be a significant constraint during invasions by other species. Although regions where emerald ash borer has been found in North America could be considered "cold," with an average low January temperature between -29 to -18°C (-20 to 0°F), colder regions have an average low January temperature frequently between -40 to -34.5°C (-40 to -30°F). The potential for emerald ash borer to survive and cause damage under these extreme conditions is not known.

Previous work suggests emerald ash borer will typically overwinter as a pre-pupa. Earlier instars may also overwinter, perhaps as part of a 2-year lifecycle. Prepupae will overwinter in a pupal cell commonly formed in the outer sapwood, but other life stages may be found in the phloem or bark.

Much of our current understanding of the cold tolerance of emerald ash borer is inferred from the presumed distribution of the insect in Asia, not careful observations of the insect. Preliminary reports on the cold hardiness of the insect in Ontario suggest that cold causes very little mortality until the insect actually freezes (Sobek et al. 2009). The temperature at which an insect freezes is known as its supercooling point. Sobek et al. (2009) indicate that the average supercooling point of emerald ash borer larvae recovered from Ontario was -30.6°C (-23°F). However, Wu et al. (2007) suggest that the supercooling point of larvae from China falls between -26.4 to -23.0°C (-15.5 to -9.4°F).

The objectives for our study were to measure supercooling points for emerald ash borer larvae recovered from naturally-infested green ash (Fraxinus pennsylvanica) in St. Paul, MN. We then developed an equation to relate the predicted extent of mortality to the lowest temperature experi-

enced by the larvae. Finally, we measured the survival of larvae in infested logs exposed to different cold regimes.

Methods

Supercooling points. Larvae were collected at random from infested trees felled in St. Paul, MN in June 2009. Supercooling points were measured using copper-constantan thermocouples (24 gage, non-stranded) following the methods of Carrillo et al. (2004). These larvae (n=11) were presumed not to be winter acclimated and provided a summer baseline. Larvae were again collected and supercooling points measured from late October to early December 2009 (n=62) and were presumed to be fully acclimated. Supercooling point data were analyzed in @Risk (Palisade Corp., Ithaca, NY) to determine whether the observations were normally distributed.

Larval winter survivorship.

Three green ash trees that were naturally infested with emerald ash borer were felled in St. Paul, MN on 28 Dec 2009. Logs (ca. 0.6 m in length) were taken from upper-, mid- and lower-canopy braches. Logs (n=20) from each tree and canopy level were sealed with paraffin wax and randomly assigned to each of five batches. Bark was peeled from logs of the first batch immediately to determine initial larval densities and condition. Each of the other batches was assigned to one of four treatments: (i) logs cooled to a target of -35°C in a sub- zero freezer; (ii) logs held outdoors in northern Minnesota near Grand Rapids; (iii) logs held outdoors in St. Paul, MN; and (iv) logs held in a walk-in cool room at approximately 4°C. We drilled 5.6-mm (7/32 in.) holes at an oblique angle to a depth of approximately 5 cm on the future north and south face of the smallest and largest diameter log within batches to be kept outdoors or in the walk-in cool room. We inserted a thermistor from a Hobo Pro v2, 2 ext temp (Onset Computer Corp., Bourne, MA) into each hole and sealed the hole with high vacuum grease. The data logger was programmed to record temperature once every five minutes. We also screwed eye-bolts into the logs that were held outdoors, chained the logs together, and secured them with a padlock to prevent unauthorized removal. Logs held near Grand Rapids were further secured behind a locked gate. All handling procedures in northern Minnesota were reviewed and formally approved by the Minnesota Department of Agriculture. With the exception of the freezer treatment, all logs were exposed to their respective treatments for 5-6 weeks. For the logs destined for the freezer, we drilled 2.8- mm (7/64in) holes on the lower (in contact with a layer of polystyrene insulation) and upper (exposed to the air) surfaces of each log. We inserted a 24 gage copper-constantan thermocouple into each hole to record log temperatures. Logs were chilled to ca. -35°C and moved to the walk-in cold room for less than 72 hrs. For all treatments, after cold exposures were complete, bark was peeled from logs, larvae counted, and the condition of each larva noted. Larvae that did not move after repeated observations over 24 hrs were considered dead. Larvae that were not damaged during the peeling process were saved for additional observation and testing. Data were analyzed by using logistic regression (PROC LOGISTIC in SAS).

Results and Discussion

Supercooling points. Winter-acclimated larvae (collected between Oct-Dec) had a mean supercooling point of -25°C (-13°F), which was significantly colder than the supercooling point of non-acclimated larvae (-18°C; 0°F; $t=5.1$, $df=13$, $P<0.01$). Supercooling point observations from the winter-acclimated larvae were not significantly different from a normal distribution (Chi-square = 5.7; $P>0.1$). From our simple model that related the coldest temperature experienced by emerald ash borer larvae to the extent of mortality, we predicted that when larvae reach -17.8°C (0°F), 5% will die; at -23°C (-10°F), 34% will die; at -29°C (-20°F), 79% will die; and at -34°C (-30°F), 98% will die.

Larval winter survivorship.

More than 90% of the larvae that were recovered at the start of the experiment were of "good" color (buff-yellow) and actively moving. A statistically equivalent proportion was moving when extracted after ca. 5.5 weeks in the walk in cold room, a treatment where we predicted no mortality. A significantly lower proportion of the larvae moved after being extracted from logs held outdoors in St. Paul. Only 5-10% of larvae moved after being extracted from logs held outdoors near Grand Rapids, MN or chilled in a sub-zero freezer. Approximately 40% of the larvae from near Grand Rapids had turned brown, clear evidence of tissue damage and strong additional evidence for mortality.

Follow-up observations confirmed that 100% of the larvae that were brown were clearly dead 3 weeks after extraction. Between 75-85% of larvae that were inactive at the time of extraction were dead 3weeks after extraction, while only 5-15% of the larvae that were active at the time of extraction were dead after the same amount of time.

Minnesota winters, especially in the northern part of the state, may cause substantial mortality of emerald ash borer larvae. However, even with the extreme cold air temperatures that were experienced near Grand Rapids, MN, some emerald ash borer larvae survived. Thus, cold temperatures may not completely eliminate the insect. However, cold temperature may help to keep populations from building quickly and may give ash trees some time to recover from initial attacks.

We have also learned that air temperatures, recorded at standard meteorological weather stations, are not necessarily the most reliable measure of the temperature experienced by overwintering emerald ash borer larvae. Trees warm considerably on sunny days through radiant heating. Larvae that are able to form a pupal cell in the outer sapwood may be afforded some protection against brief drops in temperature.

These results have significant implications for predictions of the future range of emerald ash borer, spread rates of the insect in areas with a harsh winter climate, and the time required for these insects to kill a tree.

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One Big G

By Jake Kocak, Assistant S

From open until close, this past golf season, 2013, will go down as one of the shortest in recent memory. At Somerby Golf Club, we had our hands full with not only maintaining the golf course to championship standards, but also with the construction of a one-acre putting green (the putting green was built within a subdivision of the Somerby Community surrounded by 29 new lots). With all of the challenges the construction process bought, the 2013 golf season felt much longer than the calendar indicated for the staff at Somerby,

The project was contracted out to Greenseth Golf, with Scott Greenseth being the owner/opera-

Green

Superintendent Wayzata Golf Club (Former Assistant at Somerby Golf Club)

tor; he was essentially a one man show and our staff provided him with help on a daily basis (anywhere from one person to our entire staff depending on the day). Scott is to be credited and commended for the design of the green and the overall flow of it. See pictures for the design and layout; the green is really long and not very wide, roughly about 800'x 50' with the goal being to touch as many lots as possible.

The green also has really nice flow and undulation, with two bluegrass mounds in the middle of it and a 22 foot elevation change from one end to the other. The green was seeded with A-4 bentgrass on a profile with 4" pea rock and a 10"

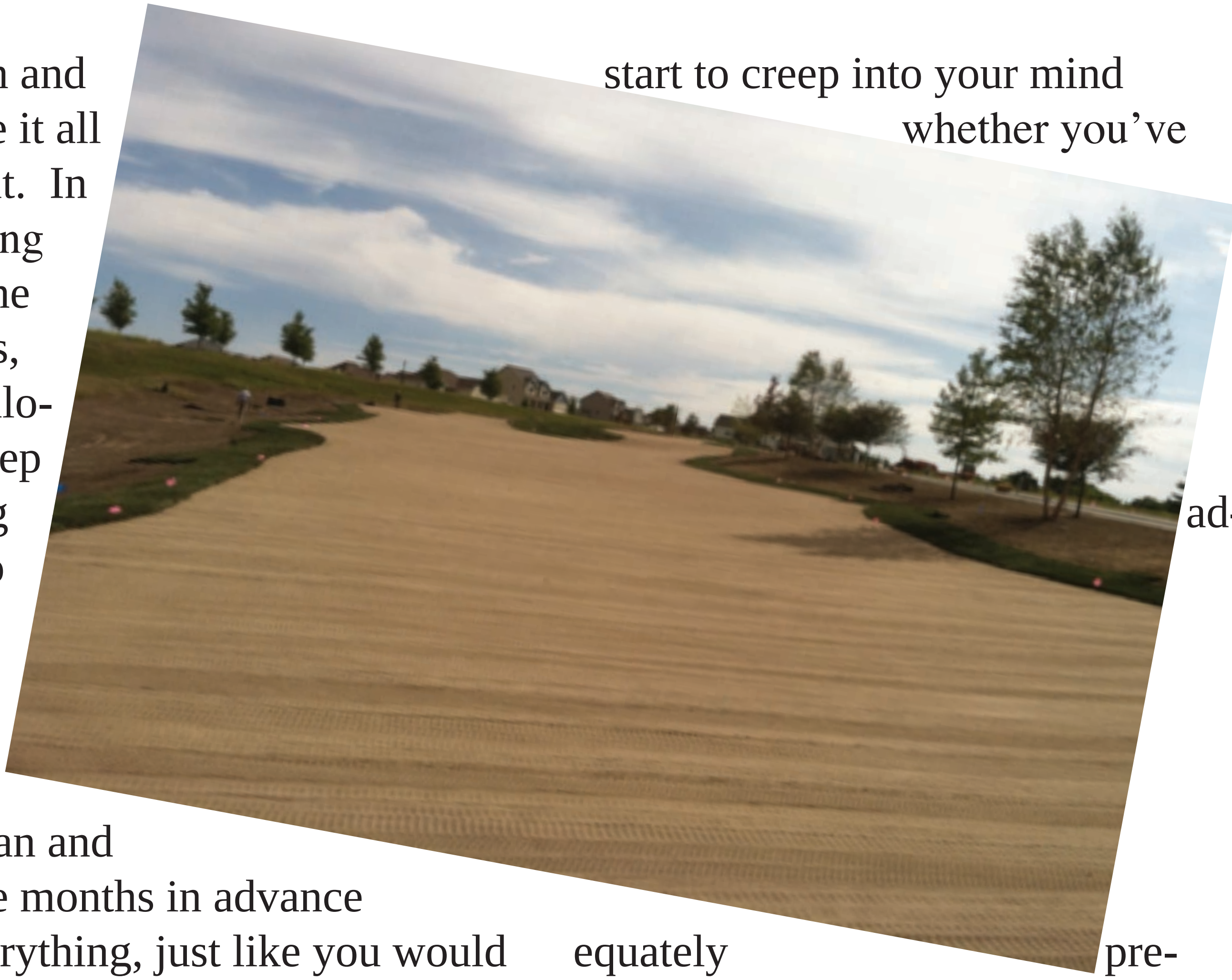
89/11 greens mix. Both sand and gravel were from a local sand/gravel pit and the sand was blended with the peat locally as well. The goal was to keep the new putting green profile and grass type similar to the

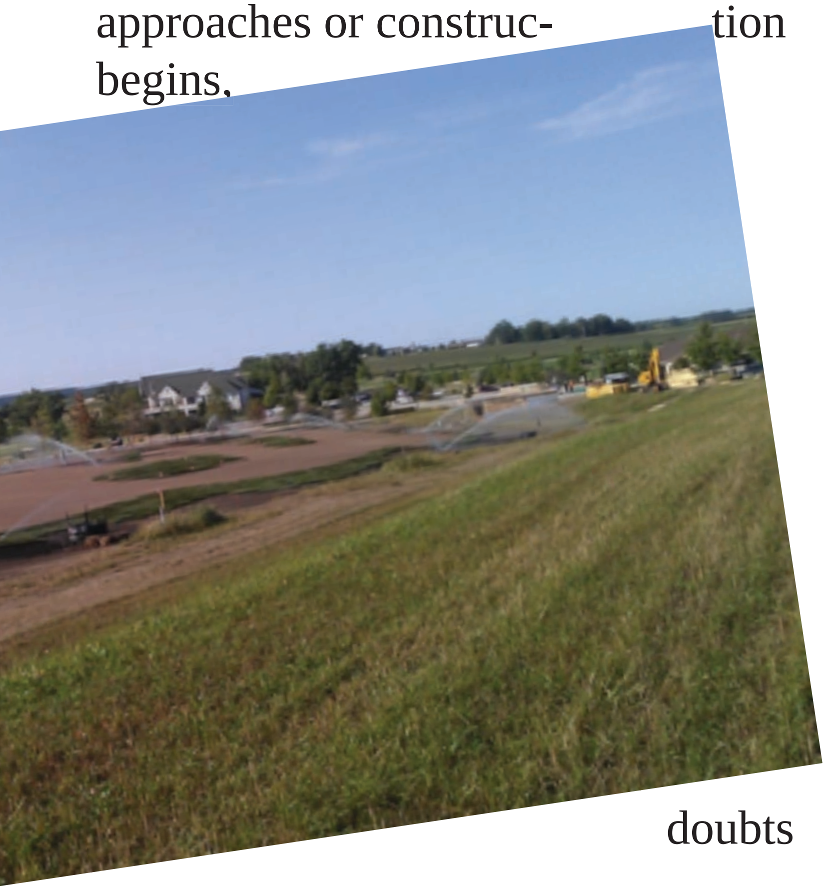
other greens on the golf course. We went through 136 pallets of sod (88 bluegrass, 48 fescue) on the surrounds and the two bluegrass mounds in the middle, and planted 47 trees as well. With the late spring, the project got a late start as well and ultimately took the better part of four months to complete from start to finish. The green was seeded on the third of September.

This project was a unique experience to be a part of, not only for myself, but everyone who was involved. Anybody who has done similar construction or renovation projects can attest to the fact that they can be mentally, physically, and emotionally draining; filled with long days, setbacks, weather interruptions, and unforeseen issues.

As soon as we seeded the green, finished the surrounds and the green began to take shape, we could see our hard work come to

fruition and it made it all worth it. In reflecting upon the process, the analogy I keep coming back to is that of running a race. You plan and prepare months in advance for everything, just like you would train prior to a race. Once race day approaches or construction begins, doubts start to creep into your mind whether you've adequately prepared or trained yourself for absolutely everything. Then, during the actual race or construction phase you encounter hardships and setbacks, but you ultimately get through them and persevere. When the race is over or the project is complete you look back on it and you're proud of what got accomplished, and all of the hardships and setbacks seem like blips on a radar and you're ready to do it again, just next time maybe something a little more normal in scale.





The entire GCM staff at Somerby is to be commended for the completion of this project; as I stated above, Scott was by himself to essentially do the shaping and technical work, the rest of the work fell to our staff. We were fortunate that our intern, Tyson De-Meyer, had many years of experience in the golf course construction/renovation side of things and so he was a huge asset and offered a unique perspective throughout the project. Obviously a lot of credit has to go to Scott as well, he put in countless hours and really had a unique eye, and it shows in the visuals of the green.

A project of this magnitude takes a ton of planning and preparing and as the project gets going, things can sometimes change and frankly this whole project would have been stuck in neutral all summer if it was not for Superintendent Eric Counselman. Getting ownership, management, contractor, and employees all on the same page and heading in the same direction was an endless task, but was also the main reason this project was a success. The pictures will do more justice than me trying to explain it, and seeing it in person will do it even more justice; so enjoy the pictures and hopefully many of you can make it down to Somerby Golf Club to see it in person. If anybody has any further curiosities or inquiries, they can contact Eric at ecounselman@somerby.com.