THE NORTHEASTERN FOREST HEALTH ATLAS

Technical Report

The Northeastern Forest Health Atlas – Technical Report

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DOI:

Acknowledgments

Preferred Citation

Executive Summary

The Northeastern Forest Health Atlas (NEFHA, https://www.uvm.edu/femc/forest-health-atlas) provides an online, searchable interface for assessing decades of forest disturbance monitoring and research data in maps, tables and charts. Prior to this effort, obtaining data on forest disturbance was difficult, and comparing it across years and programs was even harder. The objectives of NEFHA are to improve access to standardized data related to forest disturbance across both space and time for forest managers and researchers. The atlas is hosted and maintained by the Forest Ecosystem Monitoring Cooperative (FEMC), and was developed with funds provided by the Northeastern States Research Cooperative (NSRC). In this report, we describe the history of the effort, technical details about how we compiled data, and summaries of major aspects of the resulting dataset.

The NEFHA unifies monitoring and research data from two major sources. First, we compiled spatial disturbance data collected by individual states and the US Forest Service through aerial detection surveys. These annual aerial surveys have been conducted for decades to identify and map the locations of biotic and abiotic forest disturbances. The second source of data for NEFHA are research outputs derived from studies funded by NSRC. Since it began, NSRC has funded hundreds of studies examining forested ecosystems in the Northern Forest to better understand how these resources are changing, and how these changes may affect the people that depend on them.

NEFHA provides access to aerial detection survey and other insect survey data consisting of 106,966,940 hectares (ha) of disturbance mapped on 100,243 polygons attributed to 222 damage-causing agents. The data go back in time as far as 1918 in Maine, and all states have consistent coverage from 1997 to 2016. Region-wide, the most damage has been attributed to spruce budworm (78,598,995 ha), followed by forest tent caterpillar (11,152,081 ha), gypsy moth (4,550,215 ha), and balsam woolly adelgid (3,147,304 ha). NEFHA also provides access to research projects and, in some cases, associated data and publications funded by the NSRC. In total, we created archive pages for 30 projects related to forest health and disturbance, 11 of which provided data. The FEMC will maintain the NEFHA into the future. FEMC will ingest and integrate new disturbance data with the existing regional data in the NEFHA, advise and support states in digitizing additional historical disturbance data when possible, and expand the research data holdings by incorporating additional studies in NEFHA that were not originally funded by NSRC.

The tools and data access mechanisms in NEFHA provide a novel and invaluable tool for quickly finding and mapping data on forest disturbance in the northeastern US. This resource will continue to grow in volume and relevance as a changing climate, shifting land use, and new stressors continue to spur change in forests.

Contents

Introduction

Disturbance in temperate forests of the northeastern US is a fundamental diver of ecosystem dynamics and functioning that integrates land use history, the introduction of invasive species, climatic cycles, and both chronic and episodic events. Forest disturbance and damage can range in severity from light defoliation to high tree mortality and across space from localized events to those affecting thousands of hectares. The spatial and temporal dynamics of these disturbances are difficult to assess retroactively because of a lack of consistent and complete monitoring of all agents, types, and severities across the landscape. However, there are many sources of information that, when taken together, can provide an improved picture of forest damage patterns over time. To address a consistent and known information gap, the Forest Ecosystem Monitoring Cooperative (FEMC[1]) developed the Northeastern Forest Health Atlas (NEFHA) to provide a single source of data on forest disturbance and damage in the northeastern US. The NEFHA provides access to two critical sources of data – (1) historical damage polygons mapped through the Aerial Detection Surveys (ADS) and Insect and Disease Surveys (IDS) conducted by states in the region and the USDA Forest Service (USFS), and (2) field-based research findings on disturbance-related studies. This report describes the methodology and background in the development of NEFHA.

Objectives of NEFHA

Prior to this effort, obtaining data on disturbance was difficult, and comparing it across years and programs was even harder. The objectives of NEFHA are to make it easier for managers and researchers in the northeastern US to access standardized data related to forest disturbance across both space and time. NEFHA currently covers the states of Maine (ME), Massachusetts (MA), New Hampshire (NH), New York (NY), and Vermont (VT). NEFHA provides a searchable, web-based map interface for discovering disturbance-related research and monitoring data that matches a user's criteria. To populate the atlas, our effort focused on unifying monitoring and research data from two major sources. The first source of data were spatial disturbance data collected through ADS and IDS programs that are conducted by individual states and the USFS. Research outputs comprised the second source, and were derived from studies funded by the Northeastern States Research Cooperative (NSRC).

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[1] Website: https://www.uvm.edu/femc/. Note that the FEMC was called the Vermont Monitoring Cooperative until May, 2017.

History of Aerial Sketch Mapping, Aerial Detection Surveys and Insect and Disease Surveys

Throughout the US, annual aerial surveys have been conducted by state and federal agencies to identify and map locations of biotic and abiotic forest disturbance for decades (McConnell, 1999; Johnson and Wittwer, 2008). Aerial sketch mapping surveys are relatively cost-effective assessments of forest health conditions that allow technicians to respond quickly to reports of disturbance (Johnson and Wittwer, 2008) and provide a long-term, spatially explicit record of forest disturbance. Forest disturbance mapping on a large scale has generally developed through three distinct phases or time periods. Before 1997, states conducted aerial and field surveys, but the data descriptions and methodology varied by state, sometimes substantially. Usually, data were captured by sketching directly onto paper maps. In 1997, a standardized approach to aerial sketch mapping was implemented by the USDA Forest Service. All data from 1997 to 2016 were collected according to standards published in 1999 (United States Forest Service [USFS] 1999) along with accompanying geographic information systems data standards (United States Forest Service [USFS] 2005). This program eventually moved away from paper maps to using the Digital Aerial Sketch Mapping (DASM) platform, a product of the Forest Health Technology and Enterprise Team (FHTET) in support of Forest Health Protection and Forest Health Monitoring within State and Private Forestry. These data were delivered by states to the USFS for collation and standardization into the Aerial Detection Survey (ADS) program. In 2017, states began using a new collection methodology, called Digital Mobile Sketch Mapping (DMSM), to populate a national Insect and Disease Survey (IDS) database (United States Forest Service [USFS] 2016).

Utilizing data from aerial sketch mapping in the Northeast is complicated by changing methodologies and the priorities of states in conducting the surveys. However, these data could be valuable in understanding spatiotemporal patterns of forest disturbance, particularly in terms of inter-annual variability, cumulative impacts, and potentially shifting disturbance regimes. Moreover, ADS data have not been publicly available in a format that enables users to assess multiple years of disturbance across space.

History of Northeastern States Research Cooperative

The Northeastern States Research Cooperative (NSRC) is a grant-making program funded by the USDA Forest Service. Its mission is to support research in the Northern Forest that benefits "the people who live within its boundaries, work with its resources, use its products, visit it, and care about it." Creating the NSRC was a recommendation made by the Northern Forest Lands Council in 1994, leading to national legislation that authorized the formation of the NSRC. Research funding began in 2001 for studies at Hubbard Brook Experimental Forest (NH), and expanded to the remainder of the region in the next few years. As of 2018, the NSRC has awarded 335 grants totaling

nearly $24 million since its inception (Northeastern States Research Cooperative [NSRC] 2018). Research has been funded supporting four major themes: Sustaining Productive Forest Communities; Sustaining Ecosystem Health in Northern Forests; Forest Productivity and Forest Products; and, Biodiversity and Protected Area Management. Researchers have been funded from over 50 organizations in the region, yielding a wealth of data and information that should have direct relevance for understanding and managing forest resources in the region (NSRC 2018). However, although NSRC has done a significant amount of work to capture and communicate the findings of the research, providing access to the data has not been a priority, and there is a gap in archiving and accessing the data that support NSRC studies, which this project addressed.

Methods

Aerial Detection Surveys

We describe here our approach for combining the first two eras of data collection as outlined above (pre-ADS and ADS, spanning 1918 to 2016) into a cohesive dataset. The data from DMSM and IDS (since 2017) are not yet available to the public, and thus are not included in NEFHA at this time. The goal of this compilation was to walk forward the coding schemes used by each state to the standards used by DASM (USFS 1999, USFS 2005), which were the standards in use at the initiation of this project. We started with the state datasets because states continued to capture state-specific coding that they felt was useful and yet could not be accommodated in the ADS standards. The ADS standard only requires determining the damage causing agent when the damage type is defoliation or mortality, meaning other damage types may not be narrowed down to specific agents. We performed all data processing in ArcGIS 10.1-10.5 using Python scripts and, in some cases, ArcGIS models. The general pattern for data compilation was as follows:

1. **Gather data by state**
   We contacted forest health protection staff in each state to acquire historical disturbance sketch mapping data. These are the data stored by each state, generally in individual shapefiles per year.
2. **Fix spatial and topological problems**
   Some datasets were in older formats or had problems with the underlying spatial data that had to be fixed using ArcGIS tools for repairing geometries and topologies.
3. **Identify standard ADS codes**
   The codes and comments in the data as delivered were assessed and, when possible, were assigned a code from the ADS standard. At a minimum, we tried to identify the damage-causing agent (DCA1 in the ADS standard) and the damage type (DMG_TYPE1). In some

cases, the data also contained information on forest type (FOR_TYPE1) and severity (SEVERITY1). If that information was captured, we included it in the compilation.[2]

4. **Seek feedback on uncertain coding and finalize compilation**

   When determinations on the correct corresponding code could not be gleaned from the data and comments, we sought input from state partners to further refine codes. When no further information could be found to recode the polygon, we assigned "no data" value for attributes when corresponding codes could not be determined;

5. **Merge individual years**

   Once we had recorded all polygons for a state, we merged all available years into a single feature set with common attributes, including the year (RPT_YR in the ADS standard).

6. **Backfill**

   In some cases, the USFS Northeastern Area State & Private Forestry data contained polygons that were not present in the state data as delivered, or the state data contained invalid codes that were correctly attributed in the USFS dataset. After compiling all state data into a unified dataset, we identified polygons with missing or invalid codes. Looking for spatial matches with the USFS regionally compiled data for the same year, we recoded those polygons with the codes from the USFS data if we found a match, otherwise assigning the correct "no data" values for those columns.

After completing these steps for each state, the resulting layers were combined into a single feature set covering the region for all available years. The result is the most inclusive dataset for each state and each year.

Below we describe the data compiled for each state, including general observations about the datasets and coding schemes used in the datasets, with details of coding decisions given in Appendix 1. We then outline the workshop we convened of experts from each state and the USFS to discuss remaining uncertainties in the coding of the data. Then, we described additional details of merging individual states into a regional combined dataset. Finally, we describe the analytical tools developed to summarize patterns of repeated damage.

Standardizing Historical Aerial Sketch Mapping Data for Each State

Maine

Data from Maine were obtained from the USDA Forest Service Northeastern Area State and Private Forestry GIS Specialist for 1997 to 2016 (USFS 2016), and from the GIS Specialist in the Maine Forest Service for all years prior to 1997 for a smaller subset of damage-causing agents (Maine Forest

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[2] The code lists for these attributes are defined in USFS (2005) and downloads of the codebooks are available at https://www.fs.fed.us/foresthealth/technology/ads_standards.shtml.

Service 2016). This second dataset was compiled from a range of data sources including aerial surveys, general zones of occurrence and estimations from field reports on specific agents, such as spruce budworm (Figure 1). Data on spruce budworm prior to 1997 come from the Maine Forest Service spruce budworm defoliation maps, the Maine Forest Service spruce budworm reports and/or a seminal report (Weed 1977) integrating all available information on general zones of occurrence of spruce budworm. The original source of the polygon was noted in the source data. Maine also provided extents of damage from hemlock looper (1990 to 1993), gypsy moth (1990 to 1993), and browntail moth (1994 to 1997). All together, the data from Maine cover the periods 1918 to 1919, 1945 to 1979, 1981, 1983, 1990, 1992 and 1994 to 2016.
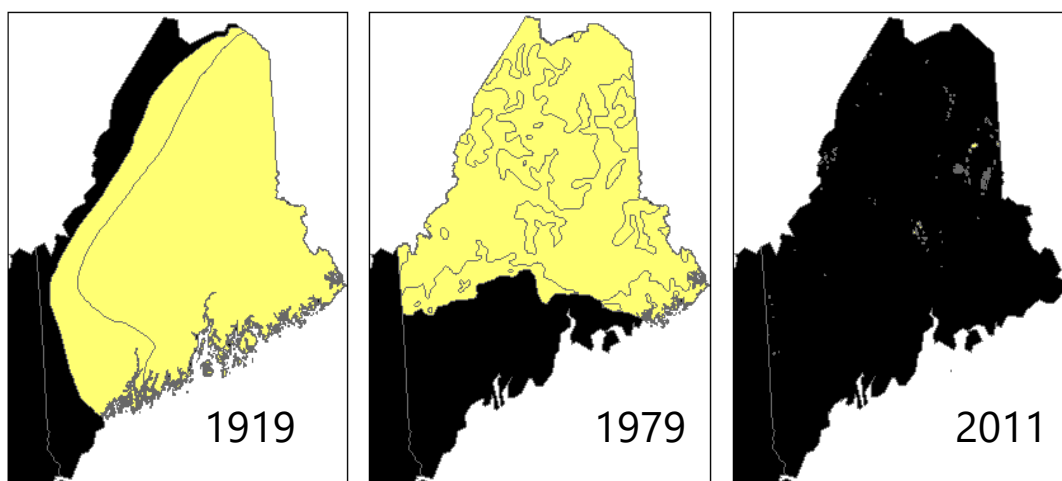
Figure 1. Mapping approaches for Maine have varied considerably over time, showing general zones of occurrence in 1919 (left), more refined combinations of delineated boundaries and general zones of occurrence in 1979 (center), and finer scale mapping in 2011 (right).

Data prior to 1997 had to be processed. We excluded two polygons that did not contain information on the year of mapping. Because of the nature of the data delivery, where data were provided by year and by agent, there was no challenge in recoding the damage-causing agent for these data. With regards to damage type, all files were marked as tracking defoliation, so damage type was coded for defoliation. Severity was present in some of the data, but it was not applied in a way that easily matched up to the existing coding structure, requiring some data reduction. The specific coding decisions are described in Appendix 1.

Massachusetts

Aerial survey data were available in Massachusetts dating back to 1934, and were obtained from the Massachusetts Bureau of Geographic Information (MassGIS) in yearly files from 1934 to 1946 and 1961 to 1997 (Massachusetts Department of Conservation and Recreation 2016), and from 1998 to 2016 from the US Forest Service (USFS 2016). As no defoliation was recorded in 1942 and 1943, no spatial data were present for these years (MassGIS 2016). According to MassGIS, prior to 1962, maps

at a scale of 1:62,500 were used, while maps at a 1:24,000 or 1:25,000 scale were used after 1961, and ground checks were conducted to verify what was observed from the air (MassGIS 2016).

Some original shapefiles had invalid geometries, which we repaired using the "Repair Geometry" tool in ArcGIS. There were significant inconsistencies in the descriptions and coding for damage agents, damage types, and severity, such as different terms for the same agent or different spellings of the same agent. For a limited number of years, surveyors would map an entire town as affected if a disturbance had been observed in that town. As best we can tell, this occurred to a significant extent in 1981, and in a more limited way in 1984 (Figure 2). Most of the recoding decisions we made involved interpreting the text in the "COMMONNAME" field, which sometimes contained damage
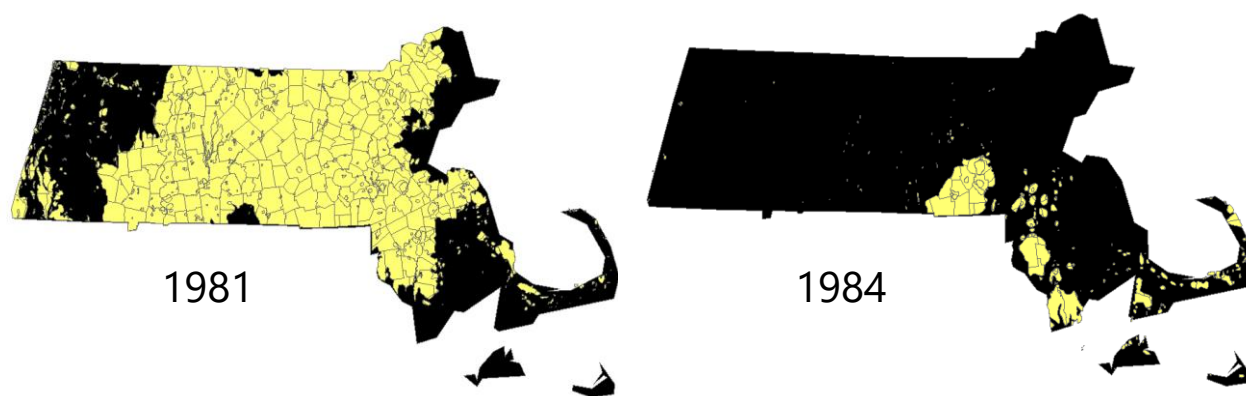
Figure 2. Mapping of defoliation using entire towns as polygon boundaries in Massachusetts for 1981 (left) and 1984 (right).

severity, agent name, or a combination of agent, damage type, and severity. Details on the translation of these codes are given in Appendix 1. More details on the data and processing can also be found in Tait and Duncan (2017).

New Hampshire

Aerial survey data in New Hampshire were available starting in 1965. Data prior to 1997 were made available by the New Hampshire Division of Forests and Lands (New Hampshire Division of Forests and Lands 2016) and more recent data came from the USFS (2016). Data were available for 1965, 1967 to 1973, 1975 to 1976, 1980 to 1983, and 1989 to 2016, but prior to 1997, the data did not include aerial survey data for the White Mountain National Forest.

The data prior to 1997 contained one column per damage causing agent, many of which we could interpret, although not all could be translated to standard agent codes. We assumed that all disturbance was defoliation given that the fields all started with "DEFO_". Damage severities were given as low, medium, high, or unknown. Data in 1969 had some codes that were indecipherable, probably due to character encoding errors; these could not be salvaged. We provide details on the translation of these codes in Appendix 1.

New York

Aerial survey data from New York were sporadically available back to 1951. Digital data from 1997 to 2002 and for the year 2016 were obtained from the USFS (2016) and the remaining years were collected from the New York Department of Environmental Conservation (New York Division of Lands and Forests 2016b). Prior to 1997, data only existed on paper maps. As part of work funded by the US Forest Service, FEMC digitized a subset of these historical aerial detection survey maps pertaining to forest tent caterpillar between 1951 and 1955 as well as between 1991 and 1994 (New York Division of Lands and Forests 2016a). We translated these historical data into the contemporary standardized codes based on the information available on the paper maps (Tait and Duncan, 2016). Because the remainder of the data met the ADS standards, no further processing was required for this dataset.

Vermont

Digital data for Vermont were available from 1985 to 2016 and were obtained from the Vermont Department of Forests, Parks and Recreation (VTFPR) for the entire period (2016b). The FEMC has been working with VTFPR on standardizing and collating aerial detection survey data since 2014. As VTFPR has been collecting ADS data with additional information that do not always match the federal standard, FEMC has provided support in maintaining archival versions of both coding frameworks. Further, the FEMC has melded these more recent data with data prior to 1997 that used a Vermont-specific coding system and translated these codes into the current ADS standard. We provide details on the translation of these codes in Appendix 1.

Workshop with State Experts

After initial work to standardize the ADS data, we convened a group of experts from the five-state region to review the work to date, clarify remaining questions and methodological changes over time, and provide feedback on the design concepts of the NEFHA. We held the meeting at the University of Vermont on December 1, 2016. The attendees are listed below:

- Dan Dillner, Forester, Vermont Department of Forests, Parks and Recreation
- Ken Gooch, Forest Health Program Director, Massachusetts Department of Conservation and Recreation
- Ryan Hanavan, Entomologist, USDA Forest Service Northeastern Area State and Private Forestry
- Nicole Keleher, Massachusetts Department of Conservation and Recreation
- Greg Miller, Maine Forest Service
- Barbara Schultz, Forest Health Program Manager, Vermont Department of Forests, Parks and Recreation
- Dave Struble, State Entomologist, Maine Forest Service

- Jennifer Weimer, Forest Health Specialist, New Hampshire Division of Forests and Lands

Jerry Carlson (Forest Health Chief) and Scott McConnell (Research Scientist) from the New York Division of Lands and Forests within the Department of Environmental Conservation were invited and planned to attend, but were not able due to in-state obligations. We provide the agenda for the meeting in Appendix 3.

Regional Compilation

After we translated all codes, the final step was to combine the individual state datasets into a regional dataset. This required three steps of additional processing. First, we merged all of the state datasets into a single dataset, retaining all fields. Second, we assigned state information to all damage polygons that were located inside a state's boundaries. In some instances, surveyors mapped damage that extended into an adjacent state (Figure 3). The most important information we needed was to identify the state where the damage occurred rather than the state that collected it, so we processed the data to assign states based on the location of the polygon. We did this by dissolving on unique polygons of damage agent (DCA1), damage type (DMG_TYPE1), reporting year (RPT_YR), and severity (SEVERITY). We clipped this result to each state boundary, added a field to identify location (STATE), and set this field to the correct value. We then merged the individual state datasets into a single regional dataset containing the limited fields required for display in NEFHA.
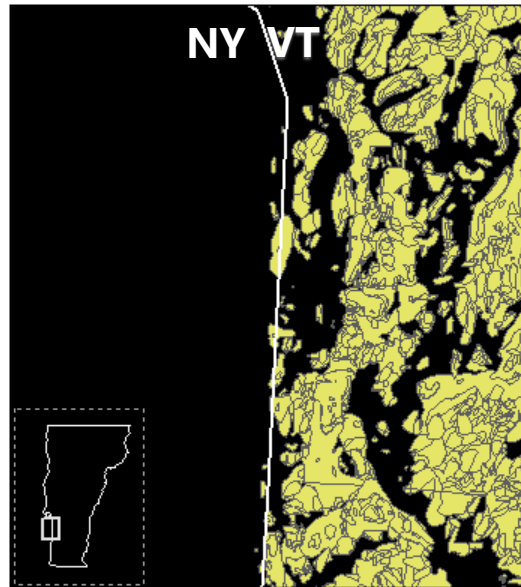
Figure 3. Occasionally surveyors will map polygons in adjacent states, which are split and assigned the proper state overlap.

Lastly, we dealt with DCA1 codes that were outside the bounds of acceptable values provided in the standardized codes. In some cases, state datasets contained negative numbers or numbers that did not correspond to a code in the standard. Before discarding these data, we performed a check with the datasets that are maintained by the USFS to see if these polygons were coded with a valid code in that compiled dataset. If so, we substituted the codes into the NEFHA dataset. We describe the ArcGIS models and scripts used to accomplish these steps more comprehensively in Appendix 1.

Spatiotemporal Analysis Tools

To summarize key patterns in the dataset, we built an ArcGIS toolkit to enable spatiotemporal analysis of the combined regional dataset along several dimensions. The toolkit provides a processing tool that computes the number of times a location was mapped as having disturbance

using inputs of damage causing agent and damage type. The toolkit also provides scripts to identify all unique damage causing agent codes in the dataset, which are used as an input into the aforementioned processing tool. The resulting vector maps computed by this toolkit are essentially heat maps of damage over time and space, based on the parameters set by the user. They provide a simple method to summarize complex, spatiotemporal datasets. We made these tools available as Python scripts utilizing ArcGIS tools, online at https://www.uvm.edu/femc/data/archive/project/northeastern_ads/files, and in Appendix 2.

Northeastern States Research Cooperative Data

To complement the monitoring data available through ADS and IDS, we gathered as many research studies on forest damage and disturbance as possible from NSRC-funded projects. Studies were included so long as they resulted in empirical output (preferably data, but published papers were acceptable) and could be geographically referenced (preferably to points). We began by compiling all NSRC-funded research into a dataset that could be examined for themes, topics, and key personnel by extracting information from the NSRC website[3]. Of the 306 studies we examined, we identified 102 studies as generally relevant to the themes of forest disturbance and damage. Of those, 59 also likely contained field data or information
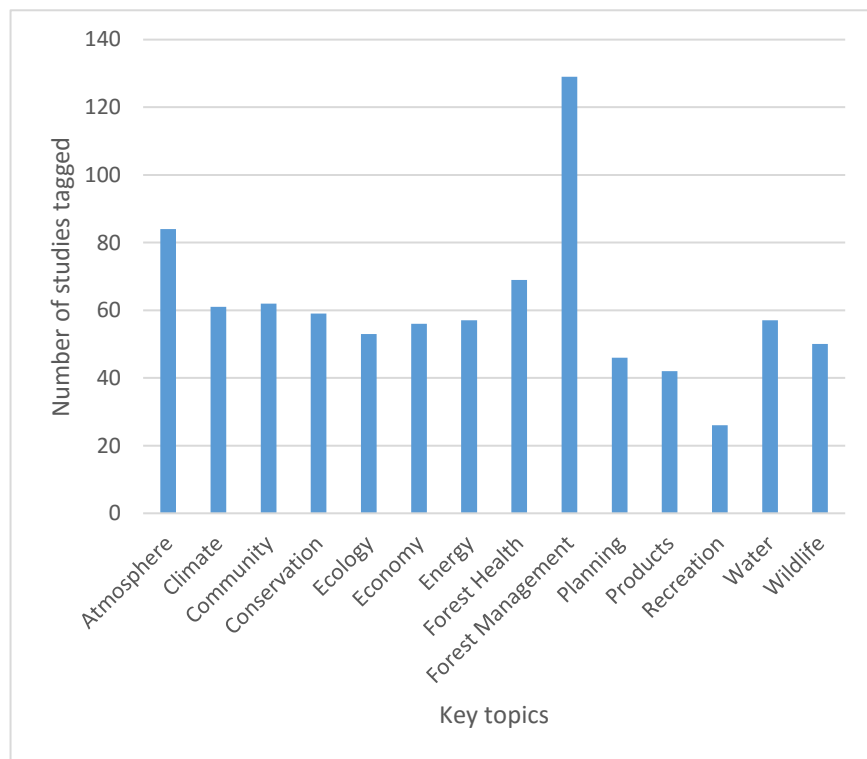
Figure 4. The number of studies tagged with each topic on the NSRC website. It is possible for a single project to be tagged with multiple terms.

relevant to the NEFHA. In total, we contacted 42 NSRC-funded researchers. Some researchers were involved in multiple projects identified by our initial assessment work, and some research had

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[3] This website scraping was conducted in early 2017, thus the information presented here is based on the projects as they appeared on the NSRC website at that time.

already been archived in the FEMC system. We provide the final subset of researcher solicitation in Appendix 4.

The goal of contacting researchers was to collate NSRC-funded information on forest disturbance and damage, and to make those data accessible to the broader community through data archiving. To do this, we created projects in the FEMC data archive for each study for which we could obtain sufficient information. In the FEMC data archive, projects are collections of datasets, documents, people, organizations and other relevant metadata that describe the data themselves and the context in which those data were collected. The FEMC archive uses the latest standards in metadata, geospatial data representation, taxonomic identification, and data security for providing secure storage and open access to data. More information on the FEMC archive is available at https://www.uvm.edu/femc/data/archive.

Once we identified the relevant research projects funded by NSRC, we initiated solicitations to researchers where we asked them to participate in the project by providing:

- Datasets generated by the funding;
- Relevant location data of study sites, study areas, or general zones of applicability;
- Relevant publications, reports, and other documents not available through the NSRC website.

As we collected this information, we created projects in the FEMC data archive. We enriched these projects with additional metadata on disturbance and damage agents using the ADS standardized codes to enable cross-linking with the ADS and IDS data. We then added these projects to NEFHA. Of the projects that we were able to collate, we found that studies examining pollution-related impacts on forest condition dominated the list, representing 42% of those studies archived. Eight of these studies focused on some aspect of acid rain and its effects on soil chemistry or tree growth, while two focused on mercury deposition. Climate change also appeared as a central theme for seven studies in the list, often in combination with other forest stressors such as insects, disease, or acid deposition. Most importantly, there was an emphasis on both biotic and abiotic disturbance agents in the list, with 19 studies addressing some aspect of forest health. These studies focused on the insects and diseases of concern in our region (e.g., emerald ash borer, beech bark disease) as well as weather-related events such as extreme temperatures and ice storms. The smallest group of studies were those that examined the role of forest management in changes in forest health, such as recovery after thinning operations or alternative silvicultural regimes. The geographic range and analytical depth of the NSRC-funded studies varied from synthesis or coordinating efforts to examinations of long-term datasets with complex interactions. This list forms a useful set of knowledge and information for future investigations of the role that forest damage and disturbance play in the Northeast.

The Northeastern Forest Health Atlas

The Northeastern Forest Health Atlas provides an online, searchable interface for assessing decades of forest disturbance monitoring and research data. NEFHA is hosted by the Forest Ecosystem Monitoring Cooperative (FEMC 2017), and delivers data in maps, tables and charts (**Error! Reference source not found.**). It is available online at https://www.uvm.edu/femc/forest-health-atlas.
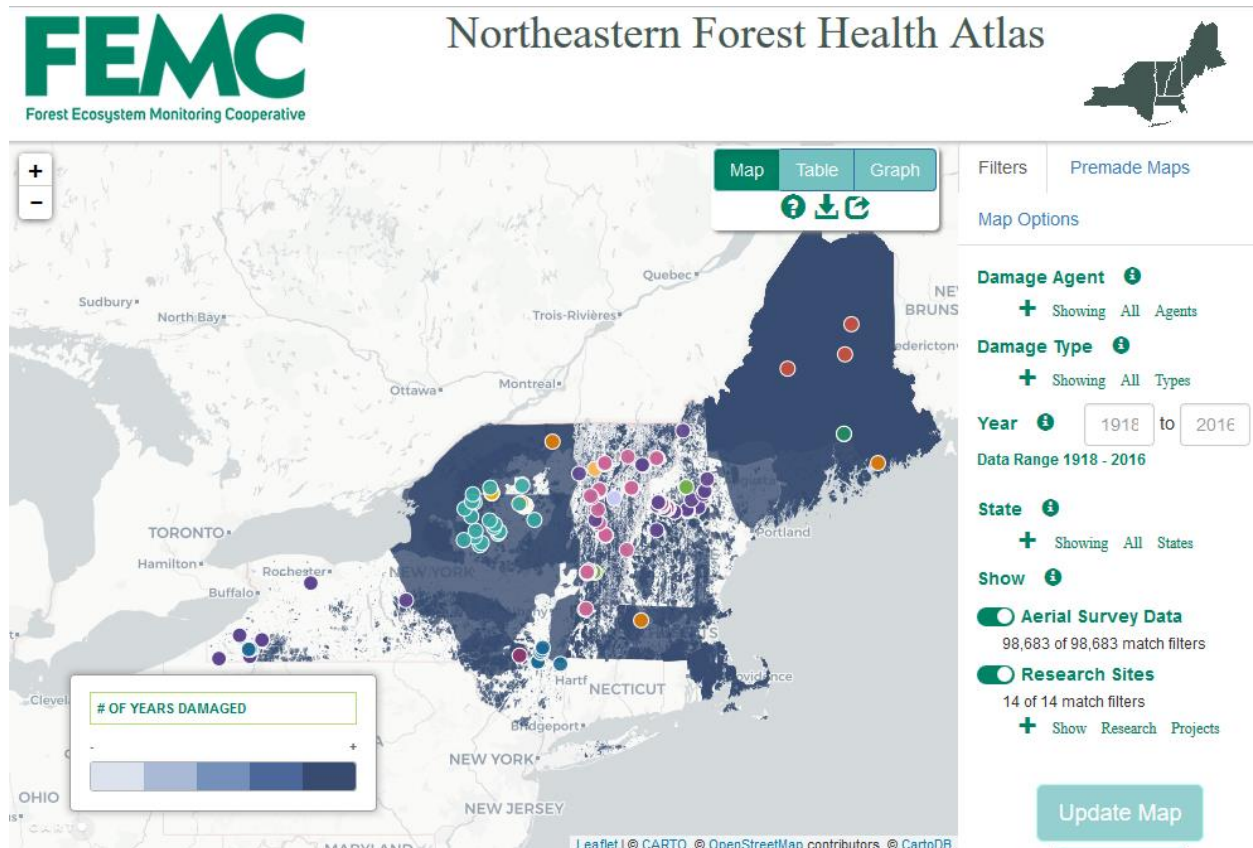
Figure 5. Screenshot of the Northeastern Forest Health Atlas. Online at https://www.uvm.edu/femc/forest-health-atlas.

The portal provides access to aerial detection survey and other insect survey data consisting of 106,966,940 hectares of disturbance mapped on 100,243 polygons (**Error! Reference source not found.**, Table 1). The data cover varying time ranges by state, going back as far as 1918 in Maine, and all states have consistent coverage from 1997 to 2016 (Figure 6**Error! Reference source not found.**). The dataset represents 222 damage-causing agents and all damage types. Note that the ADS standard only requires determining the damage causing agent when the damage type is defoliation or mortality, meaning other damage types may not be narrowed down to specific agents. The most damage has been attributed to spruce budworm (78,598,995 ha), although this may be overestimated because of the method of detection used by Maine in the early 1900s. Forest tent caterpillar (11,152,081), gypsy moth (4,550,215 ha), and balsam woolly adelgid (3,147,304 ha) are

other major damage agents in the region over time, and there are clear hotspots of disturbance activity when the full dataset is processed with the spatiotemporal analysis toolkit (Figure 7). A detailed exploration of the data from 2000 to 2016 is presented in Kosiba et al. (2018).

The portal also provides access to research projects and, in some cases, associated data and publications funded by the NSRC. In total, we created archive pages for 30 projects, 11 of which provided data in some capacity for archiving. Of the 30 projects, 19 of them have location data that make them eligible for inclusion in NEFHA, and 19 of the projects have publications or reports associated with them. Many of these relate to the effects of deposition of atmospheric pollutants on forest health, productivity, and/or soil conditions (n=11), and fewer dealt with the impacts of pests on the region's forests (n=5). Climate change and weather-related stressors made up

Table 1. Total area of mapped damage by damage type, 1918 to 2016.

Damage Type	Mapped Damage (ha)
Defoliation	94,763,695
Mortality (Current Year)	1,720,732
Discoloration	2,791,430
Dieback	2,370,420
Topkill	2,932
Branch Breakage	599,912
Main Stem Broken/Uprooted	67,374
Branch Flagging	89,053
No Damage	1,556
Other Damage	23,678
Previously Undocumented (Old) Mortality	16,495
Unknown Damage	6,167,042
Total	**106,966,940**
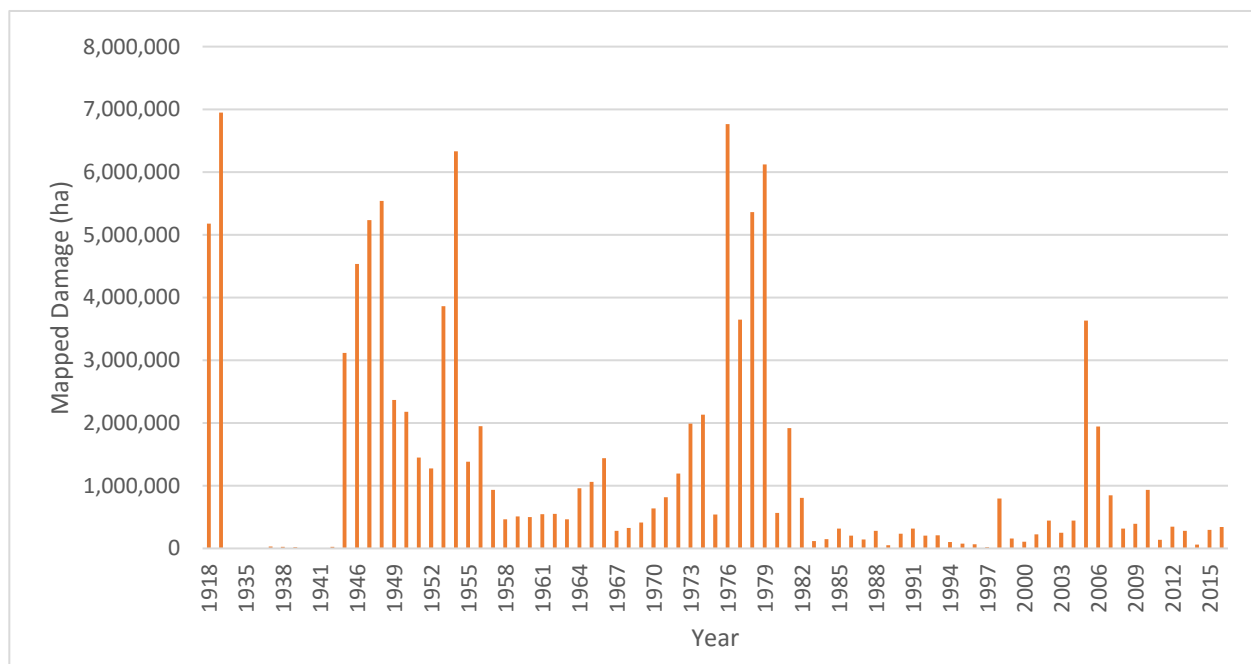
Figure 6. Mapped area of damage over time for the region.

another recurrent theme in the dataset (n=10), and there also were some connections to silviculture (n=2). There are a handful of additional projects that could be added in the near future if more information is delivered by the project's principal investigators.
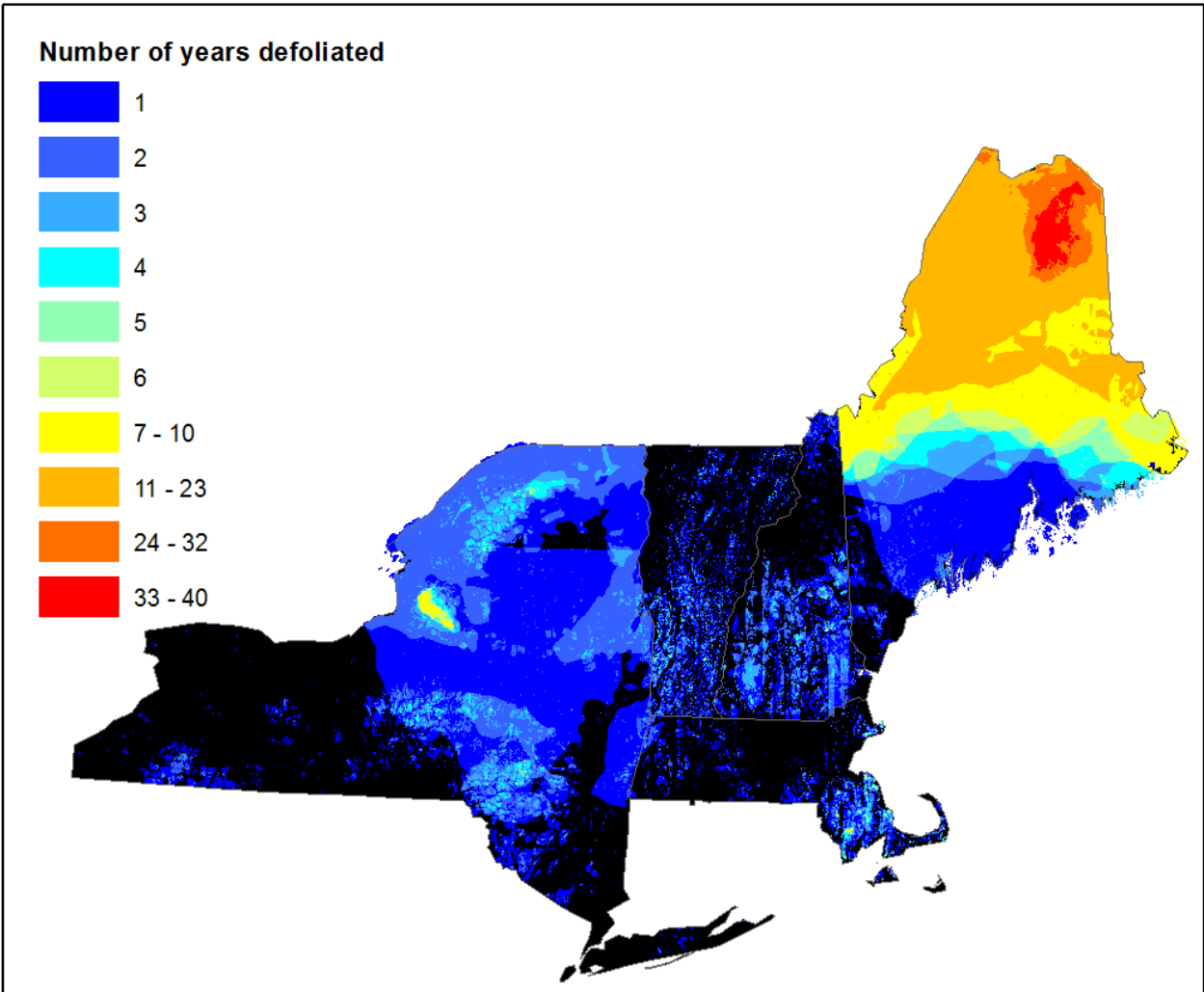
Figure 7. Patterns of repeated defoliation from 1918 to 2016.

Technical Implementation

The NEFHA is developed entirely on open source software and technology. Data are hosted on Carto (www.carto.com), which provides dynamic online mapping interaction with a free account at a level sufficient for this project. Charts are created using Highcharts (www.highcharts.com) under a Creative Commons Attribution-NonCommercial license. These components were combined in a custom web front-end framework using Bootstrap 3 to create a portal that provides seamless interaction across devices, using a map viewer, a table viewer and a chart viewer. This portal is hosted within the FEMC website, building on top of the archive infrastructure developed by the FEMC. A single filtering

mechanism allows the user to filter both the ADS and research data based on damage causing agent, damage type, year(s), state(s) and/or the type of data and to see the results in any of the three modes above. Users can also view pre-made maps that summarize spatiotemporal patterns of the number of times particular locations were damaged, generated by the analysis package described above. These maps were created for all defoliation (Figure 7), all mortality, gypsy moth defoliation, gypsy moth mortality, forest tent caterpillar defoliation, and forest tent caterpillar mortality. Users can download the standardized ADS data (filtered or unfiltered) and the premade map data as shapefiles, GeoJSON, or a CSV. Users can also export tables as Excel files, CSV, or PDFs, and can export charts as PNG, JPEG, PDF, or SVG files.

Limitations

There are limitations to this dataset that must be considered carefully before utilizing the data for analysis. The main limitations have to do with the methods of collection and the methods of standardization.

The most significant limitations for spatiotemporal analyses arise from the methods of collection. Over the entire record, cross-state and inter-annual standards have ranged from entirely consistent to completely absent. In general, data collected since 1997 have a higher likelihood of adhering to the standard, but that is only reflected in the coding – individual surveyors flying during the transition to the ADS standard may have blended methods. Prior to the ADS standardization in 1997, states have a number of different protocols, and these protocols have varied between states and across years. For Maine, data compiled prior to the late 1970s were obtained from ground-based reports of damage extents, and may not have been collected from the air. These data should be viewed as zones of occurrence rather than exact delineations of discrete disturbance events.

The accuracy and precision of the dataset are limited by the data collection methodology and surveyors. The data are collected from fixed wing aircraft traveling at high speed some distance above the ground. Prior to DASM, the data were collected by drawing on paper maps, relying on the technician to locate damages, perhaps without the assistance of GPS. In addition, the ability to detect small disturbances or declines that do not affect a significant portion of the canopy may be limited, as these cannot be seen easily from the air. There is also a fair amount of individual variation among surveyors. Some technicians will lump similar patches of disturbance into a single larger polygon, perhaps including intervening canopy that was not impacted, while others will more conservatively estimate area of occurrence, splitting up patches into discrete areas.

The dataset does not represent a consistent and/or complete sample of the landscape in space and time. The choice of when to fly also creates variability in the dataset. Flights are determined based in

part on the needs of the agency and the expected pests and pathogens that may occur in a given year. This can lead flights to happen at different times from year to year, and search effort may not be evenly spread across the landscape and/or across time in every case.

Finally, the adequacy of the available coding system to represent what was observed on the ground can be limiting in some cases. For example, during the 2016 survey of Vermont, mappers noted the presence of what they described as "red pine decline" but there is no IDS/ADS code for this symptom. The surveyors were forced to call it "red pine scale", which is slightly different from their aerial and ground-based assessment. While the effect of this limitation is likely small, the enumerated nature of the coding scheme means that specificity may have to be sacrificed to standardize the dataset.

Future Work

The FEMC will maintain the web portal into the future, delivering customized products not currently available through other outlets. As the USFS and states make the transition from ADS to IDS standards, data are expected to become available in a seamless national dataset more quickly. This will enable faster ingest and integration with the existing regional data in the NEFHA.

In addition, northeastern states have a continuing interest in digitizing past data to ensure that decades of data collection effort do not get lost to disasters, such as flooding or fire, personnel retirements or fading institutional memory. Vermont has been systematically working to expand its records back in time, digitizing or at least scanning maps back to the 1960s. New York has expressed a similar interest to expand its historical record. FEMC will advise and support these opportunities where present, and integrate the outcomes in NEFHA.

Finally, FEMC will expand the research data holdings by incorporating additional studies in NEFHA that were not originally funded by NSRC, including other studies related to disturbance that are already present in the FEMC archive. The FEMC archive contains at least 50 research and monitoring projects that would enrich the holdings on NEFHA, and FEMC staff will continue to look for opportunities for archiving additional NSRC-funded studies.

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Appendix 1: Code translations for each state and regional compilation

We created Python Scripts to process the data as delivered by each state. These scripts document the crosswalking of codes from the data to the DASM standard. The scripts used for each state are available online at Below, we also provide a set of scripts that combine the resulting state data into a single unified dataset presented on the NEFHA.

Maine

Prior to 1997, the name of the file indicated the damage causing agent. Severity data were only available for spruce budworm (in the "Defol" attribute) and browntail moth (in the "LEVEL" attribute). Surveyors provided damage ratings such as "medium to severe" or "moderate" or "light". However, the coding could span from light to severe in a single polygon. Thus, we coded polygons with "light" or "low" in the text as a severity of 1), along with polygons with only "medium" or "moderate" rankings. If the severity text contained "heavy" or "severe" and did not contain the words "light" or "low", we coded them as a severity of 2. We provide details of the severity recoding in Table 2.

Table 2. Recoding scheme used for translating severity attributes in Maine's historical data to the ADS severity standard.

Original severity rankings	Standardized severity code
"Light", "Very Light", "Continuous", "Scattered", "Medium", "Moderate", "Negl to Light", "Trace – Scattered", "Light – Scattered", "Light – continuous w/spots Med", "Light – Continuous", "Occasional Light – Medium", "Light – Medium with Occasional Heavy", "Light to Moderate", "Light – Moderate", "Light to Heavy", "Light – Heavy", "Medium – Scattered"	1
"Heavy", "Severe", "Medium – Heavy", "Medium to Heavy", "Medium and Heavy", "Medium with Occasional Heavy", "Medium with Spots of Heavy", "Medium – Severe", "Moderate – Heavy", "Moderate – Severe", "Heavy – Severe", "Heavy to Severe"	2

Python Scripts

This script was run after the individual years were merged into a single master dataset using the ArcGIS Merge tool.

ME_Aggregate.py

```
## This script standardizes the historical aerial survey data for ME into
## current Federal standards. It adds fields for severity of damage, damage
## type and state and then populates those fields according to values in
## existing fields in the input feature class.

import arcpy

#function to calculate severity based on the value in the DEFOL field in the
```

```python
#original feature class. For Maine, anything containing low or light or just
#medium was mapped to low while anything with medium-heavy or heavy was mapped
#to high.
def severity (r, row):
    if r=="medium" or r=="Moderate" or r=="Medium":
        row.SEVERITY1 = 1
    elif ((("Heavy" or "Severe" or "Medium" or "Moderate" or "high") in r) and ("Light" or "low")not in r): #and
(row.SEVERITY1 == "" or row.SEVERITY1 == " " or row.SEVERITY1 == None:
        row.SEVERITY1 = 2
    else:
        row.SEVERITY1 = 1

#location of geodatabase
folder=r"I:\Administration\Emma_Tait\Maine\ME_Historical_ADS_test.gdb";
arcpy.env.workspace=folder
arcpy.env.overwriteOutput = True

#aggregated file
data = folder + "\\ME_Historical_aggregated"
fields=["Defol","LEVEL"]
rows = arcpy.UpdateCursor(data,fields)

#add fields for damage type, severity and state
arcpy.AddField_management(data, "SEVERITY1", "SHORT")
arcpy.AddField_management(data, "DMG_TYPE1", "SHORT")
arcpy.AddField_management(data, "STATE", "TEXT")

#add state and damage type (damage type is 1 because of field name Defol and
#original file name containing word defoliation)
arcpy.CalculateField_management(data, "STATE", "'ME'")
arcpy.CalculateField_management(data, "DMG_TYPE1",1)

#get year from fields
for row in rows:
    if row.Year != None:
        row.RPT_YR = row.Year
    elif row.Y94 == 1:
        row.RPT_YR = 1994
    elif row.Y95 == 1:
        row.RPT_YR = 1995
    elif row.Y96 == 1:
        row.RPT_YR = 1996
    elif row. Y97 == 1:
        row.RPT_YR = 1997

    # if Defol row is not empty calculate severity based on its value
    if row.Defol != "" and row.Defol != " " and row.Defol != None:
        severity(row.Defol, row)

    # if LEVEL row is not empty calculate severity based on its value
    elif row.LEVEL != "" and row.LEVEL != " " and row.LEVEL != None: #(row.Defol == None or row.Defol == "" or row.Defol
== " ") and
        severity(row.LEVEL, row)

    # if neither of the above is true than there is no severity value
    else:
        row.SEVERITY1 = -1

    # commit the row updates
    rows.updateRow(row)
```

Massachusetts

The text in the column "COMMONNAME" was used for all recoding work, as it contained some combination of agent, damage type, and damage severity. We provide details of the recoding in Table 3, Table 4, and Table 5.

Table 3. Recoding scheme used for translating severity attributes in Massachusetts' historical data to the ADS severity standard.

Original severity-related text in COMMONNAME attribute	Standardized severity code
Any text containing: "50%", "30%", "Light", "Moderate", "Modrate"	1
"Rusty Pine Hard Defoliation"	2
Any text containing "Heavy", "75%"	2

Table 4. Recoding scheme used for translating damage causing agents in Massachusetts' historical data to the ADS damage causing agent standard.

Original damage causing agent related text in COMMONNAME attribute	Standardized damage causing agent code
"Gypsy Moth", "Gypsy", "Gyspy Moth"	12089
"Oak Leaf Skeletonizer", "Oak Leaf Skeltonizer", "Oak Skeletonizer"	12029
"Anthracnose"	25025
"Apple Scab"	22089
"Ash Rust"	25048
"Beech Bark Disease"	22042
"Birch Leaf Miner"	12070
"Black Locust Gall Midge"	12119
"Black Turpintine Beetle", "Black Turpingtine Beetle"	11011
"Brown Tail"	12068
"Canker"	22700
"Cankerworm", "Fall Canker Worm", "Fall Cankerworm"	12014
"Change in Water Table"	50004
"Cherry Scallop Shell Moth"	12081
"Cieda"	13006
"Dead Trees (Flooded)"	50004
"Diplodia", "Diplodia (Pine)", "Dipoldia"	25058
"Drought", "Drought (Beech)"	50003
"Fire", "Fire / Chemical Dump Site"	30000
"Flooding"	50004
"Forest Tent"	12096
"Hemlock Looper"	12083
"Insect"	10000
"Linden Looper"	12067
"Locust Leafminer", "Locust Leaf Roller", "Locust Leaf Ruller, "Locust Twig Borer"	12119
"Logging"	70007
"Looper", "Looper/Light"	12083
"Maple Saddled Prominet", "Saddle Priminet", "Saddle Prominent", "Saddle Prominet", "Saddled Prominent"	12079
"Nantucket Pine Month", "Pine Tip"	15065

"Needle Miner"	12004
"Oak Leaf Tier"	12055
"Pear Thrips"	14058
"Pine Looper", "Pine Pitch Looper"	12174
"Pine Needle Miner"	12069
"Red Spruce Winter Inj."	50014
"Satin Moth"	12086
"Spruce Gall Adelgid"	17002
"Storm Damage"	50000
"Tier"	12055
"Turp Beetle"	11011
"Willow Leaf Beetle"	12215
"Beech Maple", "Beech/Maple", "Beech Mortality", "Birch", "Brown Dying Pine/Spruce", "Browning", "Brown Pine", "Brown Pine White Spruce", "Dead & Dying Pine - Spruce", "Dead & Rotting Oaks", "Dead Hemlock", "Dead Spruce", "Dead Timber", "Dead Trees", "Defoliated Softwoods", "Dying", "Evergreen Growth", "Fuzzy Tops", "Heavy Hemlock Mortality", "Hemlock", "Housing Development", "Larch", "Miner", "No Cause", "Not Defoliated", "Oak", "Oak Leaf", "Oak Leaf Minor", "Pine", "Pine – Unknown", "Pine/Unknown", "Red Maple Thin Foliage", "Red Maple Thin Foliage No Caus", "Skeletonizer", "Sprayed Area", "Spruce", "Swamp", "Thin Crowns"	Unable to translate – 99999

Table 5. Recoding scheme used for translating damage type in Massachusetts' historical data to the ADS damage type standard.

Original damage type related text in COMMONNAME attribute	Standardized damage type code
"Off Color", "Rusty Pine Hard Defoliation", "Defoliation"	1
"Beech Mortality", "Birch", "Dead & Dying Pine - Spruce", "Dead & Rotting Oaks", "Dead Hemlock", "Dead Oak", "Dead Pine", "Dead Spruce", "Dead Timber", "Dead Trees", "Dead/Dying", "Dead Trees (Flooded)", "Defoliated Softwoods", "Pine Heavy Mortality"	2
"Brown Dying Pine/Spruce", "Browning", "Brown Pine", "Brown Pine White Spruce"	3
All Other Codes	Unable to translate: -1

Python Scripts

This script was run after the individual years were merged into a single master dataset using the ArcGIS Merge tool.

MA_Aggregate.py

```
## This script transfers Massachusetts historical aerial survey data into
## current US forest service standards. It populates the fields DCA1, DMG_TYPE2
## and SEVERITY1 from the original featureclass field COMMONNAME.

import arcpy

# locate the geodatabase and make it the workspace
folder = r"I:\Administration\Emma_Tait\Massachusetts\MASS_Historic_ADS_test.gdb"
arcpy.env.workspace = folder
arcpy.env.overwriteoutput = True;

# set output filename
data = folder+"\\MA_Historical_ADS_MergeTest"
```

```
# identify fields needed in transfer and initialize cursor
fields = ["COMMONNAME", "DCA1", "DMG_TYPE1", "SEVERITY1"]
rows = arcpy.UpdateCursor(data, fields)

# for each row, check the value in commonname and populate the correct field
# with the correct value
for row in rows:
    if "%" in row.COMMONNAME:
        if "50%" in row.COMMONNAME or "25%" in row.COMMONNAME or "30%" in row.COMMONNAME or "Light" in
row.COMMONNAME or "Moderate" in row.COMMONNAME or "Modrate" in row.COMMONNAME:
            row.SEVERITY = 1
        elif "Heavy" in row.COMMONNAME or "75%" in row.COMMONNAME:
            row.SEVERITY = 2
    if "Gypsy Moth" in row.COMMONNAME or row.COMMONNAME == "Gypsy" or "Gyspy Moth" in row.COMMONNAME:
        row.DCA1 = 12089
    elif "Oak Leaf Skeletonizer" in row.COMMONNAME or "Oak Leaf Skeltonizer" in row.COMMONNAME or
row.COMMONNAME == "Oak Skeletonizer":
        row.DCA1 = 12029
    elif row.COMMONNAME == "Anthracnose":
        row.DCA1 = 25025
    elif row.COMMONNAME == "Apple Scab":
        row.DCA1 = 22089
    elif row.COMMONNAME == "Ash Rust":
        row.DCA1 = 25048
    elif row.COMMONNAME == "Beech Bark Disease":
        row.DCA1 = 22042

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Beech Maple" or row.COMMONNAME = "Beech/Maple": #### Unknow Damage Type,
probably defoliation according to workshop questionares but not positive

    elif row.COMMONNAME == "Beech Mortality":
        row.DMG_TYPE1 = 2
    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Birch":#### Unknow Damage Type, probably defoliation according to workshop
questionares but not positive

    elif row.COMMONNAME == "Birch Leaf Miner":
        row.DCA1 = 12070
    elif row.COMMONNAME == "Black Locust Gall Midge":
        row.DCA1 = 12119 ## Actually Locust leafminer according to workshop worksheets
    elif row.COMMONNAME == "Black Turpintine Beetle" or row.COMMONNAME == "Black Turpingtine Beetle":
        row.DCA1 = 11011
    elif row.COMMONNAME == "Brown Dying Pine/Spruce" or row.COMMONNAME == "Browning" or row.COMMONNAME
== "Brown Pine" or row.COMMONNAME == "Brown Pine White Spruce":
        row.DMG_TYPE1 = 3
    elif "Brown Tail" in row.COMMONNAME and (row.DCA1 == "" or row.DCA1 == None):
        row.DCA1 = 12068
    elif "Brown Tail" in row.COMMONNAME and (row.DCA1 != "" or row.DCA1 != None):
        row.DCA2 = 12068
    elif row.COMMONNAME == "Canker":
        row.DCA1 = 22700
    elif "Cankerworm" in row.COMMONNAME or row.COMMONNAME == "Fall Canker Worm" or row.COMMONNAME ==
"Fall Cankerworm" and (row.DCA1 == "" or row.DCA1 == None):
        row.DCA1 = 12014
    elif "Cankerworm" in row.COMMONNAME or row.COMMONNAME == "Fall Canker Worm" or row.COMMONNAME ==
"Fall Cankerworm" and (row.DCA1 != "" or row.DCA1 != None):
        row.DCA2 = 12014
    elif row.COMMONNAME == "Change in Water Table":
        row.DCA1 = 50004
    elif row.COMMONNAME == "Cherry Scallop Shell Moth":
        row.DCA1 = 12081
    elif row.COMMONNAME == "Cieada":
        row.DCA1 = 13006
    elif row.COMMONNAME == "Dead & Dying Pine - Spruce" or row.COMMONNAME == "Dead & Rotting Oaks" or
row.COMMONNAME == "Dead Hemlock" or "Dead Oak" in row.COMMONNAME or "Dead Pine" in row.COMMONNAME or
```

```
    row.COMMONNAME == "Dead Spruce" or row. COMMONNAME == "Dead Timber" or row.COMMONNAME == "Dead Trees"
or "Dead/Dying" in row.COMMONNAME:
        row.DMG_TYPE1 = 2
    elif row.COMMONNAME == "Dead Trees (Flooded)":
        row.DCA1 = 50004
        row.DMG_TYPE1 = 2
    elif row.COMMONNAME == "Defoliated Softwoods":
        row.DMG_TYPE1 = 2
    elif row.COMMONNAME == "Diplodia" or row.COMMONNAME == "Diplodia (Pine)" or row.COMMONNAME ==
"Dipoldia":
        row.DCA1 = 25058
    elif row.COMMONNAME == "Drought" or row.COMMONNAME == "Drought (Beech)":
        row.DCA1 = 50003
##    elif "Dying" in row.COMMONNAME:## THIS CAN'T JUST BE DYING, HAS TO BE MORE SPECIFIC B/C IS
DISCOLORATION
        #NOT MORTALITY

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Evergreen Growth": ##
    elif "Fire" in row.COMMONNAME: #includes "Fire / Chemical Dump Site"
        row.DCA1 = 30000
    elif row.COMMONNAME == "Flooding":
        row.DCA1 = 50004
    elif "Forest Tent" in row.COMMONNAME:
        row.DCA1 = 12096

    #the rows below are commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Fuzzy Tops": ##
    #elif row.COMMONNAME == "Heavy Hemlock Mortality" or row.COMMONNAME == "Gypsy Moth-Heavy Mortality":
##    elif row.COMMONNAME == "Hemlock": ##
    elif row.COMMONNAME == "Hemlock Looper":
        row.DCA1 = 12083

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Housing Development":

    elif row.COMMONNAME == "Insect":
        row.DCA1 = 10000

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Larch":
    elif row.COMMONNAME == "Linden Looper":
        row.DCA1 = 12067
    elif row.COMMONNAME == "Locust Leafminer" or row.COMMONNAME == "Locust Leaf Roller" or row.COMMONNAME
== "Locust Leaf Ruller" or row.COMMONNAME == "Locust Twig Borer":
        row.DCA1 = 12119
    elif "Logging" in row.COMMONNAME:
        row.DCA1 = 70007
    elif row.COMMONNAME == "Looper" or row.COMMONNAME == "Looper/Light":
        row.DCA1 = 12083
    elif row.COMMONNAME == "Maple Saddled Prominet":
        row.DCA1 = 12079

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Miner": ###
    elif row.COMMONNAME == "Nantucket Pine Moth":
        row.DCA1 = 15065 #Nantucket Pine Tip Moth
    elif row.COMMONNAME == "Needle Miner":
        row.DCA1 = 12004 #General Needleminers

    #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "No Cause": ######
##    elif row.COMMONNAME == "Not Defoliated": ###
##    elif row.COMMONNAME == "Oak": ##
##    elif row.COMMONNAME == "Oak Leaf": ####
##    elif row.COMMONNAME == "Oak Leaf Minor":###

    elif "Oak Leaf Tier" in row.COMMONNAME:
```

```python
      row.DCA1 = 12055
  elif "Off Color" in row.COMMONNAME:
      row.DMG_TYPE1 = 1
  elif row.COMMONNAME == "Pear Thrips":
      row.DCA1 = 14058

  #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Pine" or row.COMMONNAME == "Pine - Unknown" or row.COMMONNAME ==
"Pine/Unknown":
  elif row.COMMONNAME == "Pine Heavy Mortality":
      row.SEVERITY = 2
      row.DMG_TYPE1 = 2
  elif row.COMMONNAME == "Pine Looper":
      row.DCA1 = 12174
  elif row.COMMONNAME == "Pine Needle Miner":
      row.DCA1 = 12069
  elif "Pine Tip" in row.COMMONNAME:
      row.DCA1 = 15065 #assumed this was the same type of pine tip moth as the nantucket pine tip moth
  elif row.COMMONNAME == "Pine Pitch Looper":
      row.DCA1 = 12174

  #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Red Maple Thin Foliage" or row.COMMONNAME = "Red Maple Thin Foliage No Caus":
  elif row.COMMONNAME == "Red Spruce Winter Inj.":
      row.DCA1 = 50014
  elif row.COMMONNAME == "Rusty Pine Hard Defoliation":
      row.SEVERITY = 2
      row.DMG_TYPE1 = 1
  elif row.COMMONNAME == "Saddle Priminet" or row.COMMONNAME == "Saddle Prominent" or row.COMMONNAME ==
"Saddle Prominet" or row.COMMONNAME == "Saddled Prominent":
      row.DCA1 = 12079
  elif row.COMMONNAME == "Satin Moth":
      row.DCA1 = 12086

  #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Skeletonizer": ###
##    elif row.COMMONNAME == "Sprayed Area": ##
##    elif row.COMMONNAME == "Spruce": ###

  elif row.COMMONNAME == "Spruce Gall Adelgid":
      row.DCA1 = 17002
  elif row.COMMONNAME == "Storm Damage":
      row.DCA1 = 50000 ## this is just the code for abiotic damage, i'm not sure if it is flooding or wind or something
else

  #the row below is commented out because it unknown what the value should be translated to.
##    elif row.COMMONNAME == "Swamp":
##    elif row.COMMONNAME == "Thin Crowns":

  elif row.COMMONNAME == "Tier":
      row.DCA1 = 12055
  elif row.COMMONNAME == "Turp Beetle":
      row.DCA1 = 11011
  elif "Unknown" in row.COMMONNAME and (row.DCA1 == "" or row.DCA1 == None):
      row.DCA1 = 99999
  elif "Unknown" in row.COMMONNAME and (row.DCA1 != "" or row.DCA1 != None):
      row.DCA2 = 99999
  elif row.COMMONNAME == "Willow Leaf Beetle":
      row.DCA1 = 12215
  if "Defoliation" in row.COMMONNAME:
      row.DMG_TYPE1 = 1

  # Commit row update
  rows.updateRow(row)
```

New Hampshire

The New Hampshire data prior to 1997 contained a column for each individual damage agent, with some sort of severity code when that agent was found in the polygon. All observations were defoliation observations, DMG_TYPE was assigned to 1 for these polygons. Severity was recorded as the following groupings: low ("l" or "L"), low to medium ("LM" or "lm"), medium ("M" or "m"), high ("H" or "h") or unknown ("UN"). We combined the groups low, low-medium, and medium to represent the lower ADS severity code (e.g., severity rating of 1), and high as the high-severity code (e.g., severity rating of 2) (Table 6). We provide details of the agent recoding in Table 7.

Table 6. Recoding scheme used for translating severity attributes in New Hampshire's historical data to the ADS severity standard.

Original severity-related text in the agent columns	Standardized severity code
"L, "M", m", l", "lm", "LM"	1
"H", "h"	2

Table 7. Recoding scheme used for translating damage causing agents in New Hampshire's historical data to the ADS damage causing agent standard.

Column name of damage agent	Interpretation	Standardized damage causing agent code
"DEFO_GM"	Gypsy Moth	12089
"DEFO_SP"	Saddled Prominent	12079
"DEFO_SB"	Spruce Budworm	12038
"DEFO_HL"	Hemlock Looper	12083
"DEFO_BLM"	Birch Leaf Miner	12070
"DEFO_CSM"	Cherry Scallop Moth	12081
"DEFO_LLM"	Locust Leaf Miner	12119
"DEFO_SMDIE"	Sugar Maple Dieback	99999
"DEFO_ANTHR"	Anthracnose	25025
"DEFO_HDIE"	Hemlock Dieback	99999
"DEFO_RSB"		99999
"DEFO_WI"	Winter Injury	50014
"DEFO_ELB"	Elm Leaf Beetle	12141
"DEFO_HAIL"	Hail	50006
"DEFO_SDD"	Sulfur Dioxide Damage	50001

Python Scripts

NH_Merge.py

```
## This script merges the individual files of New Hampshire's historical
## aerial survey data.

import arcpy

#location of geodatabase
```

```
folder=r"I:\Administration\Emma_Tait\New_Hampshire\NH_Historical_ADS.gdb";
arcpy.env.workspace=folder
arcpy.env.overwriteOutput = True;

#list of files in the database
files=arcpy.ListFeatureClasses("*")

#empty array to hold merge files
merges=[]

#get files and and add to merge list
for filename in files:
    merges.append(filename)

#merge files into aggregated feature class
arcpy.Merge_management(merges,folder+"\\NH_Historical_aggregated")
```

NH_Aggregate.py

```
## This script converts the historical New Hampshire ADS data to the current
## US forest service standards. it adds fields for Damage Causal Agent (DCA1)
## and for Severity (SEVERITY1). It then populates these fields with data from
## fields in the original dataset

import arcpy

#function to populate severity column. This needs to be modified once we find out
#what the other codes are
def severity(r, row):
    if r == "L" or r == "M" or r=="m" or r=="l" or r=="LM":
        row.SEVERITY1=1
    elif r=="H" or r=="h":
        row.SEVERITY1=2
    else:
        row.SEVERITY1=-1

# location of the geodatabase and make this the workspace
folder=r"I:\WorkingProjects\ForestHealthAtlas\New_Hampshire\NH_Historical_ADS.gdb";
arcpy.env.workspace=folder

# get the list of files in the database
files=arcpy.ListFeatureClasses("*")
arcpy.env.overwriteOutput = True;

# specify the output featureclass name. List the fields needed for the data transfer
data=folder+"\\NH_Historical_aggregated"
fields=["DEFO_GM", "DEFO_SP", "DEFO_SB", "DEFO_HL", "DEFO_BLM", "DEFO_CSM", "DEFO_LLM", "DEFO_SMDIE",
"DEFO_ANTHR", "DEFO_HDIE", "DEFO_RSB", "DEFO_WI", "DEFO_ELB", "DEFO_HAIL", "DEFO_SDD"]

# initialize curser for row transfer
rows = arcpy.UpdateCursor(data,fields)

##if damage agent row is not empty put appropriate agent code into DCA1
arcpy.AddField_management(data, "DCA1","LONG")
arcpy.AddField_management(data,"SEVERITY1","SHORT")
arcpy.AddField_management(data,"DMG_TYPE1","SHORT")


#look at all of the damage agent columns, if they are populated, put the correct
#damage agent in DCA1 and calculate the severity.
for row in rows:
    row.DMG_TYPE1=1
    if row.DEFO_GM != "" and row.DEFO_GM != "None" and row.DEFO_GM != " " and row.DEFO_GM != None:
        row.DCA1 = 12089 #gypsy moth
        severity(row.getValue("DEFO_GM"),row)
    elif row.DEFO_SP != "" and row.DEFO_SP != "None" and row.DEFO_SP != " " and row.DEFO_SP != None:
        row.DCA1=12079 #saddled prominent
        severity(row.DEFO_SP,row)
```

```
elif row.DEFO_SB != "" and row.DEFO_SB != "None" and row.DEFO_SB != " " and row.DEFO_SB != None:
    row.DCA1 = 12038 #spruce budworm
    severity(row.DEFO_SB,row)
elif row.DEFO_HL != "" and row.DEFO_HL != "None" and row.DEFO_HL != " " and row.DEFO_HL != None:
    row.DCA1 = 12083 #hemlock looper
    severity(row.DEFO_HL,row)
elif row.DEFO_BLM != "" and row.DEFO_BLM != "None" and row.DEFO_BLM != " " and row.DEFO_BLM != None: #listed in
vt as blight... not sure if this is correct
    row.DCA1=12070 #Birch leaf miner
    severity(row.DEFO_BLM,row)
elif row.DEFO_CSM != "" and row.DEFO_CSM != "None" and row.DEFO_CSM != " " and row.DEFO_CSM != None:
    row.DCA1=12081 #cherry scallop moth
    severity(row.DEFO_CSM,row)
elif row.DEFO_LLM != "" and row.DEFO_LLM != "None" and row.DEFO_LLM != " " and row.DEFO_LLM != None:
    row.DCA1=12119 #locust leafminer
    severity(row.DEFO_LLM,row)
elif row.DEFO_SMDIE != "" and row.DEFO_SMDIE != "None" and row.DEFO_SMDIE != " " and row.DEFO_SMDIE != None:
    row.DCA1=99999 #Sugar maple dieback, but code unknown
    severity(row.DEFO_SMDIE,row)
elif row.DEFO_ANTHR != "" and row.DEFO_ANTHR != "None" and row.DEFO_ANTHR != " " and row.DEFO_ANTHR !=
None:
    row.DCA1 = 25025 #anthracnose
    severity(row.DEFO_ANTHR,row)
elif row.DEFO_HDIE != "" and row.DEFO_HDIE != "None" and row.DEFO_HDIE != " " and row.DEFO_HDIE != None:
    row.DCA1=99999 #Hemlock dieback, but code unknown
    severity(row.DEFO_HDIE,row)
elif row.DEFO_RSB != "" and row.DEFO_RSB != "None" and row.DEFO_RSB != " " and row.DEFO_RSB != None:
    row.DCA1=99999 #unknown
    severity(row.DEFO_RSB,row)
elif row.DEFO_WI != "" and row.DEFO_WI != "None" and row.DEFO_WI != " " and row.DEFO_WI != None:
    row.DCA1=50014 #winter injury
    severity(row.DEFO_WI,row)
elif row.DEFO_ELB != "" and row.DEFO_ELB != "None" and row.DEFO_ELB != " " and row.DEFO_ELB != None:
    row.DCA1=12141 #elm leaf beetle
    severity(row.DEFO_ELB,row)
elif row.DEFO_HAIL != "" and row.DEFO_HAIL != "None" and row.DEFO_HAIL != " " and row.DEFO_HAIL != None:
    row.DCA1=50006 #hail
    severity(row.DEFO_HAIL,row)
elif row.DEFO_SDD != "" and row.DEFO_SDD != "None" and row.DEFO_SDD != " " and row.DEFO_SDD != None:
    row.DCA1=50001 #air pollutants
    severity(row.DEFO_SDD,row)
else:
    row.DCA1 = 99999 #unknown
    row.SEVERITY1=-1

# commit row update
rows.updateRow(row)
```

New York

No additional processing was required for New York data beyond the methods described in the
Methods section.

Vermont

Data in Vermont were collected on paper maps prior to digital collection, and Vermont had digitized
data back to 1985. However, VTFPR indicated that the compilation prior to 1995 may not include all

mapped disturbances (Barbara Schultz, personal communication, 2015). We projected data to the NAD 1983 Vermont State Plane Meters projection (EPSG code 32145).

Vermont utilized a unique coding system prior to the federal standardization of codes in 1999 (USFS 1999). We translated Vermont-specific codes into the ADS standardized coding schemes. First, if they did not exist, we added columns to each year of data for DCA1, DCA2, DMG_TYPE1, FOR_TYPE1, HOST1, STATE, and RPT_YR. For data between 1985 and 2011, we used existing codes in VTDMGTYP, VTDMGAGT, and VTHOST to populate the standardized fields. In some cases, we needed either DMGNAME to further refine the coding, or a combination of VTDMGTYP, VTDMGAGT, and VTHOST to determine the correct codes. After 2012, the standard field were consistently populated. We provide additional details of these coding changes in Table 8, Table 9, and Table 10.

Table 8. Recoding scheme used for translating damage causing agent attributes in Vermont's historical data to the ADS damage causing agent standard.

Original damage causing agent in VTDMGAGT	Standardized damage causing agent code
"ALM"	12026
"Anth"	25025
"AY"	24004
"BBD"	22042
"BLF"	25076
"BLM"	25001
"BLS"	12070
"BSW"	12120
"Bvr"	41002
"BWA"	14003
"Cns"	70006
"CSSM"	12081
"DED"	24022
"Drt"	50003
"ELB"	12141
"ETC"	12093
"FCW"	12014
"Frst"	50005
"FTC"	12096
"FWW"	12082
"Fyr"	30000
"GM"	12089
"Hail"	50006
"HL"	12083
"Ice"	50011
"LAT"	12037
"LC"	12047
"LD"	24011
"LLM"	12119
"Log"	70007
"MLC"	12127
"MS"	14051
"Mse"	41004
"Ndc"	25005
"Oys"	14028

Original damage causing agent in VTDMGAGT	Standardized damage causing agent code
"PG"[4]	12130
"PLF"	25036
"Porc"	41006
"SAS"	12167
"Sat"	12086
"SBW"	12038
"Scb"	25004
"See"	50800
"Sno"	50011
"SP"	12079
"SWI"	50014
"Thr"	14058
"Wet"	50004
"Wnd"	50013
"ZPM"	15022

Table 9. Recoding scheme used for translating damage type attributes in Vermont's historical data to the ADS damage types standard.

Original damage type in VTDMGTYP	Standardized damage type code
"bld"	7
"brk"	6
"brn"	3
"chl"	3
"col"	3
"def"	1
"dk"	4
"nDd"	2
"oDd"	11
"un"	9
"unk"	-1
"thn"	The final coding depends on what is in other fields (Barbara Schultz, Personal communication, 2013). These were applied by hand after initial processing and do not appear in the script. **For polygons in 1991** If DMGNAME is "Drought Damage" then DMG_TYPE1 is 1 **For polygons in 1992** If DMGNNAME is "Heavy Seed" then DMG_TYPE1 is 1 **For polygons in 1993** If DMGNAME is "Maple Leaf Cutter" then DMG_TYPE1 is 1 If DMGNAME is "Hardwood Decline" then DMG_TYPE1 is 4 **For polygons in 1994** If DMGNAME is "Heavy Seed" then DMG_TYPE1 is 1 If DMGNAME is "Hardwood Decline" or "Birch Decline" or "Ash Decline" or "Wet Site Related Decline" then DMG_TYPE1 is 4 If VTHOST is "Cdr" and DMGNAME is "Heavy Seed" and VTDMGTYP is "thn" then HOST1 is 241 If VTHOST is "Cdr" and DMGNAME is "Arborvitae Mortality" and VTDMGTYP is nDd" then HOST1 is 241 IF VTHOST is "Cdr" and DMGNAME is "Unknown" and VTDMGTYP is "brn" then HOST1 is 241

---

[4] The code of "PG" corresponded to combined phigalia/gypsy moth damage, so the phigalia damage was recorded as 12130 in DCA1 and the gypsy moth damage was recorded as 12089 in DCA2

Table 10. Recoding scheme used for translating host attributes in Vermont's historical data to the ADS host standard.

Original damage type in VTHOST	Standardized host code
"Ald"	350
"Apl"	660
"Ash"	541
"Be"	531
"BL"	901
"Bnt"	601
"Brc"	375
"Cdr"	Depends on values in other fields, if VTDMGAGT was "ALM" then the host code was set to 241, otherwise it was set to 99999
"Chy"	760
"Elm"	970
"F"	012
"Hk"	261
"Hwd"	001
"Lch"	071
"Mr"	316
"Ms"	318
"Mxd"	003
"Oak"	833
"Pin"	100
"Pop"	740
"Pr"	125
"Pw"	129
"SF"[5]	002
"Spr"	090
"Sr"	097
"Sw"	094
"Swd"	002
"Wlw"	920

Python Scripts

We developed two scripts, one for processing the older coding for data from 1985 to 1994 (VT_defoliation_crosscoding_1985_1994.py), and the other for combining all years into a single dataset (VT_MergeYearlyDatasets.py). Note that the processing of damage type "thn" in VTDMGTYP was dependent on other fields for certain years. Refer to Table 9 for more information.

VT_defoliation_crosscoding_1985_1994.py

```
import arcpy
filelist=["vt_defol1985","vt_defol1986","vt_defol1987","vt_defol1988","vt_defol1989","vt_defol1990","vt_defol1991","vt_d
efol1992","vt_defol1993","vt_defol1994"]

agtcodes={'ALM': 12026,'Anth': 25025,'AY': 24004,'BBD': 22042,'BLF': 25076,'BLM': 25001,'BLS': 12070,'BSW':
12120,'Bvr': 41002,'BWA': 14003,'Cns': 70006,'CSSM': 12081,'DED': 24022,'Drt': 50003,'ELB': 12141,'ETC': 12093,'FCW':
12014,'Frst': 50005,'FTC': 12096,'FWW': 12082,'Fyr': 30000,'GM': 12089,'Hail': 50006,'HL': 12083,'Ice': 50011,'LAT':
12037,'LC': 12047,'LD': 24011,'LLM': 12119,'Log': 70007,'MLC': 12127,'MS': 14051,'Mse': 41004,'Ndc': 25005,'Oys':
```

---

[5] When this host code was encountered, the FOR_TYPE1 attribute was set to 100

```
14028,'PG': 12130,'PLF': 25036,'Porc': 41006,'SAS': 12167,'Sat': 12086,'SBW': 12038,'Scb': 25004,'See': 50800,'Sno':
50011,'SP': 12079,'SWI': 50014,'Thr': 14058,'Wet': 50004,'Wnd': 50013,'ZPM': 15022}
hostcodes={'Ald': 350,'Apl': 660,'Ash': 541,'Be': 531,'BL': 901,'Bnt': 601,'Brc': 375,'Chy': 760,'Elm': 970,'F': 12,'Hk':
261,'Hwd': 1,'Lch': 71,'Mr': 316,'Ms': 318,'Mxd': 3,'Oak': 833,'Pin': 100,'Pop': 740,'Pr': 125,'Pw': 129,'SF': 2,'Spr': 90,'Sr':
97,'Sw': 94,'Swd': 2,'Wlw': 920}
hostexceptions=['Cdr']
dmgcodes={'bld': 7,'brk': 6,'brn': 3,'chl': 3,'col': 3,'def': 1,'dk': 4,'nDd': 2,'oDd': 11,'un': 9,'unk': -1}
dmgexceptions=['thn']


for filename in filelist:
    file="I:\Administration\jim_docs\FPRAerialSurveys\VT Aerial Survey Data Archive\\"+filename+".shp"
    rows = arcpy.UpdateCursor(file, "", "", "VTDMGAGT, VTHOST, VTDMGTYP,DCA1,DCA2,HOST1,DMG_TYPE1,
FOR_TYPE1","")
    for row in rows:

        ##Update the damage agent codes
        if row.VTDMGAGT in agtcodes:
            #Set the DCA value to the value matched to the Agent Code key
            row.DCA1 = agtcodes[row.VTDMGAGT]
            #Check if the code is Combined Phigalia/Gypsy Moth, and if so, add additional agent in DCA2 column
for Gypsy Moth
            if row.VTDMGAGT=="PG":
                row.DCA2 = 12089
        else:
            ##Set the DCA value to 99999, which is the code for "No Data", corresponding to when there is an
unknown or null value in VT code
            row.DCA1 = 99999

        ##Update the host codes
        if row.VTHOST in hostcodes:
            #Set the HOST1 value to the value matched to the Host Code key
            row.HOST1 = hostcodes[row.VTHOST]
            #Check if host is Spruce-Fir, if it is, also need to set FOR_TYPE1 to 0100
            if row.VTHOST=="SF":
                row.FOR_TYPE1=100
        elif row.VTHOST in hostexceptions: #The match for this value depends on other context, so flag it for review
            #If the host is cedar and the dmgtype is Arborvitae Leaf Miner, then the Host is 241, Northern White
Cedar
            if row.VTHOST=="Cdr" and row.VTDMGAGT=="ALM":
                row.HOST1 = 241
            else:
                row.HOST1 = -99
        else:
            ##Set the HOST1 value to -1, which is the code for "No Data", corresponding to when there is an
unknown or null value in VT code
            row.HOST1 = -1

        ##Update the damage type codes
        if row.VTDMGTYP in dmgcodes:
            #Set the DMG_TYPE1 value to the value matched to the Damage Code key
            row.DMG_TYPE1 = dmgcodes[row.VTDMGTYP]
        elif row.VTDMGTYP in dmgexceptions: #The match for this value depends on other context, so flag it for
review
            row.DMG_TYPE1 = -9
        else:
            ##Set the DMG_TYPE1 value to -1, which is the code for "No Data", corresponding to when there is an
unknown or null value in VT code
            row.DMG_TYPE1 = -1

        rows.updateRow(row)
del row
del rows
```

VT_MergeYearlyDatasets.py

```python
# Import arcpy module
import arcpy

arcpy.env.overwriteoutput = True;

path=" VTADS2.gdb\\ADS\\"
finalFields=["OBJECTID","SHAPE","Shape","FID","DATE","DCA1","DCA2","DCA3","DMG","DMG_TYPE1","DMG_TYPE2","DMG_T
YPE3","DMGNAME","DMGPATT","DMGSEV","DMGTYP","DMGTYPE","FOR_TYPE1","FOR_TYPE2","FOR_TYPE3","HOST1","HOST
2","HOST3","NO_TREES1","NO_TREES2","NO_TREES3","NOTES","PATTERN1","PATTERN2","PATTERN3","PCT_MORT1","PCT_
MORT2","PCT_MORT3","RPT_YR","SEVERITY1","SEVERITY2","SEVERITY3","Shape_Area","Shape_Length","STATE","SURVEY_ID
1","SURVEY_ID2","SURVEY_ID3","SURVEYOR","TPA1","TPA2","TPA3","VTDMGAGT","VTDMGHOST","VTDMGSEV","VTDMGTYP
","VTHOST"]
#if starting from scratch, 2015 DMGNAME was put in NOTES field, needs to be updated
process2015=False
#if starting from scratch, need to process 2014 a bit, set below bit to true
process2014=False
#If starting from scratch, need to delete row from 1996 where year = 0
process1996=False
#If starting from scratch, need to create expected rows in the 2016 data
process2016=False
#2014 data don't come with dmgname, so these map legend to dmg name
dmgMatch={'Discoloration from hardwood anthracnose on hardwoods':'Anthracnose','Discoloration from anthracnose
on willow':'Willow Defoliation','Mortality from beech bark disease on American beech':'Beech Bark Disease','Dieback from
beech bark disease on American beech':'Beech Bark Disease','Defoliation from birch leaf fungus on paper birch':'Birch
Leaf Fungi', 'Defoliation from hardwood anthracnose on hardwoods':'Anthracnose','Defoliation from brown spot needle
blight and Defoliation from Diplodia canker on red pine':'Red Pine Symptoms','Discoloration from brown spot needle
blight on Scotch pine':'Brown Spot Needle Blight','Discoloration from brown spot needle blight on eastern white
pine':'Brown Spot Needle Blight','Discoloration from white pine needle cast on eastern white pine':'Brown Spot Needle
Blight','Discoloration from decline on hardwoods':'Hardwood Decline','Defoliation from oak leafroller on northern red
oak':'Oak Defoliator Complex','Discoloration from flooding-high water on hardwoods':'Wet Site Related
Decline','Defoliation from hail on hardwoods':'Hail Damage','Dieback from hemlock woolly adelgid on
hemlock':'Hemlock Woolly Adelgid','Dieback from snow-ice on hardwoods':'Ice/Snow Damage','Dieback from snow-ice on
hardwoods':'Ice/Snow Damage','Mortality from snow-ice on red pine':'Ice/Snow Damage','Defoliation from locust
leafminer on black locust':'Locust Leafminer','Dieback from logging damage on hardwoods':'Logging Related
Decline','Mortality from unknown decline/complex/wilt on balsam fir':'Spruce-Fir Decline','Mortality from unknown
decline/complex/wilt on red pine':'Red Pine Symptoms','Mortality from unknown decline/complex/wilt on eastern white
pine':'White Pine Symptoms','Mortality from unknown decline/complex/wilt on softwoods':'Spruce-Fir Decline','Mortality
from unknown decline/complex/wilt on softwoods':'Spruce-Fir Decline','Previously Undocumented Mortality from birch
leaf fungus on paper birch':'Birch Decline','Previously Undocumented Mortality from unknown decline/complex/wilt on
softwoods':'Spruce-Fir Decline','Defoliation from saddled prominent on sugar maple':'Saddled Prominent','Mortality from
flooding-high water on hardwoods':'Wet Site Related Decline','Mortality from flooding-high water on eastern white
pine':'Wet Site Related Decline','Mortality from flooding-high water on softwoods':'Wet Site Related Decline','Mortality
from wind-tornado/hurricane on hardwoods':'Wind Damage','Mortality from wind-tornado/hurricane on softwoods':'Wind
Damage','Discoloration from white pine needle cast on eastern white pine':'Brown Spot Needle Blight','Mortality from
white pine blister rust on eastern white pine':'White Pine Blister Rust'}

# Local variables:
VT_2015_ADS_ALL_Final = "VT_2015_ADS_ALL_Final"
vt_defol1985 = "vt_defol1985"
vt_defol1986 = "vt_defol1986"
vt_defol1987 = "vt_defol1987"
vt_defol1988 = "vt_defol1988"
vt_defol1989 = "vt_defol1989"
vt_defol1990 = "vt_defol1990"
vt_defol1991 = "vt_defol1991"
vt_defol1992 = "vt_defol1992"
vt_defol1993 = "vt_defol1993"
vt_defol1994 = "vt_defol1994"
vt_defol1995 = "vt_defol1995"
vt_defol1996 = "vt_defol1996"
vt_defol1997 = "vt_defol1997"
vt_defol1998 = "vt_defol1998"
vt_defol1999 = "vt_defol1999"
vt_defol2000 = "vt_defol2000"
vt_defol2001 = "vt_defol2001"
vt_defol2002 = "vt_defol2002"
```

```python
vt_defol2003 = "vt_defol2003"
vt_defol2004 = "vt_defol2004"
vt_defol2005 = "vt_defol2005"
vt_defol2006 = "vt_defol2006"
vt_defol2007 = "vt_defol2007"
vt_defol2008 = "vt_defol2008"
vt_defol2009 = "vt_defol2009"
vt_defol2010 = "vt_defol2010"
vt_defol2011 = "vt_defol2011"
vt_defol2012 = "vt_defol2012"
vt_defol2013 = "vt_defol2013"
vt_defol2014 = "vt_defol2014"
AerialSurveys_1985_2015 = "AerialSurveys_1985_2015"
OutFileName="AerialSurveys_1985_2016"
VT_2016_IDS = "VT_2016_IDS"


arcpy.env.workspace=path
files=arcpy.ListFeatureClasses("*")
print files
merges=[]

print arcpy.env.workspace
#Add field to 2014 for DMGNAME
#If starting from scratch, set conditional above to allow this to run
if process1996 == True:
        rows = arcpy.UpdateCursor(vt_defol1996, "", "", "RPT_YR","")
        for row in rows:
                if row.RPT_YR==0:
                        rows.deleteRow(row)
if process2014==True:
        arcpy.AddField_management(vt_defol2014,'DMGNAME','TEXT',50)
        rows = arcpy.UpdateCursor(vt_defol2014, "", "", "DMGNAME,Legend","")
        for row in rows:
                row.DMGNAME=dmgMatch[row.Legend]
                rows.updateRow(row)


if process2015 == True:
        arcpy.AddField_management(VT_2015_ADS_ALL_Final,'DMGNAME','TEXT',50)
        rows = arcpy.UpdateCursor(VT_2015_ADS_ALL_Final, "", "", "DMGNAME,NOTES","")
        for row in rows:
                row.DMGNAME=row.NOTES.strip()
                rows.updateRow(row)
if process2016 == True:
        #DCA1, DCA2, DMG_TYPE1, HOST1, FOR_TYPE1, STATE
        arcpy.AddField_management(VT_2016_IDS,'DMGNAME','TEXT',50)
        arcpy.AddField_management(VT_2016_IDS,'DCA1','LONG',10)
        arcpy.AddField_management(VT_2016_IDS,'DCA2','LONG',10)
        arcpy.AddField_management(VT_2016_IDS,'DMG_TYPE1','LONG',5)
        arcpy.AddField_management(VT_2016_IDS,'HOST1','LONG',5)
        arcpy.AddField_management(VT_2016_IDS,'FOR_TYPE1','LONG',5)
        arcpy.AddField_management(VT_2016_IDS,'STATE','TEXT',50)
        arcpy.AddField_management(VT_2016_IDS,'RPT_YR','SHORT')
        rows = arcpy.UpdateCursor(VT_2016_IDS, "", "", "DMGNAME,NOTES,DCA1,DCA2,DCA_CODE,DMG_TYPE1,
DAMAGE_TYP,HOST1,HOST_CODE,FOR_TYPE1,STATE,RPT_YR","")
        for row in rows:
                row.DMGNAME=row.NOTES.strip()
                row.DCA1=row.DCA_CODE
                row.DCA2=99999
                row.DMG_TYPE1=row.DAMAGE_TYP
                row.HOST1=row.HOST_CODE
                row.FOR_TYPE1=9999
                row.STATE="VT"
                row.RPT_YR=2016
                rows.updateRow(row)

#Loop through files and delete fields that are not in the final list
for file in files:
        #Make a working copy
```

```
        arcpy.Copy_management(file, file+"_working")
        merges.append(file+"_working")
        field_list = arcpy.ListFields(file)
        for field in field_list:
                if field.name not in finalFields and "OBJECTID" not in field.name:
                        print "Deleting field " + field.name + " in file "+file
                        arcpy.DeleteField_management(file+"_working",  field.name )

inputs=";".join(merges)
arcpy.Merge_management(merges,OutFileName)

#Add area calculations
arcpy.AddField_management(OutFileName,'Area_Ac','Long',10)
arcpy.AddField_management(OutFileName,'Area_Ha','Long',10)
arcpy.CalculateField_management(OutFileName, "Area_Ac","!SHAPE.AREA@ACRES!","PYTHON_9.3")
arcpy.CalculateField_management(OutFileName, "Area_Ha","!SHAPE.AREA@HECTARES!","PYTHON_9.3")

for file in files:
        arcpy.Delete_management(file+"_working")
```

Regional Compilation

To compile the individual state data into a single regional dataset, we first merged all datasets together, mapping fields to common target fields where possible. After this step, we used the following models and scripts to further process the regional product. These are part of the Regional ADS Data Reduction toolkit available online at https://www.uvm.edu/femc/data/archive/project/northeastern_ads/files.

1. *Standardize state attribution of damage (Type: model; Model name: ADS_Statebased_Dataset)*
   This model dissolves all polygons by year, damage type, damage agent, and severity, clips the dataset by each individual state, and merges the results into a regional dataset with the state information in a new field (STATE).

2. *Remove extraneous fields (Type: script; Script name: Step2_SubScript_RemoveExtraFields, refers to RemovingExtraFields.py file)*
   This script creates a new datasets from the output of step 1 that contains a relevant subset of fields: RPT_YR, SURVEY_ID1, SURVEY_ID2, SURVEY_ID3, DMG_TYPE1, DMG_TYPE2, DMG_TYPE3, SEVERITY1, SEVERITY2, SEVERITY3, PATTERN1, PATTERN2, PATTERN3, TPA1, TPA2, TPA3, PCT_MORT1, PCT_MORT2, PCT_MORT3, NO_TREES1, NO_TREES2, NO_TREES3, DCA1, DCA2, DCA3, HOST1, HOST2, HOST3, FOR_TYPE1, FOR_TYPE2, FOR_TYPE3, NOTES, STATE.

3. *Identify USFS polygons to backfill invalid DCA codes (Type: model; Model name: Step3_RecodeNegativeDistAgents_allyrs)*
   This model steps through each year of the state-based regional data compilation, identifies polygons with invalid DCA1 codes (codes less than 10000), and looks in the USFS version of

the ADS data for a collocated polygon with a valid DCA1 code. The output model produces a table of original features with new DCA1 codes.

4. *Backfill invalid DCA1 codes (Type: script; Script name: Step4_RecodeDCA, refers to DCAFix.py file)*
   This script uses the output of the previous step to update the regional dataset with the valid DCA1 codes where available from the USFS dataset, or with 99999 where not available.

5. *Recode any fields without valid data to appropriate no data values (Type: script; Script Name: RecodingFieldsToNoData.py)*
   This script looks for any values in standardized fields that are zero (an invalid code) and replaces it with the appropriate "no data" value for that field.

Appendix 2: Spatiotemporal Analysis Toolkit

The Spatiotemporal Analysis Toolkit provides a tool to create polygons of repeat damage based on the user's input. Users can run the toolkit on all polygons in the regional dataset, or they can select a damage agent (e.g. "gypsy moth"), a damage type (e.g. "defoliation"), or both (e.g. "gypsy moth defoliation"). The tool identifies overlapping areas of disturbance, and computes basic information such as the first and last years of damage, the number of years damaged and ranges in severity (when available). This toolkit requires the dataset that includes severity rankings.

First, the dmg_agnt_code_generator.py script needs to be run on the data to generate a user-friendly dropdown list of the available codes, and these need to be added to the FHdamageType.py script before it is run on the regional ADS dataset. We provide these scripts in an ArcGIS toolbox at https://www.uvm.edu/femc/data/archive/project/northeastern_ads/files.

dmg_agnt_code_generator.py

```
## This script gets the correct US Forest Service Forest Health Monitoring
## aerial survey codes (Appendix E) from a feature class and creates a file
## that is formatted with the correct input for the dropdown list in the
## analysis tool and for the dictionary in the actual tool script.

import arcpy
from arcpy import env
import string
import sys
import os
import csv

#input parameters from user: the aerial survey, the output folder and
#US forest service master list of codes
survey_data=arcpy.GetParameterAsText(0);
folder=arcpy.GetParameterAsText(1);
FSmasterCodes=arcpy.GetParameterAsText(2);

# set workspace to designated folder
arcpy.env.workspace = folder;
arcpy.env.overwriteOutput=True;

#Use frequency tool to get the unique codes in the aerial survey data
codes_a = arcpy.Frequency_analysis(survey_data,folder+"\codes_1", "DCA1");

##flds=arcpy.ListFields(survey_data)
codes_b = arcpy.Frequency_analysis(survey_data,folder+"\codes_2", "DCA2");

#make a set (unique values) to hold codes contained in aerial survey data
codes=set();

#add codes to the set
with arcpy.da.SearchCursor(codes_a,"DCA1") as table_a:
    for c in table_a:
        codes.add(c);

with arcpy.da.SearchCursor(codes_b,"DCA2") as table_b:
```

```
    for c in table_b:
        codes.add(c);
code_list=[i[0] for i in codes];

#create dictionary to hold code names and codes
code_set={};

#open csv file and read contents. Find the codes that are in the aerial survey
#and match to codes in master list. Make keys that contain damage agent
#name and code. Add to dictionary with codes as value.
with open (FSmasterCodes) as master:
    master_codes = csv.DictReader(master);
    for cds in master_codes:
        for c in code_list:
            if cds['CODE'] == str(c):
                key = str(cds['CODE'])+"-"+str(cds['Common Name']);
                code_set[key]=int(cds['CODE']);

##Make a new file to hold the dictionary of damage agent names and codes
#and the list of names to go in the validation of the Arc tool to create
#a dropdown menu
codes_sorted=(sorted(code_set));

#export results to a text file in the designated folder
code_file = open(folder+'\code_lists.txt', 'w');
code_file.write("Sorted List of damage agents for dropdown menu"+
        "in Arc tool. This goes in tool validataion, under"+
        " 'def updateParameters(self)' as the list for 'self.params[3]'.\n\n");
code_file.write(str(codes_sorted));
code_file.write("\n\n\n List of damage agents and corresponding"
        +"codes to go in 'codes' list in FHdamageType.py\n\n");
code_file.write(str(code_set));
code_file.close();
```

FHdamageType.py

```
## This script provides analysis of standardized aerial survey data provided in
## a single feature class. The aerial survey data must be standardized according
## to the US Forest Service Forest Health Monitoring Aerial Survey Codes
## (Appendix E) and the US Forest Service Aerial Detection Survey GIS Handbook.
## The user is asked to select either a damage agent or damage type for the
## analysis. The tool calculates the number of times a particular polygon has
## been damaged by the given agent or type. It also counts the Mean and Sum of
## severity of the damage and the duration of the damage. These calculations
## are added as fields to the attribute table. The output of this tool is a
## shapefile that includes the new attributes.

import arcpy
from arcpy import env
import string
import sys
import os, stat

#These codes are generated by the damage agent code generator tool/script and
#can be found in the file code_list.txt that is generated as the output from
#that tool. This is the dictionary of damage agents that the tool uses to compare
#the input from the user and perform the analysis.
codes = {'71000-harvest': 71000, '50020-saltwater injury - flooding / hurricane': 50020, '50006-hail': 50006, '90002-
dead top': 90002, '22006-black knot of cherry': 22006,
        '50800-other abiotic damage (known)': 50800, '15001-shoot borers': 15001, '25052-Rhizosphaera needle cast':
25052, '25010-sycamore anthracnose': 25010, '41010-woodpeckers':
        41010, '15004-bronze birch borer': 15004, '50000-abiotic damage': 50000, '50005-frost': 50005, '90010-
dieback': 90010, '85000-invasive plants': 85000,
```

'17003-Cooley spruce gall adelgid': 17003, '12006-skeletonizer': 12006, '90001-broken top': 90001, '14016-beech scale': 14016, '23003-vine damage': 23003,
    '14004-hemlock woolly adelgid': 14004, '10000-general insects': 10000, '60000-competition': 60000, '15005-twolined chestnut borer': 15005, '70007-logging damage': 70007,
    '12125-spring cankerworm': 12125, '12147-maple leafroller': 12147, '25000-foliage and shoot diseases': 25000, '70005-land clearing': 70005, '90000-unknown': 90000,
    '90008-foliage discoloration': 90008, '14002-western larch woolly aphid': 14002, '11003-southern pine beetle': 11003, '90009-mortality': 90009,
    '50900-unknown abiotic damage': 50900, '25005-needlecast': 25005, '12082-fall webworm': 12082, '41002-American beaver': 41002, '50016-mud-land slide': 50016,
    '25043-Swiss needle cast': 25043, '24000-decline complexes/dieback': 24000, '14000-sap feeding insects': 14000, '15086-Sitka spruce weevil': 15086,
    '26000-stem rust': 26000, '22042-beech bark disease': 22042, '50009-nutrient imbalances': 50009, '21000-root/butt diseases': 21000, '50003-drought': 50003,
    '10002-pine tip moths': 10002, '12000-defoliators': 12000, '25058-Diplodia canker': 25058, '24022-Dutch elm disease': 24022, '17002-eastern spruce gall adelgid': 17002,
    '26001-white pine blister rust': 26001, '14003-balsam woolly adelgid': 14003, '17000-gallmaker insects': 17000, '25035-Lophodermium needle cast of pines': 25035,
    '70011-soil compaction': 70011, '22000-stem decays/cankers': 22000, '26002-western gall rust': 26002, '50013-wind-tornado/hurricane': 50013, '70000-human activities': 70000,
    '14033-red pine scale': 14033, '13029-eastern pine weevil': 13029, '22043-Nectria canker': 22043, '12119-locust leafminer': 12119, '11011-black turpentine beetle': 11011,
    '12089-gypsy moth': 12089, '99999-no data': 99999, '70014-road salt or deicers': 70014, '50001-air pollutants': 50001, '70004-improper planting technique': 70004,
    '50008-lightning': 50008, '50011-snow-ice': 50011, '25025-anthracnose': 25025, '12024-oak leafroller': 12024, '22030-Eutypella canker': 22030, '70006-land use conversion': 70006,
    '15090-sirex woodwasp': 15090, '24002-Norfolk Island pine decline': 24002, '15087-emerald ash borer': 15087, '50014-winter injury': 50014, '12081-cherry scallop shell moth': 12081,
    '25057-Sirococcus tip blight': 25057, '22038-Hypoxylon canker of aspen': 22038, '14020-elongate hemlock scale': 14020, '12019-orangestriped oakworm': 12019,
    '50004-flooding-high water': 50004, '15050-Engelmann spruce weevil': 15050, '12096-forest tent caterpillar': 12096, '25032-fir needle cast': 25032, '15031-sugar maple borer': 15031,
    '14042-woolly alder aphid': 14042, '24025-Verticillium wilt': 24025, '11000-bark beetles': 11000, '24014-oak decline': 24014, '12190-hickory tussock moth': 12190,
    '30000-fire': 30000, '25067-spruce needle cast': 25067, '12038-spruce budworm': 12038, '12900-unknown defoliator': 12900, '24004-ash yellows disease': 24004,
    '24008-decline complex': 24008, '15000-boring insects': 15000, '30002-human caused fire': 30002, '21001-Armillaria root disease': 21001, '12041-jack pine budworm': 12041,
    '30001-wild fire': 30001, '12093-eastern tent caterpillar': 12093}
#this is the damage agent list that goes into the tool in Arc for the
#dropdown menu. It is generated from the damage agent code generator
#tool and can be found in the code_list.txt file that is the output
dmg_agent_list=["10000-General Insects","11000-Bark Beetles","11003-Southern Pine Beetle","11011-Black Trupentine Beetle","12000-Defoliators",
        "12019-Orangestriped Oakworm","12024-Oak Leafroller","12038-Spruce Budworm","12041-Jack Pine Budworm",
        "12081-Cherry Scallop Shell Moth","12082-Fall webworm","12089-Gypsy Moth","12093-Eastern Tent Caterpillar",
        "12096-Forest Tent Caterpillar","12119-Locust Leafminer","12147-Maple Leafroller","12190-Hickory Tussock Moth",
        "12900-Unknown Defoliator","13029-Eastern Pine Weevil","14000-Sap Feeding Insects","14002-Western Larch Woolly Aphid",
        "14003-Balsam Woolly Adelgid","14004-Hemlock Woolly Adelgid","14020-Elongate Hemlock Scale","14042-Woolly Alder Ahid",
        "15000-Boring Insects","15001-Shoot Borers","15004-Bronze Birch Borer","15005-Twolined Chestnut Borer","15031-Sugar Maple Borer",
        "15050-Engelmann Spruce Weevil","15086-Sitka Spruce Weevil","15087-Emerald Ash Borer","15090-Sirex Woodwasp",
        "17000-Gallmaker Insects","17002-Estern Spruce Gall, Adelgid","17003-Cooley Spruce Gall Adelgid","21000-Root/Butt Diseases",
        "21001-Armillaria Root Disease","21010-Stem Decays/Cankers","22000-Hypoxylon Canker of Aspen","22006-Black Knot of Cherry",
        "22030-Eutypella Canker","22038-Beech Bark Disease","22042-Vine Damage","23003-Decline Complexes/Dieback",
        "24000-Norfolk Island Pine Decline","24002-Ash Yellow Disease","24004-Decline Complex","24008-Oak Decline","24014-Dutch Elm Disease",
        "24022-Foliage and Shoot Disease","25000-Foliage and Shoot Disease","25010-Sycamore Anthracnose","25025-Antrhacnose",

```
        "25032-Fir Needle Cast","25035-Lophoderminum Needle Cat of Pines","25043-Swiss Needle Cast","25052-
Rhizosphaera Needle Cast",
        "25057-Sirococcus Tip Blight","25058-Diplodia Canker","25067-Spruce Needle Cast","26000-Sterm
Rust","26001-White Pine Blister Rust",
        "26002-Western Gall rust","30000-Fire","30001-Wild Fire","30002-Human Caused Fire""41002-American
Beaver","41010-Woodpeckers",
        "50000-Abiotic Damage","50001-Air Pollutants","50003-Drought","50004-Flooding-High Water","50005-
Frost","50006-Hail","50008-Lightning",
        "50009-Nutrient Imbalances","50011-Snow-Ice","50013-Wind-Tornado/Hurricane","50016-Mud-Land Slide",
        "50020-Saltwater Injury-Flooding/Hurricane","50800-Other Abiotic Damage (Kown)","50900-Unknown Abiotic
Damage","60000-Competition",
        "70000-Human Activities",   "70004-Improper Planting Techniques","70005-Land Clearing","70006-Land Use
Conversion",
        "70007-Logging Damage","70011-Soild Compaction","70014-Road or Salt Deicers","85000-Invasive
Plants","90000-Unknown",
        "90008-Foliage Discoloration","90009-Mortality","90010-Dieback"];
#the list of possible damage types. This list is taken from
#the Aerial Detection Survey GIS handbook.
dmg_type_list=["Defoliation","Dieback","Mortality (Current Year)","Branch Breakage", "Discoloration",
        "Topkill", "Main Stem Broken/Uprooted", "Branch Flagging","No Damage", "Other Damage",
        "Previously Undocumented (Old) Mortality"]
##user defined variables
survey = arcpy.GetParameterAsText(0); # aerial survey data feature class
folder = arcpy.GetParameterAsText(1); # folder for output shapefile
dmg_type = arcpy.GetParameterAsText(2); # damage type user would like to analize. If left empty it will search all.
damage_agent = arcpy.GetParameterAsText(3); # damage agent user would like to analize. If left empty it will search all.


##Set the type code based on user input
if dmg_type == "Defoliation":
   type = 1;
elif dmg_type == "Mortality (Current Year)":
   type = 2;
   dmg_type="Mortality";
elif dmg_type == "Discoloration":
   type = 3;
elif dmg_type == "Dieback":
   type = 4;
elif dmg_type == "Topkill":
   type = 5;
elif dmg_type == "Branch Breakage":
   type = 6;
   dmg_type = "BranchBreak";
elif dmg_type == "Main Stem Broken/Uprooted":
   type = 7;
   dmg_type = "MainStemBroken";
elif dmg_type == "Branch Flagging":
   type = 8;
   dmg_type = "BranchFlag";
elif dmg_type == "No Damage":
   type = 9;
   dmg_type = "NoDamage";
elif dmg_type == "Other Damage":
   type = 10;
   dmg_type = "Other";
elif dmg_type == "Previously Undocumented (Old) Mortality":
   type = 11;
   dmg_type = "OldMortality";
else:
   type ="";

##match user input to code dictionary and get damage agent code
inList=False;
for k,v in codes.items():
   if damage_agent==k:
      dmg_agnt=str(v);
      inList=True;

#if code is not found in dictionary, check to see if user entered code
```

```
#if not make the damage agent an empty string (search all)
if inList == False :
    try:
        int (damage_agent);
        dmg_agnt = damage_agent;
    except:
        dmg_agnt = ';

##Create Search string according to user input. Include case in which
##user does not select any damage type or damage agent
search_type = "DMG_TYPE1="+str(type);
flds=arcpy.ListFields(survey)
if "DCA2" in flds:
    search_agnt = "DCA1="+dmg_agnt+" OR DCA2="+dmg_agnt;
else:
    search_agnt = "DCA1="+dmg_agnt;
if type != "" and dmg_agnt != "":
    search = search_type+ " AND " +search_agnt;
elif type == "" and dmg_agnt != "":
    search = search_agnt;
elif dmg_agnt == "" and type != "":
    search = search_type;
elif dmg_agnt == "" and type == "":
    search = "RPT_YR > 0";
if dmg_type == ':
    dmg_type="AllTypes";
if damage_agent==':
    dmg_agnt="AllAgents";


##Make temporary processing folders
arcpy.env.overwriteOutput = True;
temp=arcpy.CreateFileGDB_management(folder,"Scratch.gdb", "CURRENT");
arcpy.env.workspace=folder+"\Scratch.gdb";

##make the selection from the survey and make a new file, union the polygons and then repair the geometry to prevent
errors
arcpy.MakeFeatureLayer_management(survey,"damaged_areas", search);
arcpy.Union_analysis("damaged_areas","dmg_areas_union", "ONLY_FID");
arcpy.RepairGeometry_management("dmg_areas_union")

##Make individual polygons from the Unioned features.
arcpy.MultipartToSinglepart_management("dmg_areas_union", "dmg_areas");

##Find Duplicate polygons and give all duplicates the same ID and make this a new feature class
arcpy.FindIdentical_management("dmg_areas","dmg_duplicates","SHAPE")
lyr = arcpy.MakeFeatureLayer_management("dmg_areas", "dmg_areas_lyr")
tbl = arcpy.MakeTableView_management("dmg_duplicates","dmg_dup_tbl")
arcpy.AddJoin_management("dmg_areas_lyr","OBJECTID","dmg_dup_tbl","IN_FID")
arcpy.FeatureClassToFeatureClass_conversion("dmg_areas_lyr",temp, "dmg_areas_keys")
arcpy.CopyFeatures_management("dmg_areas_lyr","dmg_areas_keys")
arcpy.Delete_management(lyr);
arcpy.Delete_management(tbl);

#delete identical polygons in the union from above steps
arcpy.DeleteIdentical_management("dmg_areas_keys","dmg_duplicates_FEAT_SEQ")

##Spatial Join the union result to the selection result and get the union count.
arcpy.SpatialJoin_analysis("dmg_areas_keys","damaged_areas","dmg_attributes", "JOIN_ONE_TO_MANY", "", "", "WITHIN");
arcpy.DeleteField_management("dmg_attributes", "Join_Count");

##Add fields for the new attributes, accumulated severity, average severity, start and end years of damage
## and the average number of years between damage occurrences
arcpy.AddField_management("dmg_attributes","SUM_SEVERITY","SHORT")
arcpy.AddField_management("dmg_attributes","MEAN_SEVERITY","SHORT")
arcpy.AddField_management("dmg_attributes","START_YR","SHORT")
arcpy.AddField_management("dmg_attributes","END_YR","SHORT")
arcpy.AddField_management("dmg_attributes","AVG_YRS_BTWN_DMG","SHORT")
```

```
##get fields from the original dataset
fields = []
for fld in arcpy.ListFields("dmg_attributes","*"):
    fields.append(fld.name)

##Dictionary to hold data for each polygon ID (if duplicate polygons, all info will be stored in one entry)
stats={}

##Go through table and group the severity and year attributes for all of the unique polygon IDs in dictionary
with arcpy.da.UpdateCursor("dmg_attributes",["dmg_duplicates_FEAT_SEQ","SEVERITY1","RPT_YR"]) as rows:
    for row in rows:
        if row[0] in stats:
            if row[0] is not None and row[1]!= -1 and row[1] != "" and row[1] != 0 and row[1] != None:
                stats[row[0]]["SEVERITY"].append(row[1])
            if row[0] is not None and row[2] != -1 and row[2] != "" and row[2] != 0 and row[2] != None:
                stats[row[0]]["years"].append(row[2])
        else:
            stats[row[0]]={}
            stats[row[0]]["SEVERITY"] = []
            stats[row[0]]["years"] = []
            if row[1] is not None and row[1] != -1 and row[1] != "" and row[1] != 0 and row[1] != None:
                stats[row[0]]["SEVERITY"].append(row[1])
            if row[2] is not None and row[2] != -1 and row[2] != "" and row[2] != 0 and row[2] != None:
                stats[row[0]]["years"].append(row[2])
        rows.updateRow(row)
del rows

##Go through table and populate the new fields with appropriate data from the dictionary above
with
arcpy.da.UpdateCursor("dmg_attributes",["dmg_duplicates_FEAT_SEQ","SUM_SEVERITY","MEAN_SEVERITY","START_YR","E
ND_YR","AVG_YRS_BTWN_DMG"]) as rows:
    for row in rows:
        sev=0
        for s in stats[row[0]]["SEVERITY"]:
            sev+=s
        row[1]=sev
        if len(stats[row[0]]["SEVERITY"]) != 0:
            row[2]=sev/len(stats[row[0]]["SEVERITY"])
        yrs=[]
        for y in range (1, len(stats[row[0]]["years"])):
            yrs.append(abs(stats[row[0]]["years"][y]-stats[row[0]]["years"][y-1]))
        ys = 0
        for yr in yrs:
            ys+=yr
        if stats[row[0]]["years"]:
            row[3] = min(stats[row[0]]["years"])
            row[4] = max(stats[row[0]]["years"])
        if len(yrs) != 0:
            row[5]= ys/len(yrs)
        rows.updateRow(row)

# delete the cursor to ensure that temporary geodatabase can be deleted
del rows

##delete the duplicate polygons using the unique polygon ID and then rejoin the attribute data from the original
shapefile
arcpy.DeleteIdentical_management("dmg_attributes","dmg_duplicates_FEAT_SEQ")

##do a spatial join to get damage occurrences, add a new field to hold occurrence values, populate it from the join
count field and then delete the join count field.
arcpy.SpatialJoin_analysis("dmg_attributes","damaged_areas",dmg_type+"_"+dmg_agnt, "JOIN_ONE_TO_ONE", "", "",
"WITHIN");
arcpy.AddField_management(dmg_type+"_"+dmg_agnt, "DMG_OCC", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "");
arcpy.CalculateField_management(dmg_type+"_"+dmg_agnt, "DMG_OCC", '!Join_Count!','PYTHON');
arcpy.DeleteField_management(dmg_type+"_"+dmg_agnt, "Join_Count");
```

```
##add damage occurrence to list of fields to keep
fields.append("DMG_OCC")

##make list of fields to delete. These are repeats of fields that already exist.
deletefields = []
for fds in arcpy.ListFields(dmg_type+"_"+dmg_agnt,"*"):
    if fds.name not in fields:
        deletefields.append(fds.name)

## delete duplicate fields
arcpy.DeleteField_management(dmg_type+"_"+dmg_agnt, deletefields)

##convert feature class to shapefile and save
arcpy.FeatureClassToShapefile_conversion(dmg_type+"_"+dmg_agnt,folder);
arcpy.Delete_management(temp);
```

Appendix 3: Agenda for December 1, 2016 workshop with curators and users of state aerial detection survey data

Workshop: Disturbance dynamics across the Northern Forest:
Synthesizing NSRC studies of ecosystem change within a regional forest health mapping framework

AGENDA

10:30am to 4:30pm, December 1, 2016
103 Aiken Center, University of Vermont, Burlington, VT

10:30 – Arrival (coffee and fruit)
11:00 – Overview of Forest Health Atlas Project and current status of aerial detection data collation
12:30 – Lunch
13:15 – Discussion of challenges and solutions for regional aerial survey data integration
14:45 – Coffee break
15:00 – Discussion of regional synthesis – identifying emergent themes, questions and data needs most relevant to forest health protection staff in the region
16:15 – Wrap-up and next steps (looking ahead to VMC Annual Conference tomorrow
http://www.uvm.edu/vmc/annualMeeting/2016/agenda)

BRIEF OVERVIEW

This project aims to develop a regional geospatial synthesis of research and monitoring data related to forest disturbance in New York, Vermont, New Hampshire, Maine and Massachusetts. It combines data from aerial detection surveys flown in those states with field-based data on tree mortality and forest disturbance collected by Northeastern States Research Cooperative-funded (NSRC) scientists and other researchers in a single interactive data exploration platform. By integrating data from research projects and forest health aerial detection surveys in a seamless, interactive mapping framework across spatial and temporal scales,

users will be able investigate the extent and severity of different disturbances across the region. In addition, by combining the aerial survey and research datasets, this project will improve interpretation of the geospatial data and make information from research studies accessible to a much broader audience while establishing a scientific baseline for subsequent assessments. Finally, by making all products publicly available through an interactive mapping portal, this project will enable decision makers to access additional, easy-to-use information to account for historical patterns of disturbance as they respond to emerging challenges associated with global change.

Appendix 4: Northeastern States Research Cooperative Project Assessment

Following the filtering approach described in the methods section, we generated a list of 59 projects from 42 principal investigators for follow-up and solicitation to include in the NEFHA. These are shown in Table 11.

Table 11. List of projects identified as potentially relevant to the Northeastern Forest Health Atlas project.

PI First Name	PI Last Name	Project Title	Date	NSRC Website Link
Aaron	Weiskittel	Fine-tuning Predictions of Forest Tree Growth Response to Thinning and Climate Change	2008	http://nsrcforest.org/project/fine-tuning-predictions-forest-tree-growth-response-thinning-and-climate-change
Aaron	Weiskittel	Historic Studies Generate New Findings about Northern Conifer Growth and Yield	2009	http://nsrcforest.org/project/historic-studies-generate-new-findings-about-northern-conifer-growth-and-yield
Allan	Strong	Testing the Ability of a Remote-Sensing Tool (LiDAR) to Assess Tree Health and Bird and Insect Populations	2011	http://nsrcforest.org/project/testing-ability-remote-sensing-tool-lidar-assess-tree-health-and-bird-and-insect-populations
Andrew	Richardson	Webcams Monitor Changing Climate Effects on Leaf Phenology and Forest Productivity	2009	http://nsrcforest.org/project/webcams-monitor-changing-climate-effects-leaf-phenology-and-forest-productivity
Arthur	Johnson	Plant-Available Forest Soil Calcium Reduced by Half from 1930s to 2006 in Adirondacks	2005	http://nsrcforest.org/project/plant-available-forest-soil-calcium-reduced-half-1930s-2006-adirondacks
Bruce	Parker	More Tree Species Diversity in Sugarbushes Reduces Maple Pest Levels	2008	http://nsrcforest.org/project/more-tree-species-diversity-sugarbushes-reduces-maple-pest-levels
Charles	Driscoll	Hubbard Brook Research Foundation Science Links Program: Mercury in the Northeastern U.S.	2003	http://nsrcforest.org/project/hubbard-brook-research-foundation-science-links-program-mercury-northeastern-us
Charles	Driscoll	Mercury Hotspots in Montane Ecosystems of the Northern Forest	2014	http://nsrcforest.org/project/mercury-hotspots-montane-ecosystems-northern-forest
Charles	Driscoll	Mercury Hotspots in Montane Ecosystems of the Northern Forest	2014	http://nsrcforest.org/project/mercury-hotspots-montane-ecosystems-northern-forest
Charles	Driscoll	Using "Critical Loads" to Assess Air Pollution and Its Effects on Forest Ecosystems	2005	http://nsrcforest.org/project/using-%E2%80%9Ccritical-loads%E2%80%9D-assess-air-pollution-and-its-effects-forest-ecosystems
Colin	Beier	Climate Change, Acid Rain, and Insect Defoliation Interact to Decrease Sugar Maple Growth	2013	http://nsrcforest.org/project/climate-change-acid-rain-and-insect-defoliation-interact-decrease-sugar-maple-growth
Donald	DeHayes	Calcium Deficiency Implicated in Sugar Maple Decline	2001	http://nsrcforest.org/project/calcium-deficiency-implicated-sugar-maple-decline
Dylan	Parry	Northern Hardwood Forests as Refuges for Giant Silk Moths Threatened by Non-Target Biological Control	2015	http://nsrcforest.org/project/northern-hardwood-forests-refuges-giant-silk-moths-threatened-non-target-biological-control
Edward	Brzostek	Limitations on Availability of Forest Soil Nitrogen for Tree Growth	2007	http://nsrcforest.org/project/limitations-availability-forest-soil-nitrogen-tree-growth

PI First Name	PI Last Name	Project Title	Date	NSRC Website Link
Gary	Hawley	Winter Injury, Carbon Loss, but Surprising Growth Resurgence in Red Spruce	2010	http://nsrcforest.org/project/winter-injury-carbon-loss-surprising-growth-resurgence-red-spruce
Gary	Lovett	Effects of Beech Bark Disease and Soil Calcium on a Northern Hardwood Forest	2004	http://nsrcforest.org/project/effects-beech-bark-disease-and-soil-calcium-northern-hardwood-forest
Gary	Lovett	Evaluation of Policy and Management Solutions to Limit Damage by Introduced Forest Pests	2013	http://nsrcforest.org/project/evaluation-policy-and-management-solutions-limit-damage-introduced-forest-pests
Heidi	Asbjornsen	Understanding Impacts of Precipitation Change and Drought on the Northern Forest	2014	http://nsrcforest.org/project/understanding-impacts-precipitation-change-and-drought-northern-forest
Ivan	Fernandez	Soil-Site Influences on Northern White-Cedar Stem Quality and Growth	2006	http://nsrcforest.org/project/soil-site-influences-northern-white-cedar-stem-quality-and-growth
Ivan	Fernandez	Does Changing Atmospheric Deposition of Nitrogen and Sulfur Alter Stream Organic Matter in Northern Forest Watersheds?	2011	http://nsrcforest.org/project/does-changing-atmospheric-deposition-nitrogen-and-sulfur-alter-stream-organic-matter
Jennifer	Pontius	Satellite Imagery 1984-2009 Shows Stable Forest Health but Declining Spruce-Fir and Paper Birch	2008	http://nsrcforest.org/project/satellite-imagery-1984-2009-shows-stable-forest-health-declining-spruce-fir-and-paper-birch
Jeremy	Wilson	Rehabilitation of Cutover Mixedwood Stands: A Silvicultural and Economic Assessment of Alternatives	2007	http://nsrcforest.org/project/rehabilitation-cutover-mixedwood-stands-silvicultural-and-economic-assessment-alternatives
John	Castello	Multiple Stressors Play Role in Beech Bark Disease	2013	http://nsrcforest.org/project/multiple-stressors-play-role-beech-bark-disease
John	Daigle	Tribes, Landowners and Agencies Collaborate to Prepare for Emerald Ash Borer in Maine	2014	http://nsrcforest.org/project/tribes-landowners-and-agencies-collaborate-prepare-emerald-ash-borer-maine
John	Stella	Beaver Impacts on the Northern Forest of the Adirondack Mountains	2012	http://nsrcforest.org/project/beaver-impacts-northern-forest-adirondack-mountains
Kasey	Legaard	Impacts of Spruce Budworm and Forest Management on Future Wood Supply	2010	http://nsrcforest.org/project/impacts-spruce-budworm-and-forest-management-future-wood-supply
Laura	Kenefic	Relationships between Nonnative Invasive Plant Distribution and Land Use History	2005	http://nsrcforest.org/project/relationships-between-nonnative-invasive-plant-distribution-and-land-use-history
Linda	Pardo	Measuring an Isotope of Nitrogen in Forest Foliage to Understand Effects of Nitrogen Deposition	2001	http://nsrcforest.org/project/measuring-isotope-nitrogen-forest-foliage-understand-effects-nitrogen-deposition
Lindsey	Rustad	Advancing the Use of Electronic Sensors to Detect Environmental Change	2011	http://nsrcforest.org/project/advancing-use-electronic-sensors-detect-environmental-change
Lindsey	Rustad	Experimental Ice Glazing in a Northern Hardwood Forest to Understand Ecological Impacts of Ice Storms	2009	http://nsrcforest.org/project/experimental-ice-glazing-northern-hardwood-forest-understand-ecological-impacts-ice-storms
Lindsey	Rustad	Forest Ecosystem Response to Environmental Change: Regional Collaboration and Database Development	2004	http://nsrcforest.org/project/forest-ecosystem-response-environmental-change-regional-collaboration-and-database
Lindsey	Rustad	Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada	2005	http://nsrcforest.org/project/impacts-climate-change-forests-northeastern-united-states-and-eastern-canada
Margaret	Skinner	Dynamics of a Naturally-Occurring Fungus-Caused Disease of Hemlock Woolly Adelgid	2011	http://nsrcforest.org/project/dynamics-naturally-occurring-fungus-caused-disease-hemlock-woolly-adelgid

PI First Name	PI Last Name	Project Title	Date	NSRC Website Link
Martin	Dovčiak	Susceptibility of Montane Spruce-Fir Forests of the Northeastern United States to Climate Change	2011	http://nsrcforest.org/project/susceptibility-montane-spruce-fir-forests-northeastern-united-states-climate-change
Melissa	Fierke	Impact of Emerald Ash Borer Biological Control Using Wasps on the Health of Ash Trees	2013	http://nsrcforest.org/project/impact-emerald-ash-borer-biological-control-using-wasps-health-ash-trees
Michael	Day	Influence of Commercial Thinning on Recovery from Defoliation in Spruce-fir Forests	2013	http://nsrcforest.org/project/influence-commercial-thinning-recovery-defoliation-spruce-fir-forests
Michael	Saunders	Timber Productivity of Natural Disturbance-Based Forest Management	2007	http://nsrcforest.org/project/timber-productivity-natural-disturbance-based-forest-management
Mohammad	Bataineh	Incorporating Spruce Budworm Impacts into a Computer Model to Project Changes to Wood Supply	2014	http://nsrcforest.org/project/incorporating-spruce-budworm-impacts-computer-model-project-changes-wood-supply
Nathan	Torbick	Measuring Disturbance to Forests with New Remote Sensing Technologies	2010	http://nsrcforest.org/project/measuring-disturbance-forests-new-remote-sensing-technologies
Pamela	Templer	Nitrogen Deposition and Saturation in Wilderness Areas of the Northeastern United States	2006	http://nsrcforest.org/project/nitrogen-deposition-and-saturation-wilderness-areas-northeastern-united-states
Paul	Schaberg	Adding Calcium to Forest Soils Improves Growth, Health, and Wound Healing of Sugar Maple	2003	http://nsrcforest.org/project/adding-calcium-forest-soils-improves-growth-health-and-wound-healing-sugar-maple
Paul	Schaberg	Soil Calcium Depletion Predisposes Red Spruce to Winter Injury	2004	http://nsrcforest.org/project/soil-calcium-depletion-predisposes-red-spruce-winter-injury
Paul	Schaberg	Weather-Related Causes of Red Spruce Winter Injury and Impacts on Carbon Storage	2006	http://nsrcforest.org/project/weather-related-causes-red-spruce-winter-injury-and-impacts-carbon-storage
Ralph	Nyland	Using Data from Long-Term Forest Studies to Develop Management Guidelines for Uneven-aged Stands	2015	http://nsrcforest.org/project/using-data-long-term-forest-studies-develop-management-guidelines-uneven-aged-stands
Richard	Hallett	Tree Foliage Chemistry Database to Monitor Forest Health	2003	http://nsrcforest.org/project/tree-foliage-chemistry-database-monitor-forest-health
Robert	Seymour	20-Year Results from Ecologically Based Silviculture Studies in Maine	2015	http://nsrcforest.org/project/20-year-results-ecologically-based-silviculture-studies-maine
Robert	Seymour	Growth, Lumber Yields, and Financial Maturity of Isolated Eastern White Pine Crop Trees	2007	http://nsrcforest.org/project/growth-lumber-yields-and-financial-maturity-isolated-eastern-white-pine-crop-trees
Robert	Seymour	Predicting Stand Development and Structure in Multi-Aged Northern Conifer Forests	2005	http://nsrcforest.org/project/predicting-stand-development-and-structure-multi-aged-northern-conifer-forests
Robert	Seymour	Unmanaged Forest Reserves as Benchmarks to Refine Disturbance-based Ecological Forest Management	2009	http://nsrcforest.org/project/unmanaged-forest-reserves-benchmarks-refine-disturbance-based-ecological-forest-management
Ron	Zalesny	Effects of Climate Change on Growth, Productivity, and Wood Properties of White Pine in Northern Forest Ecosystems	2010	http://nsrcforest.org/project/effects-climate-change-growth-productivity-and-wood-properties-white-pine-northern-forest
Ruth	Yanai	A Decision-Support System for Management of Sugar Maple Defoliated by Forest Tent Caterpillar	2007	http://nsrcforest.org/project/decision-support-system-management-sugar-maple-defoliated-forest-tent-caterpillar
Scott	Bailey	Nutrient vs. Toxic Elements in Forest Soils and Their Impact on Forest Health	2003	http://nsrcforest.org/project/nutrient-vs-toxic-elements-forest-soils-and-their-impact-forest-health

PI First Name	PI Last Name	Project Title	Date	NSRC Website Link
Scott	Bailey	On-line Soil Database Helps Monitor Ecosystem Change in the Northeastern U.S. and Eastern Canada	2008	http://nsrcforest.org/project/line-soil-database-helps-monitor-ecosystem-change-northeastern-us-and-eastern-canada
Serita	Frey	Tracing Nitrogen in Northern Forest Soils	2014	http://nsrcforest.org/project/tracing-nitrogen-northern-forest-soils
Shelly	Rayback	Causes and Implications of Surprising Growth Resurgence of Red Spruce in the Northern Forest	2013	http://nsrcforest.org/project/causes-and-implications-surprising-growth-resurgence-red-spruce-northern-forest
Stacy	McNulty	Influence of American Beech Thickets on Biodiversity in Northern Hardwood Forests	2009	http://nsrcforest.org/project/influence-american-beech-thickets-biodiversity-northern-hardwood-forests
Stuart	Findlay	Causes of Recent Increases in Organic Carbon Release from Forest Soils	2005	http://nsrcforest.org/project/causes-recent-increases-organic-carbon-release-forest-soils
William	Keeton	Demonstration of Sustainable Forest Management Alternatives	2004	http://nsrcforest.org/project/demonstration-sustainable-forest-management-alternatives
William	Keeton	Alternative Forest Management Impacts on Forest Carbon Storage and Methane Emissions	2013	http://nsrcforest.org/project/alternative-forest-management-impacts-forest-carbon-storage-and-methane-emissions

Providing the information needed to understand, manage, and protect the region's forested ecosystems in a changing global environment