FIFTY YEARS OF SCIENCE-MANAGEMENT COOPERATION FROM THE SILVAH COMMUNITY OF PRACTICE

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Insights for Managers

- **Regular interactions between scientists and managers build a common vocabulary and framework that increase the efficiency of describing emerging problems and build shared ownership of the body of work.**
- **Managers improve applied research utility by directing a research program toward current management problems and by supporting (for example, through pilot studies) excellent work that attracts competitive funding.**
- **Collaboration between scientists and managers sharpens hypothesis formation by increasing the number and diversity of observations and perspectives on which hypotheses are based.**
- **Cooperation accelerates and diversifies site selection for designed experiments.**
- **Scientists can use their professional networks to engage colleagues from other regions with specialties not available locally, deepening the research and increasing its value.**
- **As managers participate they gain confidence in research results and become more willing to adopt new practices based on the research.**
- **Over time, a community founded on mutual respect emerges and scientists and managers coproduce both knowledge and improved practices.**
- **Continuity of participation and support by participating institutions—not just individuals—is critical to allowing research to detect answers that only emerge over the long term.**

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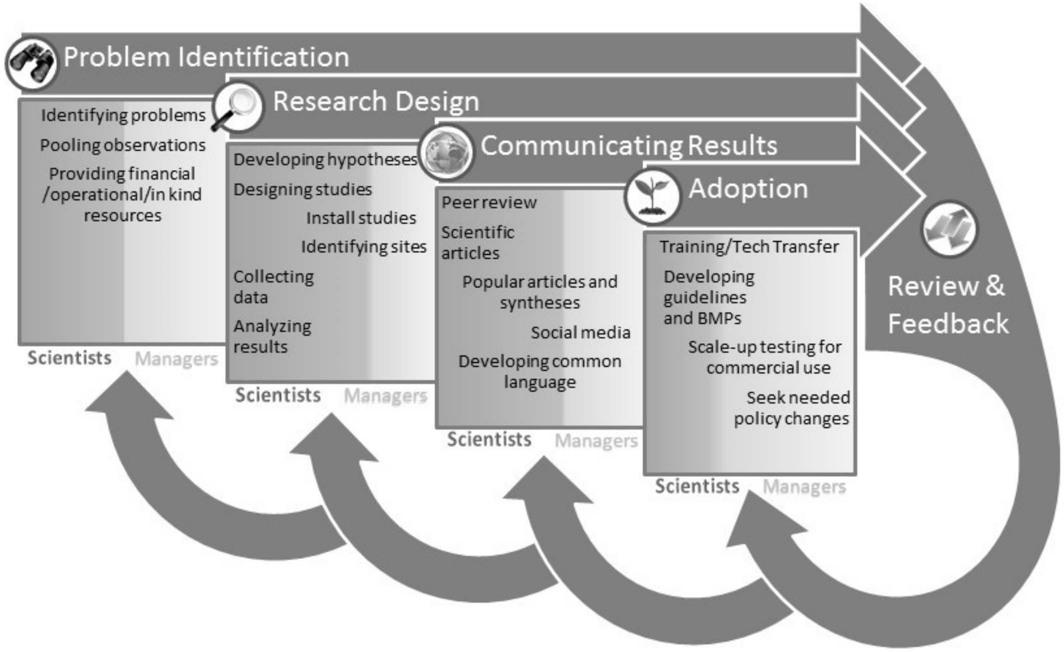

Figure 1.—Conceptual model of the SILVAH community of practice. Each step is shaded to indicate the approximate proportion of this work done by scientists (left, shaded portions of each rectangle) and managers (right, unshaded portions). The icons for each step are used to highlight examples in the text of the article.

INTRODUCTION

This chapter highlights patterns that have sustained a half century of science-management cooperation (Fig. 1) by summarizing the ways the community of practice functioned to support and benefit from seven lines of science during the last 50 years. Each demonstrates some or all of the common themes and patterns, and we use the icons from Figure 1 throughout the paper to draw attention to specific examples of mutual benefits:

 highlights cooperative work on problem identification.

 highlights work on research design.

 highlights work on communicating research results.

 highlights examples of adoption of research results.

 highlights interactive feedback between scientists and managers.

As Marquis (2019) outlines, managers have been SILVAH research partners since the beginning. The regeneration crisis in the High Allegheny Plateau region of Pennsylvania was first identified by managers who recognized that research would be an essential basis for a meaningful solution. They also recognized that merely understanding why so many final harvest cuts were failing was not enough; to sustain the region's forests, research results must lead to guidelines for new management practices.

For 50 years, forestry scientists and managers in the region became what is now called a "community of practice: a group of people who share a craft or a profession. It is through the process of sharing information and experiences with the group that members learn from each other, and have an opportunity to develop personally and professionally."[2] This community has conducted research and developed management guidelines related to many lines of science, and clear patterns have emerged (Fig. 1). The other chapters in this proceedings summarize some of the scientific progress the community has made over the last 50 years. This chapter highlights the underlying patterns of science management cooperation that have allowed this community of practice to flourish and grow.

SILVICULTURE AND DECISION SUPPORT

Managers played a key role in supporting the new research program; they were engaged from the beginning in pooling observations and developing hypotheses. The target was silvicultural strategies that would ensure successful regeneration. The research plan developed by David Marquis and the scientists on his team relied on a conceptual model: a highly accessible flow chart of hypothesized causes for regeneration problems, including soils, interfering plants, deer herbivory, and management practices, and corresponding studies designed to test these hypotheses. Managers often provided study sites or shared experiential insights about the various factors. Early results showed that deer formed a principal barrier and that sites with abundant advance regeneration were most likely to succeed. Additional research identified and tested shelterwood and herbicide practices to increase advance regeneration where absent.

Marquis and Ben Roach (who had been reassigned to the Warren, PA, office of USDA Forest Service Research and Development to participate in this exciting cooperative venture) coordinated with Sandy Cochran, the Penn State Extension forester in the region, to plan training sessions that were intended to show managers how to use guidelines and processes that were developed from the research. The structure of the training sessions was modeled on two preceding documents: the flow chart of factors that influence regeneration success and the "Silvicultural Guide for Upland Central Hardwoods" (Roach and Gingrich 1968). Both documents emphasized the link between data collected from individual stands and detailed silvicultural prescriptions. They also emphasized the relationships between factors ranging from the silvics of individual tree species to stand development patterns to biotic and abiotic influences.

The training sessions, first offered in 1976, attracted participants from public and private land management organizations and universities. It soon became apparent that the training sessions would play an important role in sustaining communication between scientists and managers. The quantitative, integrated framework, organized into decision charts, made these sessions different from usual workshops where individual talks might sometimes give contradictory suggestions, or where application of research results was not so tightly linked to an actual inventory procedure.

The silvicultural guidelines developed in the first decades of SILVAH research-management cooperation were eventually codified in a training session textbook (Marquis et al. 1992). A computer program, SILVAH (https://www.nrs.fs.fed.us/tools/silvah7/), processed stand data that were gathered using the inventory procedures taught in the training sessions and suggested a research-based, site-specific silvicultural prescription. These prescriptions included partial cuts for immature even-aged stands or stands to be managed in an uneven-age system and a variety of treatments to improve the probability of regeneration success in stands that had reached the conditions appropriate for replacement with a new, young stand.

[2] Wikipedia definition; accessed Sept. 11, 2017.

As described by Marquis (2019), the entire SILVAH process—inventory procedures, data analysis, and prescription development—were widely adopted by public and private land management agencies. One large industrial landowner, the Hammermill Paper Company, conducted a formal test of the process and found that it was consistently as good as or better than the processes it had been using before SILVAH.

As the strength of the systematic approach to inventory, analysis, and prescription became apparent, the Northeastern Forest Experiment Station created working groups to generalize the approach to other forest types and benefits such as wildlife habitat, hydrology, and forest aesthetics. The Stand Culture and Stand Regeneration working groups engaged many scientists across the station, in universities, and management partners. In 1990 the working groups traveled together across the northern Appalachians for a week to explore the potential of expanding the SILVAH idea. The working groups gave birth to a new decision support tool called NED (https://www.nrs.fs.fed.us/tools/ned/products/ned3/) (Twery 2019). SILVAH provides detailed silvicultural prescriptions for specific management objectives in individual stands; NED allows users to interpret these data from wildlife habitat, aesthetic, hydrologic, and other disciplinary perspectives, and to look at the combined attributes of neighboring stands. Data sets can be easily exchanged between SILVAH and NED to take advantage of the strengths of both programs.

When the training sessions were first offered, the organizers imagined that after a few years all managers in the region would have taken the course, and the sessions would be suspended. This vision was never realized: it became increasingly obvious that the integrated framework of the training sessions, combined with the community building aspects that resulted from scientists and managers spending time together and learning from each other, was fostering a culture of mutual respect and cooperation. As new research results emerged, they were placed in the SILVAH framework. Inconsistencies were resolved and shared with managers through the training sessions. The training sessions also became an important vehicle for managers to report emerging problems to scientists, and for management organizations to train new hires.

DEER-FOREST INTERACTIONS

Royo and Stout (2019) describe the scientific side of this line of science. For the entire five decades of this research, forest managers from public and private organizations have participated in refining hypotheses and defining the methods that would be used, especially when the research study involving deer enclosed in managed forests began in 1979 (Horsley et al. 2003). The Pennsylvania Department of Conservation and Natural Resources Bureau of Forestry (DCNR BoF)[3], the Pennsylvania Game Commission, the Allegheny National Forest (ANF), and a private land management organization all contributed forest land to serve as study sites. Individuals from each organization and from the Society of American Foresters pitched in to install the experiment. This promoted a broad sense of ownership of the research and its results.

By 1985, the fifth year of the study, visitors could see—and the data confirmed—that differences between the enclosures clearly correlated with variation in deer densities. However, regeneration in the highest deer density areas was substantially better than anyone had anticipated. Again, managers and scientists gathered to brainstorm and conceptualized the idea that deer impact on vegetation is a joint function of deer density and forage availability. The emergence of this idea, which has increased in importance over the decades, depended

[3] This is the current organizational name of the Pennsylvania State Forestry agency. During the era of the deer enclosure study, it was part of the Department of Environmental Resources.

on engaging deer and land managers and silviculturists and wildlife biologists in the conversation. Specifically, one of the design features of the enclosure study was that within each deer density treatment 10 percent of the forest was clearcut and 30 percent was thinned to ensure comparable forage production in all areas. In contrast, managed forest land at the time averaged 4 percent and 13 percent in clearcut and thinned conditions, respectively. These differences in forage-producing habitat could explain the differences in impact that similar densities of deer had in the ambient forest compared to that inside the enclosures. Formal testing of this hypothesis was a few decades away (Royo et al. 2017), but its birth is attributable to science-management cooperation.

By the mid-1990s, policymakers were eager to gather statewide data to assess whether the impacts reported from detailed research in the northwestern part of the state could be observed in forests statewide, and they turned to the SILVAH team to help them design a process to gather statewide data that could be analyzed using results from the deer enclosure study. The Pennsylvania DCNR BoF expanded its contract with the USDA Forest Service Forest Inventory and Analysis (FIA) unit to collect additional data on seedlings and interfering understory plants using methods that were similar to those taught in the SILVAH training sessions. FIA's Will McWilliams assembled a team of Forest Service and Penn State scientists to extend and fit the inventory practice into the FIA framework, and Harry Steele, from the SILVAH team, taught FIA crews how to conduct the new inventory. The results showed that 60 percent of plots taken across the state on sites where overstory shade was not limiting did not meet the standard for adequate advance regeneration (McWilliams et al. 1995), and that most of these plots were found in conditions identified as moderate to high deer impact levels.

These results increased the momentum for policy change. Public and private land managers and nongovernmental organizations were able to point to the studies to show that current deer management policy was having unsustainable ecological and economic impacts on Pennsylvania forests. Inside the Pennsylvania DCNR BoF state forester Jim Grace played a key role. In the Audubon Society, it was Executive Director Cindy Dunn. The Sierra Club's Don Gibbon led preparations for a Harrisburg, PA, workshop. Inside the Pennsylvania Game Commission the leadership of deer biologist Gary Alt was critical. Change was imminent, and interest in a landscape-scale demonstration of forest change in response to more sustainable management policies arose. The Sand County Foundation, a Wisconsin nongovernmental organization dedicated to the causes championed by Aldo Leopold, convened a breakfast meeting of public and private managers and scientists interested in deer forest interactions in Kane, PA. Could this group cooperatively manage deer, hunting, and habitat in a completely voluntary framework across ownership boundaries with some foundation support? The ease with which all participants said "yes" resulted in large part from the relationships—the community of practice—that were by then 30 years old.

The result was the Kinzua Quality Deer Cooperative (KQDC), founded in 2000. A 10-year grant from the Sand County Foundation funded the first decade of activities, which included collection of data concerning deer abundance, deer characteristics, habitat and vegetation variables, annual check stations to interact with hunters, and annual banquets to provide information about the response of the entire area to changing conditions as hunters reduced deer density (Stout et al. 2013). In 2010, Sand County Foundation sponsored an independent review of the KQDC by an international team of experts, and the results were very affirming. This affirmation and the value of the cooperative to participating managers led to a decision to continue funding KQDC with landowner contributions, and the cooperative remains active.

INTERFERING PLANTS AND THEIR TREATMENTS

Ristau (2019) and Horsley (2019) describe the important scientific advances and management guidelines that were developed through this line of research. Early research about regeneration challenges on the Allegheny Plateau highlighted the importance of abundant and well-distributed advance regeneration to stand-level regeneration success. Interfering plants that cast shade that was too dense to allow advance regeneration to establish, survive, or grow formed one important barrier. Horsley (2019) and Ristau (2019) led a series of studies to find effective treatments that would remove these barriers. Many of these studies were on land managed by partners. Hand-weeding, fire, and some herbicides were considered, and early small plot trials were undertaken. Herbicides proved most effective, and Horsley undertook detailed studies of various herbicides that examined doses and times of application. This work formed the basis for one of the herbicides becoming labeled for forestry use (Oust® herbicide with active ingredient sulfometuron-methyl).

Interactions with managers became extremely important as small-plot treatments shifted to operational tests and use. Because managers were already involved, they were poised to adopt the research results, and the management partners could focus on technology for applying herbicides at the operational scale. Ultimately, management organizations developed new equipment to improve application effectiveness. Horsley and Penn State Extension specialist Sandy Cochran hosted annual round-ups for those who were using the research results. At each round-up, Horsley updated the group on any new research, and representatives of each management organization (public and private) reported on what was and was not working and any new challenges they observed. With leadership from Ken Kane, a local forestry consultant, Dave Turner, a local heavy-equipment company owner, and the Pennsylvania DCNR BoF, most users across Pennsylvania's 4.2 million acres of public forests, nearly 1 million acres of forest land managed by the forest industry, and on some private land developed and adopted new equipment that used air-blast spray techniques. Scientists and managers discussed challenges of implementing research results at these annual meetings, which stimulated further research and improvements in the management guidelines for control of interfering vegetation (Horsley 1991).

Growing public concern about herbicide use stimulated further scientist-manager interactions. As managers began to adopt Oust® as part of their herbicide treatment toolkit, managers on the ANF undertook the environmental analyses required to use Oust® in the national forest. Some key stakeholders expressed concern about the impact of this herbicide on nontarget organisms. The forest silviculturist, Bob White, and ecologist, Brad Nelson, with Horsley and research wildlife biologist Dave deCalesta, met with these stakeholders in Pittsburgh and committed to a detailed study of nontarget impacts. Then Warren lab scientists hosted a special meeting at the Kane Experimental Forest (KEF). Scientists knew that the proposed study to determine the nontarget impacts of these operational herbicide treatments on nontarget organisms would occupy a great deal of research effort for at least a decade. Did managers support that level of investment by the local scientific staff? The answer was an overwhelming "yes" from managers working on public and private forests, and the ANF almost immediately engaged with the scientists to identify ten sites across the forest on which such research could be conducted. This research received consistent funding from the National Pesticide Impact Program and its successors, a great deal of in-kind support from the ANF, and led to landmark publications (Ristau et al. 2011, Stoleson et al. 2011, Trager et al. 2013).

SOIL NUTRIENTS AND FERTILIZATION

Long et al. (2019) describe the scientific advances associated with some of this research. Early tests of the role of site factors such as nutrition and moisture in the mid-20th century regeneration crisis did not show these as highly important causal factors. But black cherry (*Prunus serotina Ehrh.*) was known to be highly responsive to nitrogen fertilization, and managers were eager to use fertilization as a tool to hasten the height growth of seedlings out of the reach of deer. Auchmoody (1982) initiated studies of the effects of fertilization on black cherry. Among other things, this research showed that growth responses in height, diameter, and basal area of seedlings and saplings were greatest during the first 2 years after fertilization, with increases in height and diameter lasting for 4 to 5 years. A prescription of 200 pounds per acre of nitrogen and 44 pounds per acre of phosphorous sustained responses beyond the first year. Managers adopted these prescriptions operationally because they allowed regeneration to grow out of the reach of deer. The prescriptions were widely used on public and industrial forest lands through the early 1990s, when the Oklahoma City bombing resulted in dramatic restrictions on access to nitrogen fertilizers.

In the mid-1980s, managers approached Auchmoody with a new problem. Sugar maple (*Acer saccharum Marshall*), an important species in the region's forests, showed symptoms of decline. Crown health appeared weak on many trees. Sugar maple mortality, even in stands where the trees were in strong dominant and codominant positions, seemed to be increasing. Little or no sugar maple advance regeneration could be found. During the period when these observations were first brought to Auchmoody and others, society at large was engaged in vigorous debate about potential impacts of acid deposition (Likens and Bailey 2014), and some managers wondered if sugar maple decline could be associated with this problem. Auchmoody worked with managers from the Pennsylvania DCNR BoF to develop three hypotheses and design a test of three potential explanations for the dearth of sugar maple regeneration. On some plots, interfering plants were removed by herbicide treatment, on some, deer browsing was eliminated by fencing, and on some plots, soil chemistry, possibly changed by acid deposition, was changed by the additional of lime fertilizer. The Pennsylvania DCNR BoF provided four sites for this study and implemented the operational treatments. It contributed supplemental funding and contributions of in-kind labor for the 35 years that the study continued; this provided important information about sugar maple nutrient preferences (Long et al. 1997) and showed that lime fertilization improved sugar maple health and growth. The study became known as the lime study.

Auchmoody retired a few years after the study was launched. Managers were among those urging the scientific team to continue this research and link it to a better understanding of the relationships between landscape position, soil nutrients, and sugar maple health. In the context of the Allegheny Plateau community of practice, this interest in continuing research about soil nutrients and forest health, Steven Horsley agreed to continue the research, and he hosted a week-long field workshop for scientists and managers. Managers were invited to share their observations and contribute field sites to the tour, which ranged from the ANF to the sites of the lime study and included several sites owned by private forest industry organizations. Where were managers observing the most significant declines? Where, if anywhere, were they observing good sugar maple regeneration? Did the apparent link to soil nutrients confirm the hypothesis that soil chemistry in the region had changed in the recent past? In addition to local managers and scientists, Horsley invited USDA Forest Service colleagues from disciplines that were not represented on the local team.

Those who participated remember that week as highly stimulating intellectually and practically. Managers observed that differences in the health of sugar maple seemed to be associated with boundaries of historic glaciations and with landscape position; the worst declines were seen in plateau top positions on unglaciated sites, and the best regeneration was observed on glaciated sites. The field trip stimulated additional research linking sugar maple health to soil nutrients in landscapes across Pennsylvania, New York, and New England (Long et al. 2009). The quality of the early research also gave the research team access to archived soils collected by the then U.S. Department of Agriculture Soil Conservation Service for Pennsylvania soil mapping in 1967 and led to important ongoing work on long-term soil chemistry changes on the Allegheny Plateau (Bailey et al. 2005).

The study also showed that each of the two other major overstory species in the study areas—American beech (*Fagus grandifolia Ehrh.*) and black cherry—responded differently to the lime treatment. Through 35 years, there was no difference in beech growth or mortality between limed and unlimed plots. By year 10, however, it had become apparent that black cherry growth—and eventually survival—were lower on the limed than on the unlimed plots (Long et al. 2011). Continuity of the study through the full decade was key to learning this important result, underlining the importance of long-term research and ongoing relationships between managers and scientists to support such research.

The observations of negative impacts of lime fertilization on black cherry from the long-term liming study have been revisited in recent years as managers and scientists observe changes in black cherry. Current work, which involves managers and scientists working together, is again examining the effects of nitrogen/phosphorous fertilization on black cherry seedlings growing in the changed conditions created by the Clean Air Act Amendments of 1991 (Ristau and Long, unpublished).

OAK REGENERATION

Brose (2019) describes the science-management cooperation that occurred in the early 21st century to make the SILVAH system more appropriate and effective for mixed-oak forests of the mid-Atlantic region. The results were first documented in Brose et al. (2008), the textbook for the SILVAH-Oak training sessions. Brose (2019) also describes the critical roles that managers, and manager review of proposed inventory procedures and prescriptions, played in the development of SILVAH-Oak (Brose et al. 2008). He tells, for example, that it was manager feedback that led to consolidation of inventory for established and new oak seedlings for mixed-oak stands with site index below 65 feet at age 50.

The committee of managers and scientists that worked to develop SILVAH-Oak also identified research that was needed to confirm and refine management guidelines for sustaining mixed-oak forests. As with many other lines of science, the Pennsylvania DCNR BoF committed financial and in-kind resources to ensure that well-designed studies to address those research needs could be conducted, all on State Forest land. Other land management agencies, including the Pennsylvania Game Commission and the ANF, also provided land and in-kind services. One outcome of this large body of research was the award of a competitive grant from the National Joint Fire Science Program to Brose and colleagues from other parts of the mixed-oak forest range to synthesize knowledge of the role of prescribed fire in oak regeneration, resulting in both a landmark scientific paper (Brose et al. 2013) and a manager's guide to using what this synthesis showed (Brose et al. 2014). Research concerning the use of prescribed fire as a tool in the oak regeneration process had been ongoing for decades; however, this synthesis represented a genuine breakthrough. By placing each study that provided enough information to do so into a matrix that included the stages of seedling development and the season of the fire, Brose and his colleagues were able, for the first time, to provide generalized guidelines for when and how to use prescribed fire to regenerate oak.

Prescribed fire is a frequently recommended silvicultural tool in SILVAH-Oak. As SILVAH-Oak prescriptions became more widely used in Pennsylvania, the positive outcomes of appropriate use of prescribed fire became apparent, yet Pennsylvania laws regarding the use of prescribed fire did not protect even the best-trained and best-prepared practitioners from liability. Managers and users of SILVAH-Oak prescriptions worked together to pass a new public law in Pennsylvania, the Prescribed Burning Practices Act (P.L. 76, No. 17) in July 2009. This law charged the DCNR to develop standards for prescribed burn plans, prescribed burn manager training, and a process for approving prescribed burns. The law also ensured immunity from civil and criminal prosecution for landowners and practitioners who allowed and conducted prescribed burns according to the standards and training requirements.

Northern Research Station (NRS) scientists Kurt Gottschalk and Gary Miller from West Virginia were key members of the SILVAH-Oak development team. As they became increasingly familiar with the role the training sessions could play in fostering science-management cooperation and sustainable forestry, they suggested bringing the training sessions to West Virginia. Similarly, organizers of the early training sessions invited Joanne Rebbeck, a plant physiologist and collaborator from the NRS in Ohio, to become part of the SILVAH team. Under her leadership, training sessions began in Ohio in 2005. The timing was propitious, because efforts were already underway to increase cooperation among public agencies in Ohio to sustain oak forests there. SILVAH-Oak became a foundation for a community of practice in Ohio that is now supported by a consortium that includes the Wayne National Forest, the Ohio Division of Forestry, and the USDA Natural Resources Conservation Service. It will soon include the Ohio Division of Wildlife and others. Some of the efforts of this community of practice are described in Peters and Rebbeck (2019).

WILDLIFE HABITAT AND SILVICULTURE

As various organizations began using the SILVAH-Oak prescriptions to ensure continued oak abundance in mixed-oak forests, wildlife managers began to attend the SILVAH-Oak training sessions in greater numbers. Oak forests provide essential benefits for many wildlife species, and public agencies and nongovernmental organizations with a mandate to sustain wildlife habitat found SILVAH-Oak to be a valuable tool.

At the same time, scientist Scott Stoleson was completing research that showed the importance of early successional habitat to many migratory songbirds in the post-fledging period (Stoleson 2013). Other research was showing the benefits of the conditions created by shelterwood seed cuts, especially in white oak stands, to cerulean warblers (*Dendroica cerulea*) and other bird species of conservation concern (Stoleson 2004). An allied community of practice began to form to increase, update, and publicize the wildlife habitat information available from SILVAH and the associated NED software. Stoleson, SILVAH programmer Scott Thomasma, and Helene Cleveland, who had developed a matrix of Pennsylvania wildlife species habitat requirements for NED (Cleveland and Finley 1998), co-led this effort. They formed a working group with several wildlife managers that accomplished these improvements, which are now incorporated in SILVAH and NED (Thomasma and Cleveland 2019). Stoleson (2019) provides a synthesis of what is known about the interaction of silviculture and wildlife habitat that builds on the products from the working group and informs the SILVAH system for mixed-oak, Allegheny, and northern hardwood forests. This results of this work form a regular part of all SILVAH training sessions.

BLACK CHERRY DECLINE

Beginning early in the 2000s, managers and scientists began noticing changes in the ecology of black cherry in the Allegheny High Plateau ecoregion. Early discussions focused on decreased frequency of abundant black cherry seed crops and expanded to observations of reduced growth and competitiveness of black cherry seedlings, while those of black birch (*Betula lenta* L.) became more competitive. Eventually, these discussions included observations of crown dieback and of increased frequency and apparent virulence of cherry leaf spot (*Blumeriella jaapii*) attacks on seedlings. By the time of the recession in the late 2000s, as cherry timber prices declined substantially, purchasers of black cherry timber were complaining of a defect that became known as dark rings. Dave Trimpey, a manager with Collins-Kane Hardwood, approached Bob Long about this specific defect. Trimpey and other managers helped Long identify sites on which trees with dark rings had been found. Long associated these with previous defoliations and found important patterns. Long brought in experts from the Forest Products Laboratory and together they published results showing the relationship with defolation and the wood properties associated with the dark rings (Long et al. 2012).

In 2014, Long and ANF Silviculturist Andrea Hille received a grant to remeasure all the forest health plots across the ANF that included black cherry. By 2015, because black cherry vigor and survival had changed, the SILVAH research team decided they could no longer teach the current research guidelines for regenerating Allegheny hardwood stands. They began to assemble data from long-term and recent studies to better understand emerging patterns. On September 23, 2015, the SILVAH team assembled representatives of all key management partner organizations at the KEF to spend a day pooling observations and forming hypotheses. Lab teams assembled data from two stem-reconstruction studies, which suggested that before 1995 black cherry seedlings and saplings had consistently outcompeted black birch; after 1995 the opposite appeared to be true. They assessed linkages between climate data and these changes and found little. They brought in data about the scale and severity of defoliations of black cherry. Long's data concerning seed production confirmed that seed crops were less frequent and production was lower. They also showed that age of stand was not correlated with seed production. Emerging data from the revisited health plots confirmed an increase in black cherry mortality compared to earlier measurement periods, and when the Pennsylvania DCNR BoF was asked to query its permanent inventory plots for the High Allegheny Plateau ecoregion, researchers found the same trend. Data from the National Acid Deposition Program weather station on the KEF showed that nitrogen inputs from acid deposition had decreased to levels not reported since the 1960s, so old data about cherry responsiveness to nitrogen fertilization were also brought to the meeting.

Each manager present was asked to report observations, and new insights emerged from the conversation. Many foresters present were observing better cherry seedling health, survival, and growth in stands with low proportions of cherry in the overstory, and everyone was seeing cohorts of black cherry seedlings eliminated, sometimes in more than one successive year, by black cherry leaf spot. Some participants remembered that sulfur has fungicidal properties and wondered if the reduction in sulfate deposition might be playing a role in the changed ecology of cherry seedlings.

The research responding to these observations is at an early stage, and some studies are awaiting funding. But the collaboration between managers and scientists regarding this this emerging issue reaffirms the patterns that have been successful in the past.

LESSONS LEARNED

Together, scientists and managers in the High Allegheny Plateau ecoregion have learned several key lessons about sustaining the benefits of science-management collaboration. Our summary for this chapter has two parts. Table 1 highlights some specific outcomes from the half-century of collaborative work that the SILVAH community of practice has completed. We also show specific instances from the examples above that illustrate the general principles of science-management collaboration.

1) Collaboration between scientists and managers sharpens hypothesis formation by increasing the number of observations and perspectives on which hypotheses are based.

The best examples of this occurred in the silviculture, soil nutrient and fertilization, and oak regeneration lines of research. The Stand Culture and Stand Regeneration scientist-manager tour in the early 1990s led to the development of allied decision support software, NED. The 1995 sugar maple decline tour to look at research and manager-selected sites demonstrating good and bad sugar maple health and regeneration focused the attention of the entire team on the landscape distribution of key nutrients. This led to more studies, including a landscape study and a study to test soil nutrient changes over time. For oak regeneration, the team of managers and scientists convened by the Pennsylvania DCNR BoF explicitly identified and prioritized research needs and developed a new SILVAH framework into which the results of those studies could be incorporated as they became available.

2) Collaboration accelerates, diversifies, and focuses site selection for designed experiments and can support more complex designs by providing in-kind services for study and treatment installation.

At least four lines of science provide excellent examples of this principle. The original deer enclosure study involved four landowners and in-kind support for fence construction. The current study of the interaction of landscape food production and deer impact at specific sites involves seven landowners, all of whom implemented the key central shelterwood harvest as an in-kind service. Most of the oak regeneration work and the original soil nutrient study of sugar maple decline involved Pennsylvania DCNR BoF personnel identifying potential sites and collaborating with scientists to implement treatments. The study of nontarget impacts of operational herbicide treatments depended on close collaboration with ANF managers to identify sites and implement treatments.

3) Managers help scientists conduct better research by influencing the direction of a research program and by supporting (for example, through pilot studies) excellent work that attracts competitive funding.

The KQDC and the original deer enclosure study both pointed to the interaction of landscape forage production with actual deer impact on regeneration in managed stands. Those studies provided the preliminary results that enhanced the competitive success of the application to the USDA Applied Forestry Research Initiative grant program that provided 5 years of support to the resulting landscape-scale study at 25 locations across the region. Early research on interfering plants and their management formed the essential underpinning for the competitive grants awarded to the herbicide-diversity study. Preliminary research associated with oak regeneration was instrumental when Brose and his colleagues succeeded in the Joint Fire Science Competitive Grant program to synthesize the literature concerning the relationship of oak regeneration and prescribed fire.

4) Scientists can expand the net of expertise available by bringing in colleagues from other regions with relevant specialties.

As the initial sugar maple decline research began to yield results, scientists at the Irvine Lab recruited other Forest Service researchers with relevant expertise, including Robert Long, a research forest pathologist, Scott Bailey, a research ecogeologist, and Richard Hallett, a research forest ecologist with experience in nutrient-forest health interactions. Managers from the Pennsylvania DCNR BoF brought experts from their Forest Health division, including Barry Towers and Tom Hall, and managers to assist in data collection, especially Paul Lilja.

5) Regular interactions through which a common vocabulary and framework are developed increase the efficiency of describing emerging problems and promotes shared ownership of the work.

The SILVAH training sessions and frequent problem-focused interactions form one core of the community of practice. New foresters participate soon after beginning work in the ecoregion, where they are exposed to the SILVAH framework and the vocabulary that has developed to describe inventory results and stand and landscape attributes that influence management outcomes. Managers at every level participate in the training sessions, research updates, professional meetings, and working groups that rely on the vocabulary and framework. The best examples from this chapter that highlight the benefits of the shared framework are the early work on oak regeneration that became SILVAH-Oak, including beta-testing of new inventory and prescription processes by managers and the recent work on black cherry decline.

6) As managers participate in problem selection and in the design of experiments that are directly relevant to management practice, they gain confidence in research results and become more willing to adopt new practices and support policy changes based on the research.

The silvicultural practices embodied in the SILVAH training sessions and decision support software are standard operating procedure in many public agencies in Pennsylvania, Ohio, New York, and Maryland, and they inform silvicultural practice in many private management agencies. When the initial SILVAH inventory process was first announced, there might have been great resistance, because regeneration plots that were essential to the inventory could be conducted only during the growing season. This was an expensive change to implement, but because managers had been involved from the inception of the studies that led to these changes and could see the benefits in the research areas, adoption was quick and widespread. Penn State extension foresters worked with managers and scientists at the Irvine Lab to develop an application of SILVAH processes and practices for private landowners (Finley et al. 2007).

At least two major forest policy changes in Pennsylvania during the 50 years of science-manager collaboration are strongly associated with the SILVAH community of practice. As results from the deer enclosure study began to accumulate, land managers were able to show policymakers these results on the ground and tell policymakers about the impact to their bottom line. These actions, combined with productive use of the research results by leaders in the Pennsylvania DCNR BoF and the Pennsylvania Game Commission, contributed substantially to the late 20th century and early 21st century changes in deer management policy in Pennsylvania. These changes have increased the sustainability of Pennsylvania's forests.

The other important example of policy change regards prescribed fire. Pennsylvania land trusts and others used results from SILVAH-Oak research, including the meta-analysis of prescribed fire-oak regeneration interactions and the availability of study and demonstration sites, to change Pennsylvania's liability laws regarding prescribed fire. This resulted in a well-defined process that, if followed and documented, protects those who used prescribed fire from personal liability. This change in policy has increased the appropriate use of prescribed fire for oak regeneration benefits.

7) Over time, a community founded on mutual respect emerges, and scientists and managers coproduce knowledge and improved practices.

The current work to develop interim strategies for stands that are affected by black cherry decline and other forest health challenges through a working group emerging from the Allegheny High Plateau Forest Health Collaborative is the best example of the community of mutual respect and the coproduction of knowledge. As research to document the causes of the problem and develop new management practices to sustain forest benefits continues, managers and scientists together are using the SILVAH vocabulary and framework to develop a prioritization or triage scheme for which stands most urgently require silvicultural intervention (as seed source is threatened by imminent mortality, for example) and to develop silvicultural guidelines for such stands.

Equally important is the benefit to individual foresters and scientists that participate in such a community. It is rewarding in the deepest professional sense to always feel that one's work is part of a larger whole and contributes to the good of the forest in which one works. And, over time, warm personal relationships enhance these professional rewards.

Table 1.—Selected outcomes of the SILVAH community of practice for each illustrated line of science.

Line of Science				
Silviculture	**Adoption:** The SILVAH decision support system and training session textbooks are standard operating procedure on more than 4 million acres of public land and many more on private land	**Science leadership:** The SILVAH relative density measure was the model for the measure of relative density now used by FIA across the eastern United States	**Science leadership:** The SILVAH understory inventory procedure was the model for the understory inventory procedure used by FIA across the northern region	
Deer and forest management	**Policy:** Changes in deer management in Pennsylvania were influenced by results from this research, especially by the 1980s deer exclusion study	**Policy:** The Pennsylvania Game Commission uses the FIA understory measure (based on SILVAH) to assess forest health in each of Pennsylvania's deer management units	**Science leadership:** Top 3 articles from this research have been cited by other scientists around the world more than 1500 times	**Adoption:** Land managers fence regeneration harvests to exclude deer where SILVAH inventory indicates overabundance; are now looking at landscape-scale patterns that influence land management
Interfering plants and their treatment	**Adoption:** Silvicultural prescriptions based on this research are used by managers of more than 4 million acres in Pennsylvania alone	**Policy:** The registration of OUST® for forestry use was conferred based on this research	**Science leadership:** The decade-long study of nontarget impacts of operational herbicide use informs future research and management	**Technology development:** Science-manager collaboration led to development of new application equipment by users of these research results
Soil nutrients and fertilization	**Adoption:** Early results of this research led to routine operational fertilization treatments on public and private land throughout the Allegheny Plateau ecoregion to help regeneration gain height quickly	**Science leadership:** As the high-quality research on sugar maple decline accumulated, managers of soils collected in the 1960s gave SILVAH researchers access to those soils and sites, creating the basis for what is now a 50-year record of changes in soil chemistry	**Adoption and adaptive management:** Managers on the ANF are collaborating with SILVAH scientists to test fertilization in stands where black cherry seedlings are slow to establish and gain height	
Oak regeneration	**Adoption:** The SILVAH computer program and training session textbook form the basis for interagency collaboration to sustain oak in Ohio	**Adoption:** The SILVAH system is standard operating procedure on more than 4 million acres in Pennsylvania alone. Also used in OH, WV, MD, NY, and beyond	**Policy:** As research results and results from adoption showed the importance of prescribed fire in oak regeneration, Pennsylvania adopted P.L. 76, No. 17 to limit liability for well-trained users of this technique	**Science leadership:** The meta-analysis of the fire-oak hypothesis conducted by Brose et al. (2012) synthesized results of more than 30 studies brought order to this important body of work
Wildlife habitat and silviculture	**Science leadership:** Research conducted by the SILVAH team was the first to show that birds using early successional habitat were in better premigration condition than those that used closed forest habitats	**Technology development:** NED was among the first tools to help forest managers link in-stand condition, collected using SILVAH inventory techniques, to habitat needs of individual species		
Black cherry decline	**Hypothesis development:** The SILVAH community of practice has pooled observations about black cherry decline with long term data from the SILVAH science team to form key hypotheses in this emerging research field	**Science leadership:** Collaboration between land managers and SILVAH scientists enabled analysis of site-specific factors such as defoliation history to be analyzed as explanatory factors in the development of dark rings	**Adaptive management:** While scientists seek funding for detailed studies of causes and management responses to black cherry decline, multiple land management agencies are conducting pilot studies of potential treatments	

LITERATURE CITED

Auchmoody, L.R. 1982. **Response of young black cherry stands to fertilization.** Canadian Journal of Forest Research. 12(2): 319-325. https://doi.org/10.1139/x82-046.

Bailey, S.W.; Horsley, S.B.; Long, R.P. 2005. **Thirty years of change in forest soils of the Allegheny Plateau, Pennsylvania.** Soil Science Society of America Journal. 69: 681-690.

Brose, P.H. 2019. **Expanding the SILVAH decision support system to be applicable to the mixed-oak forests of the mid-Atlantic region.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 56-71. https://doi.org/10.2737/NRS-GTR-P-186-Paper6.

Brose, P.H.; Dey, D.C.; Phillips, R.J.; Waldrop, T.A. 2013. **A meta-analysis of the fire-oak hypothesis: Does prescribed burning promote oak reproduction in eastern North America?** Forest Science. 59(3): 322-334. https://doi.org/10.5849/forsci.12-039.

Brose, P.H.; Dey, D.C.; Waldrop, T.A. 2014. **The fire-oak literature of eastern North America: synthesis and guidelines.** Gen. Tech. Rep. NRS-135. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 98 p. https://doi.org/10.2737/NRS-GTR-135.

Brose, P.H.; Gottschalk, K.W.; Horsley, S.B.; Knopp, P.D.; Kochenderfer, J.N. [et al.]. 2008. **Prescribing regeneration treatments for mixed-oak forests in the mid-Atlantic region.** Gen. Tech. Rep. NRS-33. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 100 p. https://doi.org/10.2737/NRS-GTR-33.

Cleveland, H.M.; Finley, J.C. 1998. **Assessing forest wildlife diversity in Pennsylvania.** Northern Journal of Applied Forestry. 15(2): 69-76.

Finley, J.C.; Stout, S.L.; Pierson, T.G.; McGuinness, B.J. 2007. **Managing timber to promote sustainable forests: a second-level course for the Sustainable Forestry Initiative of Pennsylvania.** Gen. Tech. Rep. NRS-11. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 47 p. https://doi.org/10.2737/NRS-GTR-11.

Horsley, S.B. 1991. **Using Roundup and Oust to control interfering understories in Allegheny hardwood stands.** In: McCormick, L.H.; Gottschalk, K.W., eds. Proceedings, Central Hardwood Forest Conference; 1991 March 4-6; University Park, PA. Gen. Tech. Rep. NE-148. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 281-290.

Horsley, S.B. **2019. Using herbicides to control interfering understories in Allegheny hardwood stands, 1. Early development of prescriptions.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 37-43. https://doi.org/10.2737/NRS-GTR-P-186-Paper4.

Horsley, S.B.; Stout, S.L.; deCalesta, D.S. 2003. **White-tailed deer impact on the vegetation dynamics of a northern hardwood forest.** Ecological Applications. 13(1): 98-118. https://doi.org/10.1890/1051-0761(2003)013[0098:wtdiot]2.0.co;2.

Likens, G.E.; Bailey, S.W. 2014. **The discovery of acid rain at the Hubbard Brook Experimental Forest: A story of collaboration and long-term research.** In: Hayes, D.C.; Stout, S.L.; Crawford, R.H.; Hoover, A.P., eds. USDA Experimental Forests and Ranges: Research for the long-term. New York, NY: Springer: 463-482. Chapter 20.

Long, R.P.; Horsley, S.B.; Bailey, S.W.; Hallett, R.A.; Hall, T.J. 2019. **Sugar maple decline and lessons learned about Allegheny Plateau soils and landscapes.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 80-97. https://doi.org/10.2737/NRS-GTR-P-186-Paper8.

Long, R.P.; Horsley, S.B.; Hallett, R.A.; Bailey, S.W. 2009. **Sugar maple growth in relation to nutrition and stress in the northeastern United States.** Ecological Applications. 19(6): 1454-66. https://doi.org/10.1890/08-1535.1.

Long, R.P.; Horsley, S.B.; Hall, T.J. 2011. **Long-term impact of liming on growth and vigor of northern hardwoods.** Canadian Journal of Forest Research. 41(6): 1295-1307. https://doi.org/10.1139/x11-049.

Long, R.P.; Horsley, S.B.; Lilja, P.R. 1997. **Impact of forest liming on growth and crown vigor of sugar maple and associated hardwoods.** Canadian Journal of Forest Research. 27: 1560-63. https://doi.org/10.1139/x97-074.

Long, R.P.; Trimpey, D.W.; Wiemann, M.C.; Stout, S.L. 2012. **Anomalous dark growth rings in black cherry. Northern Journal of Applied Forestry.** 29(3): 150-54. https://doi.org/10.5849/njaf.11-043.

Marquis, D.A. 2019. **The early years of SILVAH.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 3-7. https://doi.org/10.2737/NRS-GTR-P-186-Paper1.

Marquis, D.A.; Ernst, R.L.; Stout, S.L. 1992. **Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised).** Gen. Tech. Rep. NE-96. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.

McWilliams, W.H.; Stout, S.L.; Bowersox, T.W.; McCormick, L.H. 1995. **Adequacy of advance tree-seedling regeneration in Pennsylvania's forests.** Northern Journal of Applied Forestry. 12(4): 187-91.

Peters, M.P.; Rebbeck, J. 2019. **Oak SILVAH in Ohio at the landscape scale.** In: Stout, Susan L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 72-79. https://doi.org/10.2737/NRS-GTR-P-186-Paper7.

Ristau, T. 2019. **Using herbicides to control interfering understories in the Allegheny hardwood stands, 2. Sharpening the tools in the toolbox.** In: Stout, Susan L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 45-55. https://doi.org/10.2737/NRS-GTR-P-186-Paper5.

Ristau, T.E., Stoleson, S.H.; Horsley, S.B.; deCalesta, D.S. 2011. **Ten-year response of the herbaceous layer to an operational herbicide-shelterwood treatment in a northern hardwood forest.** Forest Ecology and Management. 262: 970-979. https://doi.org/10.1016/j.foreco.2011.05.031.

Roach, B.A.; Gingrich, S.F. 1968. **Even-aged silviculture for upland central hardwoods.** Agric. Handbk. 355. Washington, DC: U.S. Department of Agriculture. 39 p.

Royo, A.A.; Kramer, D.W.; Miller, K.V.; Nibbelink, N.P.; Stout, S.L. 2017. **Spatio-temporal variation in foodscapes modifies deer browsing impact on vegetation.** Landscape Ecology. 32(12): 2281-95. https://doi.org/10.1007/s10980-017-0568-x.

Royo, A.A.; Stout, S.L. 2019. **Recognition, response, and recovery: Deer impact research in Allegheny hardwood forests.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 26-36. https://doi.org/10.2737/NRS-GTR-P-186-Paper3.

Stoleson, S.H. 2019. **Silviculture and bird habitat.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 106-119. https://doi.org/10.2737/NRS-GTR-P-186-Paper10.

Stoleson, S.H. 2004. **Cerulean warbler habitat use in an oak-northern hardwoods transition zone: implications for management.** In: Yaussy, D.A.; Hix, D.M.; Long, R.P.; Goebel, P.C., eds. Proceedings, 14th Central Hardwood Forest Conference; 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 535. [Abstract].

Stoleson, S.H. 2013. **Condition varies with habitat choice in postbreeding forest birds.** The Auk. 130(3): 417-428. https://doi.org/10.1525/auk.2013.12214.

Stoleson, S.H.; Ristau, T.E.; deCalesta, D.S.; Horsley, S.B. 2011. **Ten-year response of bird communities to an operational herbicide-shelterwood treatment in a northern hardwood forest.** Forest Ecology and Management. 262: 1205-1214. https://doi.org/10.1016/j.foreco.2011.06.017.

Stout, S.L.; Royo, A.A.; deCalesta, D.S.; McAleese, K.; Finley, J.C. 2013: **The Kinzua Quality Deer Cooperative: Can adaptive management and local stakeholder engagement sustain reduced impact of ungulate browsers in forest systems?** Boreal Environment Research. 18(suppl. A): 50-64.

Thomasma, S.; Cleveland, H. 2019. **Wildlife habitat associations in SILVAH and NED.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 120-131. https://doi.org/10.2737/NRS-GTR-P-186-Paper11.

Trager, M.D.; Ristau, T.E.; Stoleson, S.H.; Davidson, R.L.; Acciavatti, R.E. 2013. **Carabid beetle responses to herbicide application, shelterwood seed cut, and insect defoliator outbreaks.** Forest Ecology and Management. 289: 269-288. https://doi.org/10.1016/j.foreco.2012.10.025.

Twery, M.J. 2019. **NED and SILVAH: A history of the coalition.** In: Stout, S.L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 98-105. https://doi.org/10.2737/NRS-GTR-P-186-Paper9.

Stout, Susan L.; Brose, Patrick H.; Cleveland, Helene; Long, Robert P.; McGuinness, Barbara; Peters, Matthew P.; Rebbeck, Joanne; Ristau, Todd; Royo, Alejandro A.; Stoleson, Scott H.; Thomasma, Scott; Twery, Mark J.; Wurzbacher, Sarah. 2019. Fifty years of science-management cooperation from the SILVAH community of practice. In: Stout, Susan L., ed. SILVAH: 50 years of science-management cooperation. Proceedings of the Allegheny Society of American Foresters training session; 2017 Sept. 20-22; Clarion, PA. Gen. Tech. Rep. NRS-P-186. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 8-25. https://doi.org/10.2737/NRS-GTR-P-186-Paper2.