ARIZONA COOPERATIVE EXTENSION
THE UNIVERSITY OF ARIZONA
College of Agriculture and Life Sciences
AZ1418 08/06

Insects, Diseases, and Abiotic Disorders in Southwest Forests and Woodlands

Climate Change and Variability in the Southwest Ecosystem Series

Recent events in the forests of the Southwest have prompted scientists to consider the role of climate variability in insect and disease cycles. The ponderosa and piñon pine mortality due to bark beetles during 2002-2003 and the decline of aspen from 1999 to 2004 are examples of events that appear to be tied to recent climatic episodes (Breshears et al. 2005). Extreme to exceptional drought conditions in the Southwest in 2002 (U.S. Drought Monitor 2002) have plausibly tipped the balance towards bark beetle outbreaks in pine forests and woodlands. The ecological impacts of 2002 may not have been as severe if it had not been for the preceding six of seven years with below normal precipitation. Over 70 million pine trees along with millions of other conifers died in 2002-03 (USDA-FS 2002, 2003).

Fluctuations in conifer mortality caused by bark beetles can be related to climatic variation. The non-aggressive spruce bark beetle has long been known to only utilize wind-thrown or snow-broken trees, but recent bark beetle outbreaks on the Kenai Peninsula, Alaska may be linked to warmer than average temperatures in the past decade (Juday, 2004). Logan and Powell (in review) have shown that mountain pine beetle (MPB) populations increased due to elevated temperatures in the Stanley Valley of Idaho. MPB has also been implicated in unprecedented outbreaks in white bark pine at high elevation sites in Idaho. Average temperature increases of 3°C enabled the MPB at those high elevations to achieve univoltine (having one generation per year) reproduction; MPB had been known to only complete a life cycle once every two years.

An additional factor influencing pine tree mortality in the late 1990's and early 2000's points to increased stand density in pine (Covington et al. 1997). Increased stand density contributes to lowered soil moisture levels, which can contribute to reduced resistance to bark beetle attack (Kolb et al., 1998).

Based on aerial survey data, aspen tree mortality started to become evident in the late 1990's (USFS 2000). Aspen defoliation in Arizona and New Mexico averaged ~ 20,375 acres from 1990 to 1997. A series of events has contributed to the decline of aspen since 1997.

USFS

Figure 1. Ponderosa pine mortality linked to drought and bark beetle attack in central Arizona 2002.

- In 1998, 85,980 acres were defoliated in New Mexico and Arizona by western tent caterpillar (*Malacosoma californicum*), large aspen tortrix (*Choristoneura conflictana*), black leaf spot (*Marssonina populi*) (USFS 1999), and one of the species of *Melampsora* rust (Fairweather, personal comm.).

- Drought conditions that started in 1995 and continued through spring of 2004 stressed aspens throughout the Southwest (U.S. Drought Monitor 2002).

- On June 4, 5, and 6, 1999 low temperatures were 18, 12 and 8º F below normal, respectively. The timing of these frost episodes coincided with the early flush of growth on many of the aspen clones in Arizona and as a result 148,655 acres were defoliated by frost in 1999 (USFS 2000). A single defoliation event in the spring such as frost is generally tolerated by trees except when the trees have had additional stress factors such as drought or defoliation from insects or disease organisms (Manion 1991).


USFS

Figure 2. Aspen mortality and dieback at Dry Lake (center) and Woody Mountain (above right) near Flagstaff, Arizona.

- During the drought, elk browsed young shoots produced in stands of declining mature aspen. The over-grazing of young aspen shoots was particularly damaging in light of the death of the mature trees due to frost and drought. Continued grazing of aspen shoots in stands with a dead or declining overstory may eventually destroy the ability of clones to survive. (Populations of the non-native Rocky Mountain elk were estimated at 23,000 head in 1986, then peaked at 31,000 adults in 1992, and by 1999 had declined to 25,000 [Wakeling, personal comm.]. Arizona Game and Fish Department has recognized this problem and is implementing a program to help reduce these conflicts [Arizona Game and Fish Department, 2002]).

From 2000 to 2005 aspen defoliation has averaged 51,500 acres per year in Arizona (USFS 2001, 2002, 2003, 2004, 2005; Dudley, personal comm.) with little of the defoliation contributed to insects or diseases. An intensive study of the above mentioned factors is being conducted by USFS (Fairweather et al. 2005). Forest Pathologist Mary Lou Fairweather with USFS, has described the continued high levels of defoliation as "decline" (USFS 2004) and "dieback" with many clones experiencing greater than 50% mortality in the overstory and many more trees that have 10 to 30% live crown remaining (USFS 2005) (Figure 2).

Using tree-ring data, Swetnam and Lynch (1993) and Ryerson et al. (2003) examined the correlation between western spruce bud worm outbreaks and climate variability over multi-century periods. They found that "periods of increased and decreased budworm activity coincided with wetter and drier periods, respectively."

Some well-studied insect outbreaks are apparently not linked to climate; examples include recent outbreaks in New Mexico of forest tent caterpillars in aspen, as well as past outbreaks of the pandora moth (Furniss and Carolin, 2002). However, the inability of the trees to recover from defoliation has been associated with low moisture availability (Ford, 1996).

In summary, effects of insects on forests are complex, and species and site dependent. Many influences, such as increased stand density, decreased precipitation, and increased temperature, combined in nonlinear and overlapping ways to create the recent and devastating pine bark beetle outbreaks in Arizona forests. Climate plausibly plays a role in many, but not all, Southwest insect cycles. Modeling studies for the northern Rocky Mountains show potential increases in elevational and geographic range for insect pests such as the MPB (Logan et al. 2003), as a result of potentially increased temperatures associated with climate change. It would be plausible to expect similar effects in Arizona, depending on other factors, such as stand density (which humans can influence through thinning and prescribed fire treatments), plant vigor, and future precipitation variations and seasonality.

Application to Land Management

The February 2005 workshop, Climate Change & Ecosystem Impacts in Southwest Forests and Woodlands, garnered feedback from forest managers regarding opportunities and impediments to applying science-based information to operational management. Land managers struggle to determine the best and most appropriate condition to which a landscape should be restored. Uncertainty is inherent in such decisions, especially when the impacts of climate variability are added to the decision process. Land management decisions are based on multi-year plans developed years before implementation. Yet, in the intervening years the conditions may have changed enough that the proposed actions no longer meet management needs. Climate change may force decisions for current management practices and conditions. Priorities for land management may need to shift toward treatments that enhance forest resiliency and also allow for adaptive management. For example, thinning allows greater management flexibility than rehabilitation following natural stand or ecosystem replacing events.

Southwestern forests are complex systems that have been studied for decades. Synthesis of this existing research allows us to identify and address complex forest ecosystem interactions. Climate variability plays a prominent but poorly understood role in modulating forest ecosystem processes. Additional research is needed to establish relationships between climate variability and forest ecosystem functions.

Application to Education

Challenges to communicating forest and climate science include complex and confusing concepts, a lack of research addressing specific forest-climate interactions, and a lack of research pertaining specifically to Southwest ecosystems. Therefore, it may become necessary to simplify the details initially when communicating forest-climate science. Ultimately, it is important that educators demonstrate the complexity of all of the interplaying issues, in order to communicate no false impressions of an "easy" or "one-size-fits-all" solution" for land managers.

Additional Sources of Information

1. University of Arizona Cooperative Extension. Arizona Forest Health. http://ag.arizona.edu/extension/fh/
2. USDA Forest Service Southwestern Region. Forest Health: Bark Beetle Outbreak

   http://www.fs.fed.us/r3/resources/health/beetle/index.shtml
3. University of Arizona Cooperative Extension. 2003. Ponderosa Pine Bark Beetles in the Prescott Area. http://ag.arizona.edu/yavapai/anr/fh/PrescottBarkBeetles.pdf
4. Western forest insects

   An Online Catalog of Western Forest Insects and Diseases

   http://www.fs.fed.us/r6/nr/fid/wid.shtml
5. The Bugwood Network. 2001. Ips Species of the Western United States. http://www.barkbeetles.org/ips/Westips.html
6. CIRMOUNT (Consortium for Integrated Climate Research in Western Mountains)
   - 2004 MTNCLIM Meeting, Lake Tahoe, California
     - Overview

       http://www.fs.fed.us/psw/mcss/
     - Presentations and Posters

       http://www.x-cd.com/mcss04/program.html
   - 2005 MTNCLIM Meeting, Pray, Montana
   - Overview – http://www.fs.fed.us/psw/mtnclim/
   - Presentations, Posters, Committee Reports – http://www.fs.fed.us/psw/mtnclim/index_two.html#program
7. Western North America Defoliator Working Group Meeting Reports

   http://www.fs.fed.us/r6/nr/fid/pubsweb/westdef/

   2004 – http://www.fs.fed.us/r6/nr/fid/pubsweb/westdef/2004%20Meeting%20Report.pdf
8. USDA-Forest Service Aerial Surveys
   - USDA-Forest Service Southwestern Region. Locations of bark beetle activity.
   - http://www.fs.fed.us/r3/resources/health/beetle/maps.shtml
9. U.S. Forest Service-Region 3. Prescott National Forest News: Bark Beetle - Background Information. http://www.fs.fed.us/r3/prescott/health/health_beetles.htm

Research Needs – In Prioritized Order

(This list was generated during a breakout session at the Feb. 7-9, 2005 workshop "Climate Variability and Ecosystem Impacts in Southwest Forests and Woodlands")

1. Improve understanding of how changing climate, especially increasing temperatures, affects insect species distribution and range, including elevational range.
2. Determine climate-related thresholds for the initiation of outbreaks. Present the thresholds in terms of expected changes under various climate scenarios.
3. Information regarding the effects of climate variability and change on individual species, and their hosts. Research on exotic species is especially important – management tactics depend crucially on knowing whether insect pests are native or exotic.
4. Improve models used to project tree/stand growth and other characteristics. Current models do not use climate information, such as long-term temperature and precipitation, nor do they take climate variability and climatic change into account. Moreover, these models need to incorporate the effects of increasing CO2 on plant competition, insects, and insect interactions. An important question for the Southwest is – How will the distribution of ponderosa pine change?.
5. How does climate variability and change affect natural enemies to exotic pests? What is known about the science-based tools available to managers, and should they even be used?
6. Identification of triggers for management action and alternatives. For example, managers would value a decision tool-kit that allows them to determine when to take action, and what kind of action to take.
7. Research on threatened and endangered (T&E) species, especially on Southwest sky islands.
8. Determine appropriate forest restoration prescriptions and silvicultural practices, given projected climate changes.
9. Better hydroclimatic monitoring of moisture and evapotranspiration are the most important variables. What micro-scale processes affect insect outbreaks and their effects on hosts? What kinds of prescriptions can be used to maximize water yields and snowpacks, in order to reduce drought-related stress?
10. There is great concern regarding the effect of human population on the spread of insects and diseases. With climate change, will ecotypes move toward changes in insects/disease?
11. Social science research to determine how managers can best convey information on climate-insect interactions to landowners living in the middle of a forest – most of whom do not understand the science or the (ecological) processes involved.
12. Research regarding management in the face of considerable uncertainty in the regional-scale climate projections, and with regard to our limited knowledge of climate effects on individual species' populations.
13. What effect does prescribed fire have on bark beetle populations?
14. How can insect and disease factors help promote management objectives?
15. AZMET/RAMS needs expansion.

Bibliography

Arizona Game and Fish Department. 2002. Elk Harvest Management Strategy. http://www.azgfd.gov/w_c/elk_harvest.shtml

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.L. Anderson, O.B. Myers, and C.W. Meyer. Regional vegetation die-off in response to global-change-type drought. Proceeding of The National Academy of Sciences 102(42):15144-15148

Covington, W.W., P.Z. Fule, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and W.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the southwest. Journal of Forestry, 95(4):23-29.

Fairweather, M., B. Giels, and J. Rolf. 2005. 2005 Evaluation Monitoring Annual Report. USFS, Southwest Region.

Ford, D. 1996. Tent Caterpillars Defoliate Aspen. CAHE News. College of Agriculture and Home Economics, Las Cruces, N.M.

Furniss, R.L. and V.M. Carolin. 2002. Western Forest Insects. Misc. Pub. No. 1339. U.S.D.A. Forest Service.

Juday, Glenn P. 2004. The response of forest ecology and growth to climate variability in Alaska: Patterns, controls and strategies for management. Science and Education Impact/2004 Report 2004-003-05-008. Cooperative State Research, Education and Extension Services, Washington D.C.

Kolb, T.E., K.M. Holmberg, M.R. Wagner, and J.E. Stone. 1998. Regulation of ponderosa pine foliar physiology and insect resistance mechanisms by basal area treatments. Tree Physiology 18: 375-381.

Logan, J.A. and J.A. Powell. (In review). Ecological consequences of climate change altered forest insect disturbance regimes. In F.H. Wagner (ed), Climate Change in western North America: evidence and environmental effects. Allen Press. (http://www.usu.edu/beetle/documents/Logan-Powell2005.pdf).

Logan, J. A., J. Régnière, and J. A. Powell. 2003. Assessing the impacts of global climate change on forest pests. Frontiers in Ecology and the Environment 1: 130-137.

Manion, P.D. 1991. Tree disease concepts. Prentice-Hall, New Jersey.

Ryerson, D.E., T.W. Swetnam, and A.M. Lynch. 2003. A tree-ring reconstruction of western spruce budworm outbreaks in the San Juan Mountains, Colo, USA. Canadian Journal of Forest Research 33(6):1010-1028.

Swetnam, T.W. and A.M. Lynch. 1993. Multicentury, regional-scale patterns of western spruce budworm outbreaks. Ecological Monographs 63:399-424.

U.S. Drought Monitor. 2002. National Climatic Data Center, National Oceanic and Atmospheric Agency. http://drought.unl.edu/#dm/archive.html

U.S.D.A. Forest Service. 1999. Forest insect and disease conditions in the southwestern region, 1998. Southwestern Region Forestry and Forest Health Pub. No. R3-99-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2000. Forest insect and disease conditions in the southwestern region, 1999. Southwestern Region Forestry and Forest Health Pub. No. R3-00-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2000b. Forest insect and disease conditions in the southwestern region, 2000. Southwestern Region Forestry and Forest Health Pub. No. R3-00-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2002. Forest insect and disease conditions in the southwestern region, 2001. Southwestern Region Forestry and Forest Health Pub. No. R3-02-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2003. Forest insect and disease conditions in the southwestern region, 2002. Southwestern Region Forestry and Forest Health Pub. No. R3-03-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2004. Forest insect and disease conditions in the southwestern region, 2003. Southwestern Region Forestry and Forest Health Pub. No. R3-04-02. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

U.S.D.A. Forest Service. 2005. Forest insect and disease conditions in the southwestern region, 2004. Southwestern Region Forestry and Forest Health Pub. No. R3-05-01. http://www.fs.fed.us/r3/resources/health/fid_surveys.shtml

09/2006 **AZ1418**

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

TOM DEGOMEZ
Associate Specialist, Natural Resources

GREGG GARFIN
Program Manager, Climate Assessment for the Southwest (CLIMAS)

This information has been reviewed by university faculty.

cals.arizona.edu/pubs/natresources/az1418.pdf