

III. INSECTS

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RMRS research on insect pests focuses mostly on conifer pests. There is a long history of invasive insects causing significant impacts, mortality, and changes in forest ecosystem structure in North America. Perhaps the most evident example is the introduction of the gypsy moth, *Lymantria dispar*, into eastern North America in the 1860s (Forbush and Fernald 1896). Although not well understood, it has caused shifts in forest structure and significant resources have been spent in management and control efforts that continue today (<http://www.fs.fed.us/ne/morgantown/4557/gmoth/>). The smaller European elm bark beetle, *Scolytus multistriatus*, was introduced into North America in the early 1900s (Chapman 1910). Coupled with Dutch elm disease, for which the insect is the primary vector (Readio 1935), it has caused the devastation of native elms across North America (Bloomfield 1979). The Asian longhorned beetle, *Anoplophora glabripennis*, and the emerald ash borer, *Agilus planipennis*, are more recent introductions (Nowak and others 2001; Poland and McCullough 2006). The former has killed numerous maples, elms, and willows in New York and Chicago and the latter is destroying extensive areas of ash in Michigan and across the Midwest. The Sirex woodwasp, *Sirex noctilio*, which attacks several species of pines, was detected in 2004 (Hoebeke and others 2005) and is considered established in parts of Pennsylvania, New York, and Michigan (<http://www.invasivespeciesinfo.gov/animals/sirexwasp.shtml>). In the Rocky Mountain Region, the first detection of the banded elm bark beetle, *Scolytus schevyrewi*, occurred in 2003 (Negrón and others 2005). The insect utilizes various species of elms as hosts and tree mortality has been reported particularly in conjunction with drought. A number of other exotic bark beetles are established in North America (Wood 1982). Although none have been agents of extensive mortality, their ecological implications are not well known. Some other recent introductions to North America include the pine shoot beetle, *Tomicus piniperda*; the redhaired pine bark beetle, *Hylurgus ligniperda*; and the Mediterranean pine engraver, *Orthotomicus erosus* (Lee and others 2010). The mountain pine beetle, *Dendroctonus ponderosae*, a native disturbance agent in pine forests of western North America, is currently expanding its range into new areas of British Columbia and Alberta (Carroll and others 2004). Although there is evidence of historical mountain pine beetle outbreaks in high elevation five needle pine forests (Perkins and Roberts 2003), current trends in beetle-caused tree mortality appear unprecedented. Increasing temperature associated with climate change as it directly influences the insect is one important factor in mountain pine beetle range expansion and shifts in outbreak dynamics (Carroll and others 2004). Due to their extreme sensitivity to temperature, all forest insects will be directly affected by temperature increases. Moreover, climate change affects on forest insects may also manifest indirectly through affects to host trees. In addition to predicted changes in the geographic distribution of many tree species, climate change will also affect tree physiology and thus interactions with their herbivore predators (Mattson 1980; Zvereva and Kozlov 2006; McKenney and others 2007). Therefore, in a changing climate, many forest insects currently considered native may soon become invasive as their habitat changes.

Building a successful invasive species research program in entomology at the Rocky Mountain Research Station needs to be linked to the National Strategy and Implementation Plan for Invasive Species Management and must address the four national program elements:

(1) Prevention. There is some understanding of the major exotic species of concern that could impact our western forests. Pathway and risk assessments, such as the Exotic Forest Pest Information System for North America (<http://spfnic.fs.fed.us/exfor/>), have been initiated to identify priority insects. International commercial activities and unregulated transport of firewood are primary pathways for the movement of invasive insects; therefore, it is imperative to design educational programs that build public awareness of the problem. Climate change will affect host response, the likelihood of establishment of invasive insects, and the range expansion of native insects into new areas. The examination of how climate change may influence these processes is of utmost importance. At RMRS, studies are underway to examine how climate change will influence range expansion of mountain pine beetle and other bark beetles.

(2) Early Detection and Rapid Response. Between 1985 and 2000 there were almost 7,000 records of interception of exotic bark beetles by USDA APHIS (Haack 2001). These numbers will increase as worldwide commerce continues to expand. Tools in support of programs aimed at the early detection of insects such as the identification of pheromones or attractants for detection and monitoring will streamline and increase the efficiency of these programs. At RMRS, in cooperation with the PSW Research Station, we have been studying the chemical ecology of the banded elm bark beetle (Negrón and others 2005; Lee and others 2002). We continue to witness a precipitous decline in taxonomic expertise in wood-boring insects, and the available scientists are unable to address the demand for this service. This raises the need for developing taxonomic tools that can be used by personnel of agencies responsible for detection at ports of entry. In cooperation with APHIS, Colorado State University, and Forest Health, the RMRS has developed an image-based key to the Bark Beetle Genera of North America (Mercado 2010). Also in Cooperation with Colorado State University, at RMRS we are finalizing a “Revision of the Species in the Genus *Hylurgops* LeConte,” which includes potentially important exotic species (Mercado, unpublished data).

(3) Control and Management. Available control strategies against established invasive insects are laborious, expensive, unsustainable, and of unknown efficacy. Streamlined approaches need to be developed to mitigate potential impacts, and just as importantly treatment success needs to be evaluated. As not every infestation can be targeted for control, decision support systems are needed to identify proper circumstances in which active management is warranted. Exploration of biological control approaches for managing invasive insects needs to continue. At RMRS, the work on range expansion of bark beetles will partly address the identification of new areas where management approaches may be needed. Scientists at RMRS also have the expertise to develop biological control programs targeted at potentially damaging exotic insects.

(4) Rehabilitation and Restoration. The identification of native host plant material resistant to invasive insects will be needed for use in re-vegetation programs of affected areas. In cases that this is not possible, identifying alternative plants and trees that could be used to restore affected ecosystems while minimizing ecological impacts will also be needed. Finally, we will need to develop long-term cultural control approaches for restoring affected areas. Implementation of these programs should be followed by an assessment of their efficacy.

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