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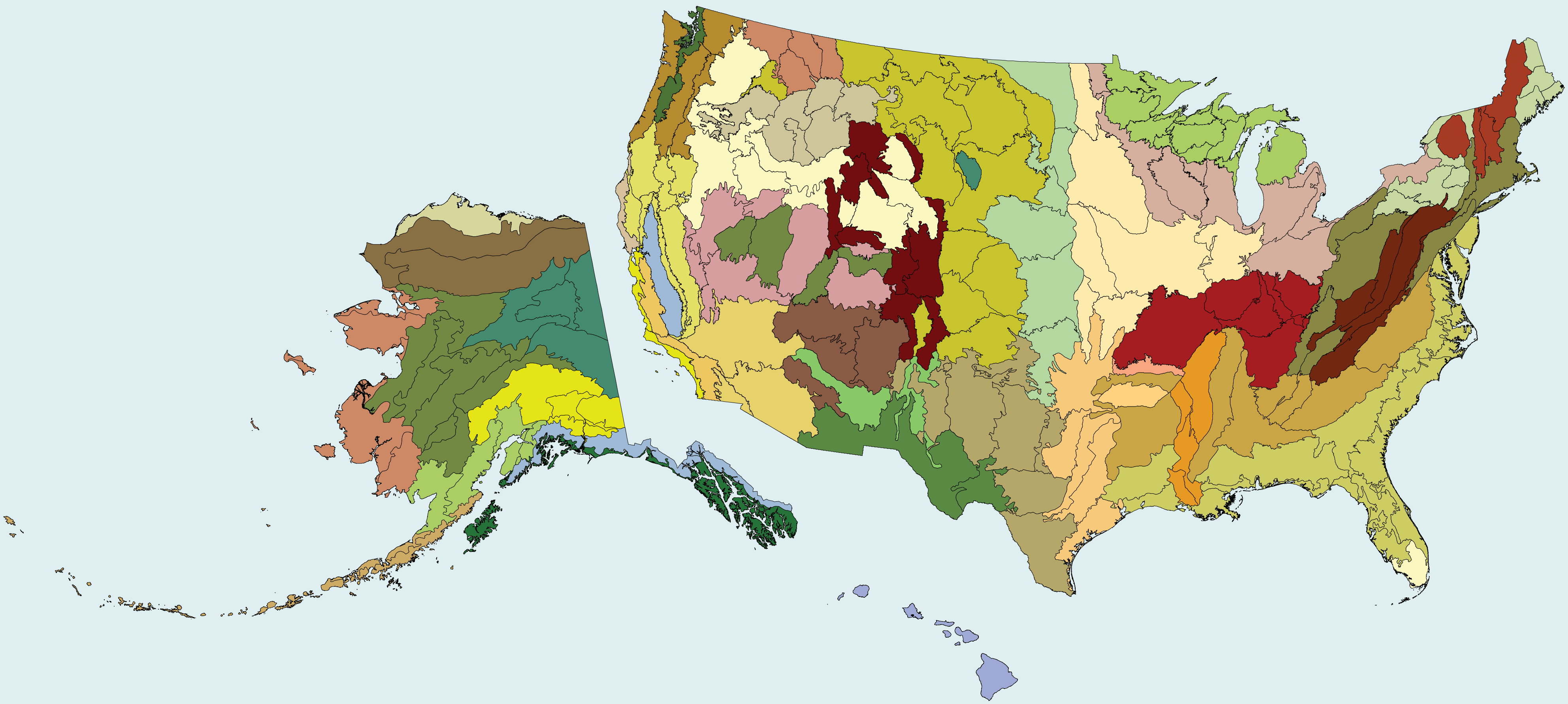
Forest Health Monitoring: National Status, Trends, and Analysis 2014

Editors Kevin M. Potter Barbara L. Conkling



Forest Service
Research & Development
Southern Research Station
General Technical Report SRS-209

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National Status, Trends, and Analysis 2014

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CHAPTER 17.

Assessing Forest Tree Risk of Extinction and Genetic Degradation from Climate Change

(Project SO–EM–09–01)

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INTRODUCTION

Research indicates that tree species are exhibiting changes in distribution and phenology in response to climate change (Root and others 2003, Woodall and others 2009, Zhu and others 2012). Climate change is expected to have large impacts on the area and location of suitable tree species habitat (Iverson and Prasad 1998, Iverson and others 2008, Schwartz and others 2001) and may pose a threat to the viability of forest tree species, many of which may be forced to either adapt to new conditions or shift to more favorable environments (Aitken and others 2008, Davis and others 2005). Managers and decisionmakers will need tools to assess the potential impacts of climate change on the broad diversity of forest tree species across North America and elsewhere.

Climate change is a priority area for Evaluation Monitoring projects funded by the Forest Health Monitoring (FHM) national program of the Forest Service, U.S. Department of Agriculture. Attendees at the 2008 FHM Working Group meeting approved a resolution calling for a baseline assessment across North American tree species of the risk of genetic degradation, local extirpation, or species-wide extinction associated with climate change.

Known as Forecasts of Climate-Associated Shifts in Tree Species (ForeCASTS), this assessment was conducted across all forest types and ownerships across the North American continent. The central focus of the assessment has been the statistical modeling of environmental niche envelopes that forecast species' geographic ranges under climate change using the Multivariate Spatio-Temporal Clustering (MSTC) technique developed by Hargrove and Hoffman (2005). The resulting maps predict the future location and quality of habitat for tree species and, along with consideration of species' biological attributes, allow for predictions of the degree to which species are likely to be able to move to areas with the appropriate environmental conditions over time and avoid the loss of extensive genetic variation.

METHODS AND RESULTS

Combining aspects of traditional geographical information systems and statistical clustering techniques, MSTC employs nonhierarchical clustering to classify Geographic Information System (GIS) raster cells with similar environmental conditions into categories (Hargrove and Hoffman 2005). The MSTC process generates output maps that group and display each pixel as part of an "ecoregion" with other pixels possessing similar environmental conditions. Global in scope, MSTC incorporates 17 environmental variables and generates maps at a resolution of 4 km^2, the finest resolution at which global environmental data are consistently available. It is an appropriate tool for the assessment of the potential genetic effects of climate change on forest tree species because (1) it is able to rapidly identify potential changes in suitable habitat for a large number of species, (2) it allows for flexible occurrence data inputs, (3) it generates relatively high-resolution results applicable at the population level, (4) it has the ability to identify potential suitable habitat beyond the borders of the United States, and (5) it incorporates pertinent environmental variables associated with plant distributions (Potter and others 2010). Details of the technique are presented elsewhere (Hargrove and Hoffman 2005, Potter and Hargrove 2013, Potter and others 2010).

We used MSTC to predict the future location and quality of habitat for 337 forest tree species under four combinations of two general circulation models (GCMs), the Hadley model and Parallel Climate Model, and two emissions scenarios, A1FI and B1, each for years 2050 and 2100. These sets of maps were generated twice for each species, once with elevation as a spatial environmental characteristic and once without. Forest Inventory and Analysis (FIA) plot data (Woudenberg and others 2010) were used as occurrence location training data for most species. For rare species not well sampled by FIA, training data came from the Global Biodiversity Information Facility (2013). Using a grayscale ramp, these maps depict areas of decreasing environmental similarity to the environmental conditions currently present at the tree species training occurrence locations.

Quality of habitat is determined spatially for each species with two sets of maps, those of Minimum Required Movement (MRM), which quantify the distance from each pixel to the nearest *environmentally suitable* location in 2050 under the Hadley low-emissions scenario, and of Optimal Required Movement (ORM) distance, which quantify the distance from each 4-km^2 pixel to the nearest *environmentally identical* location in 2050.

We used these MSTC mapped results to calculate, for each of the 337 tree species, several metrics of projected climate change pressure. Four of these were described in Potter and Hargrove (2013): (1) the degree to which the area of suitable environmental conditions is predicted to decrease or increase over time (percentage change in suitable area), (2) the amount of currently suitable area that is expected to remain suitable (range stability over time), (3) the distance that tree populations currently in areas expected to become unsuitable would have to travel to reach the nearest suitable location in the future (range shift pressure to any acceptable future habitat), and (4) the existing environmental variation across the range of a species (realized current niche occupancy). Other statistics include (5) the distance that tree populations currently in areas expected to become unsuitable would have to travel to reach the nearest identical location in the future (range shift pressure to any identical future habitat), and (6) the proportion of current habitat area with no future analogue predicted (proportion of no identical future habitat).

These maps and statistics are available, for all 337 North American tree species, at http://www.geobabble.org/~hnw/global/treeranges5/climate_change/atlas.html. Here, a page exists for each species, containing maps of (1) training occurrence locations, (2) locations with currently suitable environmental conditions, (3) locations expected to be suitable under the four GCM/scenario combinations in 2050 and 2100 (fig. 17.1), (4) current expected range compared to future expected range under Hadley B1 (low-emissions scenario) in 2050 (fig. 17.2A), and (5) MRM and ORM under Hadley B1 2050 (fig. 17.2B). When they exist, links to corresponding climate change projections from other researchers using different techniques (Crookston 2013, Prasad and others 2013) are included. GIS files are also available for download.

DISCUSSION

A variety of threats, most importantly climate change (Parmesan 2006) and insect and disease infestation (Dukes and others 2009, Logan and others 2003), may increase the likelihood that forest tree species will experience population-level extirpation or species-level extinction during the next century. In the face of multiple threats and uncertainty, an important forest management goal will be to safeguard existing adaptive capacity within tree species and create conducive conditions for future evolution, with a focus on the conservation of variability in adaptive traits (Myking 2002).

Along with the consideration of important species life-history traits and of threats other than climate change (Aitken and others 2008, Myking 2002, Sjostrom and Gross 2006), we expect that the ForeCASTS maps and climate change pressure metrics will be valuable for scientists and policymakers attempting to determine which forest tree species, in the face of climate change, should be targeted for monitoring efforts and for *in situ* and *ex situ* conservation actions such as seed banking efforts, facilitated migration, and genetic diversity studies. For example, the ForeCASTS climate change pressure maps and statistics, along with consideration of species' biological attributes, can allow for the assessment of whether migrating species might be able to track appropriate environmental conditions over time and avoid the loss of extensive genetic variation.

A loss of important adaptive genetic variation may be of particular concern for species that have narrow habitat requirements, are located exclusively at high elevations, and/or are not able to disperse their propagules effectively across long distances. Even if not locally extirpated outright, populations of these and other species could experience significant inbreeding, genetic drift, and decreased genetic variation because of reduced population size. Such populations may then become more susceptible to mortality caused both by nonnative pests and pathogens and by the environmental pressures associated with climate change. This susceptibility could generate a cycle of mortality, loss of genetic variation, and inability to adapt to change, a cycle that could ultimately result in population extirpation (Potter and others 2010).

Measures of predicted climate change pressure may be particularly helpful in multiple-species assessments across broad regional scales that take into account climate change risk to many species. For example, an analysis of climate change pressure results across 172 North American tree species using the Hadley B1 GCM/

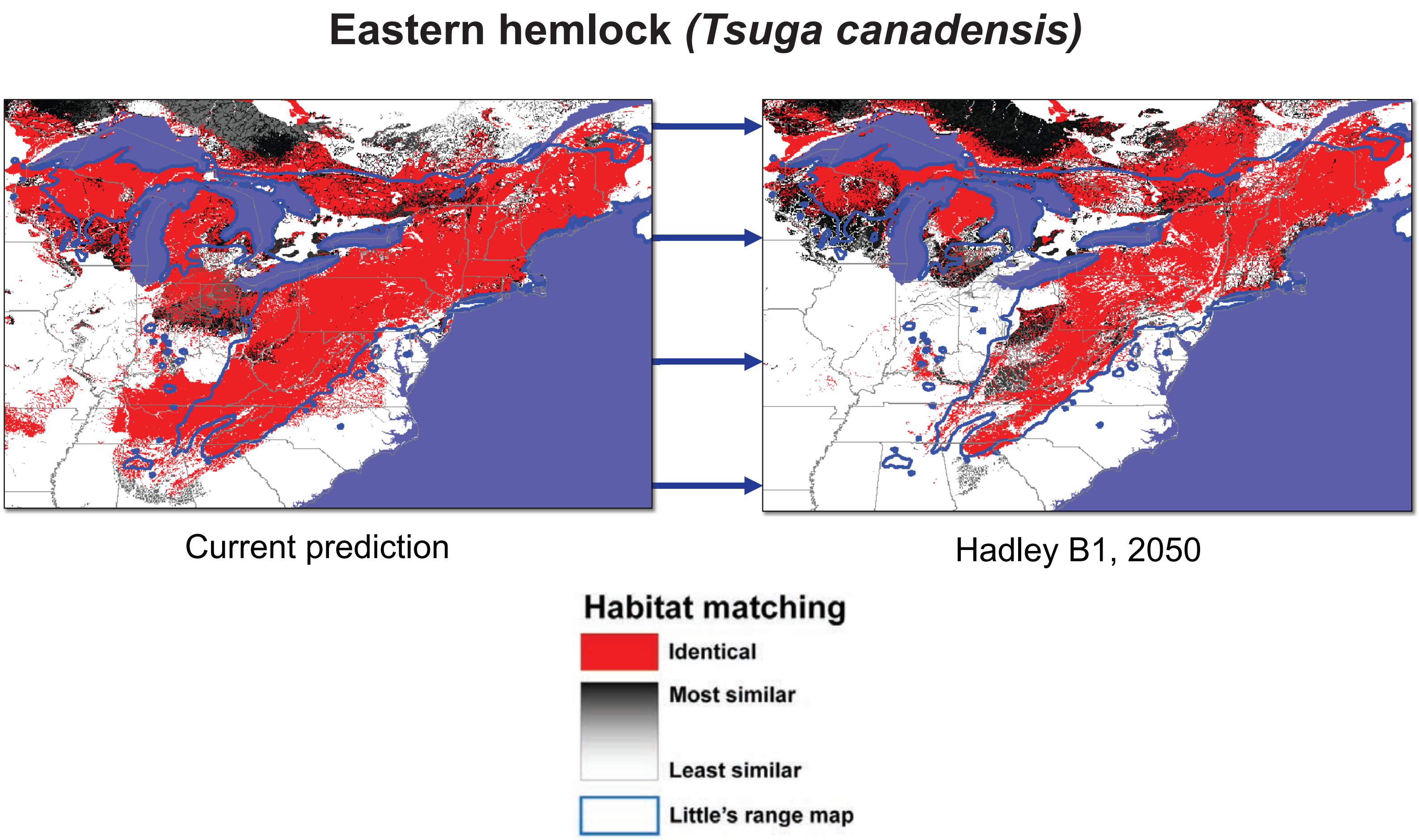

Figure 17.1—Predicted locations of eastern hemlock (Tsuga canadensis) *current suitable habitat and future suitable habitat in 2050 under the Hadley general circulation model, B1 emissions scenario, using Multivariate Spatio-Temporal Clustering. Dark blue line indicates tree range as delineated by E.L. Little (U.S. Geological Survey 1999).*

emissions scenario combination for 2050 found that all but two were projected to decline in suitable area. Eastern species were predicted to experience both a greater decline in suitable area and to maintain less range stability than Western species, although predicted range shift did not differ between the regions (Potter and Hargrove 2013). Additionally, Eastern species were more likely than Western species, on average, to be habitat generalists. In general, most species are expected to need to move a relatively short distance from newly unsuitable to the nearest future suitable locations. That study indicated that Great Basin bristlecone pine (*Pinus longaeva*) and September elm (*Ulmus serotina*) are species that need to be closely monitored, and may need to be considered as candidates for facilitated migration, because the distance from current suitable to future suitable habitat was predicted to be extensive for both.

Additionally, the ForeCASTS climate change pressure metrics are being used as inputs in Project CAPTURE (Conservation Assessment and Prioritization of Forest Trees Under Risk of Extirpation), a cooperative effort across the three Forest Service deputy areas to establish a framework for conservation priority-setting assessments of forest tree species across the entire United States.

Finally, the ForeCASTS species habitat maps can be overlaid to identify areas of high potential species richness and endemism, both in current time and in the future.

CONTACT INFORMATION

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(A)

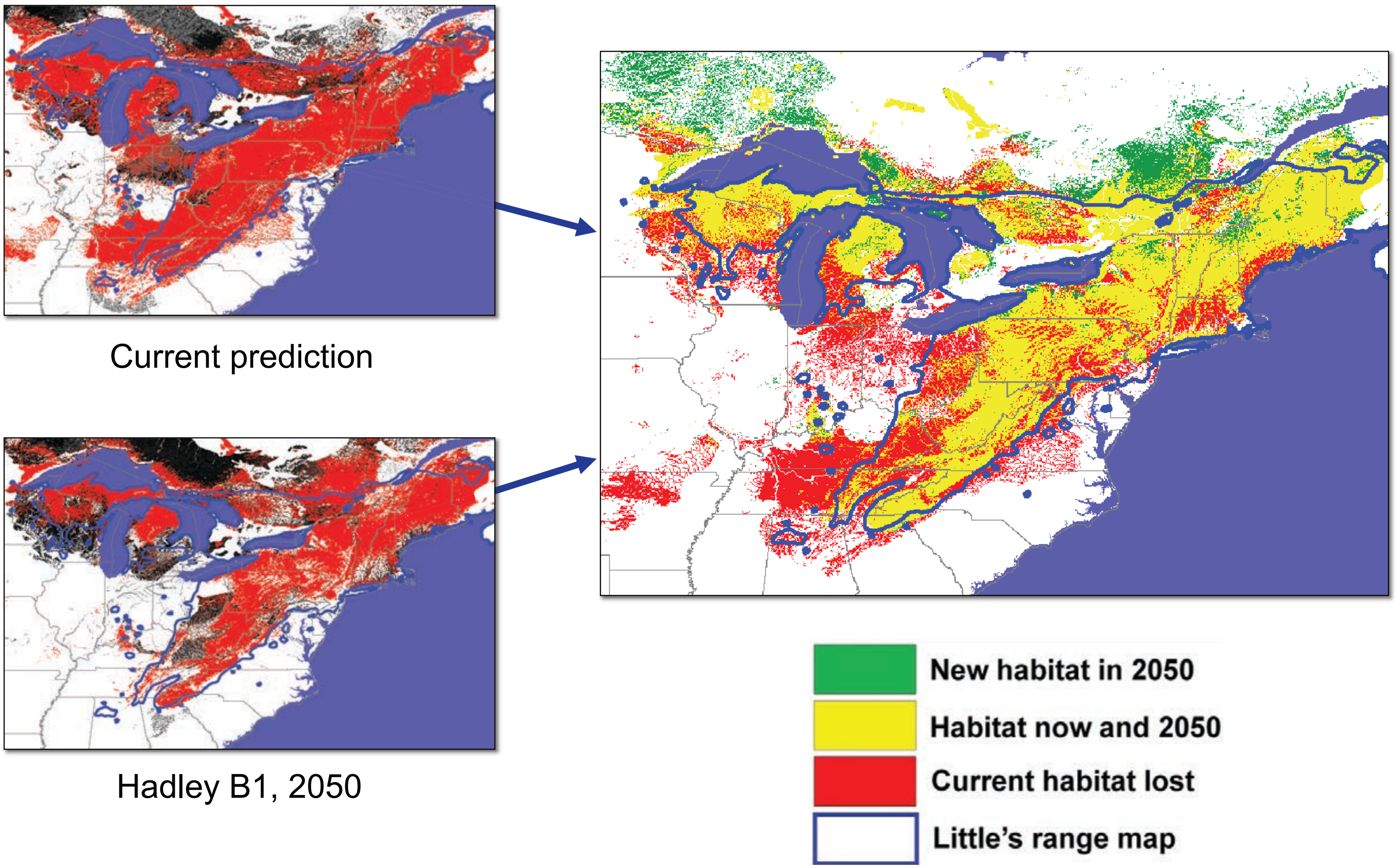

Figure 17.2—Predicted eastern hemlock (Tsuga canadensis) *(A) environmental suitability comparison for current conditions and for 2050 under the Hadley general circulation model, B1 emissions scenario, and (B) minimum required movement (MRM) distance to nearest future suitable conditions in 2050 using Multivariate Spatio-Temporal Clustering. Maps from figure 17.1 shown for reference. Dark blue line indicates tree range as delineated by E.L. Little (U.S. Geological Survey 1999).*

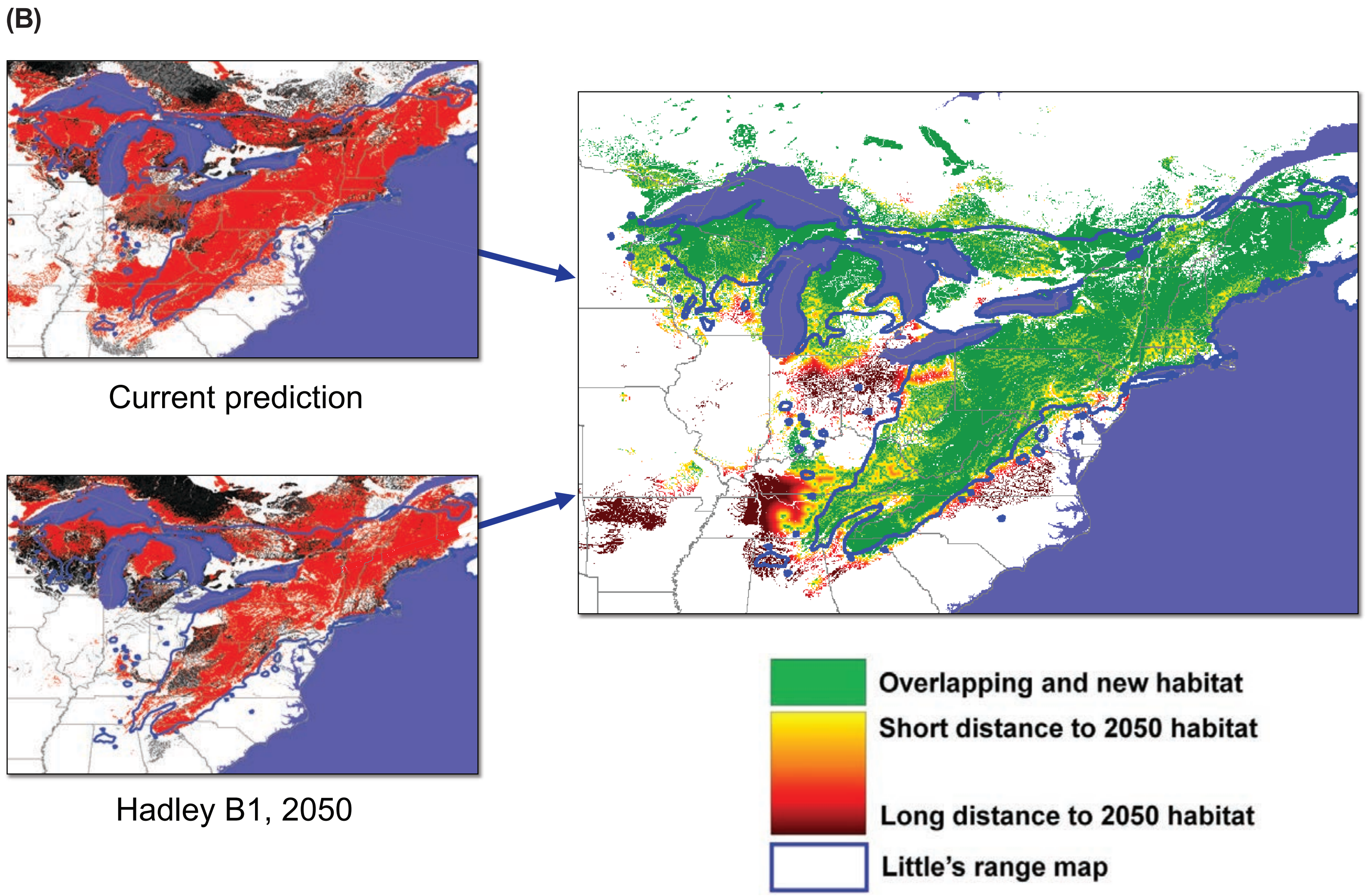

Figure 17.2(continued)—Predicted eastern hemlock (Tsuga canadensis) *(A) environmental suitability comparison for current conditions and for 2050 under the Hadley general circulation model, B1 emissions scenario, and (B) minimum required movement (MRM) distance to nearest future suitable conditions in 2050 using Multivariate Spatio-Temporal Clustering. Maps from figure 17.1 shown for reference. Dark blue line indicates tree range as delineated by E.L. Little (U.S. Geological Survey 1999).*

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The annual national report of the Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, presents forest health status and trends from a national or multi-State regional perspective using a variety of sources, introduces new techniques for analyzing forest health data, and summarizes results of recently completed Evaluation Monitoring projects funded through the FHM national program. In this 14th edition in a series of annual reports, survey data are used to identify geographic patterns of forest insect and disease activity. Satellite data are employed to detect geographic patterns of forest fire occurrence. Recent drought conditions are compared across the conterminous United States. Data collected by the Forest Inventory and Analysis (FIA) Program are employed to detect regional differences in tree mortality. Results of a national insect and disease forest risk assessment, including maps, are presented. Using FIA and national land cover data, decline of intact forest is assessed by forest type and ownership. Ten recently completed Evaluation Monitoring projects are summarized, addressing forest health concerns at smaller scales.

Keywords—Change detection, drought, fire, forest health, forest insects and disease, fragmentation, risk assessment, tree mortality.

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