Climate Change Basics

Middle School Teacher's Guide to Accompany *Bark Beetles in Arizona: Clues to Climate Change?*

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Climate Change Basics for Middle School Students

For educators
Thank you for your interest in teaching essential concepts of climate change science to our future world leaders and citizens! Climate science is an intriguing and relatively new branch of science that evaluates evidence gathered from a multitude of sources.

Currently, there is considerable confusion about climate change. *Is it really happening*? *What does the scientific community believe*? *What evidence is being considered*? *How can we be certain the data is accurate*? And perhaps most the most important question of all: *Who can I trust*?

A recent survey of Americans by Yale University indicates that many Americans lack sufficient knowledge of science to make an *informed* opinion of climate change. This same survey found that, overall, 59% of the respondents said they trust **school teachers** to provide accurate information. Source: *Knowledge of Climate Change across Global Warming's Six Americas*, Yale University, 2010

If you are a classroom educator, do you have the requisite knowledge of earth science and Earth's climate systems to help guide your students through the critical thinking needed to address this challenge? This guide may help! While it is intentionally limited and cannot answer all the questions you or your students may have about the science behind climate change, it can fill in some information gaps for the middle and high school classroom.

Bark Beetles in Arizona: Clues To Climate Change? was produced to engage students in the scientific methods, techniques, and research that have contributed to our current knowledge base and focuses upon one potential indicator of climate change: Pinyon Ips, a species of bark beetle that has been instrumental in the declining health of Arizona's forests.

Foundational lessons included in this guide focus on a specific aspect of climate change science, and are intended to augment knowledge and understanding of this complex issue. Select one or more to augment the bark beetles unit, depending upon the background level of your students.

For students
Global climate change is a very important topic these days, and not just for scientists. We are experiencing the effects of climate change right here in Arizona. The southwest region of the United States has been in a drought for more than a decade, which has led to an increase in bark beetle outbreaks, stressed forest conditions, increased risk of severe wildfire, chronic water shortages, and associated *phenological* changes. These effects are likely to become more common and increase in intensity in the coming months and years.

Want to learn about climate change, its potential impacts (present and future), and the basic science behind it all? Join us in our journey as we explore *Bark Beetles in Arizona: Clues To Climate Change?* where you will learn the basics of climate science and how one tiny insect in Arizona might provide clues to help us uncover data about climate change right here in the Grand Canyon state. And, you may even decide you want to become a “citizen scientist” and help gather data for researchers at the state and national level!

Overview of Activities

Students who enter your classroom will have varying degrees of knowledge and understanding about Earth’s systems and processes. Before embarking upon the bark beetles unit, you may find it beneficial to prepare your students with one or more of the lessons included within this guide. Each explores an essential question (EQ) related to climate change science and provides background information, objectives, necessary supplies, and procedures.

Students who have a basic understanding of these concepts will be better prepared to address the challenge they will face in the bark beetles unit. Additionally, this guide will introduce you and your students to various climate scientists at work around the world.

Foundational Lessons		
Lesson	**Essential Questions**	**Focus of lesson**
What is Climate Change Science?	How do we know that climate change is really happening?	Create a concept map of prior knowledge.
How is the Greenhouse Effect Related to Climate Change Science?	What does the greenhouse effect have to do with climate science?	Demonstrate the greenhouse effect.
Tools of Climate Change Science	How can science unlock “secrets” of the Earth’s history?	Research areas of science that contribute to our understanding of our changing climate.
Final Assessment	What might a concept map tell us about our understanding of climate change?	Edit original concept map to show increased understanding and to correct misconceptions.

These lessons contain background information sufficient for both the teacher and students to understand the basic science behind climate change, how diverse data is gathered and studied, and the tools scientists use to gather and analyze data.

What is Climate Change Science?

Essential Question: *How do we know that climate change is really happening?*

Background

What is climate change and how do we know it exists?

Scientists have been studying Earth's climate and weather patterns for centuries, but it was not until the 1950's that **climate change science** really became its own scientific discipline.

Climate change science is comprised of meteorology, climatology, biology, ecology, oceanography, geology, paleoecology, chemistry, physics, astronomy, and earth/environmental science. As you can see, climate change science is a collaboration of work from almost every scientific discipline. The effects caused by rapid climate changes around the world have increased the interest of scientists to study how and why these changes are occurring. As a result, climate change science has become a leading topic of research in today's scientific communities.

How do we know that Earth's climate is changing?

We know that Earth's climate is changing mainly by what scientists and citizens have observed, researched, and documented over the past several centuries. For example, we have all heard and felt that Earth's temperatures are increasing or, in some regions, actually getting cooler. When temperatures are altered by even **1°F** across the globe, there can be dramatic effects on natural ecosystems and cycles, including agriculture and available drinking water. Scientists are able to use certain tools to gain more information about past climates and compare historical data with present-day climate conditions. By using these tools and historical evidence, climate scientists can begin to more accurately predict our climate future.

Scientists at work:

Dr. Ian Stirling is a Research Scientist Emeritus with the Canadian Wildlife Service and an Adjunct Professor in the Department of Biological Sciences, University of Alberta Edmonton. For the past 42 years, Dr. Stirling has focused primarily on polar bears and seals. Most recently he has documented the effects of climate change on these species in relation to survival, behavior, and their biological importance in such extreme ecosystems.

http://www.ec.gc.ca/scitech/default.asp?lang=En&n=F97AE834-1&xsl=scitechprofile,form&formid=7814706B-E471-4795-B9F4-06555DE556CA

Source: http://www.gettoknow.ca/en/speakers/stirling.php

Dr. Mark Eakin is Coordinator of NOAA's Coral Reef Watch program, which focuses on the monitoring of coral reef ecosystems through satellite observations. Dr. Eakin has published a great deal of literature on various topics in coral reef ecology, especially the impact of climate change and other disturbance on coral reefs.

Source: http://www.star.nesdis.noaa.gov/star/Eakin_M.php

Dr. Charles David Keeling was a world leader in research on the carbon cycle and the increase of CO_2 in our atmosphere, also known more commonly as the "Greenhouse Effect". Dr. Keeling is known for the construction of the "Keeling Curve" often used in climate change science today. He was the first scientist to document the rise of CO_2 in the atmosphere on a continuous basis. He was a professor at Scripps Institution of Oceanography until 2005.

Source:
http://scrippsco2.ucsd.edu/sub_program_history/charles_david_keeling_biography.html

Activity Objectives

Students will gain a basic understanding of what climate change is, how we know it is occurring, and some of its potential impacts.

Supplies

- White board with several colors of markers
- Posters
- Computer with LCD projector or computer lab with access to websites provided in Background section.

Procedures

1. Initiate a group discussion about climate change to start generating ideas from students. Questions might include: *How do we know climate change is occurring? What are some of its potential impacts? Should we be concerned? Why or why not?* (Student responses will vary depending on level of background knowledge.)

2. Visit websites for the three "Scientists at Work" identified above. Discuss the role of science in helping us learn about climate change.
3. Ask students what they think a job description might look like for each scientist. *What kind of interests and education/training would be required to have that job and do it well? What might be some of the challenges such a person would encounter in his/her line of work? What areas of science does each pursue?*
4. Create a basic concept map about climate change that incorporates students' initial ideas/background knowledge OR ask students to create one. (Advanced learners may be well-acquainted with concept maps.) Revisit this map, adding or correcting it as necessary, as the unit progresses to track student learning and understanding of climate change.

Note: Teacher/instructors and students can utilize the program CMAP for instructions and tools of how to design their own concept maps. CMAP is a free and downloadable program from the internet at http://cmap.ihmc.us/conceptmap.html . This program is a great way to design concept maps for both students and teachers. Tutorials of how to use it are available on their website.

Assessment

- Ability to conduct basic research via the Internet
- Concept map (individual or class)
- Active participant and on-task in class discussion

How is the Greenhouse Effect Related to Climate Change Science?

Essential question: *What does the greenhouse effect have to do with climate science?*

Background

What is the *greenhouse effect*?

Greenhouses work by trapping heat from the sun. Most plant greenhouses are made of glass panels that allow light to enter but prevent heat from escaping. This causes the greenhouse to heat up and keep a relatively stable temperature for the plants to grow, even in winter months. When temperatures get really cold outside, most plants inside the greenhouse probably won't freeze. (A good example of this is your car. When it's all closed up, how warm does it get inside – in both summer and in winter? This is much like the greenhouse effect!)

The g*reenhouse effect* on Earth is similar to a greenhouse. It is a natural process that keeps Earth's (average) temperature at approximately 57 degrees Fahrenheit. Greenhouse gases (e.g., water vapor, carbon dioxide, nitrous oxide, and methane) absorb some of the radiation reflected by various Earth surfaces and re-radiate that heat back to earth again. This keeps the Earth warm enough to support life as we know it.

However, the amount of greenhouse gases has increased dramatically over the last 300 years, thus re-radiating more heat back to Earth and increasing its average temperature. We refer to this as the "enhanced greenhouse effect" which has been responsible for a 1 degree F rise in Earth's temperature just since 1980 or so.

How is the greenhouse effect related to climate change?

When greenhouse gas molecules trap heat in the atmosphere, the Earth's temperatures increase. Increased temperatures have an impact on ecosystems - and climates - around the world. Changing climates, in turn, initiate other changes within an ecosystem. One example: when temperatures increase, more evaporation occurs in lakes, rivers, streams, and oceans at the same time precipitation patterns are changing. Increased evaporation coupled with altered rainfall or snowfall patterns may lead to drought. Organisms which rely upon a constant source of fresh water are forced to adapt, move along, or face more dire consequences.

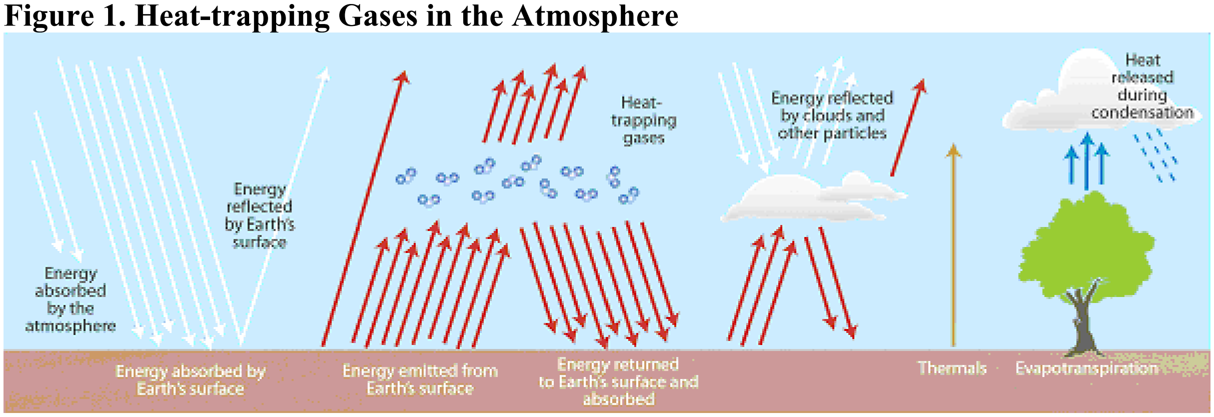
Have you heard of Newton's 3rd Law of Motion, which states that for every action there is an opposite and equal reaction? This same concept can be applied to climate change science. When greenhouse gases trap heat within Earth's atmosphere, temperatures increase, which causes climates to change. Figure 1 below illustrates this natural process.

And it is important to remember that not all regions around the Earth will warm at the same rate. The poles are already warming faster than many other places on the globe. Some areas may, in fact, become cooler. Nonetheless, virtually every spot you can find anywhere on our planet will be impacted by climate change in some manner.

Why is the Earth's greenhouse effect important?

One very important thing to remember is that the greenhouse effect is necessary for life to exist on Earth. Without the greenhouse effect, temperatures would be too cold for humans, animals, and plants to survive. However, if the greenhouse effect continues to strengthen and temperatures continue to rise, temperatures on Earth may become too hot for many animals and plants to survive. Human health will also be affected, as well as food production and the amount of available water (Refer to Figure 2).

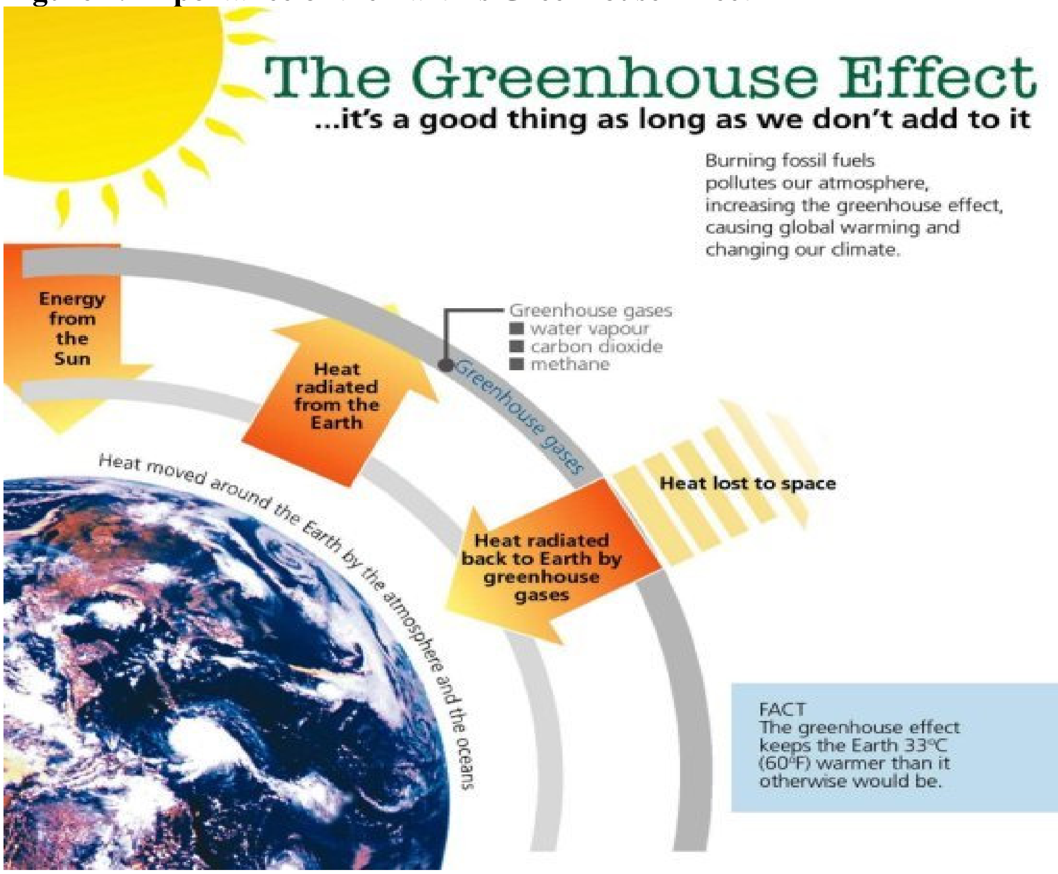
Figure 1. Heat-trapping Gases in the Atmosphere



Source: **IPCC 2007; Figure: Union of Concerned Scientists.**

The molecules depicted in the diagram represent heat-trapping gases, such as water vapor, carbon dioxide, methane, nitrous oxide. The number of incoming and outgoing arrows is proportional to the balance between incoming and outgoing energy.

Figure 2. Importance of the Earth's Greenhouse Effect

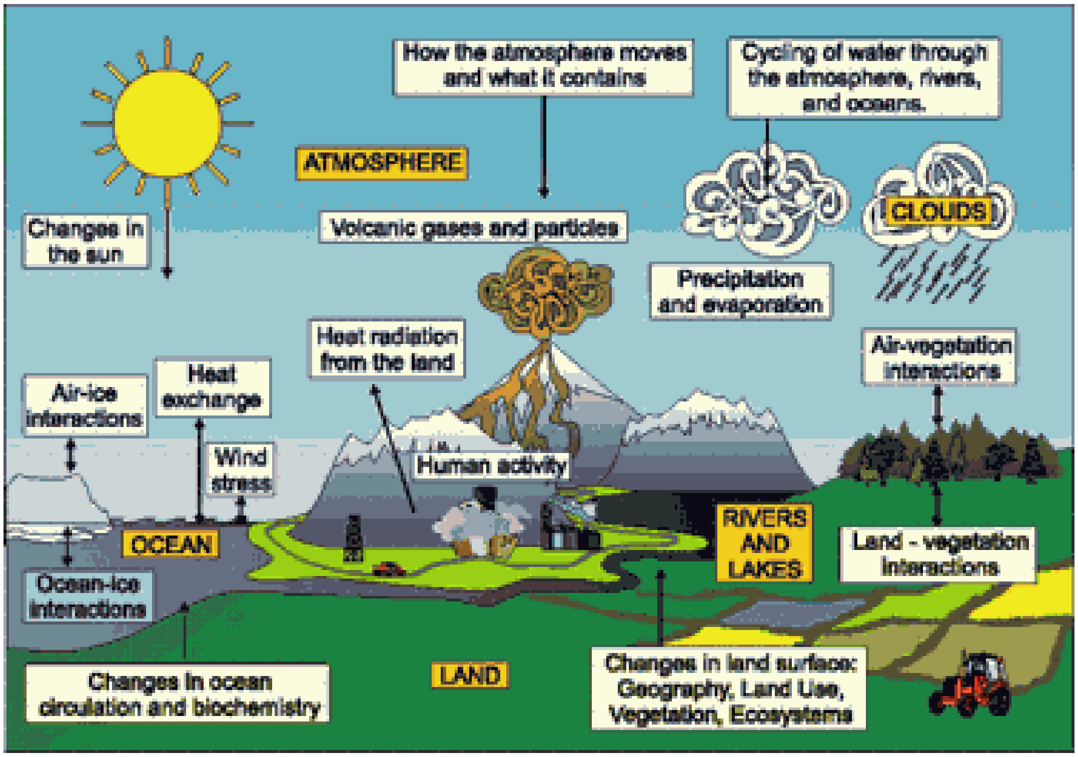


Source: **www2.cplan.org.uk**

Climate change represents a change in the *long-term weather patterns* within a specified region. This might refer to the Earth as a whole or to a more regionalized locale. For example, in the southwestern United States (specifically Arizona), there is a serious lack of water and precipitation (a drought). A drought is best described as a period of unusually persistent dry weather that lasts long enough to cause serious problems such as crop damage and/or water supply shortages. The severity of the drought depends upon the degree of moisture deficiency, the duration, and the size of the affected area.

Even during periods of drought, there may be occasional storms that bring heavy rain or snowfall. However, those intermittent storms cannot completely make up for the lack of significant and extended precipitation that this region enjoyed during earlier parts of the last century. Real-world example: the Colorado River Compact allocated water in this river to seven states, and Mexico was eventually included as well. Since the amount of the water in the river was determined during a "wet" climate cycle, and this region has suffered from a prolonged drought for more than a decade, the river is currently over-allocated and has less water than it "owes" to its eight constituents.

Earth's Climate System



Source: **http://www.orc.govt.nz/portal.asp?categoryid=53**

Additional information is available from NOAA (National Oceanic and Atmospheric Administration), including a map that portrays some of the significant events that have occurred around the world due to rapid global climate change over the past several decades.
Source**:** http://www.ncdc.noaa.gov/img/climate/research/2009/apr/extremes-200904.gif

References:

http://www.wrh.noaa.gov/fgz/science/drought.php?wfo=fgz
http://www.ncdc.noaa.gov/img/climate/research/2009/apr/extremes-200904.gif
http://epa.gov/climatechange/kids/bigdeal.html
http://www.cpc.ncep.noaa.gov/products/expert_assessment/drought_monitor.pdf

Activity Objectives

Students will learn what the greenhouse effect is and is not, how it functions, and how is it related to global climate change.

Supplies

- White board, chart paper, or butcher paper
- Markers
- Heat lamp

- 2 clear, plastic 2- liter bottles prepared according to Step A in "Directions for demonstrating the greenhouse effect" (below)
- 2 plastic containers of same size (e.g., cottage cheese or butter container)
- 2 thermometers
- Clear tape (e.g., packaging tape)
- Stopwatch or timer
- Graph paper, 1/4" grid or larger (1 sheet/student)

Procedures

1. Ask students what they know about the greenhouse effect. On white board, record student responses to address throughout the presentation. (Several common misconceptions are identified at the end of this activity and should be addressed during this demonstration.)
2. Demonstrate the greenhouse effect according to the directions provided.
3. Discuss the following questions as a group:
   a) *How does a greenhouse work? How is this concept related to Earth's atmosphere?*
   b) *How is the greenhouse effect on Earth related to global climate change?*
   c) *How is global climate change different from the depletion of the ozone layer?*

Directions for demonstrating the greenhouse effect

A. (Prepare Bottles A and B prior to class.) Cut off 2 inches from the bottom of each. Bottle A will be used as is - no slits or openings ("windows") and is demonstrating an actual greenhouse model. Make slits in Bottle B, running up and down the bottle and acting as "windows", demonstrating how the Earth's atmosphere works when an abundance of greenhouse gases are not present (e.g., before the industrial revolution).

B. Place each bottle inside a separate plastic container. Both bottles should have their lids on tightly.

C. Tape a thermometer to the outside of both bottle A and B with **clear** tape, placing them in the middle of the bottle.

D. Ask two students to record the measurements. (Explain that two people making observations lead to less bias - Nature of Science). Provide those two students with a stop watch.

E. Place both bottles under a heat lamp, making sure the light is equally distributed between both bottles and the thermometers are facing **away** from the heat lamp.

F. Student recorders should take an initial temperature reading and then additional readings every two minutes. Allow the bottles to sit undisturbed for about 20 minutes. Meanwhile, explain what you are setting up and briefly discuss the purpose of a greenhouse to the students. Distribute graph paper.

G. Continue with a brief discussion of how a greenhouse model is used to demonstrate the Greenhouse Effect on Earth. Discuss the questions (Procedures, #3) until the 20 minutes have elapsed.

H. Ask the two students to share their data with the class. Each student should copy the data to a graph with one axis representing elapsed time and the other representing the temperature recordings.
I. **Conclusions**: Students should see that in Bottle A (no windows- greenhouse model), the temperature increased much faster and is warmer than Bottle B (with windows - Earth's atmosphere without the buildup of greenhouse gases). The temperature in Bottle A will also retain the heat much longer than Bottle B. Discuss with students how this concept relates to global climate change.

Explanation:

For questions 3a and 3b: refer to Part 2 Background Information.

For question 3c: Global climate change and the depletion of the ozone are separate concerns. Depletion of the ozone (O) layer is mainly from the use of CFC's (chlorofluorocarbons) and other ozone-depleting substances (ODS). Most CFC's release bromine and chlorine when they break down in the stratosphere. Chlorine and bromine atoms break down the ozone layer that shields the Earth from harmful doses of UVB radiation. As the ozone layer continues to be depleted by the CFC's, the Earth receives stronger and more concentrated UVB radiation which can cause skin cancer, melt glaciers much faster, and reduce crop production.

Global climate change is a related environmental concern but is caused from the release of greenhouse gas molecules (e.g., CH_4, CO_2, N_2O, H_20). Greenhouse gases (GHG) are released into the atmosphere from the burning of fossil fuels, massive volcanic eruptions, and other natural processes. GHG molecules tend to trap heat inside the Earth's atmosphere instead of allowing them to pass freely into space, resulting in general warming of the Earth's surface (also known as global climate change). ***Do not refer to global climate change as "global warming**".

While a great deal of the literature explains this natural phenomenon using the term global warming, the Earth's temperatures and weather patterns are fluctuating and not always simply getting warmer. Students should recognize that the effects from the trapping of GHG's in Earth's atmosphere don't just increase temperatures, they also disrupt the *climate cycle* as a whole which disrupts climate and weather patterns globally.

Four examples of possible student misconceptions:

A. Climate change and the loss of the ozone layer are the same thing. [These are two different environmental issues with similar, but different, effects on Earth.]
B. Aerosol spray cans are a major contributor to climate change. [In the past, aerosol spray cans were a major contributor to ozone depletion, but that is not specifically related to current global climate change.]
C. Nuclear energy causes climate change. [Nuclear energy creates very little GHG emissions and is thus not a major contributor to climate change.]
D. Volcanoes are the major source of GHG emissions. [While volcanoes do produce an immense amount of GHG emissions, large volcanic eruptions occur so infrequently that they have very little effect on climate change today.]

Assessment

- Active participation in classroom discussion
- Graph of temperature versus time (from demonstration)

Tools of Climate Change Science

Essential question: How can science unlock "secrets" of the Earth's history?

Background

Scientific tools used for gathering evidence about climate change

Scientists use many different techniques and tools to gather the scientific data necessary to understand how and why the Earth's climate is changing so quickly. The most common tools that scientists use are ice cores, lake sediment cores, tree ring samples, and coral reef cores. These samples are used to help determine past environmental conditions of Earth's ecosystems and climates. This data is then compared to current day conditions to determine the climate changes that have occurred recently on Earth. These tools provide scientific evidence of past events such as temperatures on Earth, how much CO_2 was present in the atmosphere, and what types of plants lived in various ecosystems.

Ice cores contain an abundance of climate information. Evidence of past climates remains in the ice in the form of wind-blown dust, ash, pollen, bubbles of atmospheric gas, and radioactive substances. Ice cores are a very important tool in recreating past climates, also known as the study of paleoclimates.

Scientists Collecting Ice Cores

Source:
http://earthobservatory.nasa.gov/Features/GlobalWarming/Images/greenland_ice_core.jpg

Lake sediment cores provide the same information as ice cores but are based upon aquatic ecosystems. Lake sediment cores are taken from the deepest part of a lake to ensure that as much historic data is collected as possible.

Source: http://www.ucop.edu/sciencetoday/article/21580

Tree ring dating, known as **dendrochronology,** provides insight into past climates such as wildfires and lightning strikes, growing seasons and patterns, and drought cycles.

Tree Ring Sample

Source:
http://www.msstate.edu/dept/geosciences/CT/TIG/WEBSITES/LOCAL/Summer2003/Harman_Pamela/tree%20rings.JPG

Climate Science

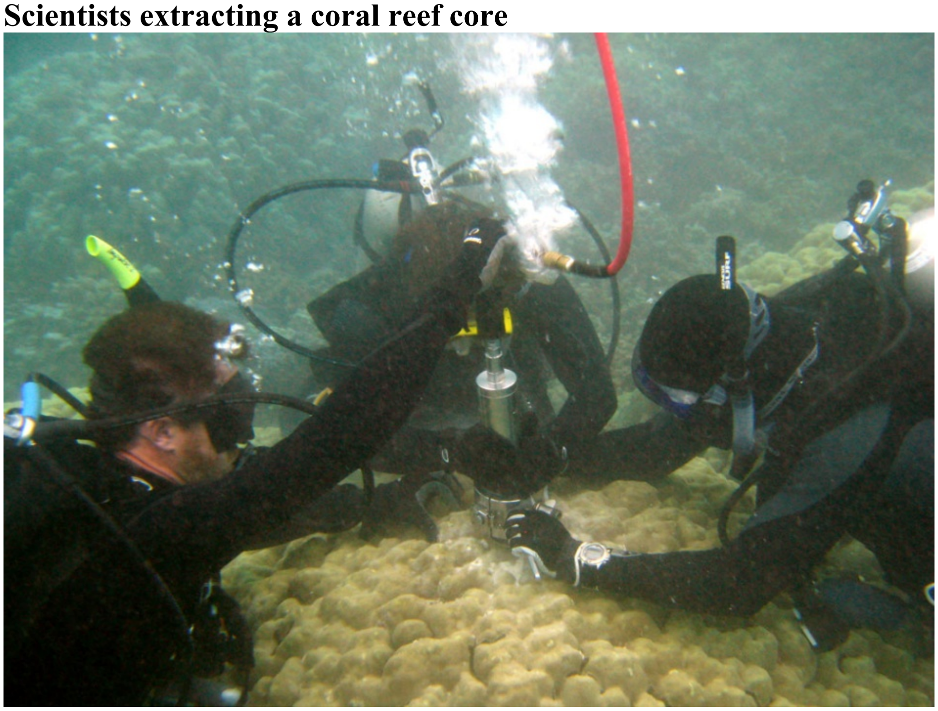
Dr. Michael Mann is a renowned climate scientist that has written over 100 peer-reviewed and edited publications, and well as a co-founder of REALCLIMATE.org. This educational website aims to inform the general public, journalists, and policy makers about the science of climate change. He is also the lead author on the "Observed Climate Variability and Change" chapter of the IPCC (Intergovernmental Panel on Climate Change) Third Scientific Assessment Report published in 2001. Dr. Mann is also a co-author of "Dire Predictions: Understanding Global Warming".

Mann M, Kump L (2008) *Dire Predictions: Understanding global warming,* DK Publishing, Inc., New York, New York.

Source: http://en.wikipedia.org/wiki/Michael_Mann_(scientist)

Coral reef cores are often used to determine past temperatures of the oceans, sea-level changes, salinity changes, and the overall ecosystem health of the oceans.

Scientists extracting a coral reef core



Source: http://soundwaves.usgs.gov/2008/01/MoDrillCoral0211LG.jpg

Coral Reef Cores

Source: http://www.marum.de/Binaries/Binary11323/PB020807.JPG

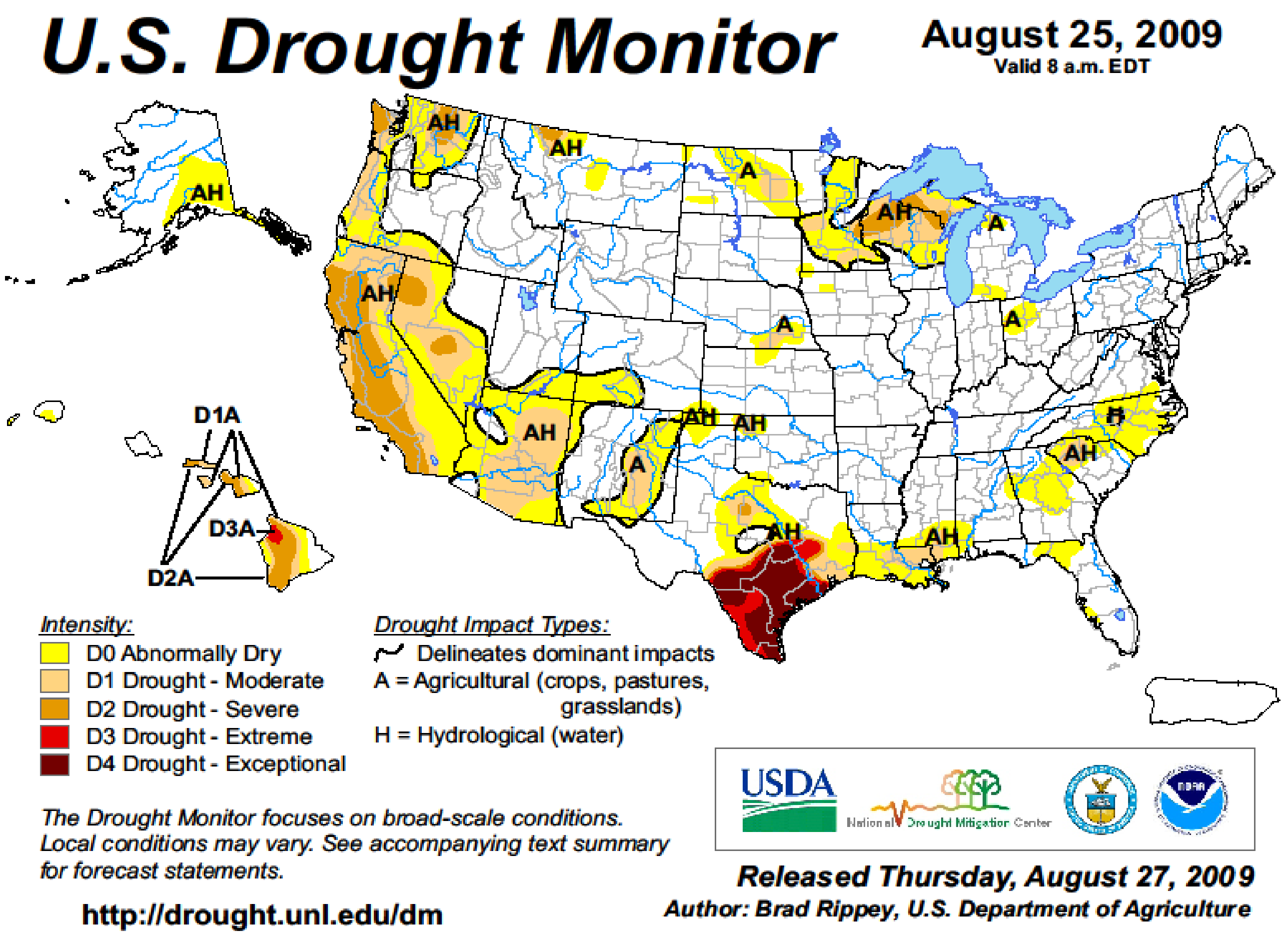
Paleoecology

Source: http://www.nau.edu/~envsci/faculty/ScottAnderson/index.htm

Dr. Scott Anderson is currently an associate professor at Northern Arizona University. His research focuses primarily on paleoecology (the study of ancient environments). He uses lake sediment cores, pollen samples, and tree ring samples to gather data to reconstruct ancient climates. This is extremely helpful information when trying to predict current and future climate change events and effects. Dr. Anderson's most frequent research in conducted in Arizona, the Rocky Mountain region, Spain, Alaska, Argentina, and California.
http://www.nau.edu/~envsci/faculty/ScottAnderson/index.htm

Global Positioning Systems (GPS)

GPS is regularly used to provide maps and other visuals necessary for monitoring and predicting both present-day and future weather and climate events.



Source: http://www.cpc.ncep.noaa.gov/products/expert_assessment/drought_monitor.pdf

Activity Objectives

Students will learn about various tools scientists use to learn about climate change and its implications.

Supplies

- Paper plates (1/student)
- Pencils
- Diagram, picture, or sample of tree rings (also known as "tree cookies")
- Computer with access to Internet (optional but recommended)

Procedures

1. Show students the ice core model and pictures of other tools (or show pictures on LCD projector). Discuss:
   - *How do scientists use these tools?*
   - *What information might they provide for us?*
2. Rings of Life Activity: Introduction to dendrochronology. Briefly discuss:
   - *What is dendrochronology?*
   - *How do scientists use it to determine the age and history of a tree? (Provide diagram and short descriptions of tree rings.)*
3. Give students a paper plate and ask them to draw their lives as a tree. Have them draw rings that represent each year of their life. If they grew a lot in one year, the ring should be wider. Have them put in "scars" or narrower rings for times when things were difficult for them.
4. Ask students to write a summary describing their own life as if they were a tree.
5. Discuss the following questions as a group:
   - *What do different ring widths and color shades tell us about the tree's life or local environmental conditions?*
   - *What is a fire scar?*
   - *What can dendrochronology and other scientific tools tell us about past environmental conditions (e.g., paleoecology: the study of ancient environments)?*
   - *How do these tools collectively provide evidence about Earth's changing climate?*

Explanation: *Dendrochronology* is the study of tree rings. Lake sediment cores, glacial cores, coral reef cores all form in layers (either seasonal or annual) like tree rings. Therefore, by analyzing different layers that developed over time we are able to infer climatic and environmental conditions of the local area. (Refer to background information and website provided earlier in this section for more information.)

Arizona students might also be interested in reviewing the information found at the University of Arizona's "Tree Ring Lab" at http://ltrr.arizona.edu/

Final Assessment

Essential question: What might a concept map tell us about our understanding of climate change?

Objectives
Students will have an opportunity to ask questions, make additions and corrections to their concept map initiated during the "What is Climate Change Science?" lesson.

Supplies
- 11 x 17" sheets of paper
- Markers/colored pencils

Procedures
1. Ask each student to revisit his/her own climate change concept maps. If this was done as a class, launch a classroom discussion on what has been learned, and what needs to be corrected or clarified. (HINT: Use a different colored marker from the one used originally, to highlight key areas of learning.)
2. Clarify any misconception (identified throughout these studies) with the class if there are still unresolved questions.
3. Compare earlier concept map with this one. Discuss what students have learned about climate science.

Assessment
- Concept maps indicate a basic level of understanding of climate change science
- Significant learning indicated by comparison between pre- and post-maps.

Arizona Academic Standards

Science
Grades 6-8
- S1C1PO1 (M07-S2C1-01): Observations, Questions and Hypotheses
- S1C3PO1, PO2 & PO5 (grade 6 MO6S2C1-2; grade 7/8 MO6S2C1-8): Analysis and conclusions
- S1C3PO6, PO7 & PO8: Formulate new questions based on results of a completed investigation.
- S1C4PO5: Communication
- S4C3PO1-PO6: Populations of Organisms in an Ecosystem (grade 7)
- S4C4PO1-PO6: Diversity, Adaptation and Behavior (grade 8)

Social Studies
Grades 6-8

- S4C1PO1, PO3: The World in Spatial Terms
- S4C5PO1: Environment and Society (grade 7)
- S4C6PO2 and PO3: Geographic Applications
- S2C9PO1: Contemporary World

Reading
Grades 7 – 8

- S1C6PO7: Using reading strategies to interpret text
- S3C1PO8: Interpret graphic features of expository text
- S3C1PO10: Make relevant inferences about expository text, supported by text evidence

Writing
Grades 7 – 8

- S3C2PO1: Record information related to the topic
- S3C2PO2: Write a summary based on the information gathered

Math
Awaiting publication of AZ Common Core

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

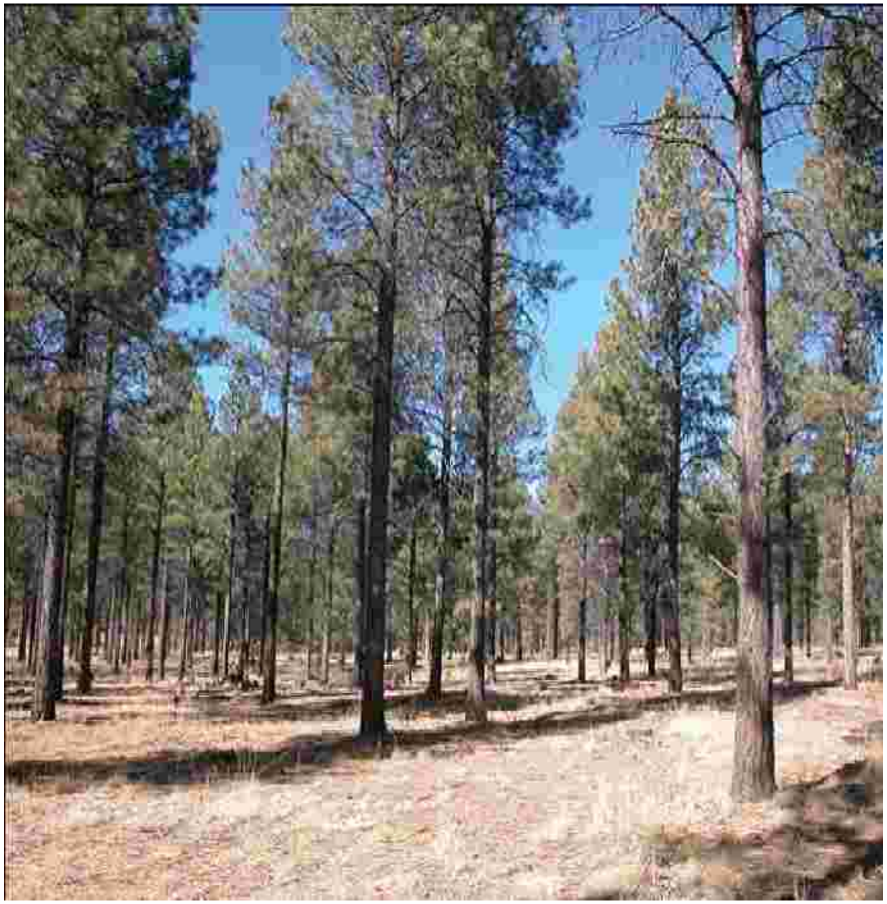


Photo 6

Photo 7

Photo 8

Photo 9

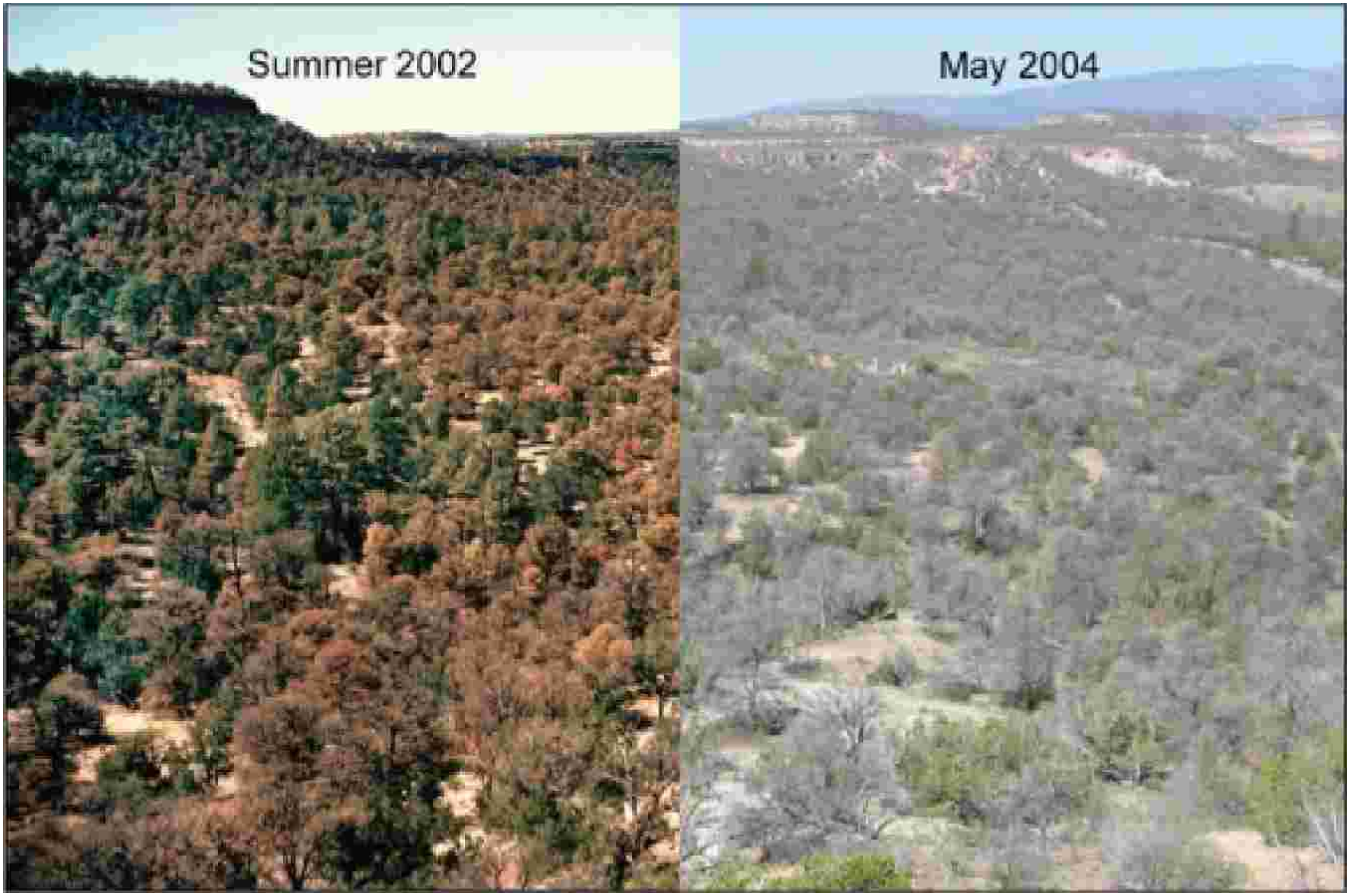
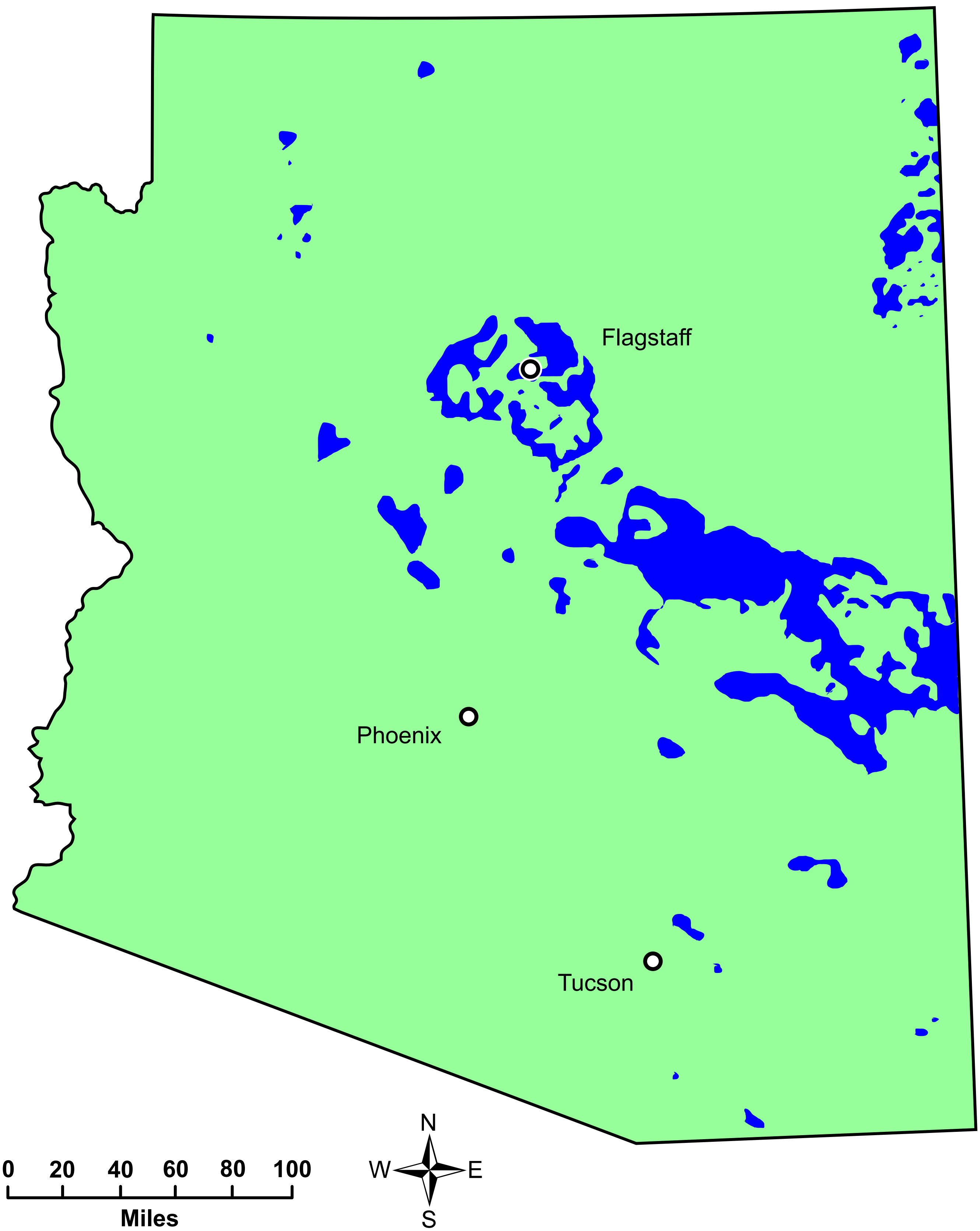


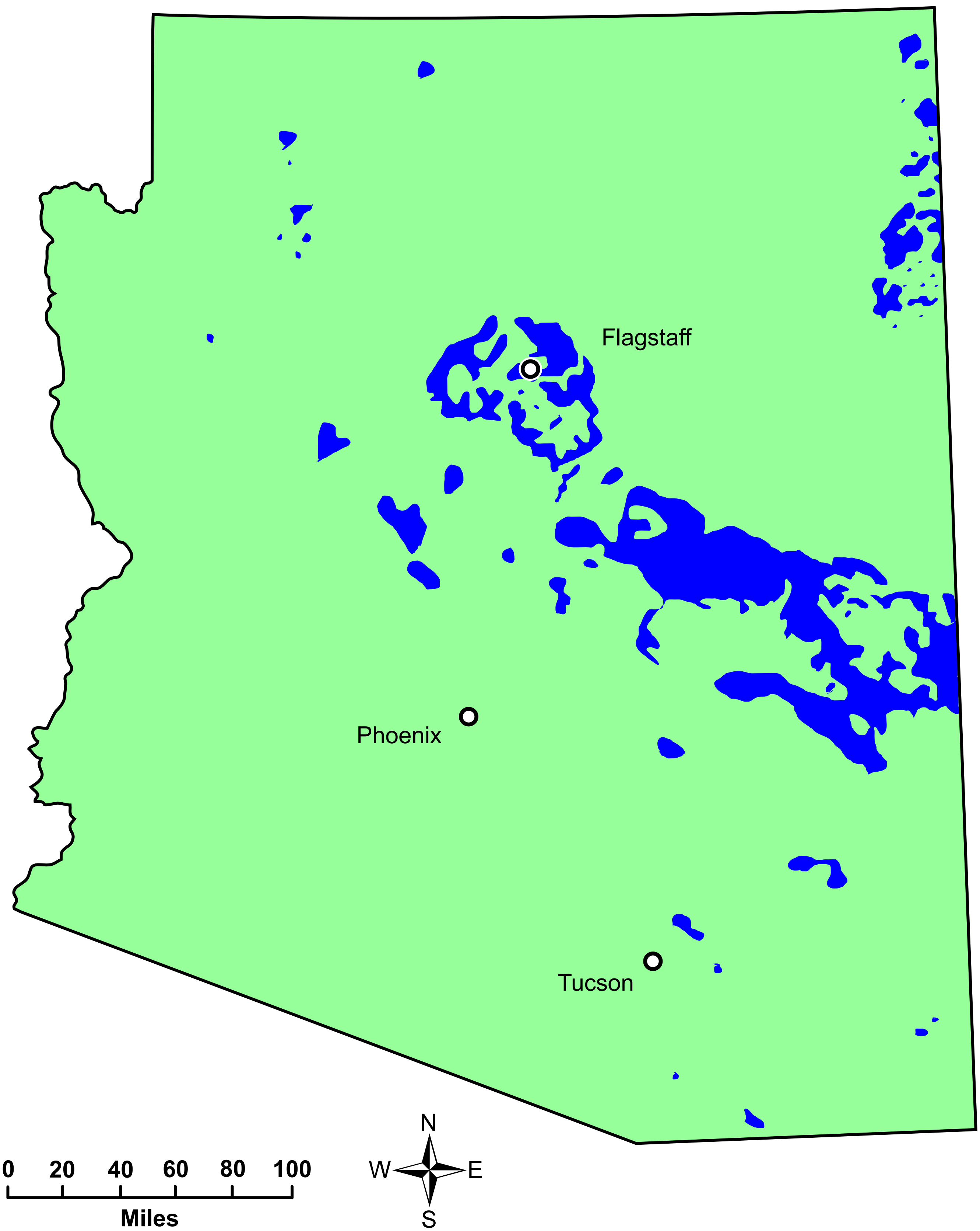
Photo 10

Forest Area Affected by Bark Beetles, 2002



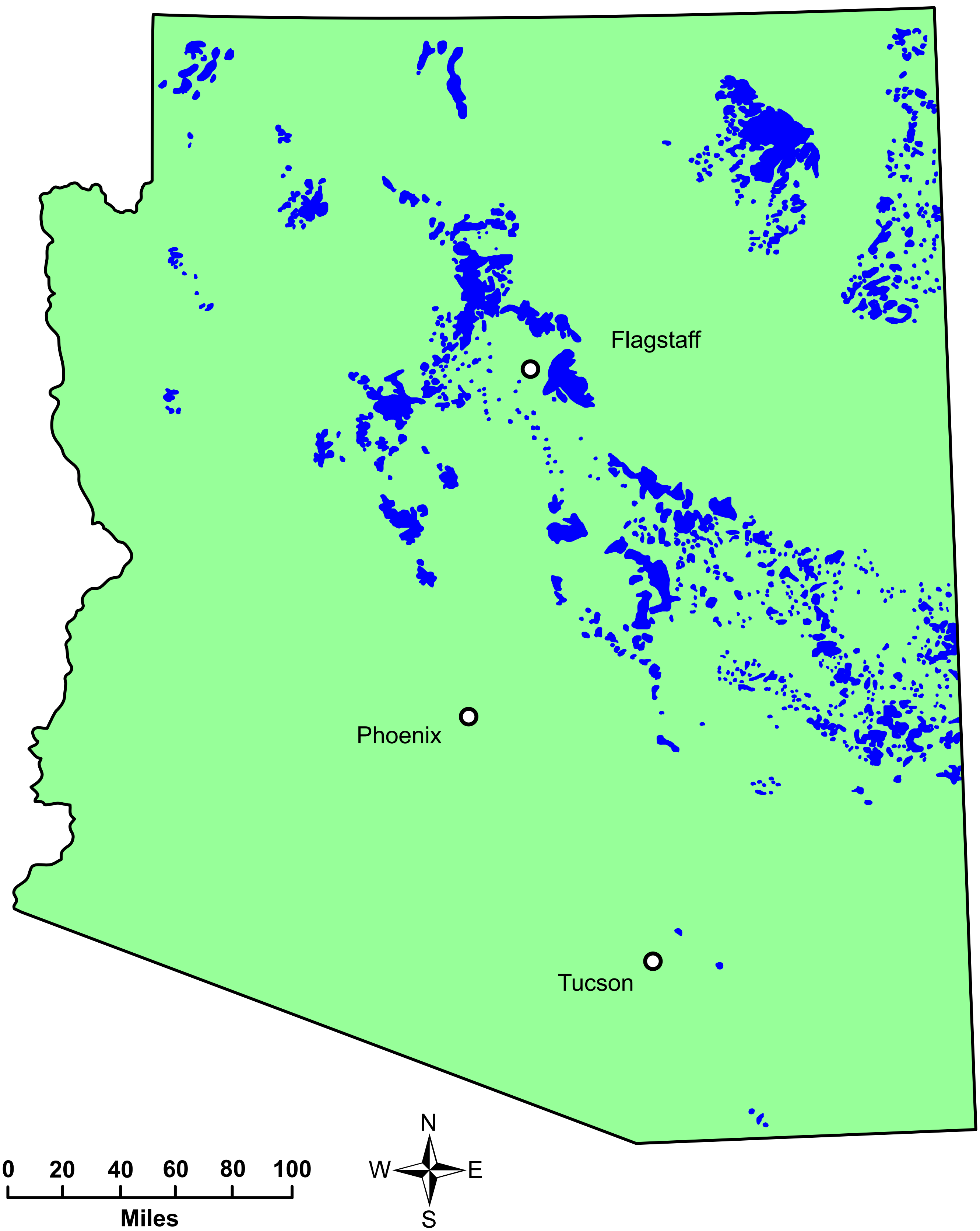
2002

Forest Area Affected by Bark Beetles, 2002

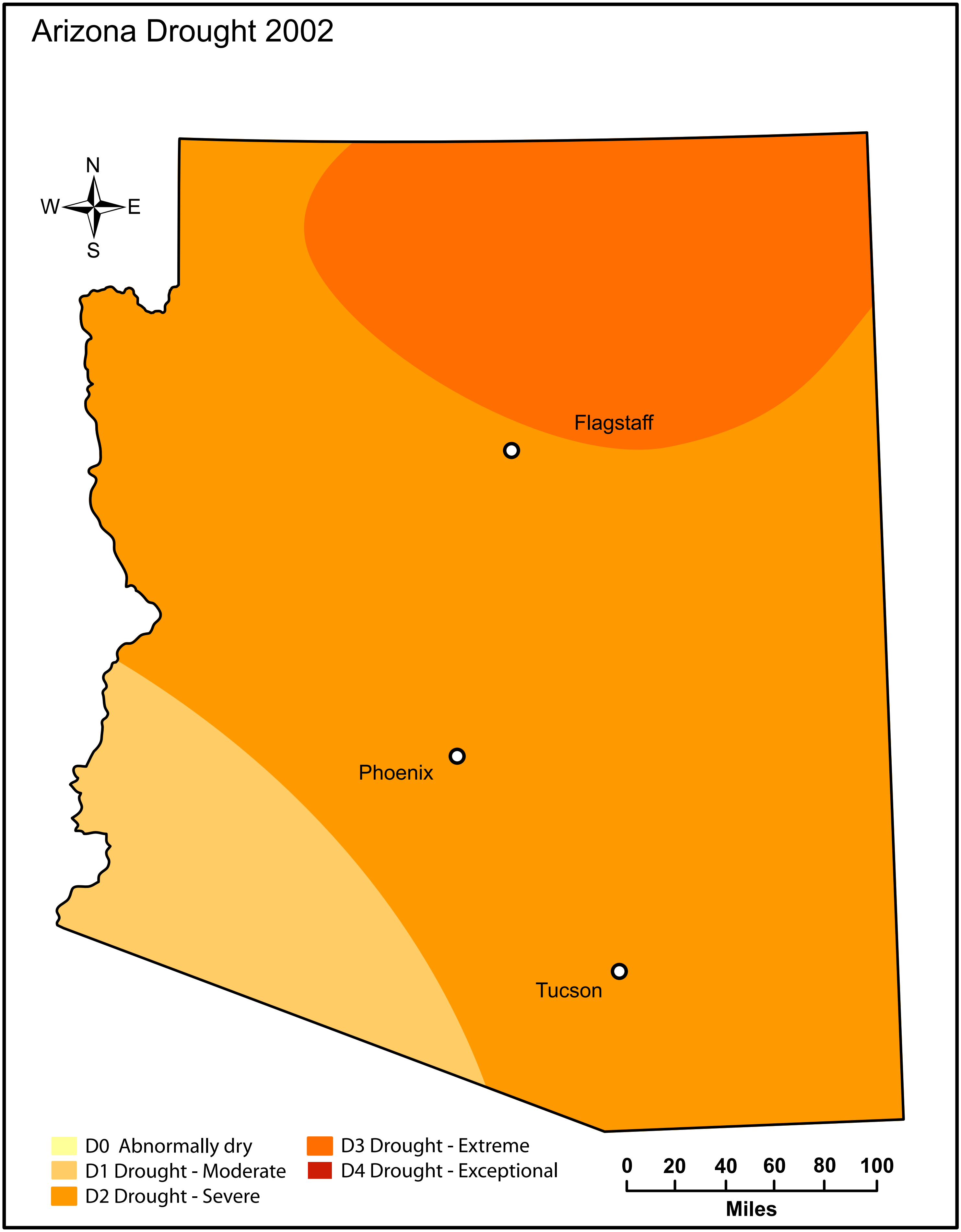


2002

Forest Area Affected by Bark Beetles, 2003



2003



Arizona Drought 2002
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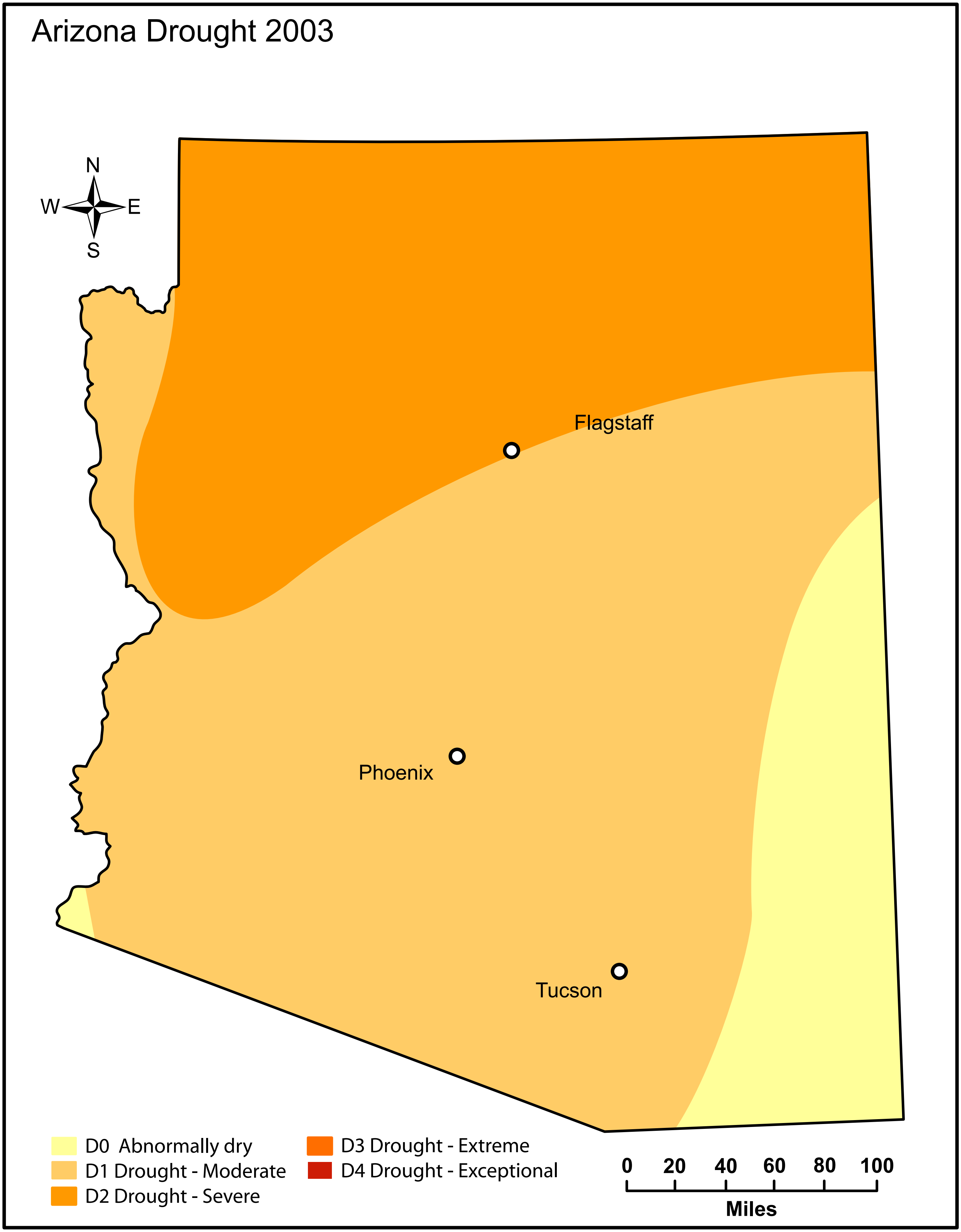
E
S
Flagstaff
Phoenix
Tucson
D0 Abnormally dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
0 20 40 60 80 100
Miles

2002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D0 Abnormally dry
D1 Drought - Moderate
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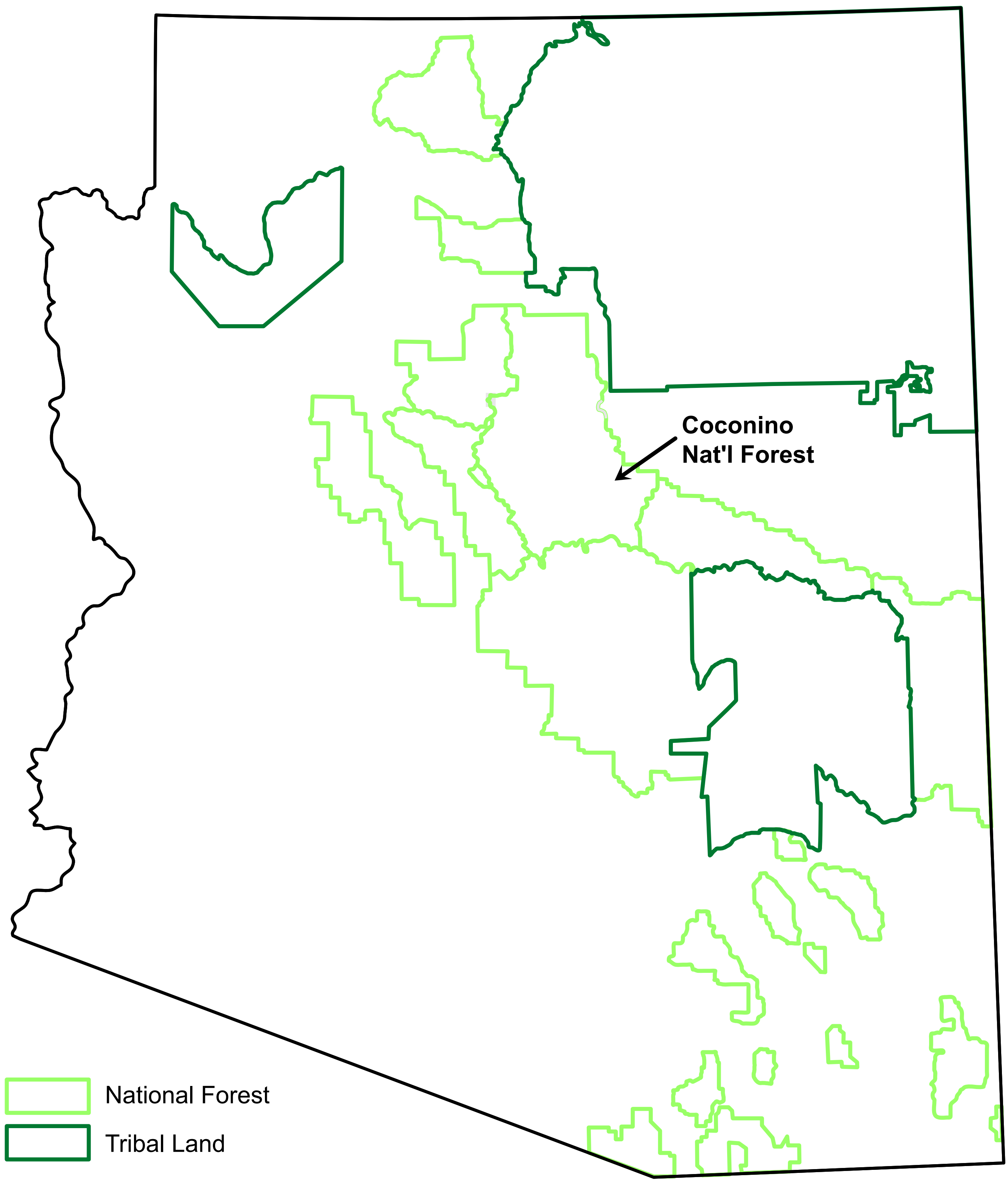
D3 Drought - Extreme
D4 Drought - Exceptional
0 20 40 60 80 100
Miles

2003

Forest Boundaries



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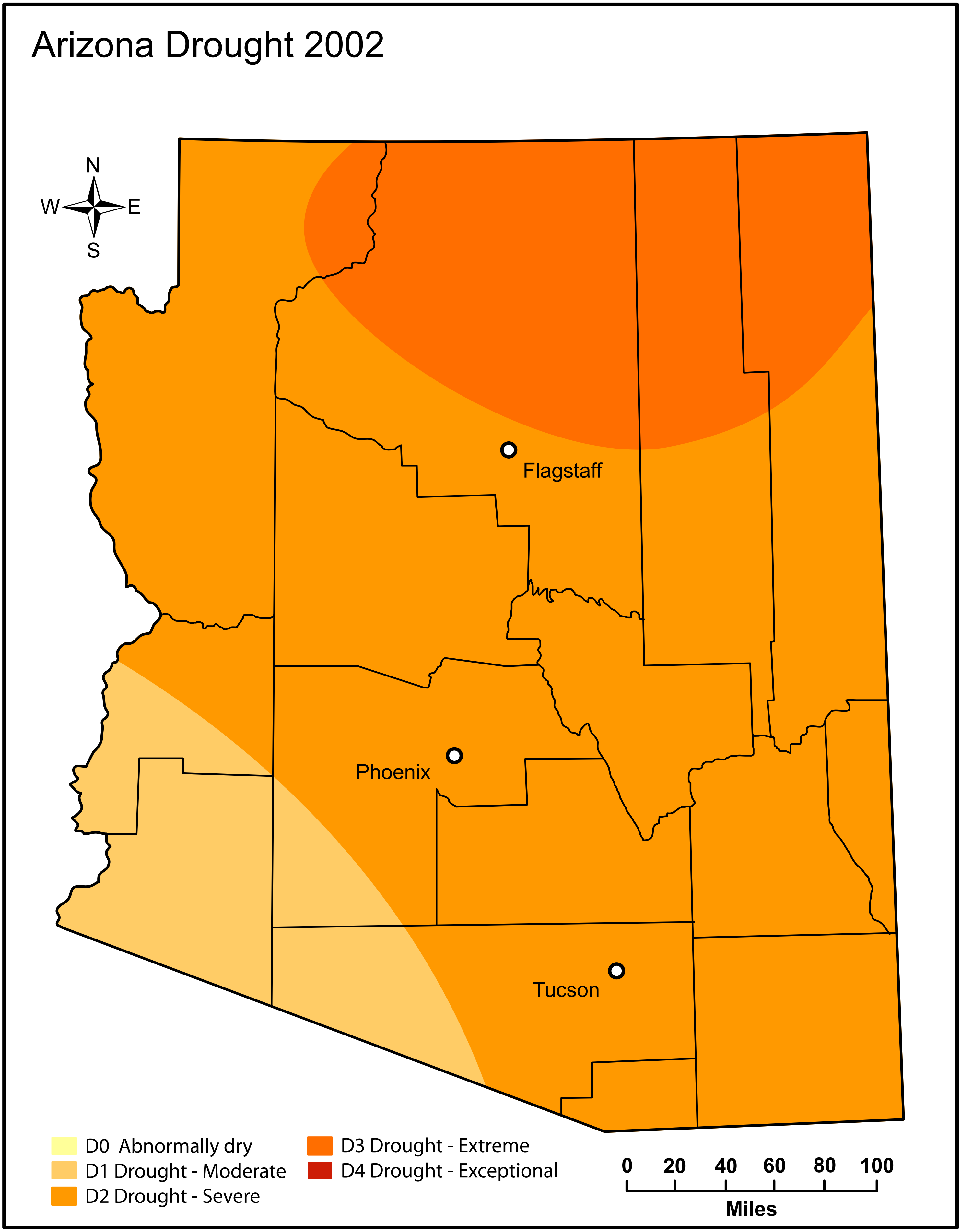

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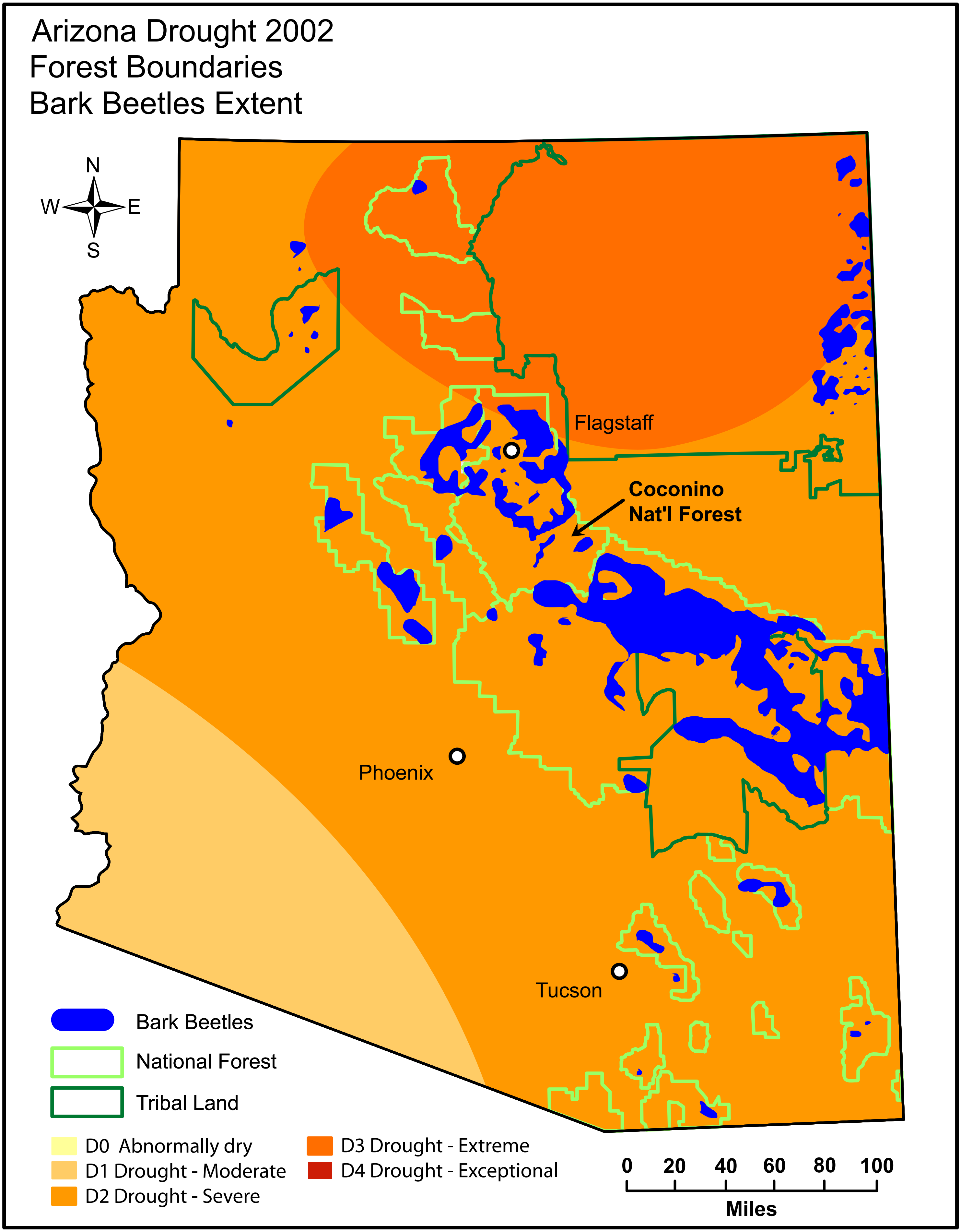
Arizona Drought 2002
Forest Boundaries
Bark Beetles Extent
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Coconino
Nat'l Forest
Phoenix
Tucson
Bark Beetles
National Forest
Tribal Land
D0 Abnormally dry
D1 Drought - Moderate
D2 Drought - Severe
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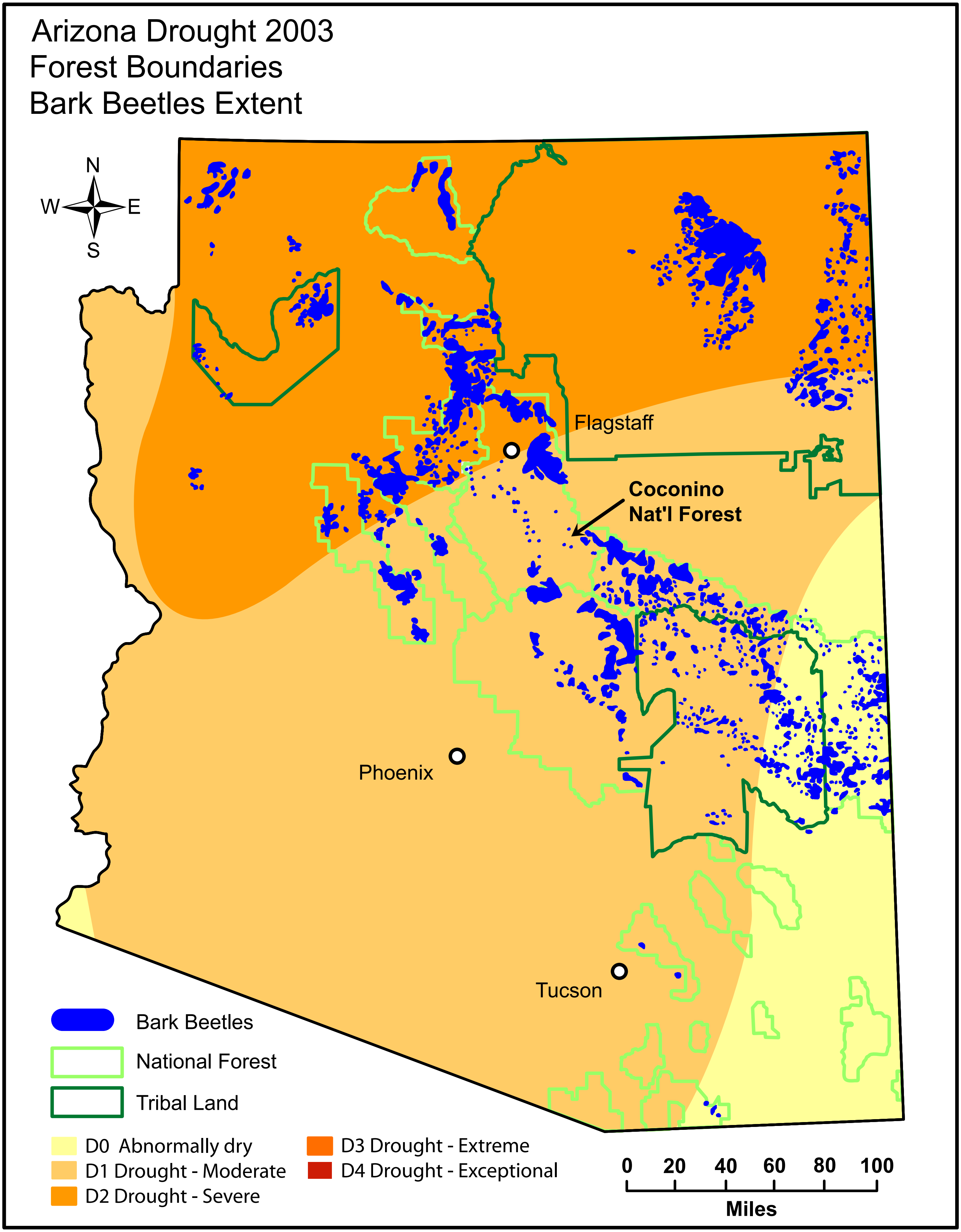
D4 Drought - Exceptional
0 20 40 60 80 100
Miles

2002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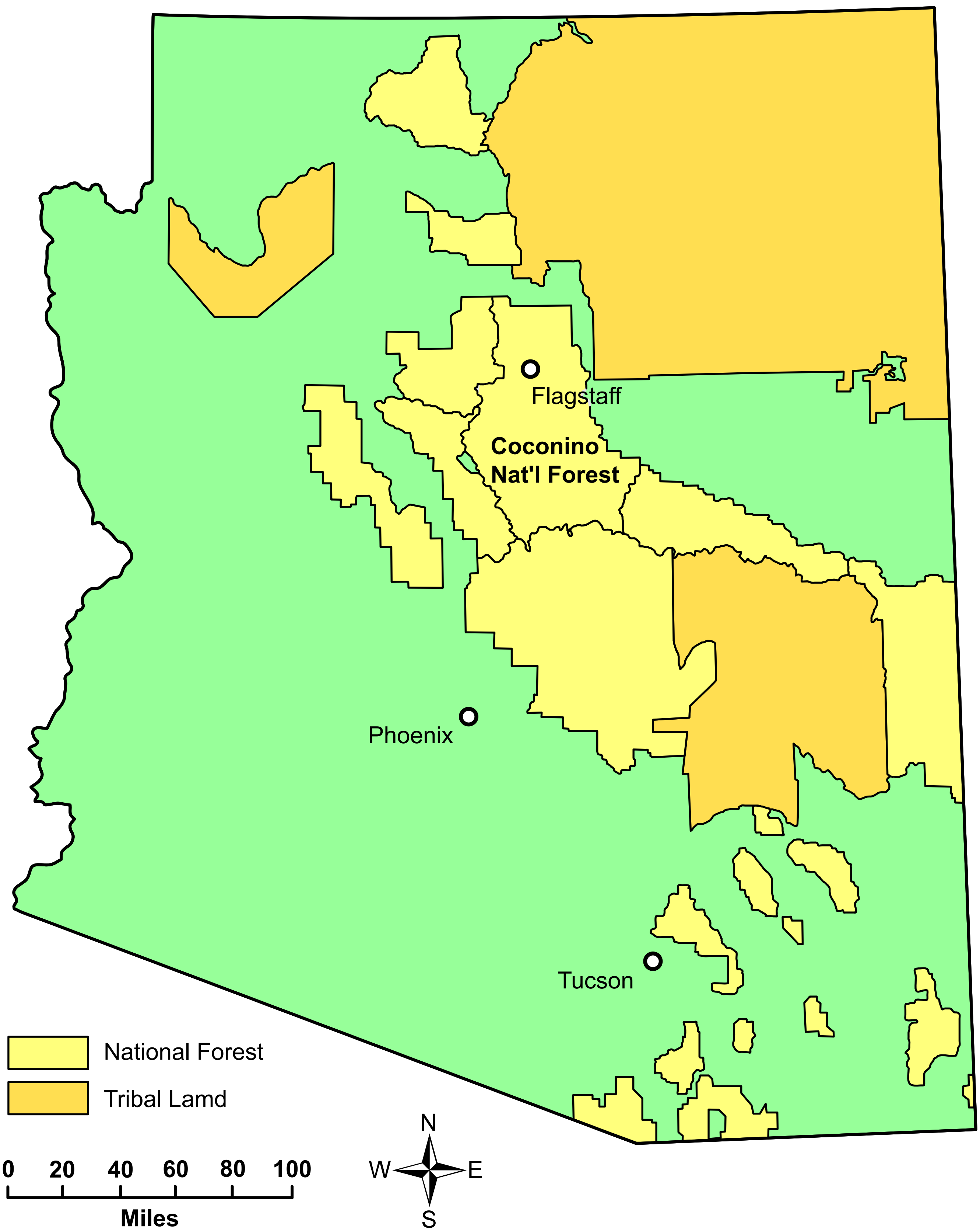
D3 Drought - Extreme
D4 Drought - Exceptional
0 20 40 60 80 100
Miles

2003

National Forest and Forested Tribal Land in Arizona



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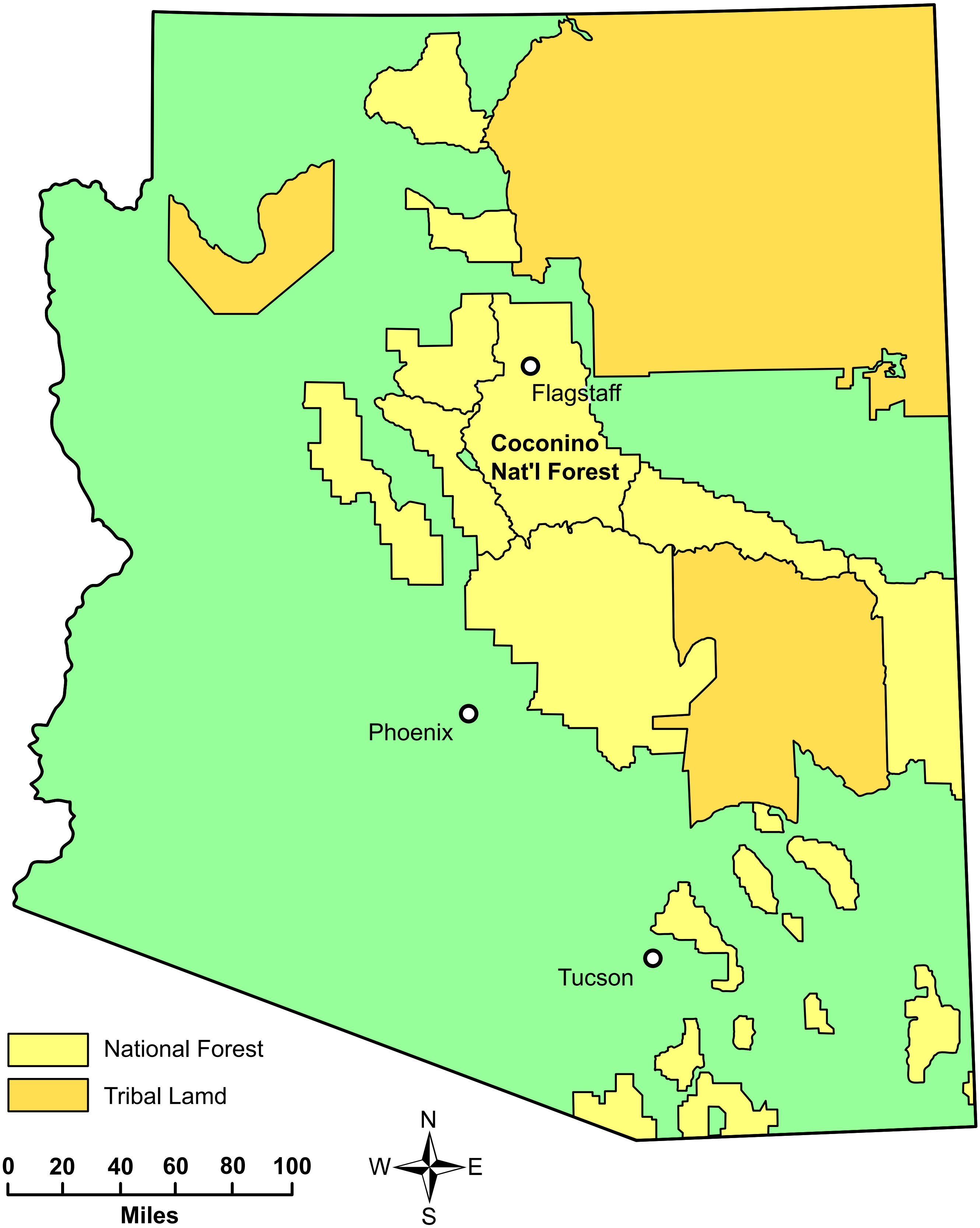
National Forest and Forested Tribal Land in Arizona



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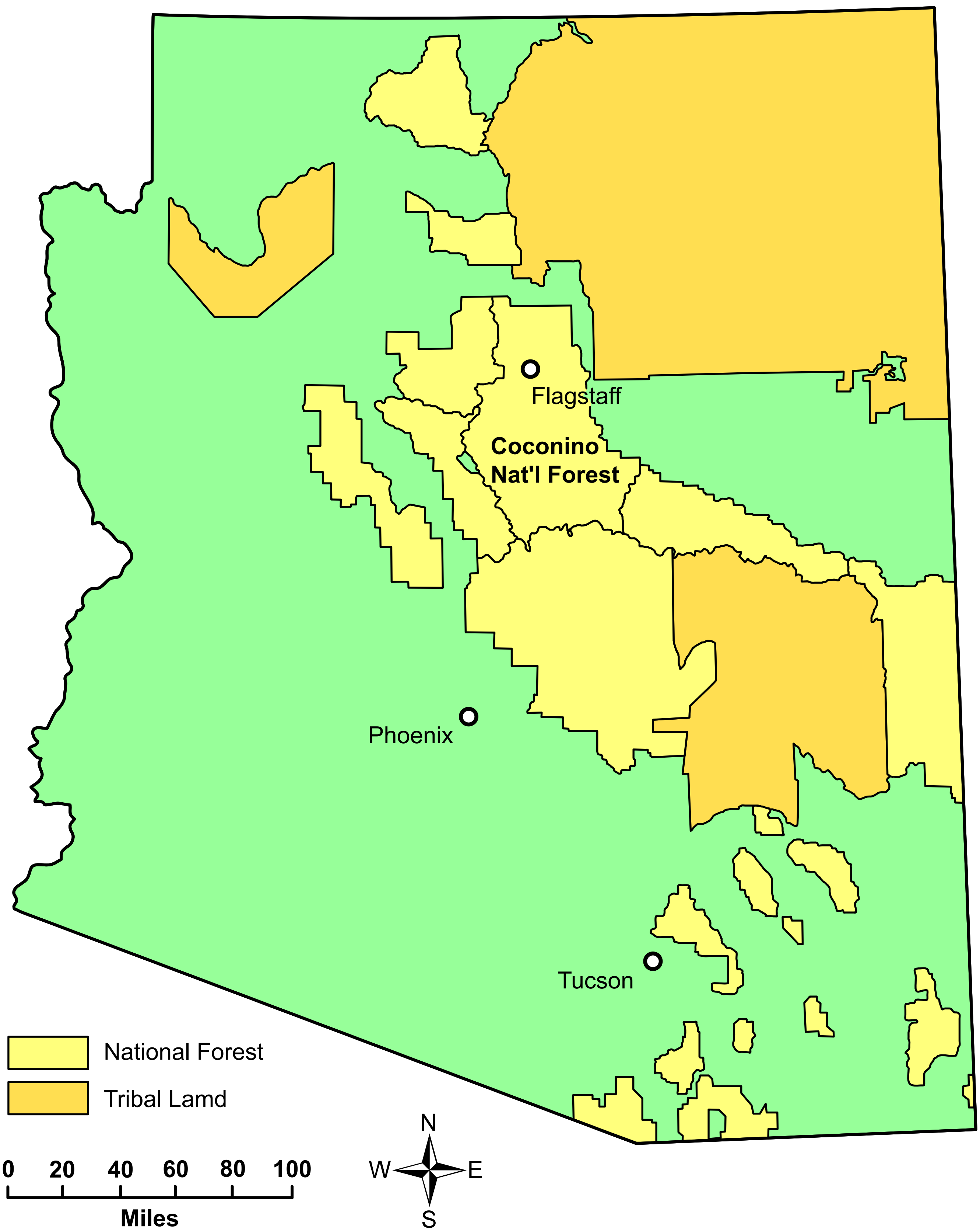
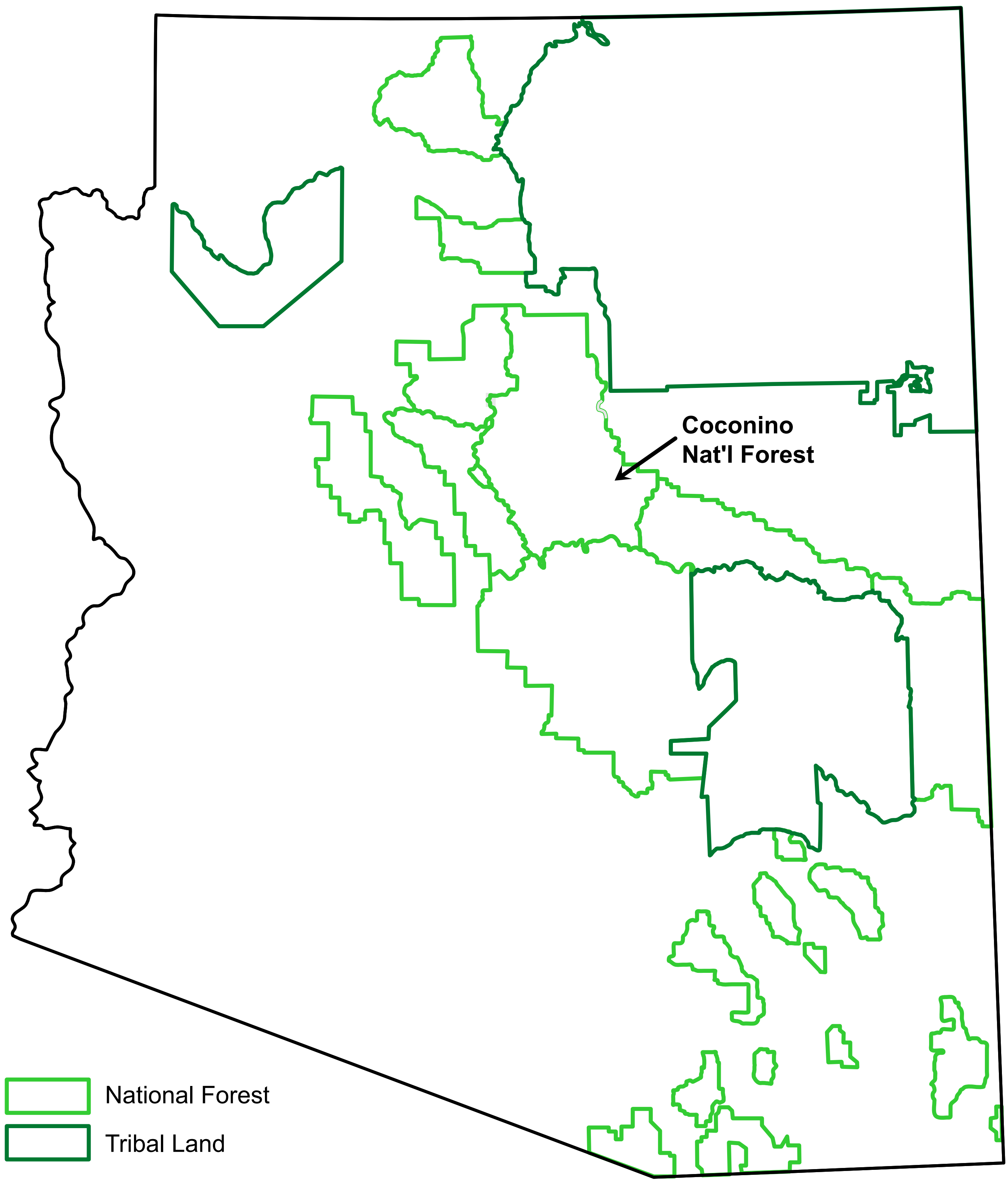
National Forest and Forested Tribal Land in Arizona



2003

Forest Boundaries



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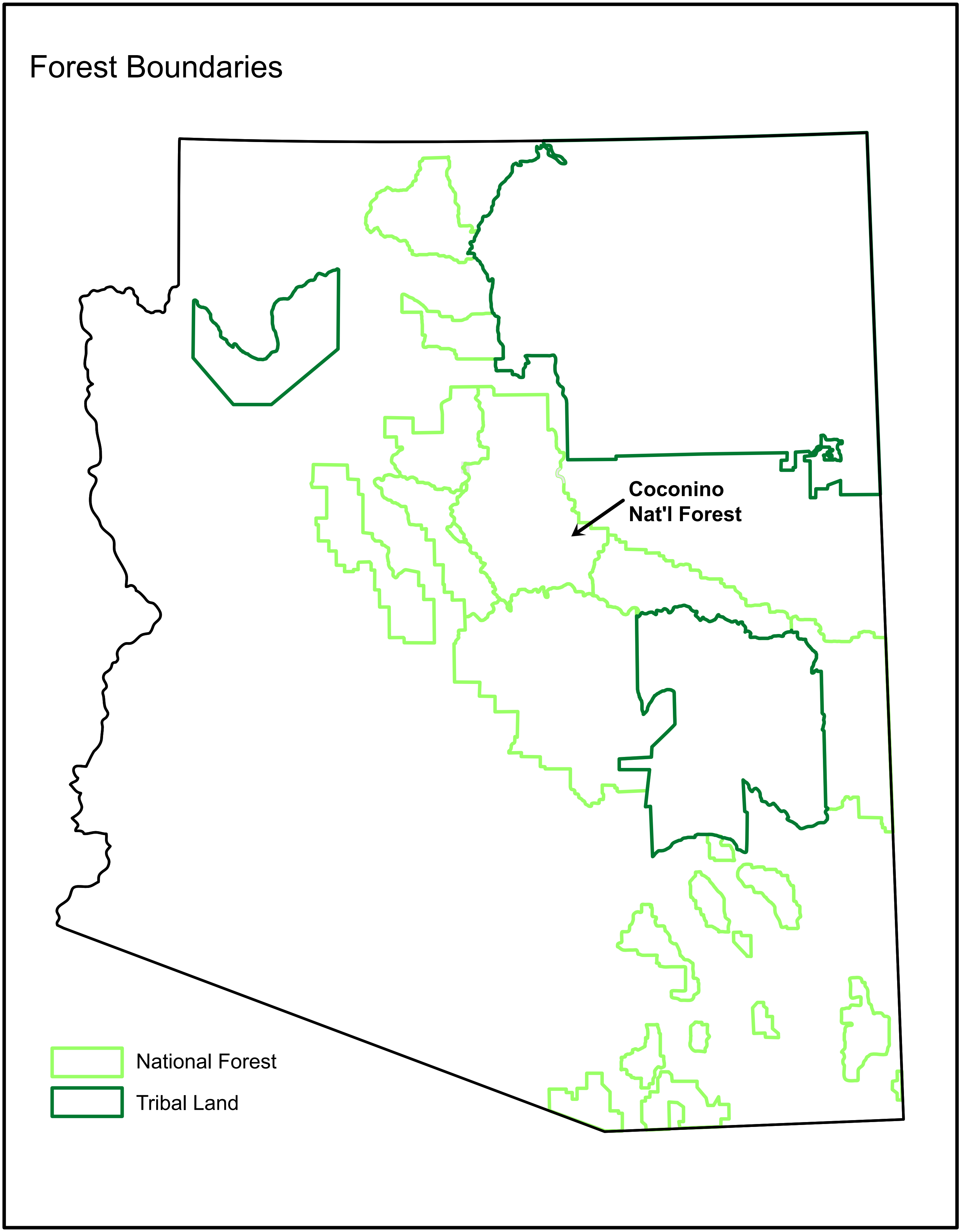
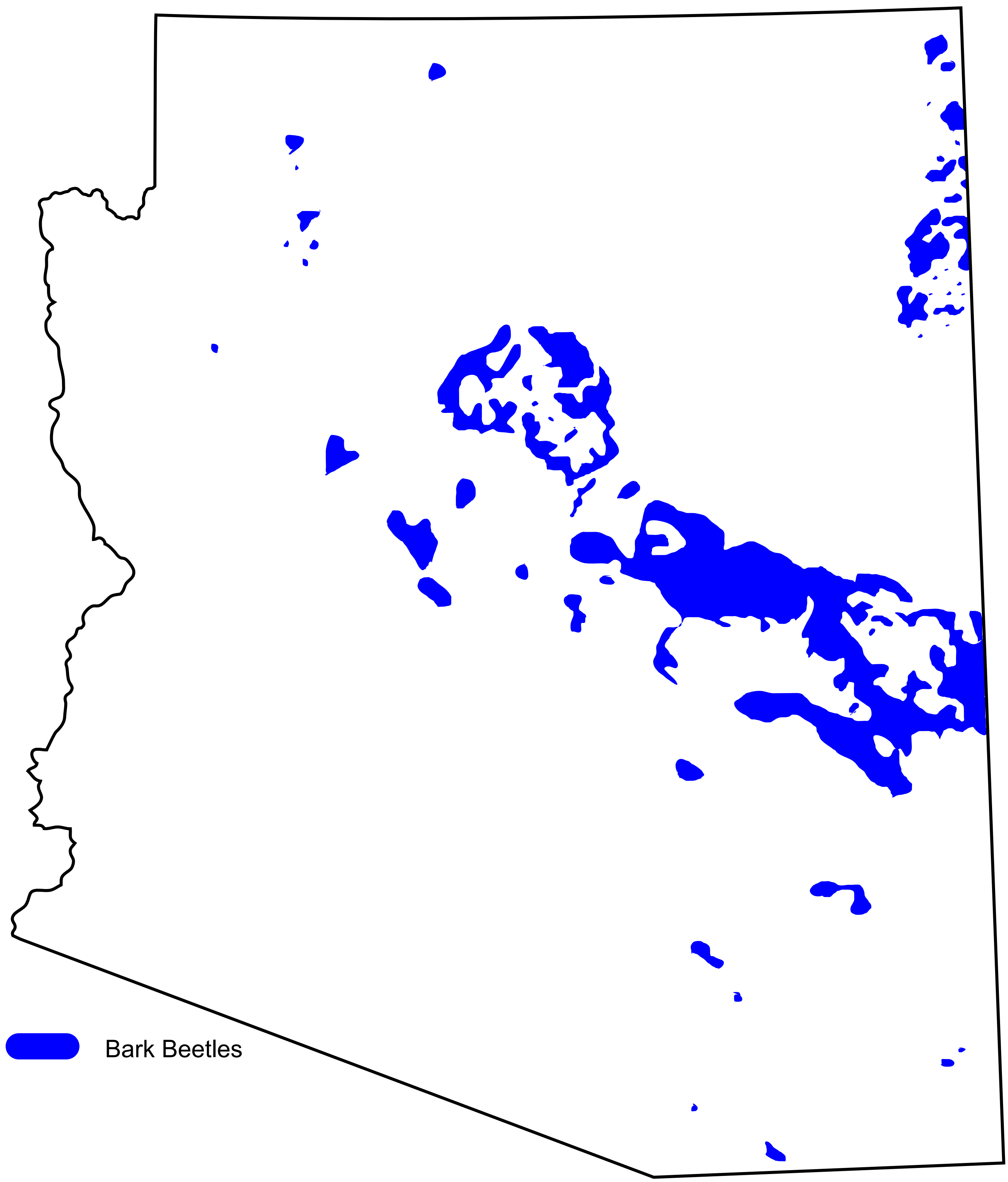


Forest Boundaries
Coconino
Nat'l Forest
National Forest
Tribal Land

2003

Bark Beetles Extent



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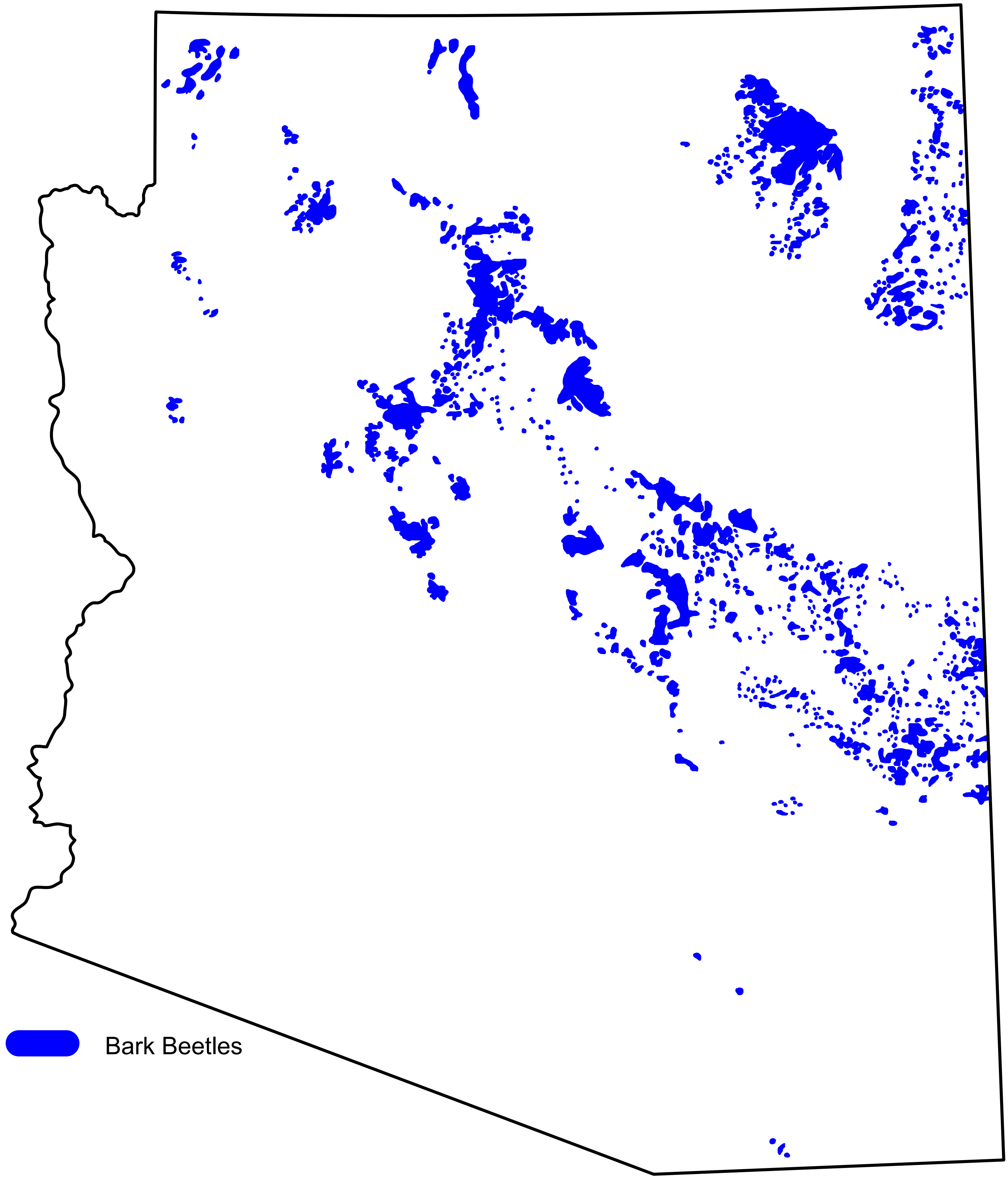
Bark Beetles Extent



2003

Bark Beetles in Arizona: Clues to Climate Change?

Classroom Unit for Grades 6-8

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Sponsored locally by intel

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Special Thanks
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Contech, Inc. for use of beetle image

Resources Used in the Development of this Unit

- Arizona Department of Water Resources - Drought Program, Arizona Drought Reports http://www.azwater.gov/dwr/Drought/DroughtStatus.html or http://www.azwater.gov/AzDWR/Statewideplanning/Drought/documents/aprildroughtstatusupdate.pdf
- Arizona Forest Health publication of the Arizona Cooperative Extension, University of Arizona http://ag.arizona.edu/extension/fh/pubs.html
- Forest Insects and Disease Conditions in Southwest Region, 2007, USDA http://www.fs.fed.us/r3/publications/documents/fidc2007.pdf
- Hereford, Richard, "Climate History of Flagstaff, Arizona 1950-2005" USGS www.mpcer.nau.edu/files/flagstaff_climate_history.pdf
- Schalau, Jeff, "Ponderosa Pine Bark Beetles in the Prescott Area". University of Arizona Cooperative Extension Yavapai County, 2003 http://ag.arizona.edu/yavapai/anr/fh/PrescottBarkBeetles.pdf
- U.S. Drought Monitor – current and historical drought conditions in the American Southwest http://drought.unl.edu/dm/DM_west.htm

Table of Contents

Introduction and Background

What are bark beetles and what is their role within an ecosystem?

Bark beetles are a normal and vital part of the forested ecosystem throughout much of Arizona. During normal weather patterns, these beetles play a critical role in nutrient cycling as they kill weak and damaged trees. The Pinyon Ips (*Ips Confusus*) beetle, which belongs to a group of beetles known as “engraver” beetles, is the focus of this unit.

Why are forest managers concerned with bark beetles in Arizona?

When weather patterns change, as in the case of prolonged drought, beetle populations can grow to epidemic levels. Severe drought in the Southwest has created a prime opportunity for beetles to infest trees already struggling for sunlight and adequate moisture. Once this occurs, these beetles can become one of the most destructive insects in our coniferous forests.

The Pinyon Ips bark beetle chooses an older tree and builds an egg gallery under the bark in the tree’s living tissue. While creating the gallery and laying the eggs, the beetle also spreads blue stain fungi. This fungus weakens the tree and makes it harder to produce sap, used as a defense mechanism against insects and other *pathogens*. Depending on the overall health of the forest, trees that are attacked usually die within one year.

When the natural balance of an ecosystem is disrupted due to either natural causes or *anthropogenic* (manmade) influence, bark beetle populations tend to increase dramatically within a very short period of time. This often results in bark beetle outbreaks or *infestations*. Examining the life cycle and role of the bark beetle in the ecosystem helps explain how an *epidemic* population (a temporary increase in the population) destroys trees in the forest. Large numbers of dead trees contribute to other forest management issues such as forest fires.

How might students relate to this issue?

Many students enjoy outings to the forest regions of Arizona for activities such as camping, skiing, fishing and other recreational activities. The startling images of a dying forest can lead to many questions. However, this also presents a unique opportunity to address a real-world problem, engage students in inquiry, and help them understand the diverse interrelationships and interdependencies within the natural world.

What does this unit address?

This unit is based on a hypothetical scenario of a middle school student selected from her class to participate in a two-week Student Ranger program in the Coconino National Forest near Flagstaff. Lessons include emails, photographs, real data, and the opportunity for students to practice their skills of interpretation, analysis, and prediction. As the adventure unfolds, students discover the relationship between forest health, temperature and precipitation changes, and bark beetle infestation.

While the focus of this unit is on bark beetles in Arizona forests, it is important to keep in mind that climatic changes play a part in the biotic activities and relationships on Earth. The climatic element most recently mentioned is the change in the Earth’s average temperature, which has increased approximately 1° F since 1880. Although the Earth has undergone warming and cooling trends for millions of years, the immediate concern is how quickly these temperature changes are happening and the corresponding challenges to many organisms whose very survival depends upon their ability to adapt to changing conditions.

What background information would be helpful?

One area greatly impacted by temperature change is the national forest surrounding Flagstaff, which we have selected as the basis of our study. Climate data used in this unit was collected about 5 miles south of Flagstaff at the Pulliam Field weather station. (Source: *Climate History of Flagstaff, AZ – 1950-2007*, by Richard Hereford, USGS).

Using this report, the following is important to know:

1. The city of Flagstaff is becoming warmer and drier each year. Estimated average temperatures in Flagstaff have risen 2.3° F since 1970.
2. The annual precipitation has been below average since 1996, giving rise to an ongoing drought since that time. (Note Hereford reference below.)
3. Even though more precipitation falls in the form of rain during the summer, winter moisture plays a more critical role in the overall health of the forest.
4. Because of the decrease in winter precipitation, the Ponderosa Pine forest in the Flagstaff area is stressed.

When the perfect combination of stressed trees (mainly due to drought), overall increasing temperatures across the state (not cold enough to reduce the beetle population during the winter months), and the increasing level of competition (for water and sunlight) among trees in dense Ponderosa Pine forests come together, severe bark beetle outbreaks are much more likely to occur.

In this investigation, students explore why beetle bark infestations occurred during the years 2002 and 2003 and use their research findings to predict future infestations.

By the end of this unit, students should be able to:

- Explain the difference between weather and climate (lesson 1)
- Identify characteristics of a healthy forest (lesson 2)
- Explain the life cycle of a bark beetle (lesson 3)
- Identify interrelationships within a forest ecosystem (lesson 3)
- Correlate prior knowledge with real-world scenarios to address a forest management challenge (lesson 3)
- Interpret precipitation and temperature data using graphs and charts (lesson 4)
- Correlate bark beetle infestation with historic temperature and precipitation data (lesson 4)
- Draw conclusions using maps of infested areas in Arizona (lesson 4)
- Predict future bark beetle outbreaks based on historic and current data (lesson 4)
- Create a visual representation that depicts interaction between trees and other elements of a forested ecosystem (lesson 5)
- Create a concept map showing interaction between trees and other elements of a forested ecosystem (lesson 5)
- Apply scientific protocol to participate as a citizen scientist to gather and report data into a national network (lesson 6)

Overview of Lessons and Procedures

Essential Question: How Do We Maintain Healthy Forests, Decimated by Bark Beetles, in the Face of a Changing Climate?

Bark beetles and forest health in Arizona offer a perfect opportunity to introduce students to a real-world challenge faced by resource managers. Students should be able to complete these activities with little or no prior knowledge, but they will need a basic understanding of **climate** and **weather** (explored in Lesson One). Through an inquiry-based approach, students begin to understand the interrelationships among climate, forest health, and bark beetles. Ultimately, students will identify how data collected on just one species (Pinyon Ips) can provide evidence of the impact of climate change upon an ecosystem familiar to most.

Each lesson opens with an essential question (EQ) to help guide inquiry and classroom discussions.

Prior to launching this unit, teachers may find it helpful to review background information in the accompanying Climate Change Basics, using activities recommended to help students fill in potential gaps in their knowledge of earth's systems and processes.

Included with this unit

- Lessons plans for each day
- Arizona Academic Standards alignment
- Rubric to assess final project
- All graphic organizers and accompanying handouts necessary for each lesson

Lesson-specific resources

- Photographs of forests
- Student handouts
    - Weather and Climate Data Sheet
    - Healthy Forests – Why Do We Care?
    - Bark Beetle Fact Sheet
    - Beetle Life Cycle
    - Elements of an Ecosystem
    - Scenario cards
    - Precipitation Committee: student directions and data
    - Temperature Committee: student directions and data
    - Map Committee: student directions, and maps (precipitation, temperature, bark beetle outbreaks)

Resource guide

Climate Change Basics: Middle School Teacher's Guide to Accompany Bark Beetles in Arizona: Clues To Climate Change? is available in a separate document.

Unit Outline At-A-Glance		
Lesson	**Essential Questions**	**Objectives**
Lesson 1: Are *weather* and *climate* the same thing?	What is the difference between weather and climate? How can I determine the weather and the climate of my community?	Understand the difference between weather and climate. Describe the weather and climate of the region where you live.
Lesson 2: What secrets can photos divulge about a forest?	How might we use photos to gather scientific evidence? What other tools do scientists use to gather data about climate change?	Identify discrepancies in forest health by analyzing photographs and drawing conclusions based upon personal observations.
Lesson 3: Do bark beetles indicate a changing climate?	What are indicators of a healthy forest? How do biotic and abiotic elements of an ecosystem relate to and with one another? What predictions can we make about a forest, using real-world weather events and our knowledge of these relationships?	Explore the relationships among bark beetles, disease, wildfire, drought, and changing climate in Arizona forests. Make educated predictions based upon scientific research.
Lesson 4: What do weather and climate data infer about forest health?	How might scientists use data to make predictions for the future?	Examine climate information to understand its roles in the forest environment.
Lesson 5: If I were a forest manager, what would I do?	How do forest managers plan for healthy forests for current and future use?	Synthesize data and draw conclusions about their ecological and climate relationships. Understand how scientific evidence contributes to knowledge of a changing climate.
Lesson 6: “Citizen Science” at Work	How might students assist scientific studies, using appropriate protocols and scientific methodology?	Learn what phenology is, how it is related to climate change, and what some local Arizona indicators are.

Scenario

Courtney Martinez, a student from your school, has been selected to participate in a special Student Ranger program. The two week program will take place in the forest surrounding Flagstaff, Arizona. While in the program Courtney, with the help of forest experts and all of you, will be learning about forest health in Arizona.

Watch for special emails from Courtney while she enjoys her experience!

Lesson One: Are *Weather* and C*limate* the Same Thing?

Objectives

Students will understand the difference between weather and climate and be able to describe the weather and climate of the region where they live.

This activity was adapted from the Little Shop of Physics at Colorado State University. See http://littleshop.physics.colostate.edu/activities/atmos1/WeatherClimate.pdf for the original activity.

Vocabulary

- Weather – daily events such as temperature, precipitation, amount of sun, cloudiness, wind
- Climate – an average of weather conditions over a number of years

Supplies for M&M activity

- Various colored chips/beads (or M&M's). For each group of three (3) students, prepare a plastic baggie with random pieces (small pieces of paper or M&M's) of 5 different colors. There should be 31 pieces total in each baggie, but the amount of each color in each bag should differ – e.g., one bag might contain 3 red, 5 yellow, 10 green, 8 orange, and 5 brown but the amount of each color will differ in each of the baggies.
- Plastic baggies (one bag with colored chips/beads or M&M's per group)
- Copies of "Weather and Climate Data Sheet" student handout (1 copy/group of 3 students)
- One large grid or table (on board or chart paper) with the numbers 1-31 identified in a column and additional columns for groups to report data. (The number of columns should equal the number of small groups in your class.)
- Scissors (1 pair/small group)
- Small bowls to collect M&M's (1/group)

Procedure

1. Introduce the lesson by reading the provided scenario (previous page) aloud.
2. Ask students to consider: Is there a difference between **weather** and **climate?**
3. Read Email #1 from Courtney Martinez.
4. Divide the class into small groups of three students each. Conduct M&M activity using the instructions (following Courtney's Email) and the graphic organizer (Weather and Climate Data Sheet).
5. **Discuss the following questions as a group**:
   - What is weather?
   - What is climate?
   - What factors influence climate?
   - How would you describe both weather and climate in Arizona?
   - Is it the same throughout the state? If not, why?
   - What factors influence how weather and climate can differ across a region?
   - How would you describe the weather and the climate of your community?

Email #1

From: Courtney Martinez
Sent: June 10, 3:05 p.m.
Subject: Forest visit

Hey everyone!

I miss you already! Today we had our first lecture and field trip in the Coconino National Forest. It is so much cooler up here than in Phoenix. The smell of the pine trees is wonderful and makes me want to stay ☺ During our field trip, the rangers talked a lot about climate and weather, and how there has been a lot less rain in northern Arizona – especially since 1996. I'm confused – what's the difference between climate and weather? Aren't they the same thing?

Can you find out and write me back? Thanks!
Courtney

Direction for M&M activity

1. Distribute one Weather and Climate Data Sheet to each group.
2. The class should identify at least five (5) different types of weather they might experience in their community and assign a color in the prepared baggie to each type. Example: orange might be sunny and warm (between 65-80 degrees), yellow might be sunny and hot (above 80 degrees), green might be cloudy, brown might be rainy, red might be cool (below 65 degrees).
3. Assign a note taker, a data collector, and a weather observer in each group. The note taker will identify the type of weather assigned to each color and write that in the Legend section of the Data Sheet. The note taker will also record the daily data for his or her small group. The weather observer will manage the M&Ms throughout the activity. The data collector will identify the color for each M&M as it is removed from the baggie and will post the group's data onto the class grid or table at the end of data collection.
4. Once all groups have their data sheets and have completed the Legend section, give one prepared baggie to each small group. Explain that the contents of each bag represent the different types of weather you might have in your vicinity and remind them what weather corresponds to each color.
5. Each weather observer carefully cuts a small hole in the corner of the baggie given to his/her group. The hole should be just large enough for a single M&M to pass through.
6. As the weather observer squeezes the first M&M out of the bag, the data collector calls out the name of the color and the note taker writes that in the line next to # 1. Once data is recorded, repeat the procedure until all 31 M&M's have been expelled from the bag.
7. The data collector will record his/her group's results on the classroom grid or table.
8. Once all groups have recorded their data on the master chart or grid, each small group will create a pie chart, graph, or other visual to display the combined classroom results. Assuming there are 30 students in a class and there are 3 students in a small group, there will be 10 different records, each representing one year of "reported weather for March."
9. Each student or small group composes an email to Courtney that answers her question.

Explanation

The difference between weather and climate is *a measure of time*.

Weather (represented by one month's data from one group) is determined by the atmospheric conditions over a short period of time. Weather is much more localized and includes day to day activities such as precipitation, amount of sun, cloudiness, temperature.

Climate (represented by all the data collected by the groups, with each group's data representing a different year – e.g., 2000, 2001, 2002, etc.) is determined by atmospheric conditions over a long period of time. Climate describes:

- regional conditions
- long-term weather patterns across a larger area
- "generic" descriptions – e.g., generally dry or humid, heavy precipitation, desert conditions, cold/hot, snowy.

Typically, climate data is updated every 30 years to reflect the averages over a relatively recent time span.

In this activity, all the data collected by the groups can be averaged to discover the "climate" for your area. While you won't have 30 small groups – representing the previous 30 years for climate averaging, you should have sufficient numbers so that students begin to see how this process unfolds.

Lesson Two: What Secrets Can Photos Divulge About a Forest?

Objectives

Identify discrepancies in forest health by analyzing photographs and drawing conclusions based upon personal observations.

Vocabulary

- Forest health – a measure of the overall condition of a forest

Supplies

- Forest photographs and key
- Student Handout: "What Makes a Forest Healthy?" student handout (1/student)
- Post-it notes or scrap paper
- "Healthy Forest" title on chart paper, bulletin board, or butcher paper
- Tape

Procedure

Students will begin looking at forest conditions and generating questions based on their observations. **At this point, do not give students any hints or answers to the questions generated.** (Make no mention of bark beetles or forest management). Through the inquiry process, students will begin to gather information as they attempt to discover answers to their questions.

1. Read Email #2 from Courtney Martinez.
2. Ask students to examine the photos of the forest. (Separate document on website) Prompts may be necessary, depending on prior knowledge students have regarding this content.
   - Photo 1: Woodpecker
   - Photo 2: Infested forest
   - Photo 3: Infested tree
   - Photo 4: Young and old trees
   - Photo 5: Beetle damage (underneath the bark)
   - Photo 6: Trees approximately the same age
   - Photo 7: Dead trees in wild land/urban interface area
   - Photo 8: Pitch tubes from bark beetles
   - Photo 9: Bark beetle encased in sap
   - Photo 10: Before and after photos of a thinned forest
3. Students generate a list of questions about their observations of the photographs, recording each question on a separate Post-It and posting onto chart paper or bulletin board. (NOTE: Leave the questions posted in the room as you explore the connection between bark beetles and forests. At the conclusion of this unit, go back over the questions to see how many were answered accurately.)

4. Students read and discuss "What Makes a Forest Healthy?" to try to learn answers to some of their questions. What questions did it answer? What questions remain? Can students formulate any new questions from the healthy forests information?
5. Students incorporate this information, their questions, and their observations into an e-mail response to Courtney Martinez.

Email #2

From: Courtney Martinez
Sent: June 11, 4 p.m.
Subject: Forest visit

Hey everyone!

Today was a lot of fun! The ranger asked us to take a bunch of pictures of all kinds of things we saw in the forest. I tried to get a lot of different pictures, and some of them I had no idea what I was looking at! The ranger wants us to make a list of questions now that we have had an up close look at the forest. Hopefully you all can help me brainstorm some great scientific questions based off of the photos. I took some of the photos and the ranger gave me some that were taken around northern Arizona. Can you please look at the photos and help me come up with some questions related to any activities you can observe happening in the forests up here?

Bye!
Courtney

Extension

Scientists search for clues about climate change in a number of different areas. See "Tools of Climate Change" in the accompanying teacher's guide.

Option A: Divide students into small groups and assign each group one of the websites provided (ice cores, tree rings, etc.). Each group creates a poster depicting how scientists use that piece of evidence and what they have learned from their research.

Option B: Use *How We Know What We Know about Our Changing Climate* by Lynne Cherry to learn about additional climate change evidence. Students create a classroom time line showing how long the evidence has been accumulating and what it might tell us about current and future climate change.

Lesson Three: Do Bark Beetles Indicate a Changing Climate?

Objectives

- Explore the relationships among bark beetles, disease, wildfire, drought, and changing climate in Arizona forests.
- Make educated predictions based upon scientific research.

Vocabulary

- Endemic population – a normal population native to the area, kept in check by natural factors
- Epidemic population – a temporary increase in the normal population of an organism
- Declining population – last stage of an epidemic cycle, where population levels return to normal levels
- Interdependency – relationship among or between organisms where one cannot without the other
- Biotic – living components (within an ecosystem)
- Abiotic – non-living components (within an ecosystem) – e.g., sunlight, soil, rocks, air
- Homeostasis – an equilibrium or "balance" (within an ecosystem)

Supplies: *before beginning,* m*ake sure all supplies are ready to be handed out to each group for each part of the activity.*

Part 1

- Copies of "What makes a forest healthy?" student handout for review (from previous day)

Part 2

- "Bark Beetle Fact Sheet" student handout (1/student or small group)
- "Bark Beetle Life Cycle" student handout (1/student or small group)
- "Relationship Diagram" student handout (1/student or small group)
- Elements of an ecosystem (1 label/student) NOTE: The chart of labels provided includes both biotic (e.g., coyote, snake, bird, and fish) and abiotic (e.g., rock, rain, sun, soil) elements within an ecosystem. You might choose to use elements from the ecosystem within your own school community.)
- Ball or skein of yarn

Part 3

- Scenario cards – cut out separately
- Paper, approximately 8 1/2" x 11" (4 sheets/group) **OR** large sheets of newsprint (1 sheet/group)
- Pencils or markers (1 set/group)

Procedure: Part 1 – Review "What Make a Forest *Healthy*?" information

1. Read Email #3 from Courtney Martinez.

2. Discuss background information (from “What Makes a Forest *Healthy*?”) with students in detail to ensure that they have some knowledge about the relationships being discussed (e.g., bark beetle populations increase as a result of warmer temperatures and drought conditions; trees attacked by

3. Bark beetles are usually stressed due to changing environmental conditions; wildfire is more likely when forests are devastated by beetles). Make sure that students understand how bark beetles can negatively affect forests before starting the next activity.

Email #3

From: Courtney Martinez
Sent: June 12, 3:12 p.m.
Subject: What’s wrong?

I miss you guys!

Oh, my, things are not good up here! I have noticed something wrong with the pine trees in the forest I am observing. I have seen drill holes in the bark. What do you think that is from? I have also noticed that the tops of some of the pine trees are brown - that can’t be good. Most of the trees that are turning brown are the oldest trees in the forest. It is so sad but I haven’t figured out what is happening yet.

The forest floor is very dry and crackles when I walk. I have also noticed sawdust at the tree bases, small pop-corn like bumps of sap on the tree bark and small holes in the pines. Some of the trees have patches of bark missing and there looks like there are little tunnels carved into the tree. What is going on?

Oh! Here are some new words the ranger wants us to know. She said we may be able to make some hypotheses about what is happening to the trees if we can relate the following words to something that lives in the forest.

a. *Endemic population* - is when there is a normal population native to the area that is kept in check by natural factors.

b. *Epidemic population* - a temporary increase in the normal population of an organism. This happened in Arizona due to drought conditions.

c. *Declining population*- last stage of an epidemic cycle, where population levels return to normal levels. The state is caused by lack of a suitable host and/or harsh climate conditions that increase death of the organism.

I am looking forward to your next email. I hope you can help me figure out what is happening up here. It is not pretty, and I feel bad for the trees!

Courtney

Procedure: Part 2 – Create an ECO-WEB

1. Give each student a participant card and have them wear it around their neck so the whole group can read what they represent in the ecosystem. (If using those provided, you might want to have students do brief research on their organism in order to understand its *niche* or role within that ecosystem, as some of the plants and animals may be unfamiliar to students.)
2. Have students stand in a big circle so that everyone is visible and they can toss a ball of yarn/string across the circle to each other. Ask students what ecological relationships they can identify in the group (e.g., a coyote eats rabbits, plants require sunlight to make food and grow, a cactus wren requires cactus for shelter and food, a rock is shelter for animals, rain/precipitation is essential for all life on Earth).
3. Hand the ball/skein of yarn to the student who has the "sun" label since all life energy emanates from the sun. (S)he identifies another participant that is dependent upon the sun for survival or healthy living and tosses the ball of yarn to that participant, hanging onto the end of the yarn. The student with the yarn identifies another member of the circle that is dependent upon it and tosses the yarn to him/her while hanging onto a part of the yarn. Continue around the entire circle, creating a "web of life" scenario. (Each student should continue to hold the yarn throughout the entire activity to depict demonstrate the numerous relationships.) Some students may find themselves hanging onto more than one strand – e.g., water – indicating the multiple relationships that exist.
4. After all participants have been identified as part of the web, ask students which cards they think are currently, or will be, affected by water shortages (predicted to be one of the impacts of climate changes in Arizona) to step out of the circle.
5. Discuss:
   - How does the elimination of any one component from the ECOWEB affect others?
   - What ecological principles are represented by this activity? [Interconnectedness of organisms, dependency upon natural resources, rapid climate change, etc.]
   - If water predictions are correct, how will climate change alter the health/balance/homeostasis of ecosystems, specifically in Arizona?
6. Distribute "Bark Beetle Fact Sheet", "Beetle Life Cycle", and "Relationship Diagram" handouts. Students read and discuss the life cycle of bark beetles (Pinyon Ips) and their relationships to healthy forests. Discuss:
   - What problem does the bark beetle create when a prolonged drought occurs?
   - At what stage of the insect's life cycle would it be the easiest to control? Defend your answer.

Procedure: Part 3 - Scenario Activity

1. Divide students into groups of 3-4 depending on class size. Explain to students that each group will face the same challenges that resource managers face when managing the Ponderosa Pine forest in northern Arizona. There will be four rounds to this activity, each with a different scenario.
2. Each group should use four smaller sheets of paper and mark each as being 1, 2, 3, or 4. If using lager sheets of newsprint, fold one large sheet twice (creating four equal portions) and number each "grid" using the numbers 1-4.
3. Pass out scenario cards to each group – one round at a time and in the sequence provided. Ask them to discuss the scenario and what they think might happen. For example: Scenario 1- The Ponderosa Pine forest has experienced drought conditions for the past three years. What might the forest look like after three years of very little precipitation? What are some other effects that the forest may experience as a result of drought conditions?

4. Using information learned thus far, each group should make educated predictions as to how each scenario could potentially affect the forest. They should try to write out predictions, but they could also draw them as well. (Remember to include all elements of a forest ecosystem – not just trees.)
5. Repeat this procedure for scenarios 2 and 3.
6. At the end of each scenario, discuss as a class the different predictions each group made. Remember to address the questions posed for each scenario. *If students are advanced science learners, you might put a variety of scenarios into a hat and have students pick them randomly, recreating the forest history according to whatever sequence of events they chose.*
7. Scenario #4 requires students to assume the role of a forest manager. Students should understand the importance of our forests to a variety of "stakeholders" or users of the forest and forest products. Discuss who or what might be a stakeholder and how each views the forest. A wise management plan will consider the overall health of the natural resource (forest) but also will try to accommodate as many different stakeholders as feasible. What concerns do various stakeholders have? (Answers will vary but should include wildlife, timber management, recreation. Other stakeholders might include hydrologists – those who manage for our water supply, a local city council whose town is dependent upon tourist dollars, outdoor enthusiasts such as birdwatchers or wildlife photographers, and numerous others.)
8. Review with students the interconnected relationships among bark beetles, disease, wildfire, drought, and changing climates in Arizona. Each composes an email to Courtney that shares his/her findings.

Lesson Four: What Do Weather and Climate Data Infer About Forest Health?

Objective
Examine climate information to understand its role in the forest environment.

Vocabulary
- Stressors – anything that places pressure upon an ecosystem (e.g., drought, flood, wildfire, insect infestations, human activity)

Supplies
- Precipitation Data (1 set for each member of the precipitation committee)
- Temperature Data (1 set for each member of the temperature committee)
- Maps (1 set overhead transparencies)
- Overhead projector (if using map overlays)
- Poster paper
- Markers

Procedure
1. Read Email #4 from Courtney Martinez.
2. Divide the class into groups of three to set up a "jigsaw" training situation within a "base committee."
3. Assign each member of the group a role as participant of one of the climate committees: temperature, precipitation, or map.
4. Each committee meets separately to analyze the data provided. Each individual should take notes during the committee discussions so they will be able to accurately share their findings with their base committee.
5. Students meet with their original base committee (one each for precipitation, temperature, map) to share their discoveries.
6. Students share their information with the rest of the class
7. Based upon what was learned, each group makes a poster to be e-mailed to Courtney. If necessary, teachers may want to prompt students with questions that will lead to the following information sharing:
   - *What has been the precipitation pattern for the past 10 years?* Precipitation for the past 10+ years has been below average. The long-term average has been approximately 21 inches a year.
   - *How have patterns for winter and spring fared*? Winter and spring precipitation has been below average.
   - *How does this precipitation pattern impact local forests*? Without enough precipitation, trees can become stressed due to the lack of water.
   - *Do bark beetles have any impact upon these trees?* Stressed or dead trees resulting from bark beetle outbreaks are more susceptible to forest fire.
   - *How might an "overpopulation" of trees impact the health of a forest*? Competition for essential resources is greater with an abundance of trees in one region of a forest.

- *Does snowfall help with forest health*? Snowfall is below average for more than a decade (except for a few years) so cannot be relied upon to help provide sufficient moisture to maintain a healthy forest.
- *What temperature patterns seem to be emerging*? Trend - low temperatures are becoming warmer.
- *Do winter temperatures have any impact upon bark beetle populations*? Mild winter conditions are often used as an indicator when trying to predict bark beetle presence and outbreaks in forested areas.
- *Is the bark beetle problem a current or a historical trend*? The most recent years of major beetle infestations in Arizona were 2002 and 2003.
- *Where are the areas of biggest concern*? Students identify the area of bark beetle damage on the blank map provided.
- *Can we predict where the next bark beetle outbreak might occur*? Students are able to make predictions regarding the locations of future bark beetle outbreaks.

Email #4

From: Courtney Martinez
Sent: June 13, 4:32 p.m.
Subject: What's wrong?

Hi!

Having a blast, except for the fact my roommate snores like a bear! I'm getting more and more confused about all this tree information. The past two days we have been in the Coconino Forest talking with experts on forest management. Who would have thought there was so much to growing a forest! The ranger told us that in 2003, 70% of the trees were at risk of being burned by wildfire due to the severe drought that was occurring. This got me to thinking about why Arizona forests are at such high risk for devastating wildfires. When I asked Dr. DeGomez, the guest lecturer from the University of Arizona, he told me to consider the climate. Now I'm more confused than ever!! I thought we were only talking about forest fire and beetles – what does that have to do with climate?

One of the rangers gave me some information about the climate of Flagstaff for the past 15 years. I'm sending you the data. Let's compare our results and see what we can discover.

Would you make me posters showing what you found out about climate conditions of the Flagstaff area and the connections to bark beetles and healthy forests? It would really help me out!

Thanks!
Courtney

Lesson Five: If I Were a Forest Manager, What Would I Do?

Objective

- Synthesize data gathered about bark beetle infestations and draw conclusions about their relationship to overall forest health.
- Correlate their conclusions to evidence of a changing climate.

Vocabulary (review from Lessons 1-4)

Supplies

- Construction paper with the numbers 1, 2, 3, 4, and 5 clearly identified
- Drawing paper
- Colored pencils, crayons, or markers
- (optional but recommended) *How We Know What We Know About Our Changing Climate* by Lynn Cherry

Procedure

1. Ask one student to serve as the recorder.
2. For each of the statements provided, the other students align themselves on a scale of 1 to 5, creating a bar graph that represents a "Human Likert Scale."
3. Using data collected by the recorder, students can graph the results and write a summary of the findings.
   1 = strongly disagree
   2 = somewhat disagree
   3 = neither agree nor disagree
   4 = somewhat agree
   5 = strongly agree

   Questions:
   1. Bark beetles are a natural part of the forest ecosystem.
   2. The climate in Arizona seems to be warming.
   3. Bark beetles mainly attack healthy, young trees
   4. A healthy forest is one with no tree-killing insects.
   5. Woodpeckers can help to control the bark beetle in non-drought times.
   6. Forests should be managed for the benefit of all animals and plants as well as for humans.

   Note: after students have lined up for each question, ask them why they chose that response. Select one or two students from different "bars" to share with the entire group.

4. Show students the video clip of Dr. DeGomez from http://C3arizona.org/educators.html. (Click on *watch video about the Bark Beetles in Arizona*)

5. Read Email #5 from Courtney Martinez.
6. Using drawing paper, colored pencils, crayons, or markers, students may work with a partner to create a graphic representation/organizer or conceptual flow design showing the relationship between the bark beetle and the forest ecosystem. *Make sure students illustrate the connection between the bark beetle and trees, the stressed trees and forest fires, the climate conditions and bark beetles, the climate and the condition of the forest, etc.* The students should find creative ways to illustrate these connections.
7. Share group projects and discuss their implication to forest health in Arizona.

Email #5

From: Courtney Martinez
Sent: June 14, 3:12 p.m.
Subject: Almost home

Hi!

I can't wait to get back to all of you and tell you about my adventures. Thank you for all of the e-mails you have been sending me; they will really help me out when I write about my findings. I hope you have been learning a lot about the forests too.

The rangers have asked for some diagrams that explain the interaction between the bark beetles and the forest ecosystem. The rangers want them to be very creative and to show the relationship between all the factors we have been learning about the past couple weeks. To help you review all of the information, I am sending you a video clip by Dr. DeGomez to watch.

Please send me your drawings as soon as possible.

See you soon!
Courtney

Conclusion

Discuss the entire unit – what was learned? Observed? Questions?
Re-visit Post It notes created during introduction to this unit. Were all of the questions answered?

Assessments

- Student responses to the four emails they have sent back to Courtney Martinez, using the rubric provided to determine assessment values.
- Graphic organizer completed thoroughly and accurately by each student or small group.
- Constructive team member.
- On task with classroom work, questions, small- and large-group discussions.

Extension Activities

1. Have students read “Management of Forests and Woodlands” article by Arizona Cooperative Extension, University of Arizona. This article examines potential impacts of climate change in the southwest ecosystem. http://cals.arizona.edu/pubs/natresources/az1424.pdf
2. Using weather records from your community, ask students to create a “climate pattern” over the past 30 years (or longer, if there are sufficient records). Read pages 10-11 of *How We Know What We Know About Our Changing Climate* by Lynn Cherry. Discuss how the research of school children 100 years ago is providing evidence to scientists today.

Lesson Six: "Citizen Science" at Work

Note to educators: This optional lesson is highly recommended as an excellent opportunity to engage students in hands-on application of their new knowledge. Students will become "citizen scientists" as they observe, gather and record data, and share their research via a national network.

To prepare this lesson, it will be important for you and your students to understand the term *phenology*. Background information is provided below. We also encourage you to visit the website for the National Phenology Network to gain a broader understanding of this science and how citizens (including your students!) can participate in advancing this bank of information.

Background Information: ***What is phenology? How is it related to climate change science?***

Phenology is the study of the life cycles and events of both plants and animals and is also known as "nature's calendar". Examples include the timing of leafing and flowering of plants, insect emergence, as well as bird, fish, and mammal migrations. Most of nature's events are cued by seasonal changes in temperature, precipitation, and other environmental factors.

As rapid **climate changes** occur all over the world, the life cycles and events of plants and animals are disrupted and can cause major problems within ecosystems. For example, many spring events are occurring earlier and fall events occurring later.

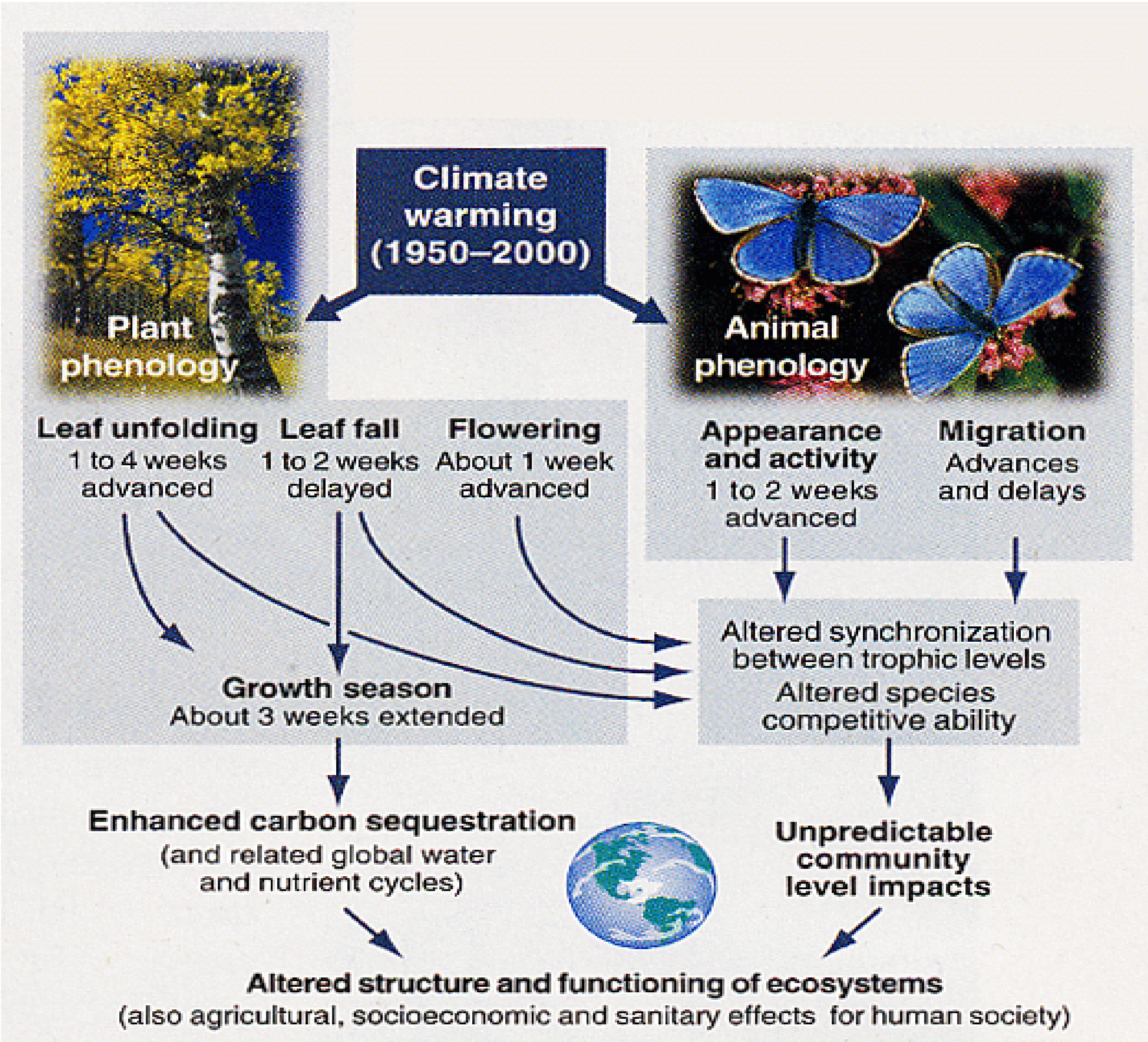
Phenological events are being monitored all over the world by students, scientists, farmers, families, and citizens. We have phenological records dating back to the 1700's, which we use to compare events of t hat day with present-day changes. By comparing the timing of phenological changes throughout history, we are able to better determine how climate change is affecting ecosystems today.

References:
http://www.usanpn.org/?q=about-phenology

Photo Source: Amy Larson, 2009

The timing of phenological events is important for:

- **health** *(allergens and infectious diseases)*
- **agriculture** *(planting and harvest times, pest control)*
- **natural resource management** *(water and timber)*
- **understanding and predicting natural hazards** *(monitoring and prediction of drought and wildfire risk)*
- **conservation** *(abundance and diversity of plants and animals)*
- **recreation** *(wildflower displays and fall colors)*
- **migrating animals** *(food source and habitat selection)*



Ecological consequences of climate warming on plant and animal phenology.

Source: Penuelas J and Filella I 2001. *Response to a warming world*. Science 294: 793 – 795.

Objective

Students will learn what phenology is, how it is related to climate change, and what some local Arizona indicators are.

Vocabulary

- Phenology - the study of the life cycles and events of both plants and animals

Supplies

- 11x17" paper (1 sheet/group)
- Small Post-its (several/group)
- (optional but recommended) Photos of plants and animals in your community, state, or region (1 photo/group). (HINT: old calendars with nature photos are good sources for these.)

Procedures

1. Read the background information on phenology before class, if you are unfamiliar with this concept.
2. Divide students into small groups (2-4 students/group).
3. In their small groups, they should spend 3-5 minutes discussing and recording their answers (on Post-its, one idea/Post-it) to the following questions. Ask the questions in the order presented to guide students to their own discovery of phenology and its relevance to global climate change. (**Do not introduce the term phenology at this time! Wait until step 7.**)
   - *What natural events, cycles, and relationships among plants and animals do you observe throughout the year?*
   - *What is the purpose of these natural events and relationships between plants and animals?*
4. Students share their group's ideas with the class.
5. Distribute an 11x17 sheet of paper and one photo to each group or to individual students, depending on class size and available supplies. Each group should create four "sections" on their paper. (These may be four columns, four grids (created by folding the paper twice), or a pie chart with four sections.)
6. Ask students what the four seasons are and have them label their chart with winter, spring, summer, and fall (in that order).
7. Ask students to place the appropriate words (on their Post-its) in the seasons they think the animals, plants, or events naturally occur in Arizona and/or the southwest in general.
8. When each group has completed its task, discuss their ideas and explanations. Discuss the following:
   - *What regular cycles do you observe that occur every year?*
   - *Have you noticed any of the described events, cycles, or relationships changing (in comparison to previous years)?*
   - *What might cause changes to occur to the described events, cycles, and relationships?*
   - *If students have not yet identified the effects of global climate change on these events, guide them in their discussion to help them understand the effects of global climate change on phenological events. Then present the term "phenology" to students and make sure they have a clear understanding of the impacts of global climate change on natural ecological events as well as food production.*

9. Share http://neoninc.org/budburst/ with your students, introducing them to Project BudBurst. Ensure that students understand the relevance of phenological changes to global climate change, specifically in Arizona and the southwest region.

Explanation

Phenology can be described as "nature's calendar" or the events and life cycles of plants and animals in an ecosystem. Phenology focuses on the timing of these natural events throughout the year. Certain plants and animals depend on one another for food sources, shelter, and even pollination of crops. Climate changes have begun to affect these natural and essential events, creating serious challenges for those species which depend upon ecosystem services being provided at a specific time.

An example: Insects hatch earlier in many parts of the world, due to temperature and precipitation variations. Migrating birds arrive at the same time as previous generations – only to find their food source has already hatched and moved along, leaving a minimal not only to feed themselves, but also to feed their incubating brood.

Extension

Using Project BudBurst or the National Phenology Network (http://www.usanpn.org/), have students create a visual presentation (poster, chart, diagram, PowerPoint) of natural events, cycles, and relationships they have observed throughout the year OR that they will research over the coming year. Using local species will make students more aware that climate change is happening within their own communities as well as across the planet.

Student Handouts

Weather and Climate: Data Sheet

Each of the numbers below represents each day for the month of March. 1 = March 1st, 2 = March 2nd, 3 + March 3rd, and so on.

The Legend at the bottom of the page will be where you record the type of weather your class assigns to each color. Write the type of weather next to the appropriate color.

1 ________________ **17** ________________

2 ________________ **18** ________________

3 ________________ **19** ________________

4 ________________ **20** ________________

5 ________________ **21** ________________

6 ________________ **22** ________________

7 ________________ **23** ________________

8 ________________ **24** ________________

9 ________________ **25** ________________

10 _______________ **26** ________________

11 _______________ **27** ________________

12 _______________ **28** ________________

13_______________ **29** ________________

14 _______________ **30** ________________

15 _______________ **31** ________________

16 _______________

Legend:

Orange = __________________ **Red =** ______________________

Green = ___________________ **Yellow =** ____________________

Brown = ___________________

What Makes a Forest *Healthy*?

Healthy forests contain all ages and types of trees and vegetation which make up a balance. A healthy forest will look like a mosaic, having different colors, open spaces, closed spaces, and younger and older trees. Below are some factors that contribute to a healthy forest:

A. Fire can be part of a healthy forest. Fire renews, recycles and rearranges vegetation in a cycle of change. This helps keep the forest in a diverse state where one species is not prevalent or taking over most of the land. Before human settlers, trees averaged 20 to 40 trees per acre. Currently there are about 800 – 1200 trees per acre. This is due to fire suppression or controlling naturally occurring forest fires.

B. Healthy trees have active resin (sap) duct systems. Resin is secreted by the tree to help protect it. This helps the trees repeal insects that try to make their homes in trees. Resin is a defense mechanism for trees that help protect them from severe fires and insect infestations.

C. Climate contributes to creating and keeping a healthy forest. Trees need enough precipitation to grow and survive unfavorable conditions. Precipitation is often in the form of rain or snow depending on the season. A healthy forest requires a substantial amount of precipitation in order to maintain simple ecosystem functions and to defend itself from severe wildfires and/or insect infestations.

D. Weather contributes to healthy forests. Cold weather controls the size of insect populations and warm weather increases growth of trees. Arizona has been in a drought for the last 10 years.

E. The denser a forest is, the easier it is for bark beetle outbreaks to occur.

F. The denser a forest is, the more competition there is among trees and other vegetation for natural resources (specifically water) which can drastically affect a tree's defense mechanisms against insect outbreaks, wildfire, and diseases.

G. After several years of drought conditions, forests are much more susceptible to high severity wildfire due to the amount of debris and leaf/needle litter on the ground and the stressed conditions of the vegetation,

H. Arizona forests historically are accustomed to frequent low intensity fires to ensure that debris and leaf/needle litter are consumed on a regular basis. When we control fire conditions and don't allow fires to happen in the forests, we are altering the natural cycles of that ecosystem.

I. Bark beetles tend to attack trees that are stressed after wildfires occur, which can lead to fungus or other diseases to invade the tree.

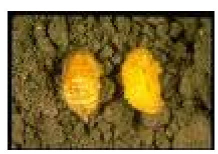
J. Healthy trees are more likely to fight off disease and protect themselves from fire. Stressed trees, due to crowed conditions and lack of precipitation, often cannot fight damage from insects or disease.

Bark Beetle Fact Sheet

1. The Pinyon Ips Bark Beetle is native to our Arizona forests. It is not a new species.
2. The beetles prefer trees that are 80 years and older. These trees are the weakest due to lack of water and overcrowding of the forest.
3. The male beetle builds an egg gallery in the tree's living tissue. The gallery runs vertically in the shape of a J. It is right underneath the outer layer of bark in the inner cambial layer. Next he produces pheromone which is like a perfume to attract female beetles to the tree. This is where she lays her eggs.
4. While laying eggs the female beetle spreads the blue stain fungi – this fungus weakens the tree and makes it harder for the tree to produce sap that could chase out the beetles. The blue stain fungus clogs the trees water conducting tissue and usually kills the tree within one year.
5. After 2 weeks the eggs hatch into larvae. The larvae grow into pupa and then adults. Adults go and find another tree, spreading the blue stain fungi.
6. There are six legs and three body parts. The body parts include the head, the thorax and the abdomen. The beetle is about 5 mm (1/4") long.
7. In cold weather beetles can produce antifreeze (glycerol) – they can do this only once. This protects them in the winter. With the warming trend more larvae are surviving and going into areas where they were not before. Beetle populations increase during drought periods. This happened in 2002 and 2003 in Arizona.
8. They have two sets of wings. There is a secret set of wings! These wings, called the hind wings, are hidden under some hard wings and are used for flying.

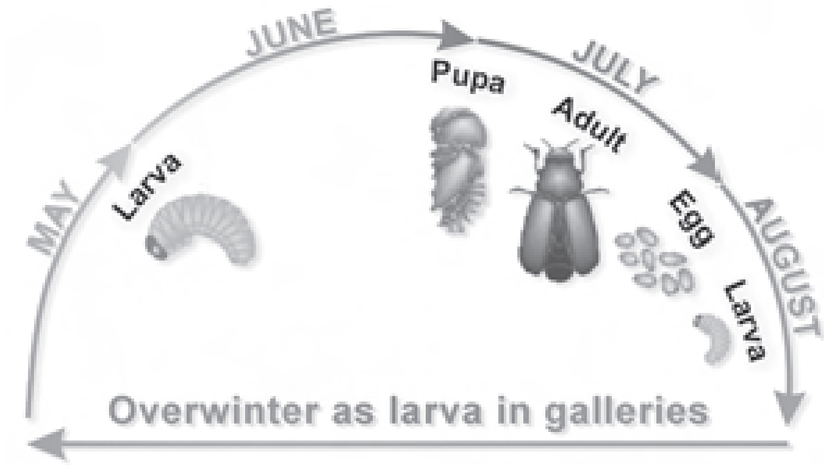

Bark Beetle


Larva


Pupa

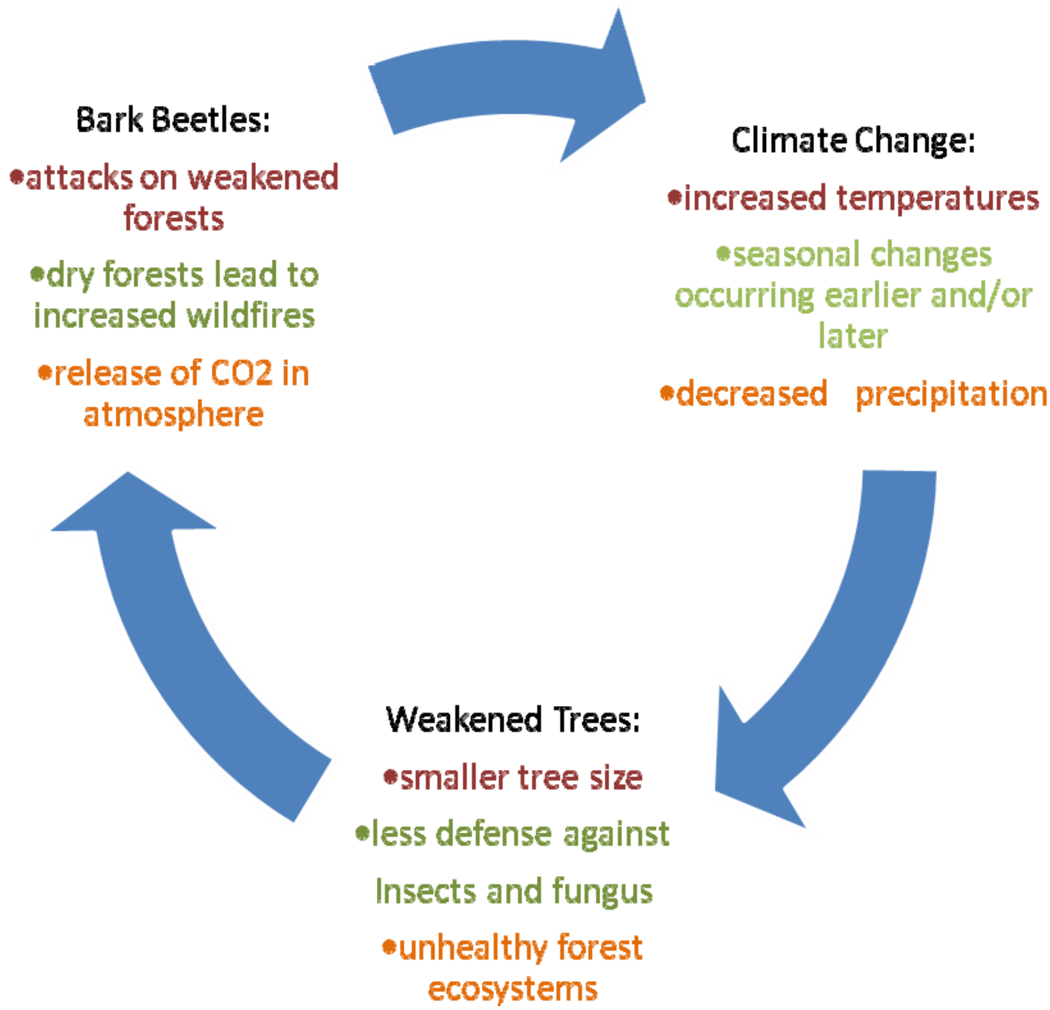

Different bark beetles

Beetle Life Cycle



This life cycle of a beetle is referred to as "complete metamorphosis."

Relationship Diagram



Elements of an Ecosystem

In these tables, all plants and animals are listed by their common names and are found in Coconino County, Arizona. (Note that some may not be found within a pine forest.) Select as many components as there are members of your class but make sure you include **both** biotic and abiotic components!

This information is presented for educators who may have limited time to research ecosystems within their school communities. If time permits, we encourage you and your students to identify and use species representative of your own area,

To prepare these for your classroom, you may wish to print these at 200% so they may be seen from a distance of several feet, or copy each label onto a file card.

More information about Arizona plants and animals may be found on the Arizona Game and Fish website at http://www.azgfd.gov/w_c/edits/species_concern.shtml. Many species also have a photo accompanying their description.

Biotic Components - Animals

Coyote	Big Brown Bat	Black Bear
Acorn Woodpecker	Sonoran Mountain Kingsnake	Lowland Leopard Frog
Wupatki Arizona Pocket Mouse	Dwarf Shrew	Black-tailed Rattlesnake
Long-eared Owl	Turkey Vulture	Black-capped Chickadee

Biotic Components – Plants

Ponderosa Pine	Gambel Oak	Arizona White Pine
Mogollon Columbine	Blue Flax	Douglas Fir
Deer Ears	Franciscan Bluebells	Scarlet Cinquefoil
Western Fairy Slipper	Woods' Rose	Kaibab Beardtongue

Abiotic Components

Sunlight	Rain	Rocks
Carbon Dioxide	Creek	Snow
Soil	Wind	Air (Oxygen)

Scenario Cards

(Note to teacher: cut into strips for ease of use.)

Scenario 1: There have been severe drought conditions for the past three years across the southwest region of the United States, specifically in Arizona.

Question #1: How might this affect bark beetle populations in northern Arizona forests?

Question #2: How does this affect ecosystem processes such as food chains, predator/prey relationships, abundance of vegetation and forest debris on the ground, risk of wildfire, and disease?

Scenario 2: A very strong and destructive wind storm swept through northern Arizona forests last month, breaking tree limbs and pushing over trees. *Remember to consider*: this wind storm occurred after three years of extreme drought conditions.

Question #1: How might this affect bark beetle populations in northern Arizona forests?

Question #2: How does this affect ecosystem processes such as food chains, predator/prey relationships, abundance of vegetation and forest debris on the ground, risk of wildfire, and disease?

Scenario 3: It is early June in Arizona, and wildfire season is in full effect; the past winter season brought precipitation that amounted to well below average.

Question #1: How might this affect bark beetle populations in northern Arizona forests?

Question #2: How does this affect ecosystem processes such as food chains, predator/prey relationships, abundance of vegetation and forest debris on the ground, risk of wildfire, and disease?

Scenario 4: You have just been appointed forest manager for the Coconino National Forest. You have learned about the three conditions described in Scenarios 1-3 and have seen firsthand the impacts of bark beetles in this forest.

Question #1: What plans would you put into place that would help reduce the effects of bark beetles within this forest?

Question #2: What conclusions might you draw about climate change and the ability of ecosystems to respond to changing conditions?

Question #3: Using the Coconino National Forest as an example, can you offer a theory as to why severe wildfires are occurring more frequently across the globe?

Precipitation Committee Handout

Bark beetle infestations have occurred in the past and have had a devastating impact on the forest regions in Arizona. Understanding the role of climate in forest health will help you better understand the important relationships between rapid climate changes, drought, disease, and insect (specifically bark beetle) outbreaks.

Key Ideas:

- *Climate* describes the weather – including precipitation (moisture in the form of rain or snow) and temperature - *averages* over years or decades (usually 30 years) in an area.
- *Weather* describes the day-to-day atmospheric conditions of an area.

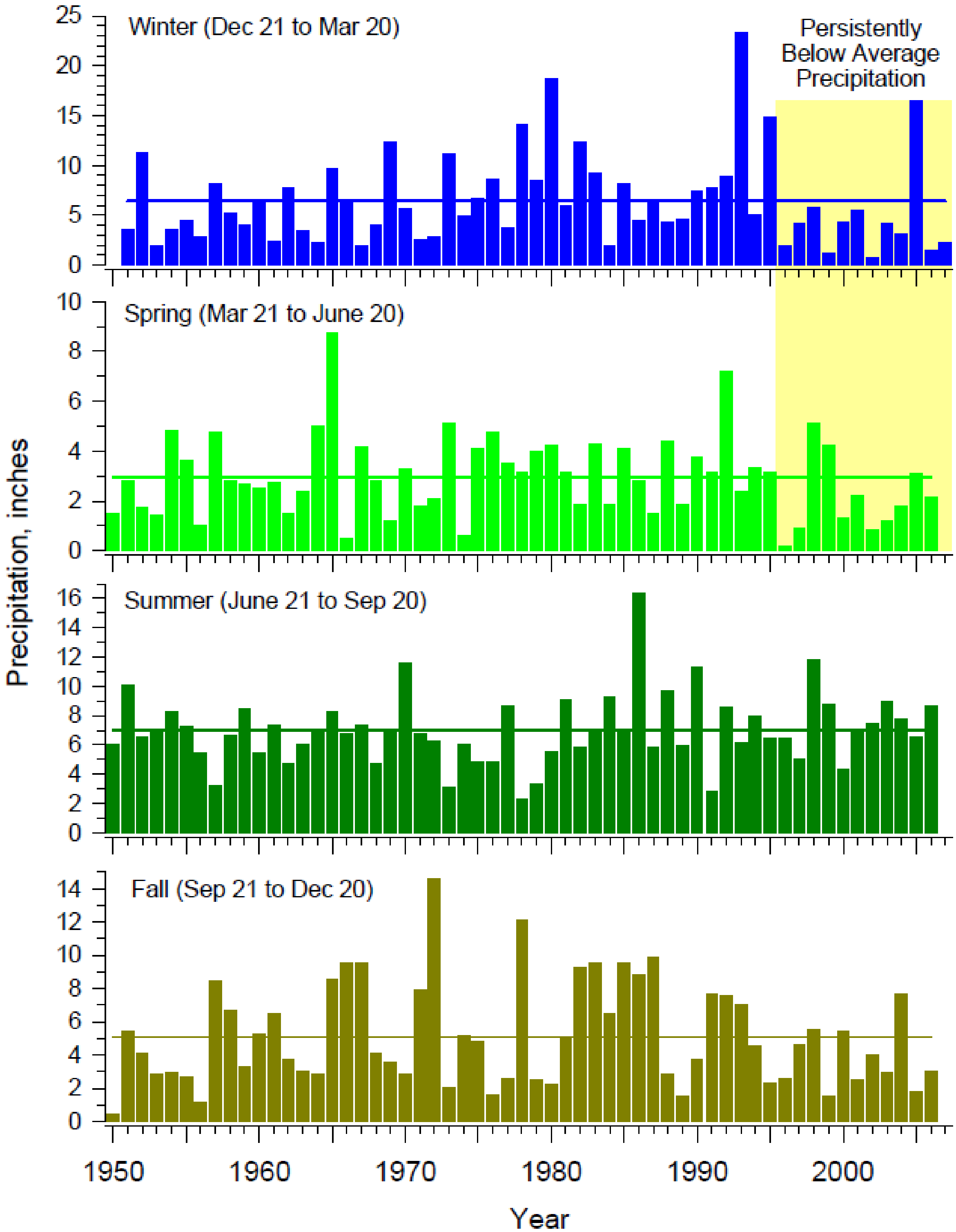
You have data on the precipitation in Flagstaff in three different formats:

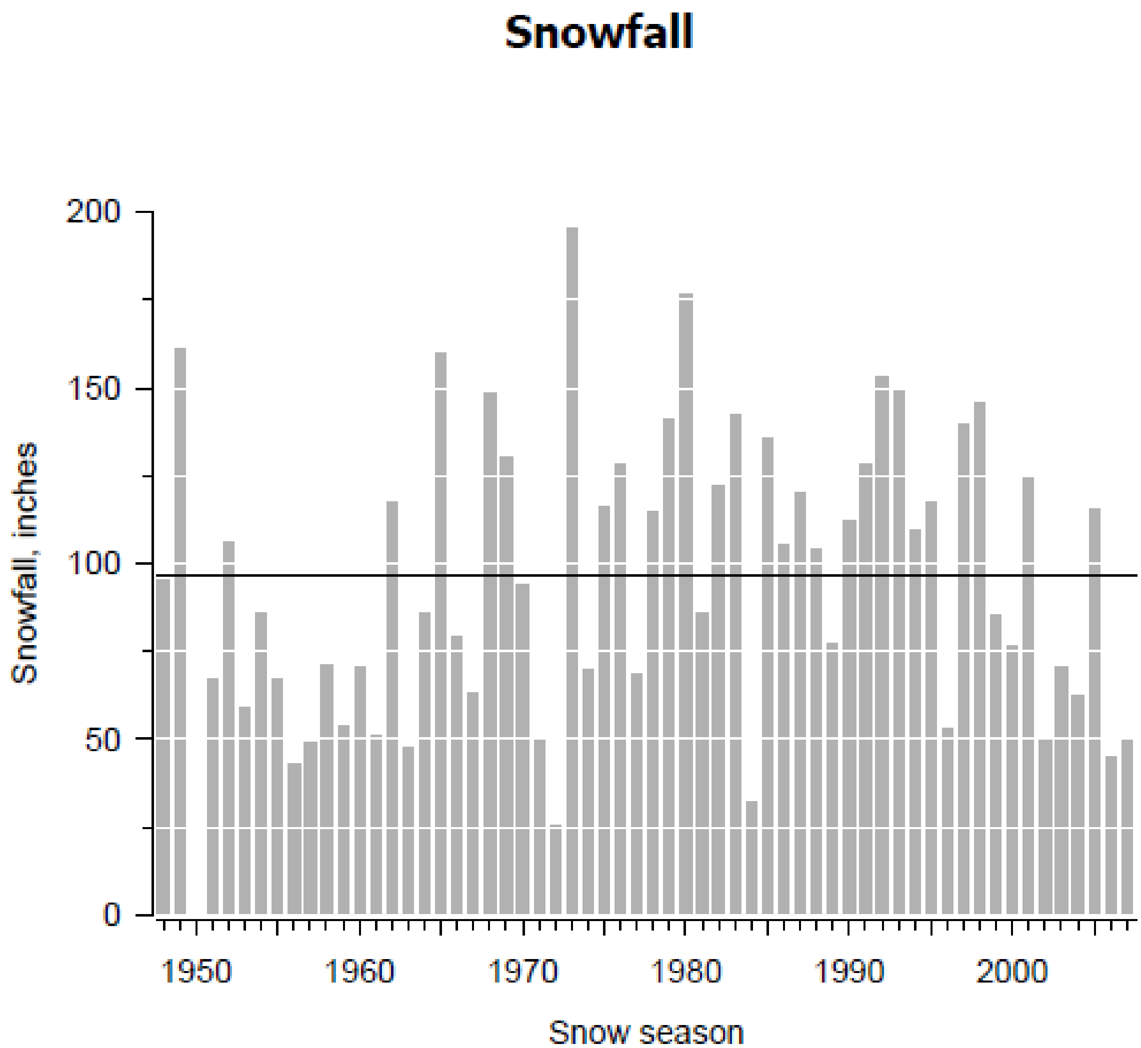
- **Precipitation by Season.** What do you know about the role of seasonal precipitation on forest health?
- **Snowfall in Inches.** What is the importance of having adequate snow in the winter, accompanied by freezing temperatures?
- **Precipitation.** This data shows 50 years of precipitation in the Flagstaff area. What does it mean to be above or below the horizontal line?

Your task is to analyze the precipitation data for the Flagstaff area and write a report to send back to Kelly, telling her how you think the amount of precipitation in the area has created conditions for bark beetle infestation. You must answer the following:

1. What trends do you observe from your data analysis?
2. What season do you believe has the greatest effect on predicting future bark beetle outbreaks? Why?
3. What affect does the amount of precipitation have on the trees? When would the trees in the forest likely be the most stressed?
4. In what year or years do you think there was a huge beetle infestation in the Coconino Forest? What evidence do you have to support that conclusion?
5. If the trends continue, what do you think will be the effect on the health of the Coconino National Forest?

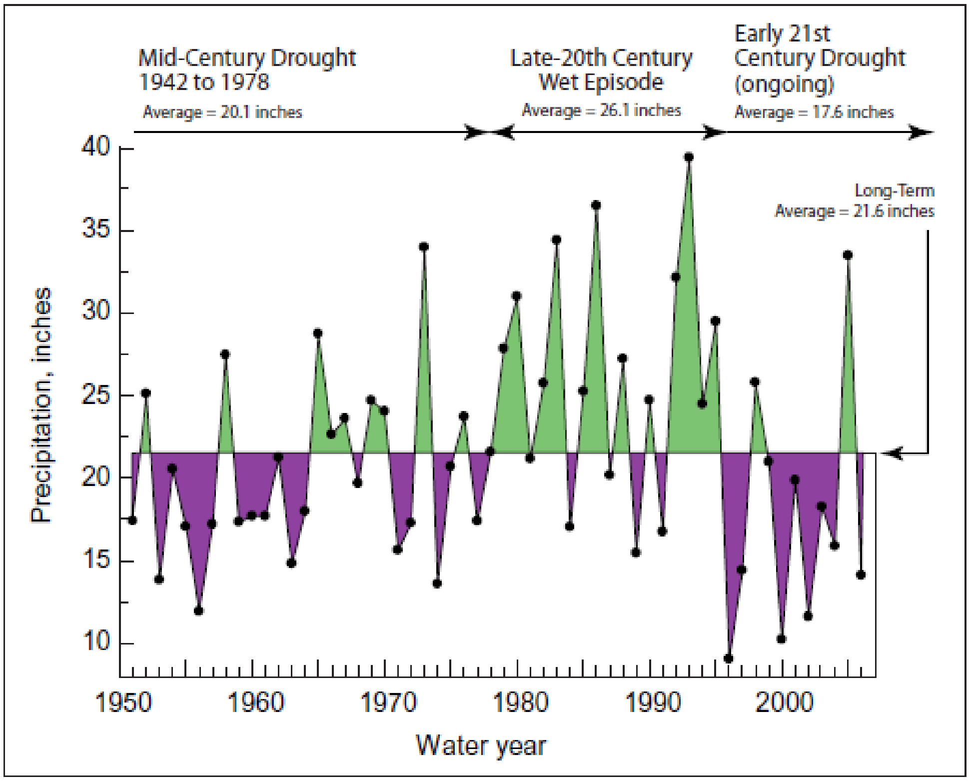
Precipitation Variability by Season



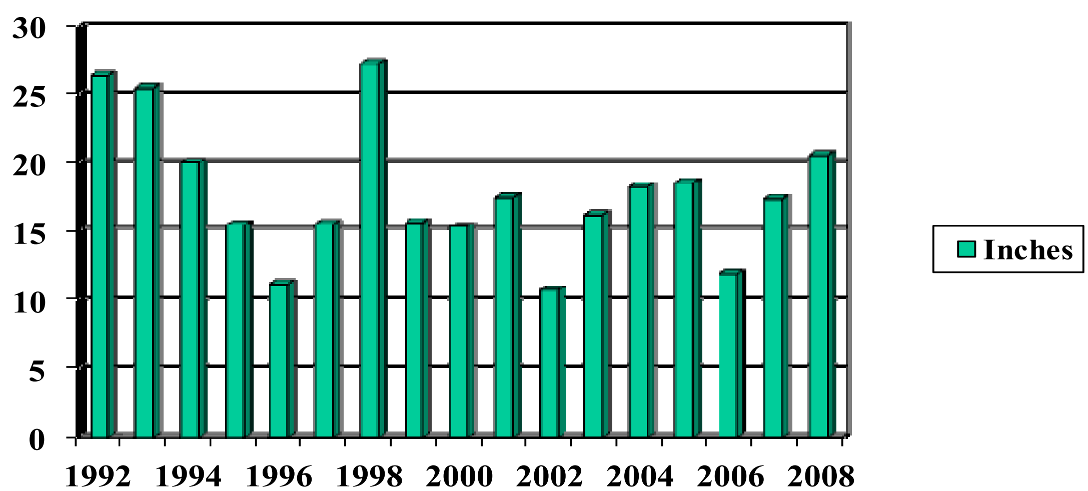


Courtesy of Richard Hereford, USGS

PRECIPITATION



Courtesy of Richard Hereford, USGS



Courtesy of Tom DeGomez, University of Arizona

Temperature Committee Handout

Bark beetle infestations have occurred in the past and have had a devastating impact on the forest regions of Arizona. Understanding the role of climate in forest health will help you better understand the important relationships between rapid climate changes, drought, disease, and insect (specifically bark beetle) outbreaks

Key Ideas:

- *Climate* describes the weather – including precipitation (moisture in the form of rain or snow) and temperature - *averages* over years or decades (usually 30 years) in an area.
- *Weather* describes the day-to-day atmospheric conditions of an area.

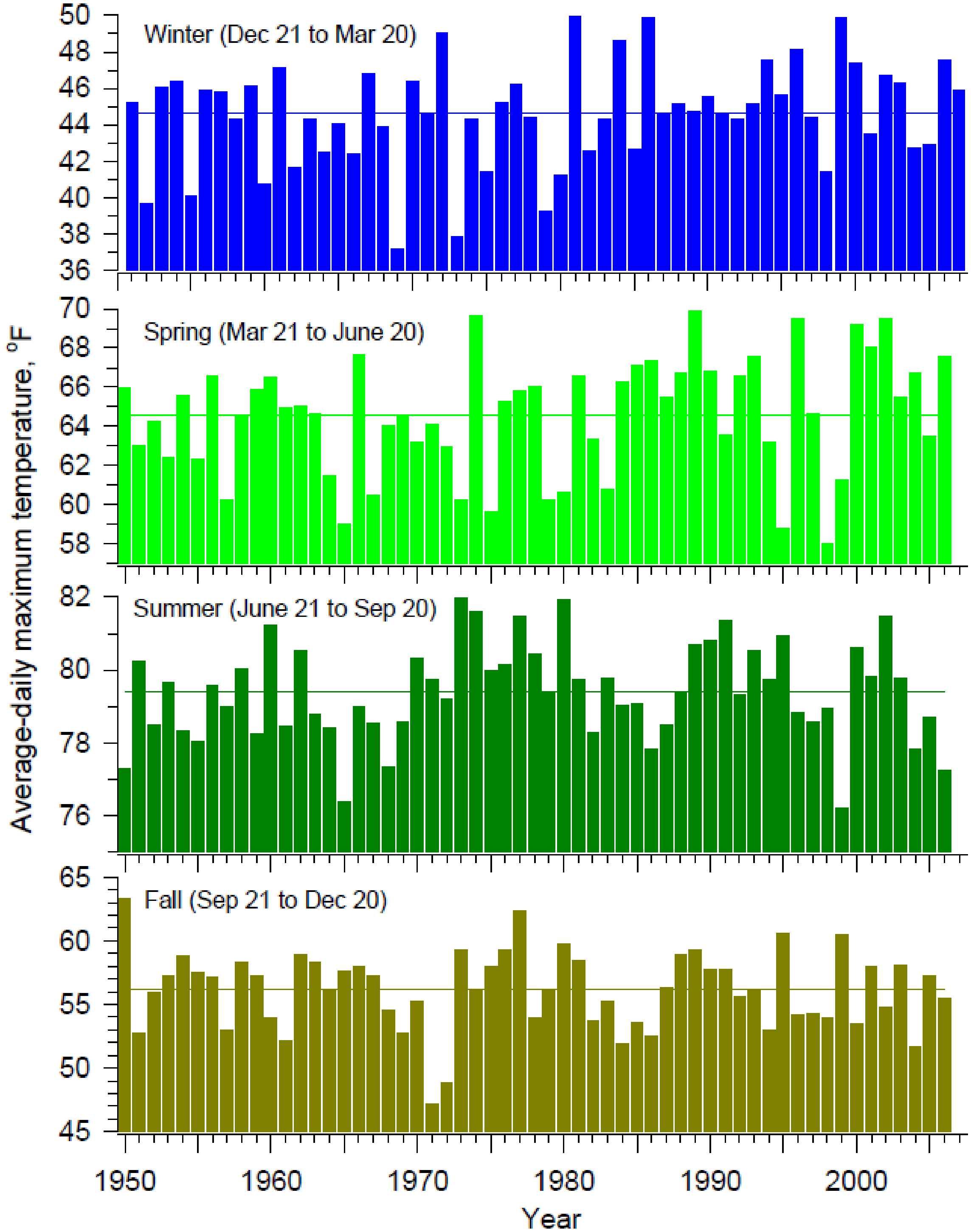
You have data on the temperature in Flagstaff in three different formats:

- **Minimum Daily Temperature by Season.** What do you know about the importance of temperature in the life cycle of the bark beetle?
- **Maximum Daily Temperature by Season.** How does temperature affect forest health? What happens if it is too hot or too cold?
- **Average Daily Temperature.** This data shows 50 years of temperature for the Flagstaff area. What does it mean to be above or below the horizontal line?

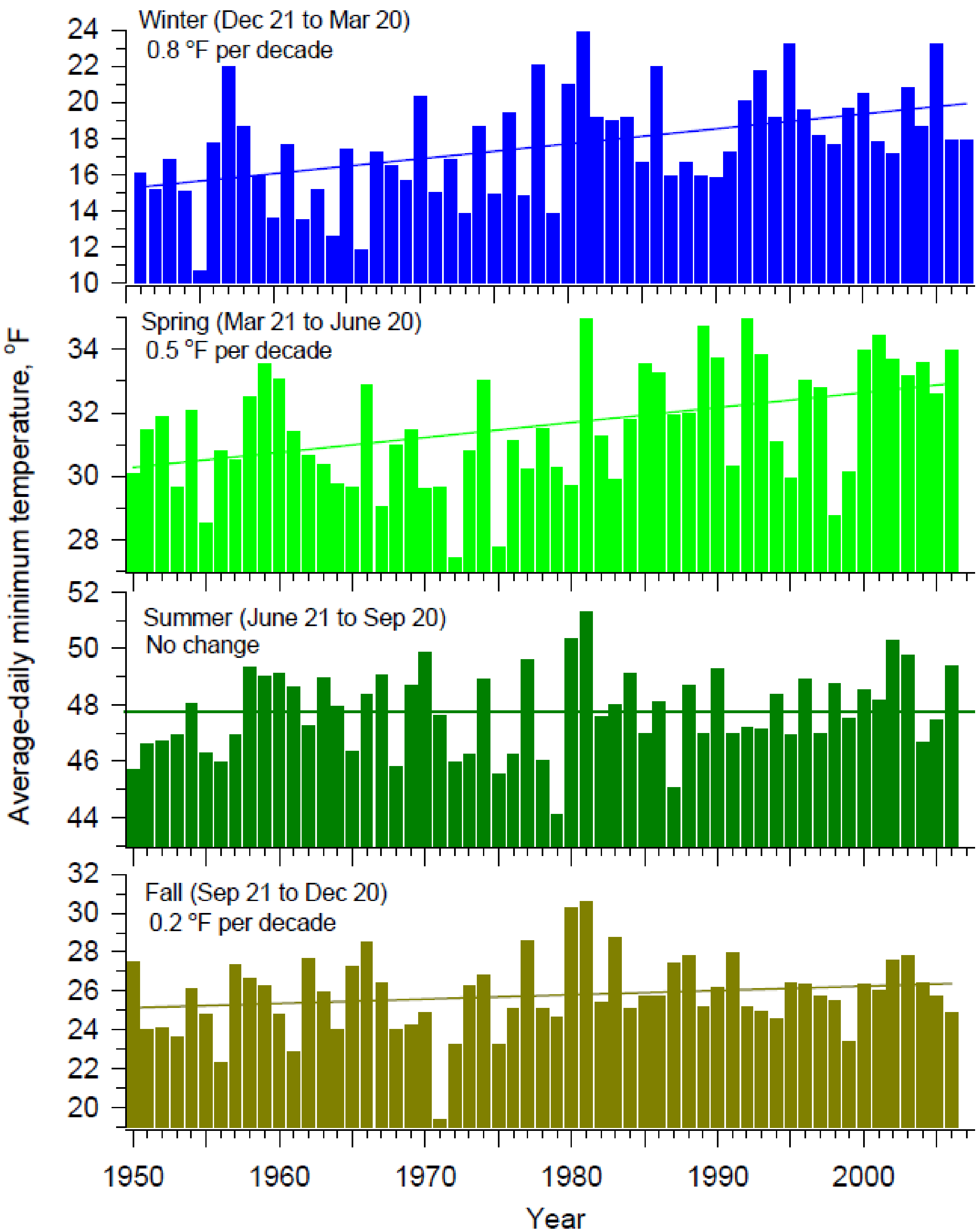
Your task is to analyze the temperature data for the Flagstaff area and write a report to send back to Kelly, telling her how you think the temperature in the area has created conditions for bark beetle infestation. You must answer the following:

1. What trends do you observe from your data analysis?
2. What season do you believe has the greatest effect on predicting future bark beetle outbreaks? Why?
3. What affect does the temperature have on the trees? When would the trees in the forest likely be the most stressed?
4. In what year or years do you think there was a huge beetle infestation in the Coconino Forest? What evidence do you have to support that conclusion?
5. If the trends continue, what do you think will be the effect on the health of the Coconino National Forest?

Maximum-Daily Temperature by Season

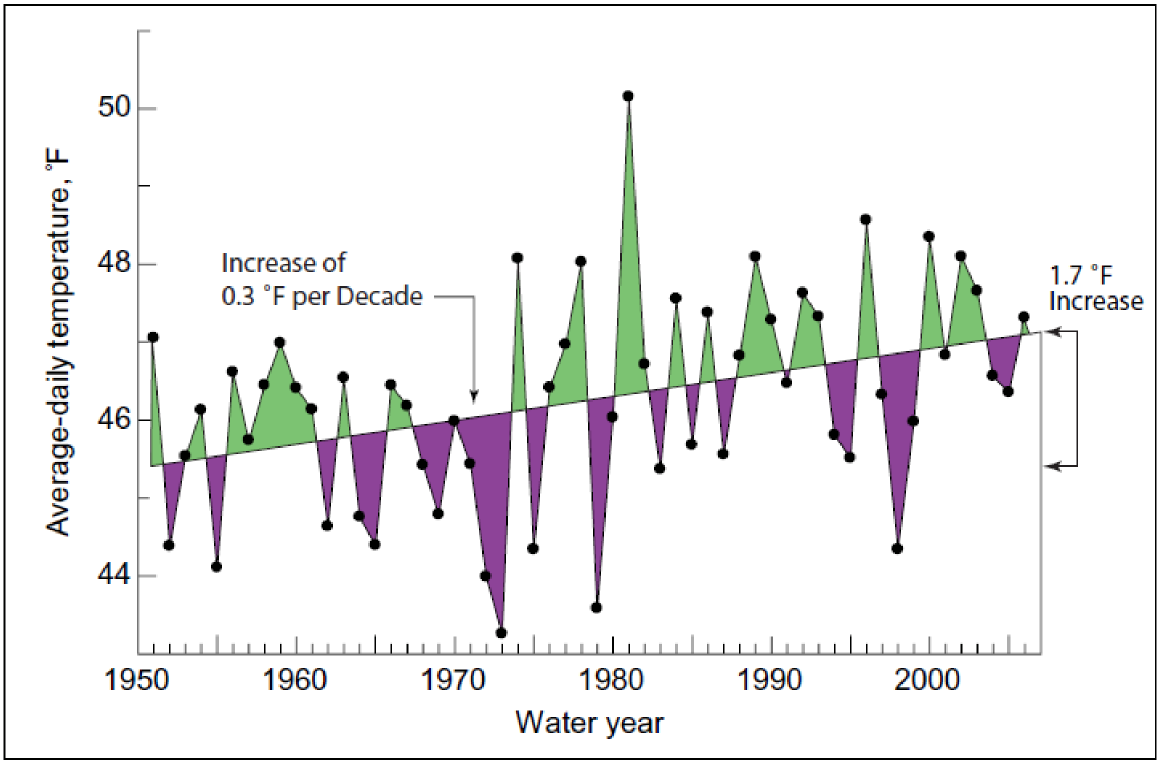


Minimum-Daily Temperature by Season



Courtesy of Richard Hereford, USGS

TEMPERATURE



Courtesy of Richard Hereford, USGS

Map Committee Handout

Bark beetle infestations have occurred in the past and have had a devastating impact on the forest regions of Arizona. Understanding the role of climate in forest health will help you better understand the important relationships between rapid climate changes, drought, disease, and insect (specifically bark beetle) outbreaks

Key Ideas:

- *Climate* describes the weather – including precipitation (moisture in the form of rain or snow) and temperature - *averages* over years or decades (usually 30 years) in an area.
- *Weather* describes the day-to-day atmospheric conditions of an area.

You have the following maps:

- **Drought Map for 2002 and 2003.** What do you know about the importance of precipitation in the life cycle of the bark beetle? How is that related to tree health?
- **Bark Beetle Infestations for 2002 and 2003.** What were the locations of bark beetle infestation outbreaks during these two years? Where might future outbreaks occur? Why?
- **Map of Arizona forest regions.** Where can we find the most pine trees in Arizona? What ecological conditions make those prime areas for pine trees?

Your task is to analyze maps and write a report to send back to Courtney Martinez telling her where bark beetle infestations have occurred in Arizona. Your report must answer the following:

1. What trends do you observe in your maps? Where are most of the infestations occurring?
2. Predict the location of future bark beetle outbreaks by shading in the area on the map of Arizona.
3. How does temperature impact trees? When might the trees in the forest be most stressed?
4. What year or years saw a huge beetle infestation in the Coconino Forest?
5. If the trends continue, what do you think will be the effect on the health of the Coconino Forest?

Assessment Rubric

An evaluation or assessment for this lesson can be based on written responses to e-mails, completion of worksheets, and class participation in discussions and activities. Because the writing assignments are in the format of an e-mail, you may want to remind students that their responses are to be more formal than if they were writing to a friend. Our imaginary student ranger will be using the e-mail messages to compile a formal report to her supervising ranger.

A suggested rubric is provided:

Student Name:			
Performance Criteria	**Points Possible**	**Points Earned**	**Comments**
Responses include explanation for all aspects of the question.			
Responses show an understanding of the scientific data and information presented.			
Responses make connections between the facts and concepts presented.			
Content and language are appropriate for the intended audience.			
Responses are organized logically and expressed clearly.			
Responses are written in complete sentences with no errors in grammar or spelling.			

Arizona Academic Standards

Science
Grades 6-8

- S1C1PO1 (M07-S2C1-01): Observations, Questions and Hypotheses
- S1C3PO1, PO2 & PO5 (grade 6 MO6S2C1-2; grade 7/8 MO6S2C1-8): Analysis and conclusions
- S1C3PO6, PO7 & PO8: Formulate new questions based on results of a completed investigation.
- S1C4PO5: Communication
- S4C3PO1-PO6: Populations of Organisms in an Ecosystem (grade 7)
- S4C4PO1-PO6: Diversity, Adaptation and Behavior (grade 8)

Social Studies
Grades 6-8

- S4C1PO1, PO3: The World in Spatial Terms
- S4C5PO1: Environment and Society (grade 7)
- S4C6PO2 and PO3: Geographic Applications
- S2C9PO1: Contemporary World

Reading
Grades 7 – 8

- S1C6PO7: Using reading strategies to interpret text
- S3C1PO8: Interpret graphic features of expository text
- S3C1PO10: Make relevant inferences about expository text, supported by text evidence

Writing
Grades 7 – 8

- S3C2PO1: Record information related to the topic
- S3C2PO2: Write a summary based on the information gathered
- S3C3PO1: Write a variety of functional texts

Math
Awaiting publication of AZ Common Core