Fire Ecology

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BIOLOGY STUDENTS often identify with the uniform of the Park Service ranger or Smokey the Bear when the effects of fire on conifer biomes are being discussed. At Kingsburg (Calif.) Joint Union High School we capitalize on this identification by providing our students with the opportunity to get involved in fire ecology research with the National Park Service.

Kings Canyon National Park in California is known for its extensive wilderness and its staff's research into the nature of fire on conifer forests. In order to become involved with a relevant study, we contacted the park research management team about possible class participation and found that there were several criteria to be met. Our research needed to be directed toward a stated management need of the Park Service. A project proposal had to be submitted defining the problem, the methods to be used, and the time necessary for research; a plant-collecting permit was to be obtained from the chief park naturalist; and annual end-of-year reports of findings, progress, and future direction were required.

A Retestable Problem

One of the general research objectives of the Sequoia and Kings Canyon National Parks Natural Sciences Research Plan is the "... restoration, insofar as possible, of the natural, undisturbed state of the montane and subalpine forests, with special attention to ... the essential ecological balance between natural fire and vegetation" (Summer 1966). To develop a research topic that would be within definite boundaries and that could be tested each year, we identified a population of black oak trees within a mountain canyon for intensive study.

Black oak, *Quercus kelloggii,* has been recognized as a major component in the pristine yellow pine forest ecosystem in the central Sierra Nevada. However, recent studies indicate the *Quercus kelloggii* is declining in numbers and distribution (Gibbens 1964; Reynolds 1959). It has been suggested that this decline is the result of suppressing natural fires for the past century, which has caused a selective successional advantage for other species found in the yellow pine forest; for example, white fir *(Abies concolor),* incense cedar *(Calocedrus decurrens),* and sugar pine *(Pinus lambertiana).*

Considerable research has been conducted in the southeastern conifer forests and in the sequoia groves of California. From this research it has been determined that fire in a mixed conifer forest has several functions (Kilgore 1972):

1. Fire prepares a seedbed by consuming downed branches and litter and duff, allowing seeds to reach mineral soil and become established after germination.
2. It cycles nutrients by releasing minerals contained in dead vegetation. Light fires often increase soil pH, stimulate nitrification, and increase available phosphorus, potassium, calcium, and magnesium.
3. Fire retards succession in certain relatively small areas by reducing or eliminating nonfire-dependent forms, including the shade-tolerant white fir, which is a climax nonfire species.
4. Because it burns in highly variable patterns, fire provides a mosaic of age classes and vegetation types.
5. Fire provides conditions that favor vertebrate wildlife. Subclimax stages of plant succession in burned areas have had a favorable effect on deer populations.
6. It reduces the numbers of trees susceptible to attack by insects and disease. Fire has a sanitizing effect on fungal and bacterial spores, and it eliminates old tree stands which may be highly susceptible to disease.
7. Small natural fires reduce the probability of serious uncontrollable fires by clearing accumulations of fuel.

Objectives

This study is designed for student involvement in determining if fire is the main influence on black oak reproduction and subsequent survival. Students who initiated the study prepared a proposal and presented it to the management team consisting of the park biologist, the game manager, and the assistant chief park naturalist. After the project was approved, a group of students met with the local subdistrict ranger and fire guards to discuss the hazards and limitations of the project. In addition, Howard Latimer, plant ecologist at California State University, Fresno, reviewed the experimental methods. California State University is assisting in our project by loaning our school vegetation sampling equipment.

Because this ongoing study is the first of its kind in our school, we felt it important to communicate with

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the school administration about the objectives of the study as they relate to the biology program. They include the following:

1. To develop a continuing student involvement project.
2. To utilize subjective and objective data for the development of evidence of succession patterns.
3. To attempt to provide important data for the solution of a recognized problem being considered by the Park Service.
4. To provide the flexibility of independent study for advanced biology students.
5. To promote an interdisciplinary approach by providing the computer math courses with quantifying project data to be analyzed.

Each year's results are interpreted to determine the degree of change in control versus experimental plots. The data is organized into tables and graphs that are open-ended to allow for the inclusion of future data. At the end of the analysis, each group assigned a specific function presents both written and experimental reports to the class for discussion and comparison.

This experimental study results in the student's mastery of the following objectives:

1. Determining mathematically the changes in a specific aspect of the vegetation.
2. Learning proper techniques for sampling vegetation to determine succession patterns.
3. Graphically representing changes in a specific aspect of the vegetation.
4. Demonstrating understanding of the subject by leading a discussion on his set of data.
5. Participating in discussion of data presented by other students on different types of vegetation.
6. Writing an experimental report on the expected results and the actual results as part of the annual year-end report.

Classroom Organization

Field ecology is introduced in the classroom through discussions of local biomes which include grasslands, chaparral, oak woodland, and conifer forests. Abiotic factors, including soil, slope, exposure, precipitation, temperature, and gravity, are considered in relation to fire. Biotic factors are studied with reference to local vegetation using keys and specimens from the study area. Wildlife normally found is discussed with an emphasis on its effect on the vegetation of the study area. A literature review on the effect of fire is conducted with discussion of major articles available from the Forest Service, Park Service, and the instructor's personal library. A discussion of national parks is conducted emphasizing legislatively mandated operations and goals and their limitations in serving all of the public as recreation and preservation areas. The Park Service has published a number of articles and teacher's guides to explain interpretive features in the parks, which can be obtained from local park naturalists and the regional office of the Department of the Interior.

For first-year biology students, slides and data taken at the experimental site are used for illustration of techniques and as an exercise in the interpretation of data. Second-year biology students who have taken first-year biology are involved in the activities of data collecton at the study site. An overnight field trip in the fall of the year gives us an opportunity to collect data, learn techniques in the field, and analyze the data while still in the area so that if mistakes are evident they can be corrected. In the spring of the year a single-day field trip is used to collect additional data. Third-year biology students who have taken the first two years are encouraged to develop independent study projects. Areas of specific interest are developed by the instructor and students, for example, determining microbial populations and comparing decomposition rates of the litter and duff in the laboratory to those in the plots as a whole. This part of the study is limited to only a few senior students.

Field Organization and Methods

Four plots, each 800 m^2, were selected on a north facing slope which varied from 3 to 13 degrees. Permanent metal stakes were placed in each corner of the plots and identified with red plastic surveyor's tape.

Table 1. Number of black oak seedlings, saplings, and trees counted in September 1972 (before burning) and September 1974 (after burning).

Plot		*Seedlings*	*Saplings*	*Trees*
1 (burned)	Before	0	0	3
	After	8	0	3
2 (control)	Before	1	0	0
	After	11	0	0
3 (control)	Before	2	0	12
	After	27	0	12
4 (burned)	Before	2	20	10
	After	13	16	5

Plots were selected to give a cross-section of the mosaics of vegetation that exist in a conifer forest. Two plots were burned while the other two acted as controls. Varying the degree of slope enabled us to note the behavior of the fire with this variable.

Data were obtained on tree, sapling, and seedling abundance for the major conifer species and black oak. Herbaceous cover was measured by the plot and the point quadrat method (Cottam and Curtis 1956). Ten quadrats were sampled per plot and the results were converted to percentage data (table 1). Litter and duff accumulation was measured, taking ten samples per plot and averaging the results to determine total flash-fuel levels (fig. 1, table 2). Permanent photo points were established so that pictures could be taken every five years to compare with the quantitative data. Orange juice can bottoms were perforated with a nail to indicate photo point.

Each tree and group of saplings were identified, measured, and plotted on a map. A giant protractor was made with half of a large wire spool that was subdivided into 360 degrees (fig. 2). Beginning in a corner

Fig. 1. Litter and duff accumulation was measured to determine total flash-fuel levels before burning.

of the plot, we used a tape measure to determine the distance and the angle each tree or group of saplings were from the fixed corner. A diameter tape was used to measure the diameter of each tree at breast height. This information was then plotted on maps in the classroom and serves as a reference point for future changes.

Seedlings are measured throughout the plot. Each seedling is staked and marked with plastic surveyor's tape. Other methods of random sampling were discarded because of the wide variability in the mosaic pattern of vegetation.

An increment borer is used to determine the relationship between diameter at breast height and the number of annual rings. This data is plotted to give an estimate of the age of trees in the plots not actually cored. In the field some of the other species can be cored to show comparisons of different species growth rates.

Students were involved in the formation of fire lines around the experimental plots and in transporting fire equipment to the site. Data were gathered and indexes determined for wind speed, temperature, relative humidity, precipitation, timber buildup, fine fuel, spread, intensity, timber burning, moisture code, and fuel stick weight. To determine the temperature generated by the fire, mica sheets can be painted with Tempilaq (available from Tempil Division, Hamilton Blvd., South Plainfield, N.J. 07080). Because each color of this paint melts at a specific temperature, these can be used to determine the variation of fire intensity and to measure convection currents throughout the plot, both beneath the litter layer and above the ground.

Prescribed burning of the two plots occurred in the fall of 1972 under criteria set forth in the U.S. Forest Service Schmipke fire formulas and under the direct supervision and participation of the Park Service. Students recorded data on the rate of spread, location of hot spots, and the candeling that took place in white fir thickets (fig. 4). Students who participated in the burn were impressed with the amount of physical work that accompanies some science problems.

Table 2. Distribution of cover (in percentages) before and after the prescribed burn.

Plot	*Month Measured*	*Herbaceous*	*Litter*	*Bare rock and soil*
1 (burned)	*9/72	7	91	2
	5/73	0	76	24
	9/74	3	86	11
2 (control)	*9/72	3	97	0
	5/73	6	88	6
	9/74	3	90	7
3 (control)	*9/72	17	77	6
	5/73	23	74	3
	9/74	30	66	4
4 (burned)	*9/72	24	71	5
	5/73	2	93	5
	9/74	8	77	15

*before burning

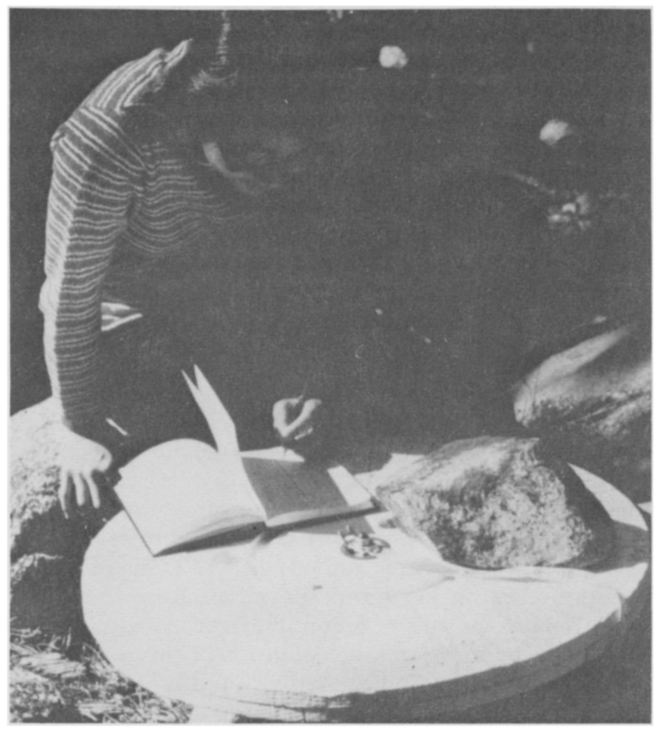

Fig. 2. A giant protractor made of half of a large wire spool was used to determine the distance and angle of each tree or group of saplings from a fixed corner of the plot.

Projects proposed by students for future studies that will expand on the data presently being collected include the establishment of deer enclosures to monitor the effects of deer browse on fire-stimulated shoot growth, determining the change in the amount of sunlight received on the forest floor, microfauna analysis of soils, and establishing the production rate of acorns

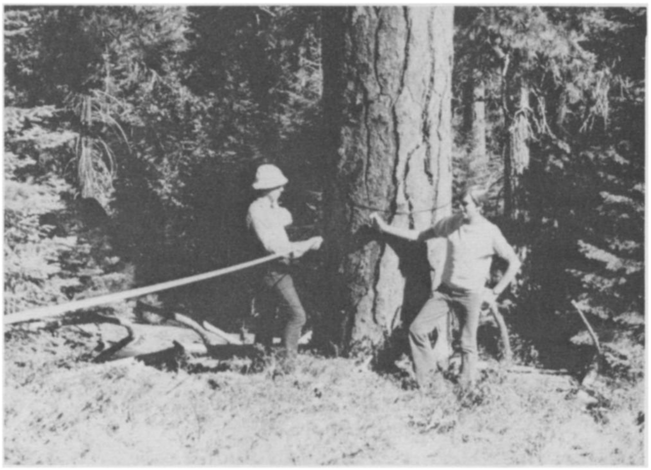

Fig. 3. The diameter of each tree was measured at breast height.

in black oak. These projects require experimental designs that enable third year biology students to turn their projects over to second year students who will be taking another year of biology to maintain continuity of data.

Results

Data taken two years after the fire indicate black oak seedlings have increased, although the increase is not directly attributable to fire since the control plots show the same general increasing trend as the experimental plots. Black oak saplings were susceptible to fire as were the black oak trees in the lower age-classes. Large trees were resistant to the effects of fire (table 1). Herbaceous cover was reduced by fire and continues to be lower than control plots (table 2). Rates of litter and duff accumulation are more rapid in experimental plots and are expected to reach preburn levels by the spring of 1976 (table 3). One of the problems in studying plant succession is the length of time necessary to acknowledge definite response patterns.

Fig. 4. Students recorded data on the rate of spread, location of hot spots, and candeling.

Table 3. Litter and duff buildup before and after the prescribed burn.

Plot	*Reduction by fire*	*Rate of Buildup in cm/yr (May 1973-Sept. 1974)*	*Total Buildup in cm (Sept. 1974)*
1 (burned)	65%	2.03	4.8
2 (control)		1.12	7.1
3 (control)		0.82	3.2
4 (burned)	83%	1.12	3.2

Summary

This project is providing a great deal of tangible positive feedback. Students who have since gone to college write to find out the latest results. Other students are stimulated to develop independent study projects arising out of questions previously unanswered in the field. All students seem to appreciate the feeling of helping to gather useful data which will aid park managers in preserving the National Park Forests in as natural a state as possible. The data generated is also useful in other biology classes as an exercise in interpreting data, understanding of experimental design, and becoming aware of the necessity of studying conifer forest succession over long periods of time.

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The Ideal Companion

I think I could turn and live with animals, they are so placid and self-contained; I stand and look at them long and long. They do not sweat and whine about their condition; they do not lie awake in the dark and weep for their sins; not one is dissatisfied; not one is demented with the mania of owning things.

Walt Whitman