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Native Pests in Novel Places: The Southern Pine Beetle Example

SEPTEMBER 5, 2018 / BY JENNIFER HUSHAW SHAKUN

Climate-driven changes in pests and disease are already causing significant near-term impacts on forest health—a reality that we highlighted in an earlier bulletin on *Forest Pests and Climate Change*. Notably, several important native pests, including spruce budworm (Gray 2013), mountain pine beetle (Cullingham et al. 2011; de la Giroday et al. 2012), and southern pine beetle (Dodds et al. 2018), have shown signs that their range is expanding with warmer temperatures or is predicted to do so in the near future. They are prime examples of a phenomenon that is likely to become more common in the future, i.e. native pests that are well-known in one region move into new geographies where they were previously unknown.

The novelty creates some immediate challenges for forest managers (Aoki et al. 2018). The good news is that, unlike with most alien invasive species, we have far more information (both research and institutional knowledge) about these organisms. We also have examples of systems and best practices that have worked (or failed) in other regions. With the right networks in place for sharing information across jurisdictions (e.g. the CSLN), the learning curve for managers encountering a particular pest for the first time will not be as steep and the likelihood of an effective and rapid response is increased (Ayres & Lombardero 2018; Morris et al. 2018).

Southern Pine Beetle: An Overview

Southern pine beetle (*Dendroctonus frontalis* Zimmermann) (SPB) is one of the most destructive pests in the southern U.S. (Anonymous 1989; Coulson & Klepzig 2011), with a loss to timber producers of an estimated $43 million per year (Pye et al. 2011). Its historic range in the U.S. extends from Florida into southern New Jersey and as far west as central Arizona (Hain et al. 2011). Although, "given its wide host range, genetic plasticity, and ability to sustain epidemics in nontraditional species, it appears that the geographic range of the SPB is only constrained by host availability and climatic conditions" (Hain et al. 2011).

Adult southern pine beetle.
Photograph by: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org. CC-BY

The small adults (~ 3 mm long) bore into the tree and create S-shaped galleries in the inner bark where they lay their eggs. The larvae develop in the inner bark and move into the outer bark to pupate before

emerging as adults. The entire life cycle can take place in just 30 days under ideal conditions, which allows SPB to have three to seven generations per year (Anonymous 1989).

While SPB "infests and kills all pine species in its range" (Hain et al. 2011), its preferred hosts are southern yellow pines such as loblolly, shortleaf, Virginia, pond, and pitch pines (Anonymous 1989).

Southern pine beetle pitch tubes.
Photograph by: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org. CC-BY

Pioneer beetles will often infest weakened or stressed trees and begin producing aggregation pheromones that attract additional beetles, which ultimately overwhelms the tree's defenses. At this stage, the beetles can reproduce within the infested tree and attacks begin on neighboring trees when the new adults emerge, forming the distinctive "spots" of an SPB outbreak (Hain et al. 2011). Pitch tubes (about the size of a piece of popcorn) on the bark and discoloration of foliage are two noticeable indications of an infestation (Anonymous 1989). SPB's rapid life cycle and its ability to attack and kill healthy trees make it particularly destructive (Dodds et al. 2018).

Over the past several decades, there has been a decline in major SPB outbreaks within its historic range in the southeastern U.S. There are a number of hypotheses for why this reduction has happened, but recent research suggests an "increase among several variables associated with intensive pine silviculture and genetic tree improvement efforts" is a possible explanation (Asaro et al. 2017). Forest management and SPB suppression efforts are known to have had an important influence on the frequency, intensity, and extent of SPB outbreaks (Clarke et al. 2016)—an important insight for managers encountering this pest in new regions.

Southern pine beetle damage in Texas.
Photograph by: Ronald F. Billings, Texas A&M Forest Service , Bugwood.org. CC-BY-NC

Southern Pine Beetle Outbreak Risk

As with most forest pests, the risk that an infestation will become a severe outbreak depends on the size and location of the pest population *and* the susceptibility of the host (Aoki et al. 2018) at the tree, stand, or landscape level. One well-established method for assessing SPB risk relies on one of these two components—using the number of SPB caught per day in traps, along with the ratio of SPB to one

of its major predators—to predict infestation trends (Billings & Upton 2010). Alternatively, southern pine beetle hazard maps generated by the US Forest Service use variables related to average diameter, basal area/density, and proximity to the infestation (Krist et al. 2014).

Weakened or stressed trees, e.g. those struck by lightning, are a risk factor (Hain et al. 2011) because they are often the "patient zero" of SPB spots during an outbreak. There are also a variety of stand-level characteristics that affect the vulnerability of host trees by influencing resource availability, density, stand age/size, and the dispersal of beetle pheromones (see Table 1; Aoki et al. 2018). High stand density, in particular, is known to increase the risk of an SPB outbreak (Clarke & Nowak 2009; Guldin 2011), by making it easier for the beetles to attract each other with pheromone plumes and to travel from the infested tree to a new host.

Table 1: Factors known to affect SPB susceptibility and the stand characteristics that influence them.

FACTORS INFLUENCING SPB RISK		Stand Characteristics						
		Distance between trees	Basal area	% Pine	Site moisture/ site index	% Canopy cover	DBH/ Height	Age
Resource Availability	Trees with abundant resources often put energy into growth over production of defensive compounds like the resins that help pitch out attacking beetles, but trees that are severely resource limited (e.g. due to intense drought or high density) may not have enough resources to put toward growth OR resin production, so evidence suggests a Goldilocks effect may produce the most resistant trees.	✓	✓		✓			
Distance Between Hosts	Greater distance between host trees (i.e. lower stand density) reduces their vulnerability to SPB attack by increasing the distance individual beetles must fly in order to reach new hosts and reducing the ability of beetle pheromone attractants to draw new recruits to an infestation.	✓	✓	✓				✓
Stand Age/Size	Historically, older pine stands have tended to be less vulnerable to SPB infestation. Proposed reasons include a greater distance between trees in older stands, the effect of canopy closure on beetle pheromone plumes, better beetle resistance with larger trees, and others.						✓	✓
Pheromone Plume	Canopy conditions affect airflow and the dispersal of pheromones generated by attacking beetles—denser, closed canopies may help keep the pheromone plume intact and easier for other beetles to detect.					✓		

(Aoki et al. 2018; Lorio 1986; Reeve et al. 1995; Ayres et al. 2011)

Southern Pine Beetle in the Northern Context

Warmer winter temperatures have facilitated the northern expansion of the SPB range (via improved over-winter survival) and model projections suggest that the climate will become progressively more suitable for SPB in these areas over time (Lesk et al. 2017). But it is more difficult to predict the impact of SPB in this new environment because its population dynamics may be altered and the susceptibility of northern pine species is not completely understood.

SIMILAR RISK FACTORS

Site index and site moisture can be useful predictors of SPB infestation risk in the southern U.S., but they appear to be less important in new areas like the New Jersey Pinelands (Aoki et al. 2018). However, the same study found that "stands with high percentage pine and high pine basal area were more susceptible. Stands composed of smaller, closer together, shorter, and younger trees, with lower percent live crown, were also more susceptible," i.e. SPB risk seems to vary with stand characteristics in the newly invaded areas in much the same way it did in well-studied systems farther south (Aoki et al. 2018). If that holds true, it may be easier to successfully predict SPB infestations in the Northeast going forward.

NEW HOSTS

SPB primarily attacks hard pines (preferably loblolly and shortleaf) in the Southeast, but it will successfully attack "nontraditional" host species, such as eastern white pine, red spruce, Norway spruce, eastern hemlock, and others, when outbreak populations are large enough (Hain et al. 2011). Pitch pine has proven to be a suitable host in the recent outbreaks in New Jersey and Long Island, while red and Scots pine were identified as hosts in the Connecticut infestation (Dodds et al. 2018). The potential threat to eastern white pine is top of mind for many in the Northeast and, fortunately, successful reproduction of SPB has not be documented in that species so far. Although, both white and jack pine (farther north) have the potential to act as suitable hosts (Hain et al. 2011; Dodds et al. 2018).

LANDSCAPE-LEVEL RISK

Many northeastern pine species may be susceptible to SPB, but it is possible that the composition of northeastern forests (specifically the absence of many pure pine stands and more isolated and disbursed populations of potential hosts) will reduce the risk of severe outbreaks at the landscape level. The risk may be greatest in certain unique, pine-dominated ecosystems, including pitch pine barrens and natural red pine stands. Pitch pine barrens, in particular, are often unmanaged and lack the regular occurrence of fire and management intervention necessary to reduce overstocking and the dense canopy conditions that are conducive to SPB (Dodds et al. 2018). Areas where potential host species occur in relatively pure, high density stands across large areas (such as red spruce) will also be at high risk for SPB infestations.

NEW RESEARCH

A new study (Lesk et al. 2017) maps where and when the climate will likely become suitable for southern pine beetle in the northeastern U.S. and southeastern Canada.

Winter minimum temperatures between 7 and -4 ºF are sufficient to kill SPB while they overwinter within the inner bark of trees. This limited cold tolerance restricts the northern extent of their geographic range. Bark also has an insulating effect that provides the beetles with some protection and buffers cold extremes by 4-7 ºF, which researchers accounted for in this study.

They found that, currently, the northernmost SPB sites are generally at latitudes where the lowest winter temperature in the inner bark is 14 ºF. They estimate that an "SPB-suitable" climate will eventually develop in other areas if conditions warm up enough to keep the winter inner bark temperature above 14 ºF for ten consecutive years. Using these parameters and the results from two dozen global climate models (which project an increase in annual minimum air temperature of 6-13 ºF by mid-century), researchers modeled the emergence of SPB-suitable climate over this century.

On average, they found that by 2090 all of the northeastern U.S. and large areas of southeastern Canada will be hospitable for SPB (see Figure 2a). Although, they also noted that there is considerable uncertainty, with a spread of several decades between the low- (see Figure 2b) and high-end (see Figure 2c) of estimates. The results suggest that several likely northern host species will be vulnerable over large portions of their range by mid- to late-century—by 2050, an estimated 78% of the pitch pine range will be suitable for SPB and by 2080, 71% of red pine and 48% of jack pine range will be suitable.

SPB Management: Things to Do

For managers encountering this pest for the first time, there is extensive literature and practice to draw on for determining the best response. Within its historic range, managers have developed and honed management strategies that control the spread and severity of infestations when they occur and reduce the risk of future outbreaks.

The "things to do" include:

- **prevention** (i.e. thinning high hazard areas),
- **landscape prioritization and hazard models** (i.e. assessing susceptibility based on stand characteristics to identify priority areas for treatment),
- **detection and monitoring** (i.e. aerial surveys and pheromone-baited traps), and
- **evaluation and direct control** (i.e. cutting infested trees and a green tree buffer using the cut-and-leave or cut-and-remove method).

(Dodds et al. 2018)

The management tactics used in the southern U.S. appear to have worked equally well in the recent northern outbreaks. They included early monitoring, rapid treatment of initial SPB "spots," and preventative thinning (Aoki et al. 2018). In fact, thinning (and other methods of reducing density) in pine-dominated stands has proven to be the most effective tactic for reducing susceptibility to SPB. As

one source puts it: “The best silvicultural defense against SPB is to manage forest stands so that individual trees are vigorous and stands are not overstocked” (Guldin 2011). Evidence for the effectiveness of this approach can be found within the historic SPB range where there are examples of outbreaks that occurred almost entirely on unthinned stands (Nowak et al. 2015). Although, it is worth noting that sufficient markets and timber harvesting infrastructure must be present to make such preventative treatments feasible and cost-neutral (at best). That may be more of an impediment for northern landowners than in the southeastern U.S. where SPB suppression has been very successful (Ayres & Lombardero 2018; Morris et al. 2018).

Example of a cut-and-leave southern pine beetle treatment.
Photograph by: Ronald F. Billings, Texas A&M Forest Service , Bugwood.org. CC-BY-NC

RESOURCES:

- See the Southern Pine Beetle II General Technical Report from the U.S. Forest Service Southern Research Station for a comprehensive resource on the topic of SPB.
- The Southern Pine Beetle Prevention and Restoration program is a good example of an existing program in the Southeast that managers in the Northeast might use as a model. In particular, the use of similar outreach efforts and management recommendations may become important as SPB moves into the Northeastern region where forest ownership is dominated by non-industrial private owners.
- The Forest Pest Conditions application and the Insect and Disease Detection Survey Data Explorer can provide maps of areas recently affected by SPB.
- The National Insect & Disease Risk Map has mapped potential risk from numerous pests, including southern pine beetle, through 2027.

Conclusion

The general management recommendations described above can apply to any pest infestation, not just southern pine beetle—be proactive where possible, watch for change, and plan for control efforts in susceptible areas. As some native pests move into new areas, it will be important to draw on the existing knowledgebase from their historic range, but it is also likely that traditional host species, risk factors, and effective management may be different because of changes in the biology of the pest or differences in host susceptibility. The mountain pine beetle (MPB) in the West provides a recent example, with evidence that MPB enjoyed greater reproductive success in lodgepole pine as it encountered "naïve" host trees in areas where the climate was previously unsuitable—a factor that likely contributed to the unprecedented scale of recent outbreaks in western Canada (Cudmore et al. 2010). This highlights the importance of staying attuned to the expanding range limits of particularly destructive pests, like SPB, and closely monitoring reports from newly affected areas to learn whether there are notable changes in pest behavior or outbreak patterns.

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References

Anonymous. 1989. "Southern Pine Beetle. *In*: Insects and Diseases of Trees in the South. USDA Forest Service. Protection Report R8-PR16. 98 pp.

Aoki, C.F., Cook, M., Dunn, J., Finley, D., Fleming, L., Yoo, R., and M.P. Ayres. 2018. Old pests in new places: Effects of stand structure and forest type on susceptibility to a bark beetle on the edge of its native range. *Forest Ecology and Management*. 419-420:206-219.

Asaro, C., Nowak, J.T., and A. Elledge. 2017. Why have southern pine beetle outbreaks declined in the southeastern U.S. with the expansion of intensive pine silviculture? A brief review of hypotheses. *Forest Ecology and Management*. 391:338–348. doi:http://dx.doi.org/10.1016/j.foreco.2017.01.035.

Ayres, M.P. and M.J. Lombardero. 2018. Forest pests and their management in the Anthropocene. *Canadian Journal of Forest Research*. 48: 292–301 doi:dx.doi.org/10.1139/cjfr-2017-0033.

Ayres, M.P., Martinson, S.J., and N.A. Friedenberg. 2011. Southern Pine Beetle Ecology: Populations within Stands. *In*: Coulson, R.N.,; Klepzig, K.D. 2011. Southern Pine Beetle II. Gen. Tech. Rep. SRS-140. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 75-89.

Billings, R.F. and W.W. Upton. 2010. A methodology for assessing annual risk of southern pine beetle outbreaks across the southern region using pheromone traps. *In*: Pye, J. M., Rauscher, H.M., Sands, Y., Lee, D.C., Beatty, J.S. (Eds.), Advances in Threat Assessment and Their Application to Forest and Rangeland Management. Gen. Tech. Rep. PNW-GTR-802. U.S. Department of Agriculture, Forest Service, Pacific Northwest and Southern Research Stations, Portland, OR, pp. 73–85.

Clarke, S.R. and J.T. Nowak. 2009. Southern Pine Beetle. USDA Forest Service Forest Insect & Disease Leaflet 49. USDA Forest Service, Pacific Northwest Region, Portland, OR.

Clarke, S.R., Riggins, J.J., and F.M. Stephen. 2016. Forest Management and Southern Pine Beetle Outbreaks: A Historical Perspective. *Forest Science*. 62(2):166-180. doi: http://dx.doi.org/10.5849/forsci.15-071.

Coulson, R.N. and K.D. Klepzig. 2011. The Southern Pine Beetle. USDA Forest Service, GTR, SRS-140. pp. 512.

Cudmore, T.J., Björklund, N., Carroll, A.L., and B.S. Lindgren. 2010. Climate change and range expansion of an aggressive bark beetle: evidence of higher beetle reproduction in naïve host tree populations. *Journal of Applied Ecology*. 47:1036–1043. doi:10.1111/j.1365-2664.2010.01848.x.

Cullingham, C.I., Cooke, J.E.K., Dang, S., Davis, C.S., Cooke, B.J., and D.W.Coltman. 2011. Mountain pine beetle host-range expansion threatens the boreal forest. *Molecular Ecology*. 20:2157-2171. doi: http://dx.doi.org/10.1111/j.1365-294X.2011.05086.x.

de la Giroday, H.-M.C., Carroll, A.L., and B.H. Aukema. 2012. Breach of the northern Rocky Mountain geoclimatic barrier: initiation of range expansion by the mountain pine beetle. *Journal of Biogeography*. 39:1112-1123. doi:http://dx.doi.org/10.1111/j.1365-2699.2011.02673.x.

Dodds, K.J., Aoki, C.F., Arango-Velez, A., Cancelliere, J., D'Amato, A.W., DiGirolomo, M.F., and R.J. Rabaglia. 2018. Expansion of Southern Pine Beetle into Northeastern Forests: Management and Impact of a Primary Bark Beetle in a New Region. *Journal of Forestry*. 116(2):178-191. doi:10.1093/jofore/fvx009.

Gray, D.R. 2013. The influence of forest composition and climate on outbreak characteristics of the spruce budworm in eastern Canada. *Canadian Journal of Forest Research*. 43(12):1181-1195, doi:https://doi.org/10.1139/cjfr-2013-0240.

Guldin, J.M., 2011. Silvicultural considerations in managing southern pine stands in the context of southern pine beetle. *In*: Coulson, R.N., Klepzig, K.D. (Eds.). Southern Pine Beetle II. USDA For. Serv. Gen. Tech. Rep. SRS-140, pp. 317–352.

Hain, F.P., Duehl, A.J., Gardner, M.J., and T.L Payne. 2011. Natural History of the Southern Pine Beetle. *In*: Coulson, R.N.; Klepzig, K.D. 2011. Southern Pine Beetle II. Gen. Tech. Rep. SRS-140. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 13-24.

Krist, F.J., Ellenwood, J.R., Woods, M.E., McMahan, A.J., Cowardin, J.P., Ryerson, D.E., Sapio, F.J., Zweifler, M.O., and S.A. Romero. 2014. 2013–2027 National Insect and Disease Forest Risk Assessment. FHTET 14-01, USDA Forest Service Forest Health Technology Enterprise Team, Fort Collins, Colorado, USA.

Lesk, C., Coffel, E., D'Amato, A.W., Dodds, K., and R. Horton. 2017. Threats to North American forests from southern pine beetle with warming winters. *Nature Climate Change*. 7:713-717. doi:10.1038/NCLIMATE3375,

Lorio, Jr., P.L. 1986. Growth-Differentiation Balance: A Basis for Understanding Southern Pine Beetle-Tree Interactions. *Forest Ecology and Management*. 14:259-273.

Morris, J.L., Cottrell, S., Fettig, C.J., DeRose, R.J., Mattor, K.M., Carter, V.A., Clear, J., Clement, J., Hansen, W.D., Hicke, J.A., Higuera, P.E., Seddon, A.W.R., Seppä, H., Sherriff, R.L., Stednick, J.D., and S.J. Seybold. 2018. Bark beetles as agents of change in social-ecological systems. *Front. Ecol. Environ.* 16(S1):S34-S43. doi:10.1002/fee.1754,

Nowak, J.T., Meeker, J.R., Coyle, D.R., Steiner, C.A., and C. Brownie. 2015. Southern Pine Beetle Infestations in Relation to Forest Stand Conditions, Previous Thinning, and Prescribed Burning: Evaluation of the Southern Pine Beetle Prevention Program. Journal of Forestry. *Journal of Forestry*. 113(5):454–462. doi:https://doi.org/10.5849/jof.15-002.

Pye, J.M., Holmes, T.P., Prestemon, J.P., and, D.N. Wear. 2011. Economic Impacts of the Southern Pine Beetle. *In*: Coulson, R.N.; Klepzig, K.D. 2011. Southern Pine Beetle II. Gen. Tech. Rep. SRS-140. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 213-222.

Reeve, J.R., Ayres, M.P., and P.L. Lorio, Jr. 1995. Host suitability, predation, and bark beetle population dynamics. *In*: N. Cappuccino and P.W. Price (Eds.) Population dynamics: New approaches and synthesis. Academic Press, San Diego, CA. Pp 339-357.