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RESEARCH REPORT

Effects of Winter Cut-and-Leave Suppression on SPB Overwintering Success

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Jessica Cancelliere[1]

[1]Research Scientist, NYS DEC Division of Lands & Forests, Bureau of Invasive Species & Ecosystem Health, jessica.cancelliere@dec.ny.gov

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Introduction

DEC Forest Health uses cut-and-leave suppression to slow the spread of southern pine beetle (SPB) on Long Island. This technique involves felling infested trees and uninfested buffer trees towards the center of an infestation (spot) and leaving the trees on the ground. The treatment reduces spot growth by disrupting semiochemical communication between beetles. Emerging adults disperse into the surrounding forest instead of attacking new trees on the periphery of a spot (Billings, 1995). Cut-and-leave is traditionally applied during periods when SPB spots are actively expanding (May-October). However, in the Northeast, it was considered that applying this treatment in the winter months would promote SPB brood mortality by exposing larvae to cold temperatures and moisture (K. Dodds, pers. comm., November 25, 2015). Increased brood mortality during the winter results in fewer SPB emerging in the spring to attack new trees. The objective of this study was to compare the success of overwintering SPB within infested pitch pine trees that were cut (experimental) or left standing (control), to determine if cut-and-leave applied in the winter increases SPB brood mortality and reduces spring-emerging populations. This was a two-year study that occurred within the Central Pine Barrens Preserve in Suffolk County, New York.

Methods

To determine if our suppression affected the overwintering success of SPB, we defined a "successful" SPB as one that, at the time of sampling, was alive and in the late stages of development in the outer bark (larval instars 3 and 4). Early stage larvae are more vulnerable to cold-temperature mortality. If an SPB can survive the winter long enough to progress to a late-stage larva in the outer bark, then it has a high likelihood of surviving until spring emergence (Tran et al. 2007). We assumed that any late-stage larvae that were alive at the time of sampling would have successfully emerged in the spring.

Three different methods were utilized during the study to assess the success of SPB overwintering populations. The first method was to quantify SPB emergence by placing infested bolts into rearing chambers and counting the number of SPB that emerged. The second method utilized destructive bark sampling, in which circular bark discs were extracted from the tree and dissected for various life stages. The third method was to count the number of entrance and exit holes on a subset of standardized samples from each tree to quantify attack (entrance) and success (exit). In Year 1, our sampling design included emergence and bark sampling, and in Year 2, it included emergence and entrance/exit hole counts.

Year 1

Emergence

Thirty SPB-infested pitch pine (*Pinus rigida*) were randomly selected from stands where cut-and-leave suppression had occurred and stands where no cut-and-leave had occurred (60 trees total) at Sears Bellows Park, Suffolk County, New York (Fig. 1). Spots were located through SPB aerial survey data and discussions with DEC SPB Operations staff on Long Island. Sample trees needed to be within a spot with no less than 10

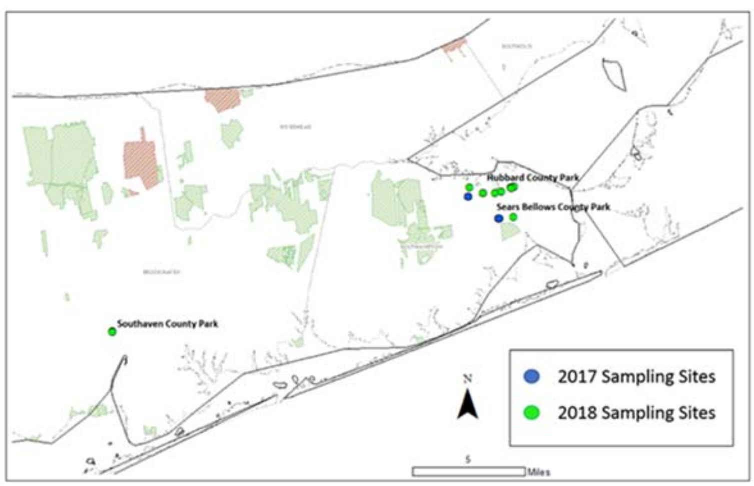


Figure 1.Sampling locations within Sears Bellows, Hubbard, and Southaven County Parks, Suffolk County, NY.

infested trees to be considered for the study. Individual trees within spots were selected based on the presence of pitch tubes indicating recent SPB attacks. Experimental trees were felled towards the center of the spot between December 1, 2016 and January 31, 2017 and left on the ground until the week of March 27, 2017. Control trees were left standing for the winter and then felled in early spring during the week of March 27, 2017. Two 1 m bolts (A & B) were extracted from all sample trees between a bole height of 3-6 m (Fig.2). GPS coordinates were collected for each tree's location and each tree was given a tag designation indicating its treatment (cut or standing), tree number (1-15), and bolt (A or B). The diameter and number of pitch tubes for each bolt were recorded prior to transport to the NYSDEC Forest Health Diagnostic Lab (FHDL) located in Delmar, New York on March 30, 2017. Bolts were placed in individual emergence chambers for SPB rearing. Emergence chambers consisted of 3' long, 12" diameter Sonotube concrete forms with plastic end caps affixed to each end. A removeable collection jar was attached to the plastic end cap that faced a light source which was left on 24 hours/day (Fig.3). The collection jar allowed light to pass through into the chamber. Insects emerging from the bolts inside, attracted to the light, would fly into the jar and get trapped, where they were collected. The emergence chambers were stored in an unheated facility where average temperatures ranged from ~ 0 -23°C. SPB were collected and counted from each chamber once each week, from April 1- June 30, 2017, when emergence ceased. Upon completion of the sampling, bolts and woody debris were chipped to destroy infested material.

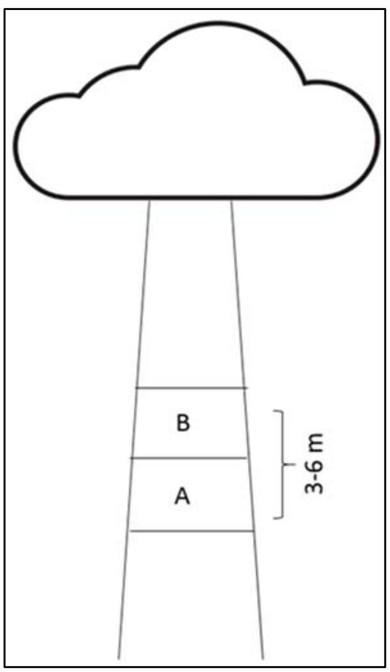


Figure 2. Location of extracted bolts (A &B) on sample trees.

Figure 3. SPB emergence chambers

Bark Sampling

An additional 5 cut and 5 standing SPB-infested pitch pine were randomly selected from stands where cut-and-leave suppression had occurred and stands where no cut-and-leave had occurred, at Southaven County Park, Suffolk County, New York. For the cut treatment, trees were selected that had been felled toward the center of a spot during the winter suppression season (November 1, 2016-January 31, 2017) and left on the ground. For the control (standing), trees were selected from spots that had been identified through aerial survey data and groundtruthed by DEC SPB Operations staff, but had not been suppressed during the 2016-2017 season. Individual trees were selected based on the presence of pitch tubes indicating recent SPB attacks. GPS coordinates were collected from each tree, and an ID number was assigned to each (1-5 cut, 1-5 standing). Standing trees were felled during the week of April 3, 2017. The same week, six 3” circular bark discs (Fig. 4) were extracted from the 5 cut and 5 standing trees using a 3” hole saw: 3 discs between 0-2 m and 3 discs between 2-4 m. Trees were divided into 4 longitudinal quadrants and bark discs were extracted from the three quadrants not in contact with the ground. Bark discs were stored in plastic bags labeled with the site name, date, tree ID, aspect, and extraction height. Bark discs were transported to the FHDL in Delmar, NY for processing. Each bark disc was dissected by removing one layer of woody tissue at a time with a small knife or scalpel, working from the phloem through to the outer bark. SPB brood residing in the phloem or outer bark were exposed as layers of bark were removed. For each SPB identified, we recorded life-stage (larval instar 1-4 [L1, L2, L3, L4] or adult), whether it was alive or dead, and where it was located (outer bark/phloem).

Figure 4. Three-inch circular bark discs extracted from sample trees.

Analysis

Differences in SPB emergence between cut and standing trees were analyzed using the Mann Whitney U test, because data associated with the cut treatment was positively skewed (skew = 2.6). For bark sampling data, a one-tailed t-test was used to compare survival of early and late instar larvae among treatments. All analyses were performed in Excel.

Year 2

Emergence

Infested polygons that were prioritized for cut-and-leave were identified through aerial survey data and through discussions with DEC SPB Operations staff on Long Island. Before each polygon was suppressed, SPB sawyer crews visited the sites and randomly selected 30 sample trees for our study. Sample trees needed to be within a spot with no less than 10 infested trees to be considered for the study. Trees were selected based on the presence of pitch tubes indicating recent SPB attacks. Sample trees were categorized into groups of 3, with each group containing 2 experimental trees (1 cut, 1 cut/scored), and 1 control tree (standing). Each group was replicated 10 times. In the cut/scored treatment, added in Year 2, a longitudinal groove was cut through the bark, phloem and surface of the sapwood the entire length of the tree. Scoring allows moisture to enter under the bark, resulting in the quick separation of bark from the sapwood to potentially increase brood mortality by exposing them to moisture and cold temperatures (K. Dodds, pers. comm., November 25, 2015). Sample trees were tagged and flagged a different color for each treatment, and DBH and GPS coordinates were collected. Experimental trees were felled between January 15 and January 30, 2018, towards the center of the spot, and left on the ground until March 17-18, 2018. Experimental trees were felled after all other infested trees in the spot had already been suppressed, so that they would be accessible for sampling. Control trees were left standing for the winter and then felled in early spring on March 17- 18, 2018. Canopy height, height and length of the infested bole, DBH were collected. Two 1 m bolts were extracted from all trees. The length of the infested bole was measured and divided in half. From each tree, one bolt was extracted from the bottom half (M1) and one bolt from the top half (M2) (Fig.5) (K. Dodds, pers. comm., March 1, 2018). The diameter of each bolt was collected. Bolts were transported to the FHDL on March 18, 2018 and placed in individual emergence chambers for SPB rearing. Protocols for emergence were the same as described for Year 1, but in Year 2, the emergence room was moved inside the FHDL, where bolts were stored at temperatures closer to room temperature, ~18-22°C. SPB were collected once each week from March 19 – June 20, 2018, when emergence ceased. High humidity levels in the FHDL made bolt storage there problematic, so a fan was added and run 24 hours a day to maintain air flow and reduce fungal growth on the bolts.

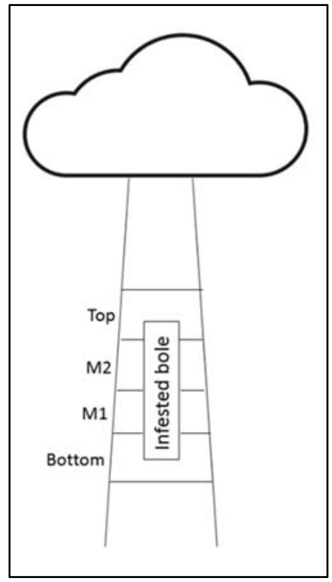


Figure 5. Location of extracted bolts (M1&M2) on sample trees. Courtesy of K. Dodds, USFS.

Entrance/Exit Hole Counts

After emergence ceased, bolts were removed from the chambers and dried out for one month to make bark removal easier. Four 15 x 15 cm bark sections were randomly selected and removed from each bolt and entrance and exit holes were counted for each. Exit holes could be differentiated from entrance holes because they were evident from the outer bark. When SPB enter, they first crawl into fissures, but when they emerge they come straight out through the bark. Locations with successful larval development have corresponding exit holes. Accurately quantifying the number of exit holes can be difficult, because they cannot always be differentiated from air holes that ovipositing adults make as they tunnel through the phloem (M. Ayres, personal communication, June 5, 2018). We determined that inserting a small pin through the hole in question could help differentiate between an exit hole and an air hole. With exit holes, the pin would always penetrate all the way through from the outer to the inner bark. With air holes, the pin would frequently not penetrate all the way through the bark, yet no evidence of an unsuccessful beetle emergence was visible. We used this exercise to differentiate between the exit and air holes. Upon completion of sampling, bolts and woody debris were chipped to destroy infested material.

The entrance/exit hole count method was added to supplement the data after Year 2 SPB emergence counts were so low compared to Year 1. It is possible to get reliable estimates of attack by counting entrance holes via bark dissection, but emergence estimates by counting exit holes can be complicated by several factors, such as more than one beetle using the same hole, or holes made by other species. Despite these problems, independently quantifying entrance and exit holes within a standardized area, could potentially provide an unbiased estimate of SPB activity (M. Ayres, personal communication, June 5, 2018). We considered another well-known method that dependently quantifies entrance and exit hole counts - the attack/emergence ratio, in which the number of entrance holes (attack) is divided by the number of exit holes (emergence) to provide an index of SPB success. A few studies in the 1970's and 1980's utilized attack/emergence ratios (Thatcher and Pickard 1964, Coulson et al. 1976, Moore 1978, and Gagne et al. 1980). The methodology and accuracy of these ratios is considered suspect and has been the target of a lot of criticism (F. Stephen, personal communication, November 20, 2018). In the end, we excluded the attack/emergence ratios from our analysis, because we felt our sampling area was not large enough to make any conclusions regarding the relationship between entrance and exit holes.

Analysis

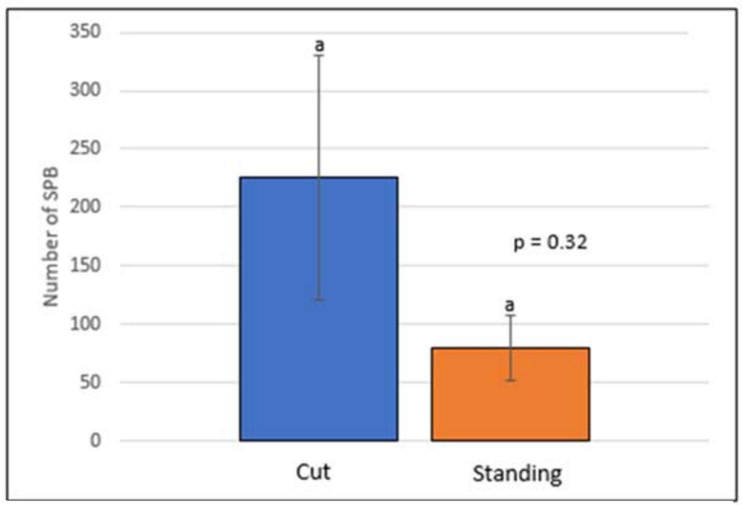
Differences between SPB emergence between control (standing) and experimental (cut, cut/scored) trees were analyzed using a one-way ANOVA. Mean entrance and exit hole counts were converted from mean counts/cm^2 to mean counts/m^2, and then mean entrance and exit hole counts between treatments were examined using a Kruskal-Wallis H test, because data associated with all three treatments were positively skewed (skew = 2.58-3.03).

Results

Year 1

Emergence

A total of 4,586 SPB (3,390 from cut, 1,196 from standing) emerged from 22 (12 cut, 10 standing) of the 30 total pitch pine trees included in the experiment. SPB emergence data was right-skewed and over-dispersed in both cut and standing treatments, with 45% of SPB from the cut treatment emerging from the same tree and 32% of SPB from the standing treatment emerging from a single bolt. Eight trees (3 cut, 5 standing) did not yield any SPB and 3 trees (2 cut, 1 standing) only yielded a single SPB during the collection period. Mean SPB emergence counts were 226.0 ± 104.9 SE in the cut and 79.8 ± 28.1 SE in the standing treatment (Fig. 5), but this comparison was not statistically significant (U = 101.0, p = 0.32).



Bark sampling

A total of 92 SPB larvae (79 from cut, 13 from standing) were found within 27 (15 felled, 12 standing) of the 60 total bark samples (Tab. 1). Mean SPB survival of both early and late-stage larvae (alive SPB/total SPB x 100) was 38.5% ± 16.9% SE in the cut and 41.7% ± 25.0% SE in the standing treatments (Fig. 6), but

Table 1. Total SPB life stages extracted from bark discs in Year 1.

		All individuals		Average Across Trees	
Treatment	**Life Stage**	***n***	**Alive (%)**	n_{trees}	**Average alive(%)**
Cut	Early stage	3	0	0.6	0
	Late stage	76	52.7	15.2	31.9
Standing	Early stage	7	57.1	1.4	33.3
	Late Stage	6	0	1.4	0

this comparison was not statistically significant (p = 0.46). Mean survival was skewed by the 57.1% survival of early-stage larvae in the standing treatment (Tab. 1). When early-stage larvae were removed from the analysis (because they did not meet the criterion for a "successful" overwintering SPB described in *Methods*), we saw a different result. Mean SPB survival of late-stage larvae was 49.4% ± 20.8% SE in the cut and 0.0% ± 0.0% SE in the standing treatment, and this result was significant (p = .02) (Fig. 6).

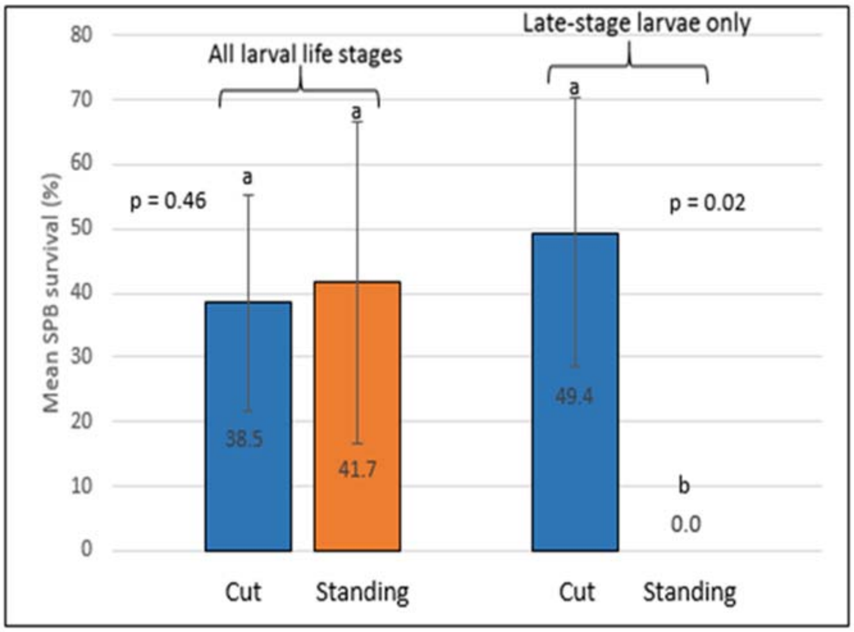


Figure 6. Mean survival of SPB larvae in bark discs in Year 1.

Year 2

Emergence

A total of 134 SPB (68 from cut, 43 from cut/scored, 23 from standing) emerged from 18 (5 cut, 6 cut/scored, 7 standing) of the 30 total pitch pine trees included in the experiment. Mean SPB emergence counts were 6.8 ± 2.9 SE in the cut, 4.3 ± 2.3 SE in the cut/scored, and 2.3 ± 0.8 SE in the standing treatment, but this relationship was not statistically significant [F (2, 27) = 1.03, p = 0.37) (Fig. 7). Because SPB emergence was much lower in Year 2 than in Year 1, we dissected a subset of the 15 x 15 cm bark sections used for the entrance/exit hole counts (48

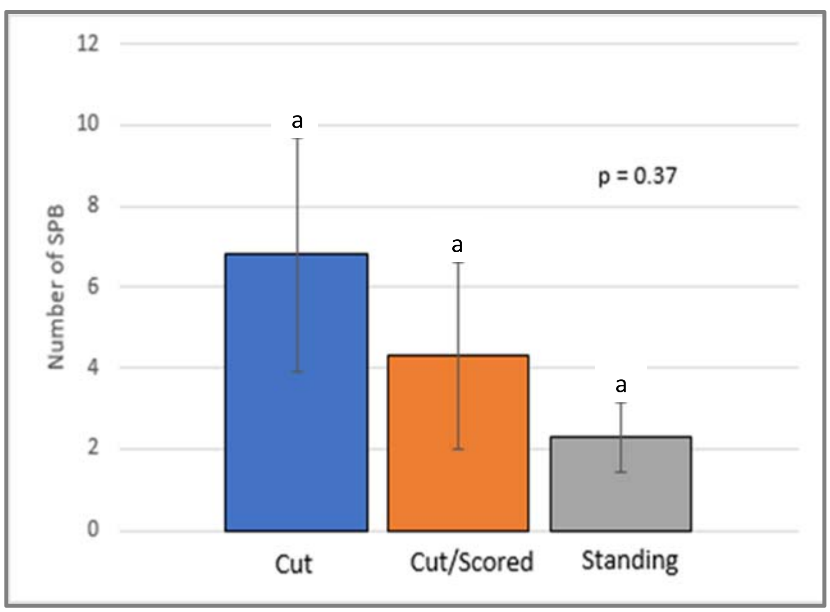


Figure 7. Mean number of SPB that emerged from cut, cut/scored and standing bolts in Year 2.

of 170 total bark sections) to collect data to help understand the reason for the low emergence. We observed high early instar mortality, and lack of successful feeding gallery establishment.

Entrance/Exit Hole Counts

Mean entrance hole counts were 183.3/m^2 ± 22.5 SE in the cut, 162.8 /m^2 ± 13.4 SE in the cut/scored, and 171.8 /m^2 ± 27.7 SE in the standing treatments (Fig. 8). Mean entrance hole counts among treatments was highly insignificant (Chi square = 0.26, p = 0.88, df = 2), which was expected because attack should have been relatively equal among treatments. Mean exit hole counts were 175.9/m^2 ± 110.6 SE in the cut, 123.3 /m^2 ± 27.1 SE in the cut/scored, and 55.9 /m^2 ± 24.6 SE in the standing treatment, and these results were also insignificant (Chi square = 4.91, p = 0.09, df = 2).

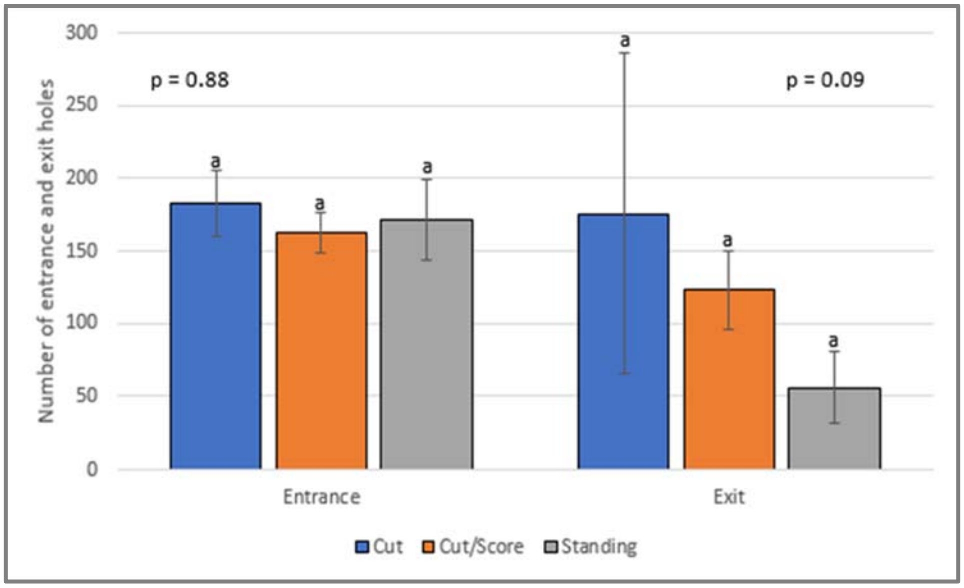


Figure 8. Mean entrance and exit hole counts across treatments (per square meter).

Discussion

The goal of applying cut-and-leave suppression in the winter months was to increase brood mortality by exposing larvae to cold temperatures and moisture. However, our results generally indicate no significant difference in the overwintering success of SPB between trees treated with cut-and-leave and trees left standing for the winter. Although statistically insignificant, data trends often showed results contrary to our goal, in which SPB success was higher in the cut trees than the standing trees. In the first year of the study, 2,194 more SPB emerged from cut bolts than from standing bolts. The same year, late-stage larval survival was 49.4% in the cut treatment, but 0% in the standing treatment. In Year 2, more SPB emerged from the cut and cut/scored treatments than the standing treatment (68, 43, and 23, respectively) although the difference was much smaller than in Year 1. In Year 2, mean entrance hole counts were highly insignificant, which means that trees exhibited about the same attack density across treatments (p = 0.88; M_{cut} = 183.3/$m^{2;}$ $M_{cut/scored}$= 162.8; $M_{standing}$ =171.8). However, the mean exit hole counts showed higher variability between treated and untreated trees, and the result was much closer to significance (p = 0.09; M_{cut} = 175.9/$m^{2;}$ $M_{cut/scored}$= 123.3; $M_{standing}$ = 55.9).

There are a few explanations for why SPB could survive better in cut trees as opposed to standing trees, as found in the Year 1 bark sampling. Natural predators of SPB, namely woodpeckers, might be more active on standing trees than on cut trees. Woodpeckers prey on the late-stage larvae in the outer bark, because they are larger and easier to access than the early life stages (Kroll and Fleet, 1979). Our bark sampling results (Tab. 1) showed a much higher number of late-stage larvae present in the cut trees versus the standing trees (76 in cut, 6 in standing), and we attributed that difference to higher predation in the standing trees. Additionally, cut trees are felled towards the center of a spot, creating an open canopy condition that increases the amount of solar radiation reaching the trees. The solar radiation may increase the temperature of the phloem and outer bark where SPB reside and protect them from lethal cold temperatures. Finally, Northeastern winters (specifically on Long Island) may not provide the lower lethal temperatures needed to induce significant SPB brood mortality within cut-and-leave treatments. SPB are limited by minimum winter temperatures that kill overwintering larvae (Ungerer et al. 1999, Trân et al. 2007). But Dodds et al. (2018) noted that "while average annual temperatures have not increased very much across New Jersey in the 50 years between 1960 and 2010, minimum winter temperatures have increased approximately 4.2° C (Weed et al. 2013)". To kill 95% of SPB, air temperatures on the coldest night must reach about -22° C (Trân et al. 2007). Temperature records from the Northeast Regional Climate Center show that the last record of a minimum temperature in that range on Long Island was in 1988. From 2000-2017, the average minimum temperature on Long Island in January was -13.8° C, which would only kill an estimated 25% of SPB (Trân et al. 2007). The most significant cold spell on Long Island since SPB was detected occurred in February 2016 when temperatures dropped to -20° C, resulting in about 80% mortality of SPB at study sites (Cancelliere, 2015).

Our results indicate that natural forces, such as predation, may play a larger role in killing overwintering SPB populations than our cut-and-leave suppression. If our management cannot induce mortality greater than what SPB naturally experience in their environment, then devoting significant resources to winter suppression is impractical. A more effective strategy is to restrict cut-and-leave to the warmer months when SPB are active, and when studies have shown it to be most effective (Billings 1995, Clarke and Billings 2003).

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