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ISSUES : *FRONTIERS* ISSUE TO TEACH ECOLOGY

Landscape Ecology of Large, Infrequent Fires in Yellowstone Park

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ARTICLE:
Turner, M.G., W.H. Romme, and D.B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment*. 1 (7): 351-358.

ECOLOGICAL CONTENT:
landscape ecology, Yellowstone National Park, fire ecology, patch, disturbance, succession, regeneration, lodgepole pine

TEACHING FOCUS:
Landscape ecology is a relatively new aspect of ecology, and the first author of this paper, Monica Turner, is one of its strong proponents. This would be a good paper for discussion about what landscape ecology is and why it is interesting. The 1988 Yellowstone Fire made headline news and so the topic would draw in students. By working with the figures in this paper students will come to understand how fires produce a mosaic of plant communities and how different plants respond to fire. The Scientific Teaching section focuses on the misconception that fire is “bad” for the environment.

OVERVIEW

Yellowstone National Park, established in 1872, is the oldest national park in the world. In 1988, there was a massive fire that made headline news and stimulated a good deal of ecological interest. The Turner et al. (2003) *Frontiers in Ecology and the Environment* article focuses on spatial heterogeneity resulting from fires like this one and application of lessons learned to fire management generally.

This article is a synthesis of the research on vegetation and ecosystem processes over 15 years in the Yellowstone National Park (YNP). The authors of the article begin by contrasting low intensity understory fires (intervals of years to decades, easily suppressed, resulting in an open forest) and high intensity, stand-replacing fires (kills most of the canopy, long intervals from 50 to hundreds of years). According to the authors, stand-replacing fires characterize boreal forests such as those in the YNP in the northern Rockies. These rarer extensive fires occur under severe drought conditions and are little influenced by variations in fuel and therefore by fire suppression policies. As described below, the 1988 fire was a result of severe drought and high winds. Turner et al. clearly state that weather-related factors rather than fuel availability were responsible for this fire. This is important because of controversies around the “let it burn” policies.

The authors emphasize the heterogeneity of the burned landscape created by the 1988 fire and rapid plant establishment post-fire. They describe (p. 352-353) how the fires created a mosaic of burned and unburned patches and the great increases in plant cover four years after the fire. They were surprised to find that the most of the viable seeds came from plants that survived the fire and not from nearby, unburned sites. Several years post-fire, plant communities were similar in composition in burned and unburned areas.

The Figures section of this *Issue* includes two of the figures found in Turner et al. 2003 *Frontiers* (figure 3 and figure 5). Figure 3 concerns effect of patch size and fire severity on post-fire plant cover and species richness. The figure shows that small patches have more forbs, grasses, and total cover compared to large patches. In addition, cover of forbs, grasses, and shrubs is lower in more severely burned locations. However, Turner et al. state that “the effects of environmental composition on species richness and community composition are becoming more pronounced (figure 3), and post-fire communities are similar in composition to nearby forests that did not burn. The influence of the abiotic template on vegetation is, therefore, becoming more evident as succession proceeds.”

Figure 5 focuses on lodgepole pine. Adult lodgepoles do not survive fire and regeneration depends on release of seeds from serotinous cones at high temperatures (see background information below). Seedlings grow well in the bright, burnt forest, resulting in dense, even-aged stands. Figure 5 shows influences of fire severity, patch size, and geographic location on densities of pine seedlings post-fire.

Background Information

Nearly all plant communities in Yellowstone have experienced fire, but the response of the vegetation differs, resulting in a complicated pattern of responses and effects. For example, Douglas-fir trees have thick, insulating bark; mature Douglas-firs are not often killed by fire. In contrast, other trees (lodgepole pine, Engelmann pine, subalpine fir) have thin bark but have other adaptations to fire. Some lodgepole pines have serotinous cones “glued” tight with resin that only melts at high temperatures, releasing seeds onto the well-burned landscape. Engelmann pine and subalpine fir grow in cooler, wetter habitats where fire is less likely; therefore they “escape” fire. Aspen has thin bark and the above-ground trees burn fairly readily;

belowground is a network of cloned roots which sprout after fires. In contrast to the much more frequent intervals of historic fires in shrub grasslands (about 25 years), “natural” intervals for lodegpole pine forests in Yellowstone may be 300 years or more (Houston 1973).

The 1988 Yellowstone fire attracted a lot of attention in part because it was so large – about a third of the park (roughly 800,000 acres) burned. Over 9000 firefighters from all over the country tried to suppress the fire at a cost of 140 million dollars; in the end rainfall and snow stopped the fires. In addition to its size, the economic cost and damage to property near the park resulted in heated debates about the National Park Service’s “let burn” policies.

There are a number of websites with detailed accounts of the fire (e.g., http://www.x98ruhf.net/yellowstone/fire.htm). When lightening started the fire in late June officials assumed that summer rains would eventually extinguish it; however, that summer turned out to be historically dry and windy (data are in above website).

Although stories appeared in the popular press about the “death” of Yellowstone, the forest regenerated faster than expected because of the patchiness of the burn. "Even close to the center of the largest burn, there were areas that were relatively unburned, that served as sources of propagules," says William Hargove, a research associate at Oak Ridge National Laboratory who also studied the fire (http://whyfiles.org/018forest_fire/main2.html). Wildflowers and shrubs survived because soils were affected only a few centimeters deep on average. By 1990, wildflowers were abundant. Finally, surprisingly few large animals such as elk and bison were impacted with rates of mortality at most about 10% above expected by winter weather (ibid).

References

- Houston, D.B. 1973. Wildfires in Northern Yellowstone National Park. *Ecology* 54(5): 1111-1117.
- Turner, M.G., W.H. Romme, and D.B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment*. 1 (7): 351-358.

SCIENTIFIC TEACHING

Although ecology faculty have extensive research training, most do not realize that they can do research in their own courses. This is a different kind of research than we are used to — often not controlled, without replicates, and so on. But it is still research because we can develop hypotheses, ask specific questions based on these hypotheses, and then collect and analyze data which in turn inform the questions and hypotheses. There are numerous journals dedicated to interesting research on teaching (e.g., *Journal of Research in Science Teaching*).

One type of classroom research is called “action research.” In this research, faculty ask specific questions about their students or their teaching, gain information about these questions, and use this information to learn about teaching and their course in particular. A list of action research websites is below. Action research is an aspect of “scientific teaching” (Handelsman et al. 2004).

Below we describe a four-step process which you can use to conduct research on your use of the *Frontiers* article. The theoretical bases for this TIEE Scientific Teaching section are three areas of research on learning (D’Avanzo 2003 a,b): *metacognition* (knowing what we know), *misconceptions* (firmly held beliefs that are incorrect), and *adult development stage theory* (stages that learners are thought to go through as their thinking about a discipline matures).

TIEE is designed to stimulate faculty to think more deeply about teaching and learning and apply what they learn here to their particular styles and situations. In contrast, this section is more prescribed because it is a four-step process that we recommend. This is because pre-post testing and classroom research are such foreign ideas for faculty that we believed more guidance was required. However, we very much encourage teachers to look at the resources below and design action research approaches most suitable for them.

Action Research with the Turner et al. article: Misconceptions About Disturbance

Misconceptions: Students come to class with background knowledge that may or may not be correct; when incorrect this information is called a misconception (or prior/alternative/intuitive conception). Students’ misconceptions are notoriously difficult to change, and numerous studies show that students come to class — and leave — with the same content misinformation even when the content is directly dealt with in a class.

As stated in the “Notes to Faculty” section, **you can use this article to address a misconception shared by many ecology students: disturbances such as fire have irreparable and permanent effects on natural systems**. That students have this misconception may surprise you — which is one of the reasons why students retain these alternative conceptions. Faculty are unaware of them!

The next section provides suggestions for assessing whether your students have this misconception, how you can use the Turner et al. article to specifically address it, and then seeing if/how much the misconception changed as a result of your “interception”:

Step One: Pre-test — Use questions that expose the misconception that environmental change is a “bad” thing — in this case that disturbances cause irreparable harm. How you do this depends in part on the size of your class. Below are several examples.

- In a **small class** you can ask students to answer a short list of questions (in class, not as homework). Be clear that this is not a test, is anonymous, and has no bearing on their grade. Tell the class that it will help you better design the course for them. Students can write very short essays in response to images and/or questions you pose to them such as the following. "*Look at this photograph of a forest fire. Some people say that fires like this can be normal ecological events that have occurred in the past and will likely occur in the future. Therefore, unless the fire will destroy homes and businesses, it should be allowed to burn. Others disagree and believe that large fires like this are very destructive to the environment and should be controlled. What do you think?*" You can also use multiple-choice questions as described below.

Photo taken by Alaskan Type I Incident Management Team.
Photographer: John McColgan, Bureau of Land Management, Alaska Fire Service.
http://fire.ak.blm.gov/

- In **larger classes**, it is harder but not impossible to ask students to write short essays. A real benefit of polling large classes is the large sample size. You can hand out index cards, pose the essay question described above, and simply ask students to drop the cards in a box as they leave the classroom. (Again, explain that this is not a test and is anonymous). You don't need to look at all the cards; you can randomly sample them until the answers become repetitive.

- In any size class, you can also use **multiple-choice** questions. The question above could be modified with choices, such as: (a) I think that fires like this can be normal ecological events and unless they destroy property, they should be allowed to burn, (b) I don't think that fires like this are normal ecological events and therefore they should be controlled (c) I don't know.

Step Two: Intervention (your teaching) — Use the Turner et al. article in a class session, being sure to clearly bring out the idea that large forest forests can be normal events in certain habitats.

Step Three: Post-test — Decide on a way to assess your students' learning in regard to the misconception. This could be through a brief essay or multiple-choice question similar to the ones described above but specifically concerning information from the Turner et al. article. Another way is to give students a new statement to analyze, such as the one below.

For this essay, students are asked to respond to a comment about fire supposedly written by another student. The idea is to compare their response to an ecology expert's (e.g., you). For homework give students the paragraph below written by "a student" and ask them to write a one-page (300 words or so) analysis of the student's commentary.

Student comment about Large and Infrequent Forest Fires:
Small to moderate-sized fires that take place every so often are OK in forests where fires historically have occurred because it's a normal thing and the forest can recover pretty quickly. But very big fires that happen rarely, like once in 50 years or something, are not normal. They just destroy too much of the forest and it takes a really long time before the trees and other plants and the wildlife to come back. It's like a huge flood or a hurricane that just wipes everything out.

If you have a large class, you can skim these essays, or look at a sample subset. You don't need to grade these, but give students a point or two for doing the work.

Step Four: Reflection and Response — This is probably the hardest part of the whole process — once you have your "data," what you do with it?

- This kind of evaluation is a way for you to think more deeply about your students' learning — what you really want them to learn and what inhibits them from achieving this goal. When done well, classroom research like this can help make students' thinking more transparent so that you can better design on ways to "get through" to them. The idea is to reflect on their learning as opposed to your teaching.

- Discussing your findings with a trusted and knowledgeable colleague may be the best thing to do, if you have such a colleague. You could also email one of the TIEE editors or post a question on ESA's Ecolog (http://www.listserv.umd.edu/archives/ecolog-l.html) or the Ecology Education listserv (http://ecoed.net/mailman/listinfo/ecoed).

- What you do in the class of course depends upon what you have learned as well as the amount of time you are able to spend on follow-up. At a minimum, in the next class session you should report back to the students and give an overview of their writings — good points and ones many missed — and use this as a way to again discuss how ecologists think about change.

- If students made good progress between the pre and post-tests, say so and praise them. Don't expect a big change; modest growth as a result of one class session is a real achievement.

A specific example: Professor Smith learned from the post-test essays that about half of her students agreed with the idea that large fires cause irreparable harm. In response, she again showed data from the Turner et al. paper, told students that many still believed that large-scale fires were "bad" for the environment, and asked why this might be so, in light of the Turner et al. findings. She discovered that some students did not make the connection between the Turner paper and their misconception.

References

- D'Avanzo, C. 2003a. Application of research on learning to college teaching: ecological examples. *BioScience* 53:1121-1128.

- D'Avanzo, C. 2003b. Research on learning: Potential for improving college science teaching. *Frontiers for Ecology and the Environment* 1:533-540.

- Handelsman, J. et al. 2004. Scientific Teaching. *Science* 304:521-522.

Resources

General

- Handelsman, J., D. Ebert-May, R. Beichner, P. Bruns, A. Chang, R. DeHaan, J. Gentile, S. Lauffer, J. Stewart, S. M. Tilghman, and W. B. Wood. 2004. Scientific Teaching, *Science*. 304:521-522.

Action Research

- Good overview and history of Action Research
  http://www.infed.org/research/b-actres.htm

- Overview with focus on curriculum development
  http://informationr.net/ir/1-1/paper2.html

- San Jose State University; brief overview and ideas for how to start
  http://www.accessexcellence.org/21st/TL/AR/

- University of Colorado site; has many articles
  http://carbon.cudenver.edu/~mryder/itc/act_res.html

Misconceptions

- Five misconceptions about evolution
  http://www.talkorigins.org/faqs/faq-misconceptions.html

- Articles about biology misconceptions
  http://tortoise.oise.utoronto.ca/~science/biomisc.htm

- “Bioliteracy and teaching efficacy: what biologists can learn from physicists”; from *Cell Biology Education Journal*, good overview that contains many links
  http://www.cellbioed.org/articles/vol2no3/article.cfm?articleID=67

- Munson, B.H. 1994. Ecological misconceptions. *Journal of Environmental Education* 25: 30-34.

- Overcoming Ecological Misconceptions
  http://ecomisconceptions.binghamton.edu

NOTES TO FACULTY

The emphasis in TIEE Issues is use of figures and tables for discussion and other types of student-active teaching and learning. These notes will give you ideas about using the figures in this paper in your ecology class. The Student-Active Teaching table will introduce you to a variety of approaches you can use in your class to actively engage your students. To see an essay on leading good discussions, go to Guided Class Discussions.

You can use the Turner et al (*Frontiers*, 2003) paper to discuss many ecological topics including disturbance, landscape ecology, patches, adaptations of trees to fire, and succession. Students will also be interested in the more applied aspects and some will likely recall seeing the fire on TV or in the news. For example, George W. Bush used this and other large fires to promote his "healthy forests" initiative. Also, as discussed in the Scientific Teaching section of this issue, the Turner et al. paper is a good opportunity to discuss a misconception that many students have — that disturbances such as fire have irreparable, negative ecological effects.

Points of emphasis for Figure 3: These data show clear effects of fire severity and patch size on plant cover and richness in the 10 years right after the fire. Although these effects are diminishing, smaller patches have more forbs (e.g., wildflowers and other herbaceous plants), grasses, and total cover. In addition, in more severely burned areas, forb, grass, and shrub cover is less. (In this study a small area is one hectare (ha), moderate is 70-200 ha, and large is 500-3600 ha.) Dispersal from surrounding unburned areas has not been an important reestablishment mechanism; most plant cover in the first three years is from re-sprouting survivors. Therefore, community composition (types of plants but not distribution, abundance, etc.) may eventually be similar to what it was before the fire. The three locations in Figure 3 "c" are meant to be replicates although they show considerable variation; therefore the authors state that despite the significant effects of patch size and burn severity, response varied a great deal by geographic location, showing the importance of landscape-scale effects on ecosystems.

For more details, see Turner, M.G., W.H. Romme, R.H. Gardner, and W.W. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. *Ecological Monographs*. 67(4): 411-433 (Click here for PDF). Figure 1 from this paper shows the three site locations and Figures 2-5 (figure 2, figure 3, figure 4, figure 5) are data for forbs, grasses, and shrubs separately.

Points of emphasis for Figure 5: The response of this serotinous tree is clearly seen in this figure. Tree seedling density was higher in large patches and areas with severe surface burning. Crown fires appeared to be so hot as to reduce seed viability.

As described below, these are good figures to use for "turn-to-your neighbor" although you can of course just use them for a general class discussion as well. (Approaches like turn-to-your-neighbor usually result in better discussions.)

Note: "Turn-to-Your-Neighbor" is an easy and effective group approach you can use in large classes.

Project or hand out Turner et al.'s Figure 3 and/or 5. With the class as a whole or in small groups (no more than five students per group), ask students to first describe and then interpret the figure. (Ahead of time explain terms such as "% cover" and S.E. and sources of the data). For students working in groups, ask each group to present one question or comment they have about the figure. You can call on one group at random to describe and interpret the figure, and then ask for additional comments/questions.

Additional discussion questions:

1. Looking at the data in Figure 3 (or 5), describe what the sites looked like in 1990 right after the 1988 fire. What did they look like in 2000? In other words, if you were walking around looking at these locations, what would you see?

2. Based on the experimental design (e.g., types of areas studied) for Figure 3, what specific questions were the scientists asking? Why might these be interesting or important questions?

3. In this paper the researchers said, “We were surprised to find that most post-fire colonization occurred from plant parts that survived within the burned areas and then produced seed ...”. Why were they surprised? How else might the burned areas become revegetated?

4. How would the speed of revegetation/recovery be affected by different methods of burning an area, or by different degrees of natural burn. How would plant diversity in the re-colonizing community be affected by the different methods employed in a prescribed burn or by different degrees of a natural burn?

5. The ecologists doing this research say that they are studying “patch dynamics” and “landscape scale phenomena." Explain.

6. The researchers conclude, “post-fire plant communities were similar in composition to nearby, unburned sites.” Why were they similar and what are the management implications of this statement? How did the researchers measure similarity?

7. The 1988 Yellowstone fire appears to be the result of an exceptionally dry and windy summer. What are the management implications of this?

Another idea: In a small class use this topic as the focus of a citizen’s argument or role-playing in a town meeting-type setting. Students could be assigned roles and asked to use the resources below and other sources as evidence for their point of view, now that 20 years has passed since the Yellowstone fire. For instance, did the worst-case economic scenarios pan out or, as with the vegetation, was the recovery faster than anticipated?

Additional Discussion Point: Turner’s Concept of Large, Infrequent Disturbances (LIDs)

In their 1998 paper in *Ecosystems*, "Comparing Large, Infrequent Disturbances: What Have We Learned?" Turner and Dale introduce a series of papers in this issue of *Ecosystems* on large, infrequent disturbances (LIDs). They cite the Yellowstone 1988 fire as an example along with Hurricane Hugo in 1989, Mount St. Helens in 1980, and the 1993 Midwest floods. They describe LIDs as “much larger in spatial extent (terrestrial systems), or in depth/duration (floods) than the disturbances that ‘typically’ affect the system.” To avoid a circular definition of LIDs they go on to more specifically define them (e.g., by size and frequency of fires). They consider LIDs to be important ecologically because of the large and persistent effect on ecosystems that endure for very long periods of time.

An important point is that despite their scale, LIDs do not uniformly impact the area but instead create “complex heterogeneous patterns across the landscape....and have the potential to generate more heterogeneity than do small or weak disturbances.” (p. 494).

A note about landscape ecology

Landscape ecology is a relatively new subdiscipline of ecology. It is the study of landscape structure and processes and the scale is usually larger than that studied by community or ecosystems ecologists. A central tenet is that the patterning of landscape elements (patches) strongly influences ecological processes. The resource list below will direct you to more information.

References

- Turner, M.G. and V.H. Dale. 1998. Comparing large, infrequent disturbances: what have we learned? *Ecosystems*. 1:493-496.
- Turner, M.G., W.H. Romme, R.H. Gardner, and W.W. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. *Ecological Monographs*. 67(4): 411-433.
- Turner, M.G., W.H. Romme, and D.B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment*. 1 (7): 351-358.

Resources

Yellowstone Fire

- NASA's "Exploring the Environment" for teachers: the Yellowstone Fires
  http://www.cotf.edu/ete/modules/yellowstone/YFmain.html
- Yellowstone National Park site; has many “facts and figures”
  http://www.yellowstone-natl-park.com/fire.htm

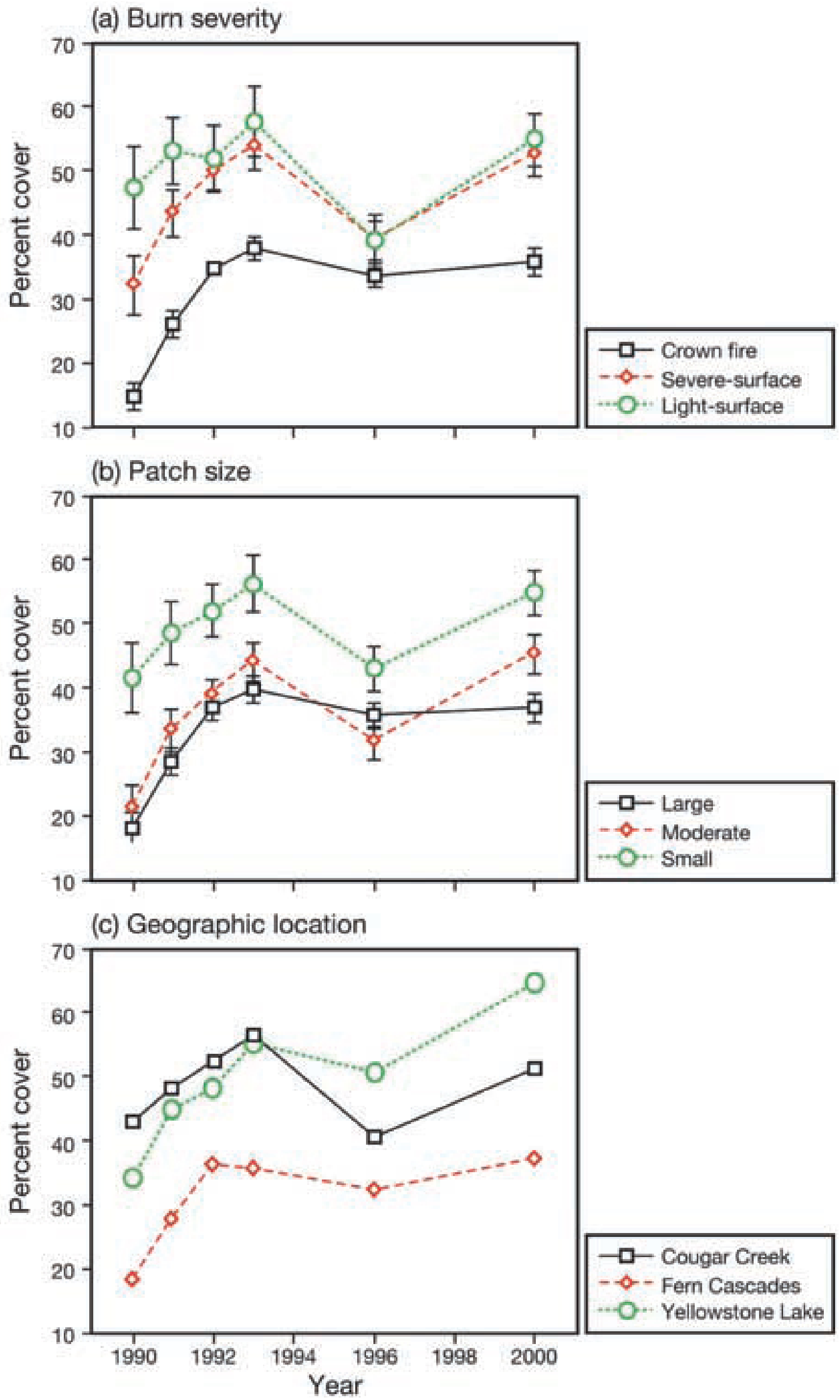
Landscape Ecology

- Overview: ARC/INFO site
  http://www.innovativegis.com/products/fragstatsarc/aboutlc.htm
- Monica Turner's Landscape Ecology Lab: includes description of the field
  http://brahms.zoology.wisc.edu/
- EPA site; lists landscape ecology study areas throughout the US
  http://www.epa.gov/nerlesd1/land-sci/default.htm
- US Regional Association of the International Association for Landscape Ecology
  http://www.usiale.org/

FIGURES

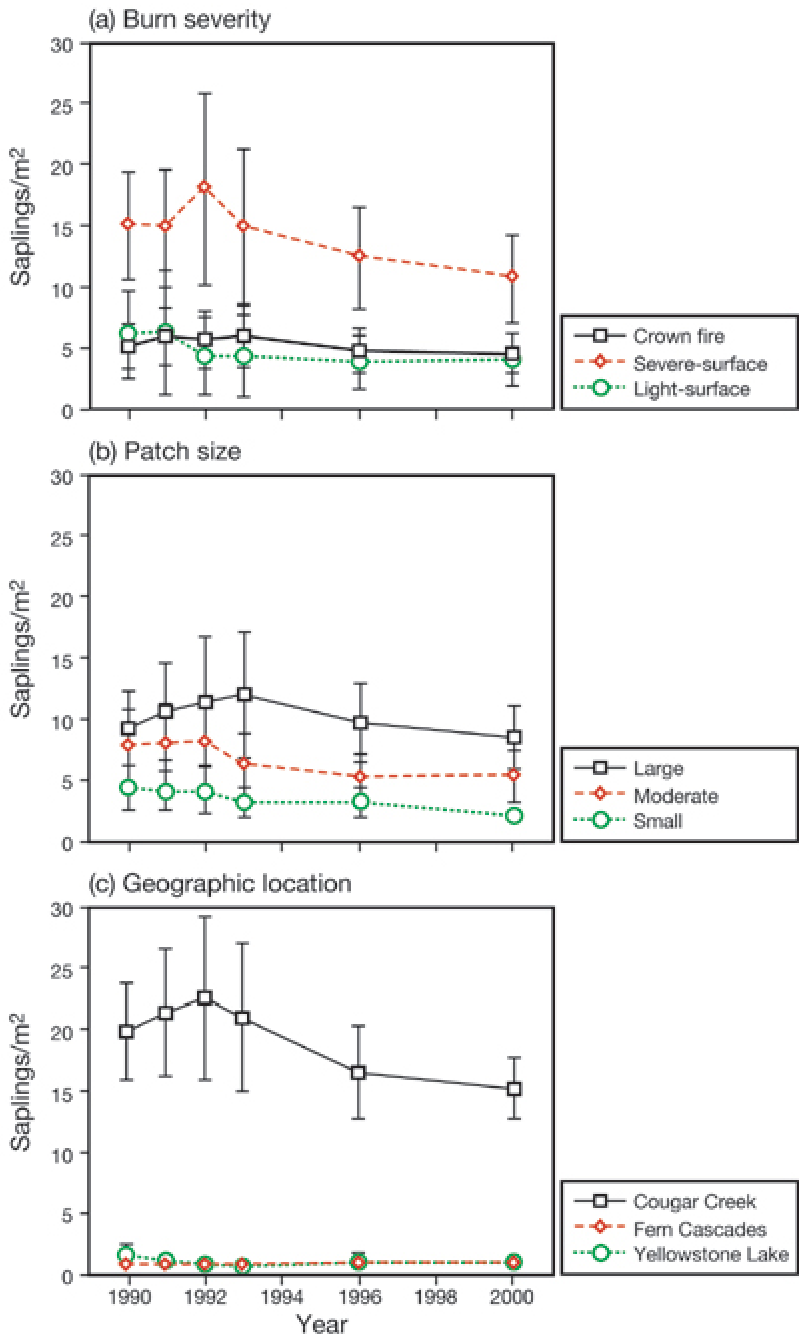
Frontiers Figure 3

Percent total biotic cover as measured in over 700 permanent plots established in 1990 by burn severity, patch size, and location. Sampling occurred in patches of stand-replacing fire that were small (1 ha), moderate (70–200 ha) and large (>500 ha) in size (methods described in Turner et al. 1997). Error bars are 2 SE.



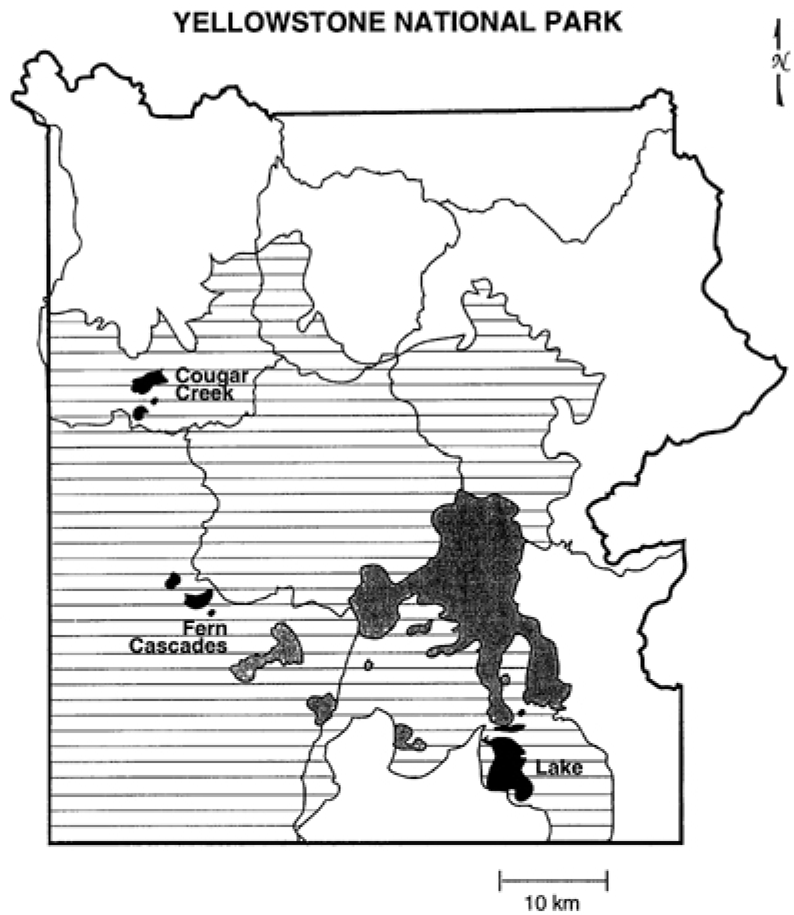
***Frontiers* Figure 5**

Post-fire density of lodgepole pine as measured in over 700 permanent plots established in 1990 by burn severity, patch size, and geographic location. Sampling occurred in patches of stand-replacing fire that were small (1 ha), moderate (70–200 ha) and large (> 500 ha) in size (methods described in Turner et al. 1997). Error bars are 2 SE.



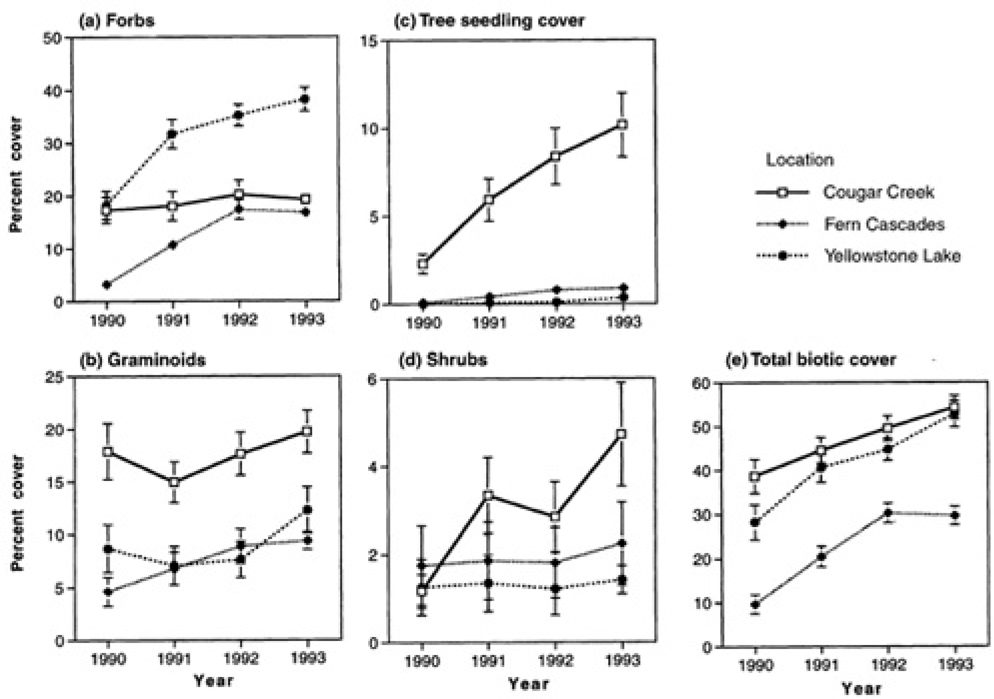
***Monographs* Figure 1**

Map of Yellowstone National Park showing the locations of the three study locations (Cougar Creek, Fern Cascades, and Yellowstone Lake). A small (1-2 ha), moderate (80-200 ha), and large (480-3698 ha) patch of crown fire was studied at each location. The hatched area depicts the Yellowstone Plateau, the gray shading illustrates major lakes, solid black areas show the nine burned patches used in this study, and irregular solid lines indicate Park roads.



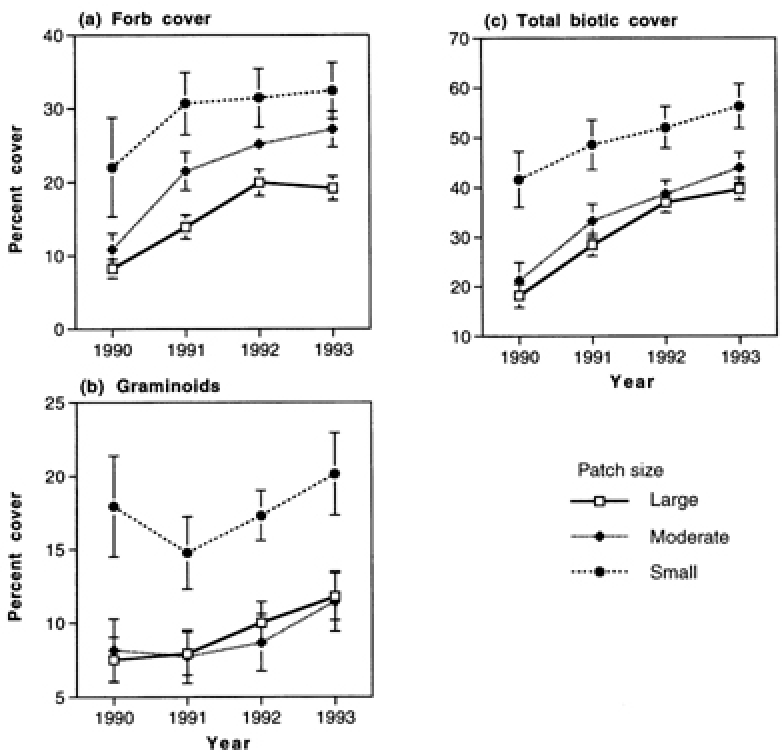
***Monographs* Figure 2**

Percent cover by year at each of the three study locations (Cougar Creek, Fern Cascades, and Yellowstone Lake) in Yellowstone National Park. Data show means ±2 SE.



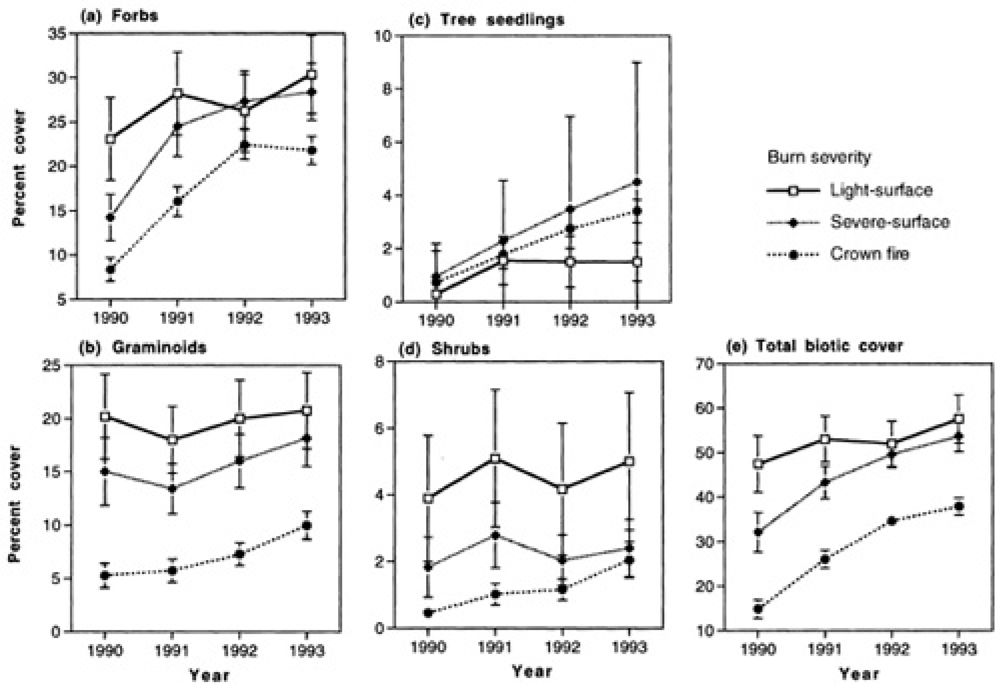
***Monographs* Figure 3**

Percent cover by year for small, moderate, and large burned patches for forb, graminoid, and total biotic cover after the extensive 1988 fires. Data show means ±2 SE.



***Monographs* Figure 4**

Percent cover by year for the three burn severity classes. Data show means ±2 SE.



***Monographs* Figure 5**

Mean density of *Pinus contorta* (PICO) seedlings across all samplings points by year. "All PICOs" refers to all seedlings that germinated following the 1988 fires. The first-year PICOs are those seedlings that germinated during the indicated year. Data show means ±2 SE.