another concern for utilization of this digital measurement strategy may be the exposure of subject trees to illumination from the front, biasing the foliage density measurement. This issue warrants further investigation - by someone more photographically qualified than myself. But heavy overcast, dusk or dawn appear to offer the optimal conditions for photos that can be used most effectively in this measurement procedure.

Below is a second application of the method to a 50 beetle release site in Sapphire NC.

mid-April mid-July mid-April mid-July





The 50% "Rule"??

One of the core elements of public advice offered by Forest Service officials in western NC is that hemlocks that are more than 50% defoliated by HWA cannot be helped by beetle releases. That advice clearly conflicts with images above, as the "before" pictures are well below 50% foliage levels – probably closer to the 10-20% range. So while this advice may be correct for chemical interventions, it does **not** apply to biological interventions. In addition, while the largest trees in an area are often the most defoliated, biological control will help all the hemlocks in an area. This suggests a much broader applicability for beetle releases in both public and private hemlock areas than is currently advocated by USDA Forest Service.

2007 Expanding Private Beetle Release Efforts

News about the surprising results of my 2006 releases was circulated through local media in Brevard and Cashiers and via presentations to local property owner and other public interest groups. This led to a grass-roots movement in the Brevard area, involving public officials, residential developments and private landowners, and leading to the 2007 release of about 25,000 Sassie beetles purchased from Conservation Concepts and EcoScientific Solutions. Efforts in the Sapphire/Cashiers area resulted in the release of about 12,000 beetles.

While these release efforts were limited by the supply of beetles available, several obstacles to the involvement of private individuals in biological control of HWA were also noted. Foremost among these were active USDA Forest Service media efforts (by personnel in Asheville, Pisgah NF and Nantahala NF) to discourage landowner involvement, both for larger woodland tracks and for neighborhood-level applications. This was reinforced by numerous statements by local Forest Service officials stating that there was "no information" about the effectiveness of HWA predator beetles and by an active media campaign by chemical interests (led by Will Blozan) (Slade 2007, Preston 2007) dismissing the effectiveness of HWA biological control efforts. While the latter efforts are understandable in light of the economic incentives, the former suggest the need for more careful attention to evidence-based HWA policies on the part of USDA Forest Service policy-makers.

Most hemlocks in the Brevard area appeared to be in an earlier stage of HWA infestation than trees at my 2006 sites, and were in less-defoliated condition. In contrast many hemlocks in the Cashiers and Sapphire area were just as, or possibly even more defoliated, than 2006 sites with a significant number of dead trees present in some locations. Generally speaking, the results at these 2007 private release sites paralleled those observed in 2006 and reported above. The dramatic renewals of new top growth in defoliated larger trees were apparent here as well, but the large hemlock tree-hedges (15-30' in height) that were common in Brevard neighborhoods also proved to be very responsive to beetle-induced re-foliation. Several wild 2007 "test releases", designed to obtain more accurate distance measures for predator beetle releases on waterways, will also be reported.

Case 1: **In-town neighborhood area**. A condominium 4-plex in downtown Brevard had a 15' hemlock hedge along the front and one side (pictured), totaling about 400'. Trees were in mid-level infestation with adelgids present at all levels and with foliage graying and bare tips present on many branches. A release was made of 200 beetles at 25 beetles per site, distributed at equal intervals along the hedge. By mid-July all areas of the hedge were covered with extensive new growth, as indicated in photo. Adjoining properties benefited as well: Two larger (30') and more severely defoliated tree hedges – one 100' in length and running parallel to the complex across a 2-lane highway and another perpendicular to this and running 300' feet away from the property also experienced substantial new foliage, especially at crowns.

Case 2: Residential Development area. Sherwood Forest, a large, environmentally-oriented development (1000 acres) in the Brevard area initiated biological control efforts to replace chemical control efforts. About 6000 beetles were released on "green" and trail areas as well as on privately-owned tracts of residents and adjoining property owners. Assessments after leaf-fall indicated substantial re-foliation of larger hemlocks in release areas and along waterways. Plans are in place to extend biological control coverage in 2008.

Case 3: Municipal efforts for biological control of HWA. Proposals were made in Fall 2006 to both the City of Brevard and Transylvania County for purchase of predator beetles for release at municipal sites in the Brevard area. City officials agreed to a 1000 beetle purchase for release in several small parks and a 400 acre watershed area adjacent to the city. County deliberations included USDA extension officials in a series of meetings that lead to a positive vote by County Commissioners for a 1000 beetle purchase. The County release was directed to an 8 acre mansion property (Silvermont) in downtown Brevard. This property contained ~300 medium to large hemlocks, and was surrounded on three sides by private properties containing large hemlocks.

Brevard City park and watershed releases involved younger trees in relatively early infestation areas, where hemlock health was not yet significantly impaired and defoliation was at an early stage. Spot checks at these release sites indicate reductions in adelgid densities and continued production of new growth, but none of the dramatic foliage changes observed on more severely defoliated trees. The County release at Silvermont was done by ecology students at Brevard College. These trees were larger and more heavily infested than those above. Heavy HWA infestations had moved from the ground level to higher level branches and some "graying"

of the hemlock foliage was apparent. While a formal assessment will be conducted by the release group, significant new growth is apparent on the crowns of many hemlocks in this release area.

Case 4: Wild waterway test areas. Observations from 2006 releases along waterways suggested an unexpectedly long range of influence by newly released Sassie predator beetles. Several tests were conducted in 2007 to further examine this issue. The first was a relatively isolated waterway (Democrat Creek) in a new Nature Conservancy tract (Silver Run Preserve) surrounded by Nantahala National Forest.

Democrat Creek Site

This site was located in the general vicinity of the 2006 release area and the medium to large trees (15-30" DBH) along the waterways were severely defoliated, with little new foliage being produced. In March 2007, two sets of 50 *Sasajiscymnus tsugae* beetles were released at locations (●) near the confluence where two tributaries come together to form the creek, which then runs several miles south before emptying into the Whitewater River. (The Whitewater River is benefiting from several USDA-sponsored beetle releases by the Clemson Lab, beginning in 2005 and creating large areas of re-foliating hemlocks along areas of this waterway.)

Dramatic new crown growth was observed at the two release sites by mid-July, but a more careful assessment was delayed until after the leaf-fall in mid-November. Because of the defoliated state of hemlocks in this area, new crown growth offered a clear indicator of beetle activity. New growth was observed continuing at least 1500 feet south down the creek, over 800 feet east up one tributary and 600 feet north up the other tributary.

A release at a second private waterway site (Slippery Witch Falls) also utilized 100 beetles distributed over several large trees. After leaf-fall, new crown growth was observed for a Nantahala National Forest area extending over 2000 feet downstream and about 500 feet upstream. Together, these sites suggest that a series of low-density waterway releases could be an effective strategy for extending biological control into riparian areas.

Discussion:

Forest Managers: Evidence from low-density releases of *Sasajiscymnus tsugae* predator beetles offers new options for extending biological control of HWA across a broader range of woodland areas. Unlike high-density beetle releases that require relatively healthy trees with heavy adelgid infestations, low-density releases can be utilized in hemlock areas with trees experiencing substantial defoliation and relatively low adelgid densities. While not all trees may be saved in such areas, a release of 100 beetles in a severely defoliated hemlock cove or waterway area can establish a self-sustaining beetle colony that will cover a substantial area. This can provide immediate support for recovery of surviving hemlocks in the area, as well as longer-run protection to these ecologically critical zones. And waterway releases (e.g., at roadway crossings of creeks or rivers) offer an effective way of dispersing beetles into riparian woodlands to protect important hemlock habitats.

USDA Forest Service: Evidence from low-density *Sasajiscymnus tsugae* releases in both private woodlands and neighborhood areas suggests the need for a more careful evaluation of USDA policy statements in light of evidence-based criteria. Several public statements made by Forest Service representatives in western North Carolina: Predator beetles cannot help trees that are more than 50% defoliated; Predator beetles are not effective for use in neighborhoods … are not supported by the empirical evidence. And efforts to discourage private landowners from utilizing biological control strategies appear to be misguided, at the very least. The USDA Forest Service should assist, rather than discourage, private participation in biological control of HWA. For example, there are many nature-oriented groups in our communities (hikers, anglers, birders) that would be capable of purchasing beetles in 1000 unit lots and conducting low-density releases in environmentally sensitive public areas – areas that are not being addressed by current USDA release efforts.

Private Landowners: Low-density "Sassie" releases can achieve 10 times the acreage coverage of conventional release protocols and represent a cost-effective strategy for HWA control on a wide range of property types. The primary needs are for more private labs to supply beetles and for more commercial arborists to participate in providing biological control services to landowners.

Acknowledgements:

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