UNIT LESSON PLAN

RX-310, INTRODUCTION TO FIRE EFFECTS

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LESSON: Ecosystem Stressors

UNIT: Unit 3E

OBJECTIVES:

Upon completion of this lesson, participants will be able to:

1. **Identify and describe stressors impacting physical, biological, and chemical components of ecosystems.**

2. **Discuss the relationship between fire regimes and identified stressors.**

3. **Discuss how to adapt management practices to address ecosystem stressors.**

4. **Identify key attributes to evaluate the impact of stressors on ecosystems.**

NARRATIVE:

I. INTRODUCTION

A. Welcome, Introduce Myself
B. Learning Goals for the Unit:
C. Outline of the Unit

II. Ecosystem Overview

A. Definition of Ecosystem
   1. A community of species populations living together in the same place at the same time, plus abiotic factors of the environment
      a. Ecosystems are often envisioned and modeled as closed systems with inputs and outputs (species, energy, nutrients, water, etc).
      b. Ecosystems are “energy machines and nutrient processors” (Krebs 2009).
      c. The Ecosystem perspective looks beyond individual species and their interactions.
      d. Ecosystems are dynamic, never static.

   2. Ecosystem Properties:
      a. Productivity - biomass generation per acre per year

b. “Site” quality used by foresters approximates productivity — what real life factors are involved?
c. Nutrient Cycling - water, Nitrogen, Phosphorus, Potassium, Calcium, and others
d. Food webs of living creatures
e. Nonliving, yet important structures: Coarse woody debris, Large hollow snags, soil profile development

3. Are ecosystems really closed systems?
   a. Community and Ecosystem boundaries are often more gradients than sharp ecotones. Where does the forest end and the prairie begin?
   b. Plants and Animals can move and disperse from one place to another
   c. Often, ecosystems are defined according to the scale of interest or necessity
   d. It is good to recognize the interconnectedness, as management practices that occur on one state forest may impact other species at another location at a different time!

B. Examples of Ecosystems: Depends on Scale of Interest
   1. A rotting log
   2. State Game Lands 48
   3. Regional landscape of interconnected forested stands in Bedford County
   4. A beaver pond
   5. The Juniata River
   6. The Chesapeake Bay Watershed
   7. An ecoregion (terrestrial and aquatic)

C. How to study ecosystems
   1. Experimental watershed model: Hubbard Brook and Coweeta Basin using weirs and streamflow monitors
   2. CO2 and photosynthesis monitors in forests
   3. Some ecosystem processes only occur and can be understood on the large scale, while others occur and can be observed at the local scale.
   4. Foresters are mostly interested in the stand-level to state forest or national forest scale.

III. Ecosystem Processes and Stressors

A. Physical
   1. Rock Weathering and Soil Development
   2. Precipitation, Evapotranspiration, Groundwater, Stream flow
   3. Solar radiation

B. Biological
   1. Food Web, Production, Herbivory, Predation, Decomposition
   2. Energy transformation from Solar to Biochemical
   3. Nutrient transformation from inorganic to organic
   4. Forest succession (not just plants)

C. Chemical
   1. Nutrient Cycling (C, N, P, K, and others)

D. However, it is hard to pigeonhole processes into one of the three categories above, as all may be at functioning at the same time, working together. For example: Nitrogen Cycle
    1. Show diagram of N cycle
    2. N exists in inorganic and organic forms
    3. Biological organisms help to change its chemistry at many stages
    4. N moves from abiotic to biotic systems and back again

E. Anthropogenic influences can cause imbalances in ecosystem nutrient pools and flows.
    1. Running with Nitrogen as our example:
        a. N pulses due to deforestation (decomposition)
        b. N deposition from atmospheric sources (NOx)
        c. N runoff from fertilizers (NH3)
        d. Changes outcomes of plant composition and soil microbe competition
        e. Acidifies the soil, making other nutrients less accessible to plant roots
        f. Utrophies water bodies
    2. Or the Carbon cycle:
        a. Increasing CO2 in atmosphere because of combusting fossil carbon
        b. Doubling of CO2 levels by 2100
        c. CO2 is a greenhouse gas
        d. CH4 is also a greenhouse gas, released from natural gas wells
        e. Changes global climate

IV. Fire and Ecosystem Stressors

A. Fire is a natural ecosystem process, as are other physical disturbances (storms, drought, flooding, landslides, volcanism, etc.). Biological disturbances also occur (herbivory, insect outbreaks, disease outbreaks, human impacts).

B. Interactions between biological and physical processes can create larger impacts, for example:
    1. Drought-insects-fire
    2. Precipitation event-avalanche
    3. Air pollution-growth stress-insects/disease-fire
    4. Fire exclusion-insects/disease-drought-fire
    5. Hurricane-windwthrow-fire
    6. Climate change-insects/disease-fire

C. Effects of Fire include:
    1. Direct plant and animal mortality
    2. Seedbed preparation (pitch pine)
    3. Changes plant community composition
    4. Biogeochemical cycling (volatilizes N and produces CO2)
    5. Soil heating
    6. Changes in nutrient, water, and light availability
    7. Fuel load changes (increase or decrease)
    8. Formation of structural elements such as coarse woody debris and standing dead snags
    9. Insect and disease population regulation
    10. Plant successional changes

11. Spatial patterning of vegetation mosaics
12. And others!

D. Fire has properties that can be characterized:
   1. Spatial (size, heterogeneity)
   2. Temporal (seasonality, MFI)
   3. Magnitude (intensity, severity, type of fire)

E. Role of Fire In Dynamic Ecosystems
   1. Individual fires, which occur infrequently
   2. Repeated patterns of fire over time (fire regimes)
      a. The latter produce adaptations in species over evolutionary time
      b. Just as important in ecosystems as soil, air, precipitation, and climate
      c. Changes to fire regimes create large changes in ecosystem structure, function, composition, and distribution.

F. Fire-Associated Ecosystems include:
   1. Fire-Independent ecosystems
      a. Fire is not a regularly occurring process
      b. No species adaptations to fire
      c. Succession progresses towards a stable climax community (usually based on shade tolerance)
      d. Fires set succession back to an earlier stage
      e. Examples: temperate rain forests out west. In PA: possibly northern hardwood and hemlock stands where MFI is > 500 years.
   2. Fire-dependent ecosystems
      a. Fire occurs regularly
      b. Species need fire in order to persist (kills their competitors, prepares seedbeds)
      c. Fuel accumulations are regulated by fire (or unregulated when fire is suppressed)
      d. Fire required for persistence of ecosystem and of obligate associated animals
      e. Examples: Ponderosa pine forests, redwood forests, chaparral out west. In PA: the existence of dwarf pitch pine barrens depends on fire
   3. Fire Initiated Ecosystems
      1. Fire occurs at longer intervals
      2. Fire resets succession
      3. Species and ecosystems need fire to renew stands
      4. Examples: lodgepole pine out west; in PA: pitch pine-scrub oak woodlands

   4. Where do our Appalachian/PA oak-pine forests fall? I don't like any of the 3 categories above to describe them.
      1. Fire-adapted does not necessarily equal fire-dependent; however, fire is probably a key component of their ecology.
      2. Fire in the Apps is not always stand-replacing; can be gap forming
      3. Fire is usually stand-replacing in western forest models; not necessarily so in the east.

V. Management and Monitoring of Ecosystem Stressors

A. Key Attributes to Evaluate Ecosystem Stressors

1. Refer to the excellent Monitoring section of Scott & Pat's 1st & 2nd order Fire Effects presentation. Fire severity in an ecosystem can be accurately measured.

B. Indicators of Healthy Ecosystems
   1. Biodiversity
      a. Species richness (number of species)
      b. Presence of rare and endangered species
      c. Presence of major functional groups of species
         - N-fixers
         - Species that add structural complexity (ecosystem engineers)
         - Partners in mutualisms
         - Keystone species

   2. Heterogeneity
      a. Diversity in species
      b. Vertical Heterogeneity (structural complexity)
      c. Horizontal Heterogeneity (across the landscape)

   3. Food chain / food web
      a. Many links
      b. Presence of top predators

   4. Presence of natural ecological processes that species in the ecosystem evolved with
      a. Competition
      b. Predation
      c. Dispersal
      d. Succession
      e. Disturbances (Fire, flooding, ice storms, etc.)
      f. Local and Landscape Spatial Scales
      g. Short and Long Time Scales

   5. Inputs and outputs balance (equilibrium)
      a. Ecosystem not "leaking" mineral nutrients
      b. Loss of N into streams, for example

   6. Resistance vs. Resilience
      a. Resistance = not departing far from equilibrium in response to disturbance
      b. Resilience = quickly returning to equilibrium in response to a disturbance

C. Group Discussion Questions
   1. What are some practical real-world variables that you can measure to gauge the health of a PA oak-pine forest ecosystem?
      a. Pre-Burn vs. Post-Burn Monitoring
   2. How can you know if a controlled burn is beneficial to a forest ecosystem?
      a. Different than accomplishing a single goal, like "increase oak regeneration" or "increase wild turkeys."

VI. Summary

A. Ecosystems are the sum of the biological community and the abiotic environment it inhabits.

B. Ecosystems dynamically process energy and nutrients at different spatial and time scales.
C. Physical, Biological, and Chemical processes are all important to ecosystem function.
D. Fire is a natural process in many ecosystems.
E. The degree of integration of fire depends on the system.
F. Healthy ecosystems exhibit:
    1. Biodiversity
    2. Heterogeneity
    3. Complex food web
    4. Functioning ecosystem processes
    5. Equilibrium (not leaking mineral nutrients)
    6. Resistance and Resilience to natural disturbance