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Determining Potential Wildlife Benefits from Wildfire in Arizona Ponderosa Pine Forests

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Abstract

Large wildfires are frequently destructive to the timber resource, but wildlife may not be so adversely affected. A study of selected species of wildlife (deer, elk, rodents, and birds) that were present on large burned areas, 1, 3, 7, and 20 years old, indicated population fluctuations and habitat changes that are, for the most part, predictable, and can be expressed in economic terms. An "Index to Benefits" was developed that converts the flows of benefits or losses after fire to annuities. By assuming values for wildlife use, the manager can interpret these changes in terms of dollars in order to describe the total impact of wildfire on the wildlife resource.

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Ponderosa pine[3] forests extend over more than 26 million acres in the four neighboring States of Arizona, Colorado, New Mexico, and Utah (Schubert 1974). These forests not only represent the single most important timber resource in the 4-state area, but also provide an environment that encourages heavy recreational use. In Arizona and New Mexico, ponderosa pine forests cover 8 million acres, and, while there are many isolated stands, the large continuous blocks lend themselves well to the true concept of multiple use management.

Ponderosa pine forests occur in an elevational zone between 5,000 and 9,000 feet, and develop well under conditions where annual precipitation is within a range of 15 to 26 inches. Runoff from the ponderosa pine forests supplies local communities with domestic water. Much of the water that finds its way into the Salt-Verde River system in Arizona and into the arid valley around Phoenix comes from ponderosa pine forests along the Mogollon Rim. Some of the Southwest's richest wildlife resources are found in the ponderosa pine type. Deer and elk herds receive the heaviest hunting pressure, but turkey and other small game are hunted extensively. Grazing allotments for domestic livestock are an important use throughout the type; wood fiber, provided through saw-log and pulpwood timber sales, contributes significantly to local and regional economies.

Critical burning conditions are more common in Arizona and New Mexico than in any other region of the country (Schroeder 1964). High temperatures, low relative humidities, light precipitation, and moderately strong winds are common. Combine these weather conditions with the fact that Arizona and New Mexico have a higher percentage of lightning fires (80%) than any other region of the United States (Barrows et al. 1957), and one can readily see why fire has played such a dominant role in the ecology of southwestern ponderosa pine. If ponderosa pine were not able to withstand periodic wildfires, during the past several centuries, the species would be much more limited in its range and much less important commercially.

[3]Scientific names of plants and animals are listed at the end of this report.

The relatively low incidence of man-caused fires in Arizona and New Mexico (20%) is somewhat misleading, and does not adequately reflect the importance of man's influence as a fire-starting agent. Actually, many of the fires in ponderosa pine forests that have reached class E size and larger (300 acres and up) have been caused by man.

Since the advent of organized fire protection shortly after the turn of the century, the policy has been to extinguish all wildfires as quickly as possible and to report damages caused by each fire. Suppression efforts have been effective in controlling most fires while they are still small. However, this efficient fire suppression effort has resulted in a gradual buildup of natural fuels throughout the region that inevitably makes the suppression job more difficult once a fire starts under critical conditions. The occasional large fire continues to be the principal problem in Arizona and New Mexico; annually 80% of the burned area is caused by less than 1% of the fires.

Although fire damages do not always relate to fire size, the large fires in timber stands are generally of higher intensity and cause more damage per unit area than the smaller, less intense wildfires. In the past, damage estimates have been based largely on arbitrary resource values and a limited knowledge of what the fire effects might be. In assessing damage to standing timber, the estimates, although still imperfect, are more realistic and may actually reflect changes in market conditions and the economy of the wood-using industry.

In spite of these uncertainties, the USDA Forest Service prepares an Individual Fire Report (Form 5100-29) for each reportable fire, which includes acres burned on commercial and noncommercial forest lands, and estimates of damage to nontimber resources such as watersheds, recreation, range and wildlife, and improvements. Although there are damages, sometimes serious ones, associated with each of these real and amenity values, both formal studies and casual field observations confirm that benefits also are apparent when fire effects are evaluated on short- as well as long-term bases. Resource managers are beginning to accept the idea that benefits as well as damages should be evaluated to arrive at a more realistic value for expressing the economic impact of wildfires.

In an effort to look at both sides of the ledger concerning values relating to wildlife habitat, a cooperative study was begun in 1974 between the School of Renewable Natural Resources, University of Arizona, and the Rocky Mountain Forest and Range Experiment Station.

Objectives

Most studies have as their primary objective the collection and analysis of data, and the reporting of the results of the study in terms of cause and effect. This study digresses somewhat from this trend in that the primary objective is to illustrate a methodology for equating changes in wildlife habitat resulting from wildfire with an economic index that can be used for expressing potential benefits or losses in terms of dollars.

In order to test the methodology, source data was needed. It was decided that rather than use assumed values for the data, observations and measurements would be made in the field that could be used as input for developing the economic index of wildlife benefits. Input data collected included observations and measurements on (1) relative use by deer, elk, rodents, and birds; (2) changes in ground cover in relation to years since the fires; and (3) wildlife use in relation to vegetative parameters. Due to the statistical deficiencies of the sampling method used, the numerical results obtained can only be regarded as illustrative.

Study Areas

Large fires have burned often enough in Arizona ponderosa pine forests to permit the selection of four burned areas for study. The selected fires occurred within 10 miles of each other near Flagstaff, Ariz. (fig. 1), and the areas represent similar conditions of vegetation and physiography. Elevation of the study areas ranged from 7,500 to 7,900 feet, and all areas were on basaltic soils. Differences observed in wildlife and habitats can reasonably be ascribed to those induced by the fires.

The oldest burn, Kelly Tank Fire No. 1 (fig. 2A), burned 4,100 acres in 1954. The area was reseeded to perennial grasses. In 1976, the burned area resembled a grassland. Most of the fire-killed trees have been removed or have fallen. There is little postfire regeneration, although ponderosa pine seedlings have been planted on the area several times. Aspen has returned on areas where it was originally found.

The White Horse Fire (fig. 2B) burned 865 acres in 1967. The fire was on the Wild Bill Study Area (Pearson and Jameson 1967). Many of the dead unmerchantable trees have fallen but are not yet decomposed. The burned area was seeded to orchardgrass, wheatgrasses, and yellow sweetclover.
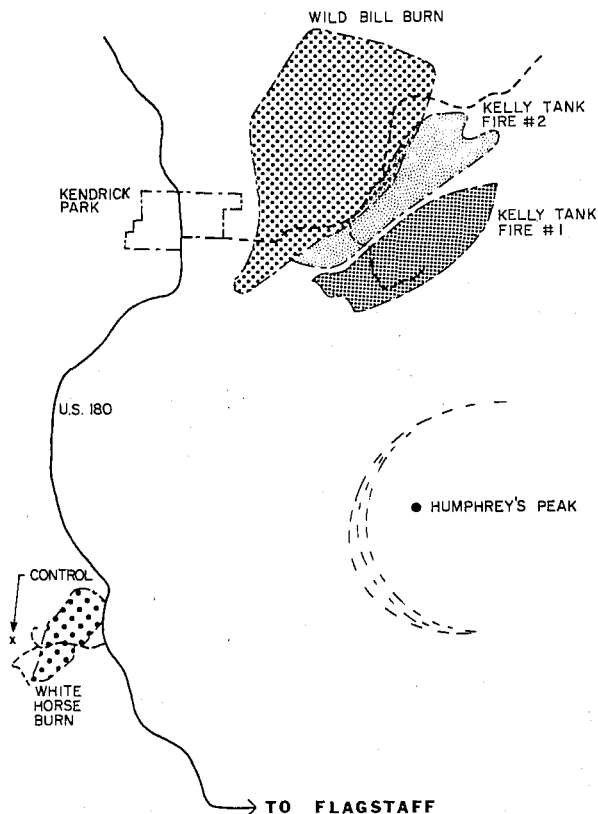

Figure 1.—Location of four large wildfires within a 10-mile radius of Flagstaff, Ariz., used in a study of potential wildlife benefits.
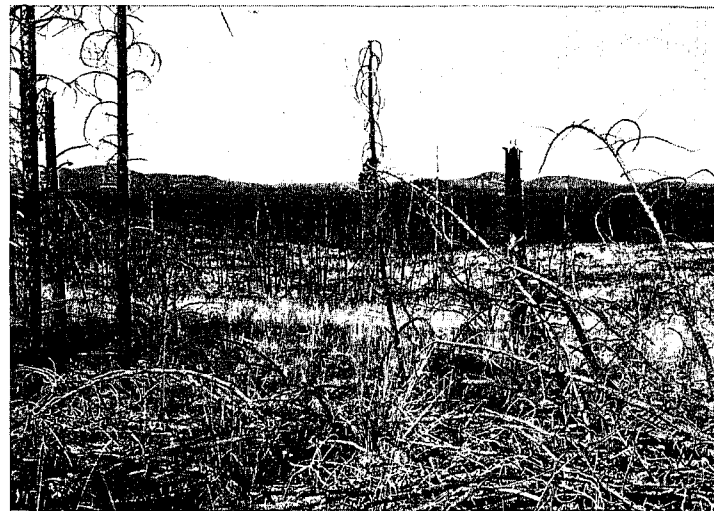
The **Kelly Tank Fire No. 2** (fig. 2C) burned 3,550 acres in 1971. Many dead trees remain standing. The area was planted to perennial ryegrass, intermediate wheatgrass, yellow sweetclover, and smooth brome. Ponderosa pine was both planted and seeded, but success has been marginal.

The **Wild Bill Fire** (fig. 2D), the most recent burn studied, burned 7,140 acres in 1973. Many fire-killed trees have been salvaged, but most were still standing during the first summer of data collection. The area was seeded with a mixture of orchardgrass, perennial ryegrass, intermediate wheatgrass, yellow sweetclover, and smooth brome. Ponderosa pine seedlings were also planted.

The **Control Plot** (fig. 1), located west of the White Horse Fire and installed in the summer of 1974, showed no evidence of recent fires or logging. In the spring of 1975, however, a few trees were removed from the area by a logging operation.

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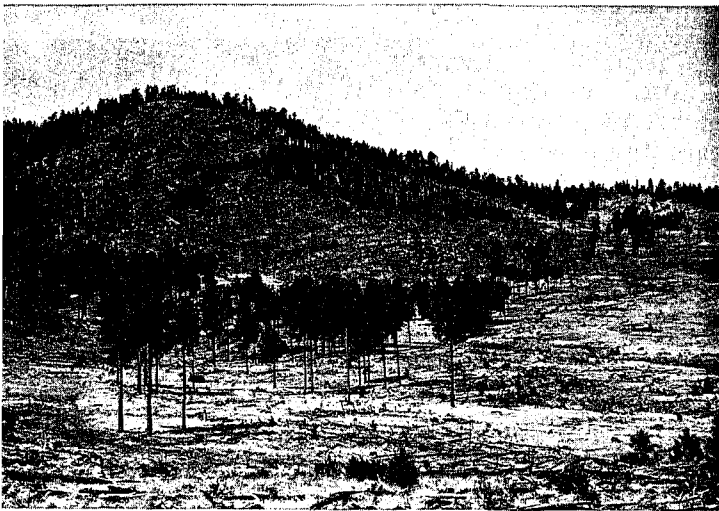
Figure 2.—Four burned areas chosen for study: A, Kelly Tank Fire No. 1 burned 4,100 acres in 1954; B, White Horse Fire burned 865 acres in 1967; C, Kelly Tank Fire No. 2 burned 3,550 acres in 1971; and D, Wild Bill Fire burned 7,140 acres in 1973.

Wildlife and Vegetation Measurements

A 40-acre block was selected for the control and for each burned area in June 1974. Within each block an 11 by 11 grid of sample points was established at 2-chain (132-foot) intervals. For each of the four burned areas the grid included a portion of the interior of the burn, the edge, and a portion of the adjacent unburned forest.

Deer and Elk

Mule deer and elk fecal pellets were counted and cleared from 0.01-acre circular plots centered over each grid point in the 40-acre block in June 1974, October 1974, and May 1975. The two latter dates were chosen to measure summer-fall and winter-spring use.

Rodents

Rodents were collected with snap traps at each sample point for 3 consecutive days in August 1974 and May 1975. Data obtained were: species, sex, reproductive condition, and weight. During the second trapping, animals were not weighed.

Rodent densities were estimated by dividing the numbers of animals caught by the areas sampled. The number of acres sampled varied among the study areas because (1) comparisons were made only between rodents caught on the burned portions of the grids and the control, and (2) a strip around the edge of the trap grid as wide as the radius of the home range of the particular animal was considered to have been sampled. Home range values taken from the literature were: 1.7 acres for mice (King 1968), 6.4 acres for ground squirrels (Gordon 1943), and 2.2 acres for the chipmunks (Gordon 1943).

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Birds

The number of birds was determined by systematically walking along the grids in the early morning and mapping the location of each species observed. Activity of each bird was also recorded. For two consecutive days in May 1975, each grid was walked twice a day; the average of the birds seen was assumed indicative of the number of birds on each grid.

Bird numbers were compared by the same methods as that used for rodents. Densities computed for birds seen on the burned portions of the grid were compared with those on the control. Area sampled was that confined by the grid. Densities were expressed in birds per 100 acres to facilitate comparison with other studies. For comparisons, birds were grouped into feeding categories, after Bock and Lynch (1970). These categories were tree-foliage-searching birds, timber-gleaning birds, ground- and brush-foraging birds, flycatching birds, timber-drilling birds, and aerial flycatching birds. Total bird populations also were compared.

In addition to density differences, variations between bird communities were tested in two ways. The first test classified a species on two areas being compared as "characteristic" (present in only one habitat) or "exclusive" (three times as abundant on one habitat if either density was less than 10 pairs per 100 acres, or twice as abundant on one area if both densities were greater than 10 pairs per 100 acres) (Martin 1960). Two areas were considered to support different bird communities if more than 50% of the birds on both areas were either characteristic or exclusive.

The second test involved percent differences, specifically defined as the sum of the differences between the numbers of each bird species seen on either of two areas divided by the total number of individuals seen on both areas (Odum 1950). If the percent difference was greater than 50, the areas were considered separate bird communities.

Standing crop biomass and consuming biomass (a measure of the energy needs of the community) were also measured. Standing crop biomass of each bird community was computed through the use of bird weight information from Carothers et al. (1973) and Bock and Lynch (1970). Consuming biomass, a measure of biomass that compensates for differences in metabolism or energy needs due to differences in body weight, was calculated by raising the weight of each bird species to the 0.633 power (Karr 1968).

The ratio of standing crop to consuming biomass is a measure of the efficiency of energy utilization of the community, and is related to body size. As the ratio approaches 1.0, the less efficiently the community is utilizing energy. This stems from the fact that larger-bodied animals generally require less energy maintenance per unit of body weight than do smaller animals.

Ground Cover and Forage

Ground cover was estimated using a 12- by 18-inch wooden frame divided into sixths. This frame was set on the ground beside the sample points on each grid, and total coverage of forb and grass basal area and litter was estimated in July 1974.

Following a procedure described by Aldous (1944), frequency of occurrence of browse species was estimated on 0.01-acre plots, 5 feet high, centered at each sample point. Browse species were considered present or absent within this cylindrical plot.

Development of an Index of Benefits

In an effort to represent the data uniformly, the index value for each variable (deer and elk fecal counts, rodent and bird densities) on each burned grid was divided by the control value to give a dimensionless ratio. We have assumed that wildlife and habitat levels found on each area respond in the same relative manner to fluctuations in weather conditions, season of the year and cyclic changes; and that the ratios can be considered to be indicators of changes that are attributable primarily to the effects of the fires.

Graphs were designed for each situation (figs. 3, 4, 5) with ratios plotted on the Y-axis, and time after fire on the X-axis. The control was represented by a horizontal line ($r = 1.0$) and was considered to indicate conditions as they would have been with no fire. A schematic curve represented a flow of benefits or losses for a 20-year period after the fire; the curve was drawn with respect to the four plotted ratios and was guided by the authors' wildlife backgrounds.

Time-trend response curves were converted to an index of benefits (Lowe 1975). The technique converts the flows of benefits or losses after fire (the stream of annual ratios) to annuities, or equal annual returns from the resource. Although annuities are normally thought of in terms of dollars, the concept is equally applicable to nonmonetary flows. Annuities were calculated from:

$$a = V_0 \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad [1]$$

where
a = the annuity,
V_0 = the present net worth, or the total of all (yearly) values from the response curves discounted to time zero,
i = the discount (interest) rate, and
n = the total number of years of analysis (20 years).
Present value of the wildlife ratios was calculated from:

$$V_0 = \sum_{n=1}^{20} \left[\frac{V_n}{(1+i)^n} \right] \quad [2]$$

where

V_n = the value of the wildlife ratio (Y-axis) taken from the time-trend response curves for individual years in the analysis (1 to 20).

For this paper, the annuities were calculated for a 20-year period of analysis at an arbitrary 5% discount rate.

The annuities allow a condensation of annual values into a single annual index value. Theoretically, the annuity value 1.0 is indifferent at the stated discount rate to the annuity each year, or to the actual stream of values (in this case, ratios) over a similar time period. Since the ratio for the control is 1.0 for each year, the annuity is also 1.0. Annuity values that are higher or lower than 1.0 indicate benefits or losses respectively.

Annuities calculated for 20-year periods, as in this illustration, are highly responsive to the discount rate used. The discount rate determines how much weight is given to the different annual values (ratios). The greater the discount rate, the more heavily future yields are discounted. For example, if a 5% discount rate is used, ratios for 1 year after a fire are weighted 2.5 times as heavily as ratios for 20 years following the fire. If a 10% discount rate is used, however, ratios for 1 year after a fire are weighted more than six times as heavily as ratios for 20 years following a fire.

Results and Discussion

Deer and Elk

Deer summer-fall use (annuity value 1.9) declined the first year after fire, but then increased to levels approaching 2.5 times the control through the rest of the 20-year evaluation period (fig. 3). Deer winter-spring use also declined immediately following fire, returned to the control level for a few years, and then increased to levels exceeding 10 times that of the control. For winter-spring, annuity value was 3.3, which reflected the relatively high use in the latter years of the evaluation period. The increase in deer use after fire was probably a result of increased forage produc-
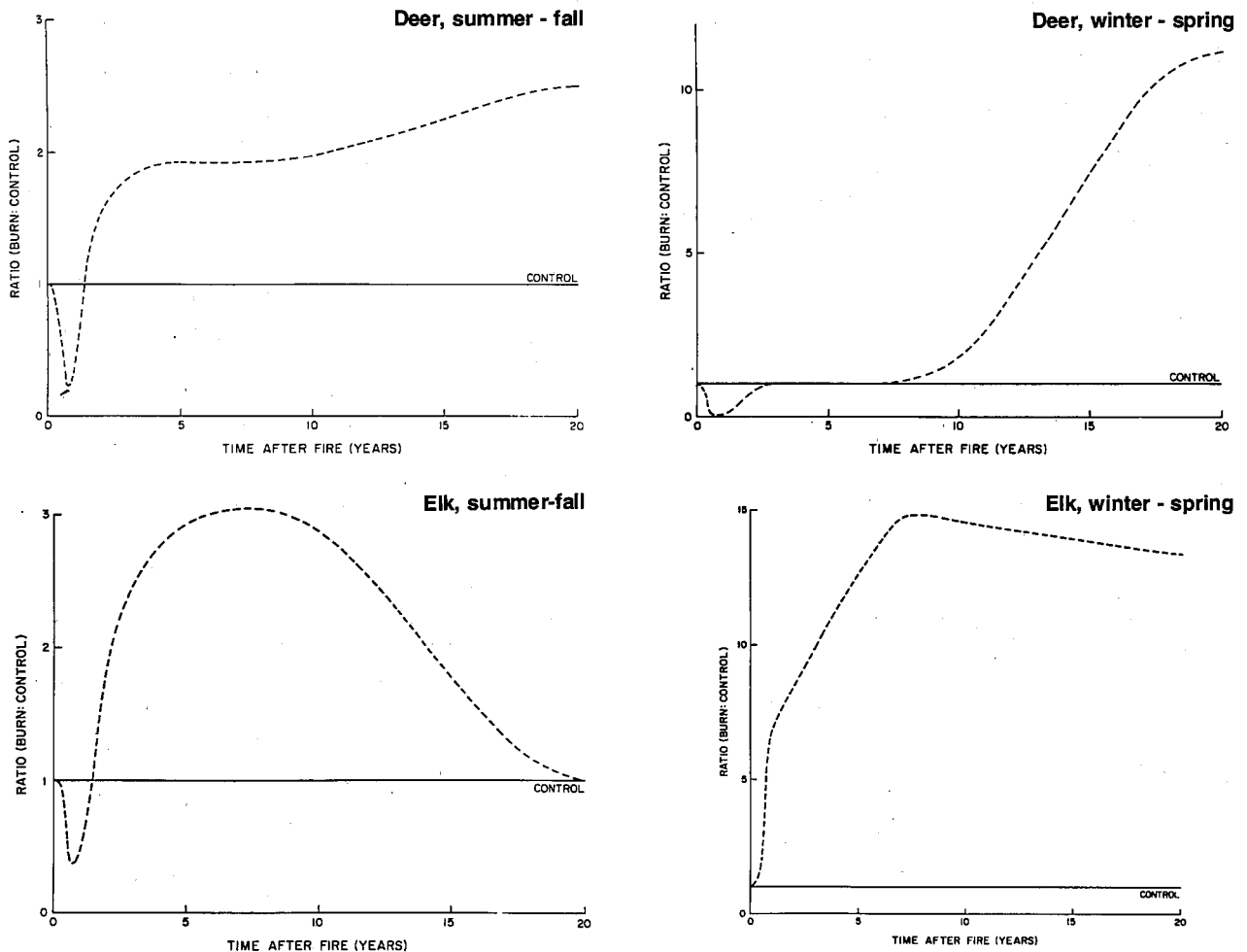

Figure 3.—Time-trend response curves for deer and elk.

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tion, especially forbs and ceanothus, and an increase in edge. Low winter-spring deer use on all areas except the 20-year-old burn indicated an annual shift to winter range as the summer range became increasingly uninhabitable. The 20-year-old burn was used more as winter range because it was relatively open and provided easy movement along the edge to and from the nearby lower elevations.

Elk summer-fall use (annuity 2.2) declined after fire, then increased to levels nearly three times the level of the control before finally dropping back to 1.0 at the end of the 20-year period (fig. 3). Elk winter-spring use (annuity 13) was higher than the control level throughout the entire evaluation period, with the highest recorded postfire use 7 years after fire.

The relatively low elk summer-fall use 20 years after fire was due to unpredictable shifts in elk population centers, or to the fact that sheep used the 20-year-old burn for a few weeks in late spring and early summer of 1974. Similar shifts in elk use were reported by Neff (1971a) after the introduction of cattle on the Beaver Creek watershed south of Flagstaff.

The winter-spring elk use of the burned areas could have been due to increased grass production. Neff (1971b) found that, instead of moving entirely out of the summer range on the Beaver Creek watershed, most elk preferred to remain on the ridges during the winter as long as forage was available. The winter of 1974-75 was severe enough to move most elk out of the control area. However, higher grass production on the burned areas was sufficient during the winter to sustain at least seven times the elk use of the control.

Rodents

Five species of rodents were caught: deer mice, golden-mantled ground squirrels, gray-collared chipmunks, Mexican voles, and Mexican woodrats. Only deer mice, ground squirrels, and chipmunks, were numerous enough to allow detailed evaluations.

For both trap periods, deer mice increased the first year after fire, then declined to the level of the control at 7 years. After 7 years, there was another increase to 2.5 times the control level in the summer, and 6 times the control level in the spring. Annuities were 1.8 and 3.3 for summer and spring, respectively.

Deer mice were the only rodents trapped whose reproductive condition differed among study areas. All burned areas with higher populations than the control had higher percentages of sexual activity. The increase in deer mouse populations after fire was probably due to two factors — food and cover. An increase in food supply created the necessary energy base for a large mouse population, while an increase in stumps and fallen logs provided hiding and living space.

Higher populations were found on the burns that had significantly more cover and forbs, a major food item for deer mice (Goodwin 1975). The exception was

the 1-year-old-burn, where numerous holes left by burned-out stumps may have provided cover. Insects could have been a food source for deer mice the first year after fire (Gashwiler 1959). Winter mortality apparently had little effect on deer mice, except on those areas with the least cover or food. Spring populations on the burned areas with both cover and food were very similar to summer populations, which reflected higher winter survival and breeding rates.

Ground squirrels reacted differently to fire than deer mice. Summer ground squirrel populations were lowest 3 years after fire, then increased to 2.5 times the control 7 years after fire. After 20 years, the ground squirrel population (annuity 1.5) had dropped to the control level. Spring ground squirrel populations were so low that no time-trend response curve could be drawn. Expected higher ground squirrel populations on the 3- and 20-year-old burns were not realized, perhaps because of mutual exclusion by mice or low original populations.

Chipmunks are more dependent on live trees than on a ground food supply (Gashwiler 1959); thus, where trees were removed by fire, chipmunks declined accordingly. The highest postfire population (annuity 0.55) was on the 7-year-old burn, where there were several patches of live trees. Chipmunks will probably not become established again until trees are large enough to supply habitat and food.

Birds

Birds seen on each study area were recorded by species and foraging category (table 1). In all, 31 species were seen: 16 on the control, 14 on the 1-year-old burn, 22 on the 3-year-old burn, 10 on the 7-year-old burn, and 11 on the 20-year-old burn. Total bird numbers (annuity value 0.71) increased the first year after fire, then decreased to below the prefire level for the remainder of the evaluation period (fig. 4).

Tree-foliage-searching birds (annuity 0.65) responded in much the same manner as total bird numbers (fig. 4). After an initial increase, they decreased to approximately half the control and remained there. The initial increase was due to flocks of transient Yellow-rumped warblers which, although classified as tree-foliage-searching birds, were behaving as ground and brush forages on the Wild Bill Fire.

Timber-gleaning birds (annuity value 0.17) decreased immediately after fire to an eventual low of less than 10% of the control (fig. 4). After an initial increase, ground- and brush-foraging birds (annuity value 1.2) decreased to slightly below the control 7 years after fire, and then slightly above the control 20 years after fire (fig. 4).

Flycatching birds peaked 7 years after the fire, then declined to zero at 20 years (fig. 4). The annuity of 2.7 was the highest for any bird category.

Table 1.—Spring densities of birds (per 100 acres), by foraging categories and number of years following fire.

| Foraging category and species	Years following fire				
	Control	1 year	3 years	7 years	20 years
Tree-Foliage-Searching Birds					
Yellow-rumped warbler	13	41	9	0	0
Clark's nutcracker	0	0	6	0	0
Grace's warbler	0	0	3	0	0
Mountain chickadee	15	4	3	6	3
Solitary vireo	5	0	0	0	0
Steller's jay	8	19	19	11	19
Virginia's warbler	3	0	0	0	0
Western tanager	3	0	6	0	0
Timber-Gleaning Birds					
Brown creeper	8	0	3	0	0
Pygmy nuthatch	35	15	16	8	6
White-breasted nuthatch	3	0	6	0	0
Ground- and Brush-Foraging Birds					
American robin	3	0	3	0	0
Black-headed grosbeak	0	0	0	6	0
Brown-headed cowbird	3	0	0	0	0
Chipping sparrow	0	19	22	0	0
Green-tailed towhee	0	0	9	3	0
Gray-headed junco	30	93	16	22	3
Mountain bluebird	0	7	0	0	0
Mourning dove	0	4	6	0	19
Common flicker	5	7	9	0	9
Vesper sparrow	0	0	9	0	22
Western bluebird	20	22	13	14	0
Flycatching Birds					
Empidonax flycatchers	0	4	0	0	0
Olive-sided flycatcher	0	0	3	3	0
Western wood pewee	3	0	6	11	0
Timber-Drilling Birds					
Acorn woodpecker	0	4	0	0	0
Hairy woodpecker	15	26	22	8	0
Aerial Flycatching Birds					
Purple martin	0	0	0	0	3
Violet-green swallow	28	22	0	0	11
Other Birds					
Broad-tailed hummingbird	0	0	9	0	6
American kestrel	0	0	3	0	6
	200	287	201	92	107
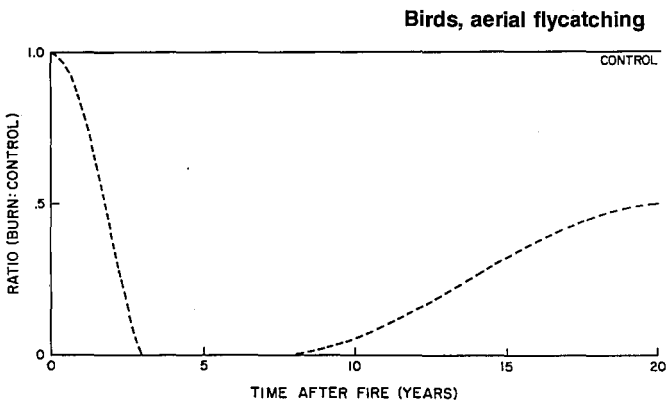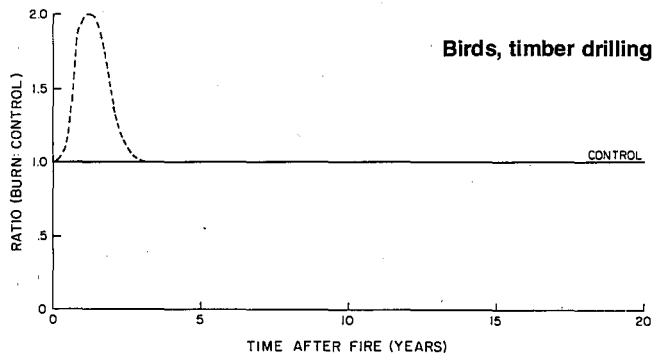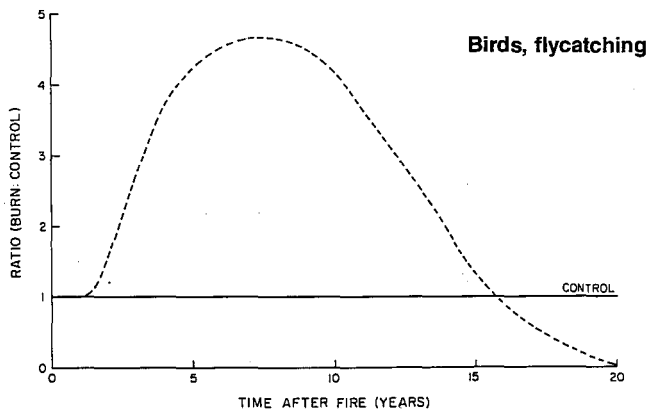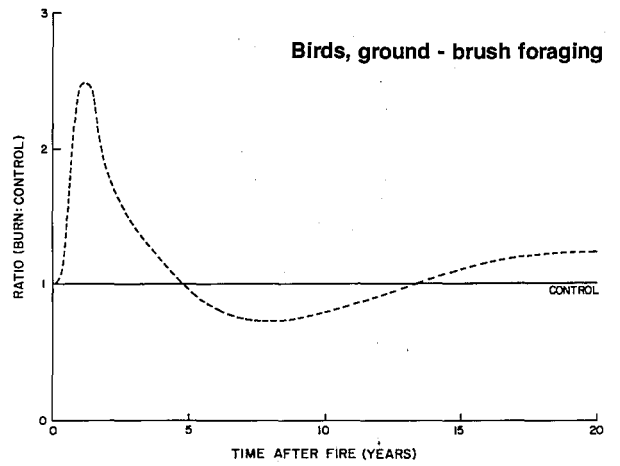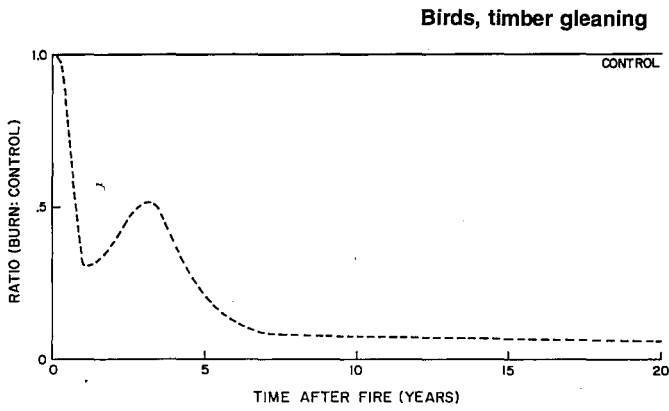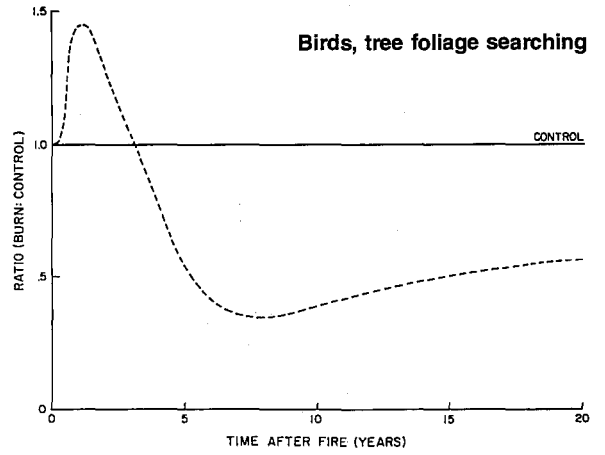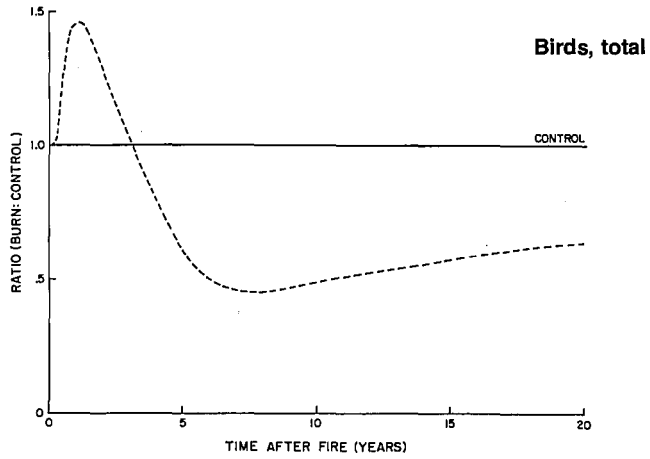
Figure 4.—Time-trend response curves, by total number of birds and by foraging categories.

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Timber-drilling birds (annuity value 1.1) were two times the control 1 year after fire, and no different from the control at all other times (fig. 4). The high woodpecker population 1 year after fire was probably due to a temporary increase in woodboring insects on dead trees.

Aerial flycatching birds decreased to zero 3 years after fire and were never above half the control density (fig. 4). An annuity of 0.21 could be expected. The decrease in aerial flycatching birds reflects a reduction in nest sites. Violet-green swallows, for example, are cavity nesters. On the control, they were usually seen flying around large dead trees, a favorite nest site (Scott and Patton 1975).

The relative abundance of birds in each foraging category was largely determined by the nature of the vegetation present. Birds adapted to feed in coniferous forests were most abundant on the control, while birds adapted to feed closer to the ground or in open areas were most numerous on the burned areas.

Differences between the bird communities on the burns and the control were most likely due to changes in habitat and foraging sites resulting from fire. In general, the burns were occupied by fewer but heavier birds. Bock and Lynch (1970) found a similar relationship. The difference was attributed to the type of forage available. Most forage in ponderosa pine forests is distributed among needles and branches. Smaller birds, such as nuthatches, chickadees, and warblers, are better suited to take advantage of that type of forage than are larger birds. Consequently, smaller birds live in the forest, while birds such as towhees, suited to ground forage conditions on the burns, are generally larger.

The apparent low ratio of standing crop biomass to consuming biomass on the control is another indication of the type of forage site available (table 2). Instead of increased efficiency of energy utilization indicated by a high ratio at the highest successional stage, as was found by Salt (1957) and Karr (1968), foraging efficiency was evidently the determining factor in the composition of the bird community.

Habitat Components

Forb basal area (annuity value 5.2) was highest 3 years after fire. It was lowest on the control area and at 7 years after fire (fig. 5). Grass basal area (annuity value
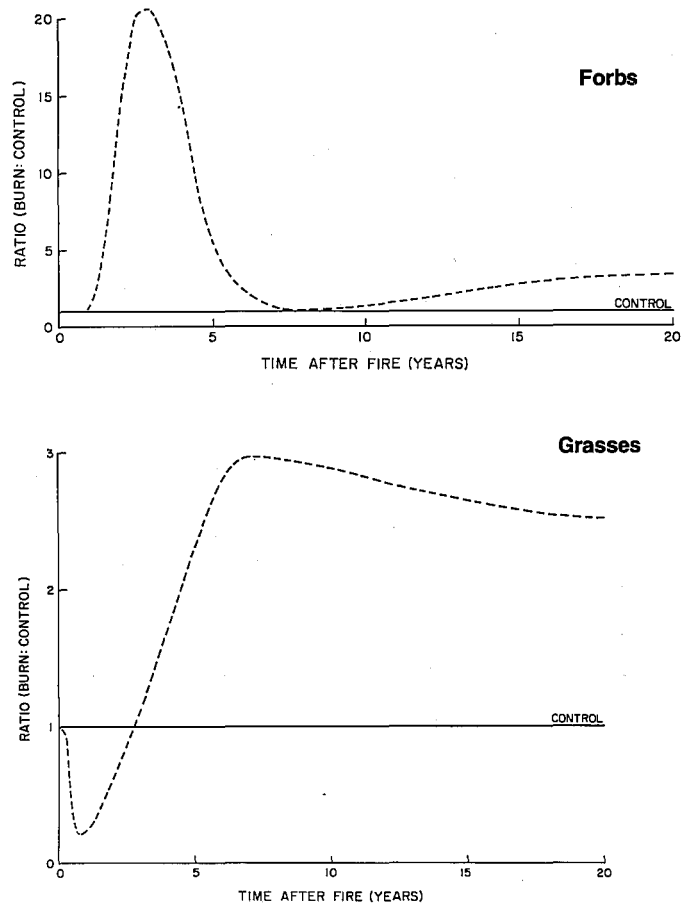

Figure 5.—Time-trend response curves for basal area of forbs and grasses.

2.2) decreased the first year after fire, then increased to levels approaching three times the control basal area (fig. 5). Increases in forb and grass densities resulted from a reduction in overstory and a decrease in forest litter.

The relative lack of forbs 7 years after fire may be due to a combination of direct competition with grasses, along with grazing by deer, elk, and ground squirrels, which were at their highest recorded levels on the 7-year-old burn.

Table 2.—Community standing crop biomass (SCB) and consuming biomass (CB) (grams per 100 acres)

Fire	Year burned	Standing crop biomass	Consuming biomass	SCB/CB
Control	Unburned	4,774	1,482	3.2
Wild Bill Fire	1973	9,490	2,076	4.6
Kelly Tank Fire 2	1971	9,392	2,212	4.2
White Horse Fire	1967	3,265	1,043	3.1
Kelly Tank Fire 1	1954	10,945	2,075	5.3

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A decrease in grass production the first growing season after fire was also noted by Pearson et al. (1972) on the White Horse Fire. In both cases, grasses probably did not have time to become established the first year.

Litter coverage (annuity value 0.69) decreased immediately after fire and did not return to the control level during the 20-year evaluation period. After an initial drop, litter leveled off at 75% of the control level. One year after fire, ceanothus frequency (annuity value 2.7) decreased to zero then increased to three to four times the prefire condition. Ponderosa pine forage consisting of seedlings (annuity value 0.27) decreased immediately after fire, then increased gradually after 7 years to a postfire high 20 years after fire.

Dominance of grasses and the lack of ponderosa pine on the 20-year-old burn probably resulted from the lack of a suitable seedbed (Schubert 1974). Most of the ponderosa pine on the 20-year-old burn was regeneration and, therefore, more likely to fall within the plots.

Management Implications

Using the model of expected wildlife benefits and the corresponding annuities, a natural resource manager can estimate changes in the value of wildlife and forage immediately following a fire in Arizona ponderosa pine forests. Perhaps the best way to illustrate the use of the annuities is through a hypothetical example.

If a manager is concerned with summer-fall deer use, he can assume that the average annual return for 20 years after fire will be 1.9 times what it was before fire.

To interpret this change in dollars, the manager must initially assume a value for deer use. For example, Martin et al. (1974) synthesized a resource value for deer hunting in the plateau region of north-central Arizona of $97 per square mile. While this value does not necessarily reflect the value of the land in terms of its capacity to produce deer, it does indicate demand and hunter use. Using $97 per square mile as an example of a prefire deer value, a projected yearly increase to $184.30 ($97 × 1.9) per square mile could be computed for 20 years after a fire.

Unfortunately, monetary values are not currently available for all the wildlife species and habitat components assessed in this study. Once such knowledge becomes available, however, the use of the annuities described herein may help to calculate overall benefits or losses.

Although most time-trend response curves represent irregular flows of benefits, the annuities were calculated to be equal for each year of analysis. This even flow simplifies comparison with the control, which was also represented as an even flow. The unitless nature of the annuities allows wide application under different value systems. Each natural resource manager can make his own decisions as to how to use the annuities and what values to put on the resources.

Conclusions

Using the approach described here the land manager can more accurately assess the potential for wildlife benefits, losses, and habitat changes following wildfire, and can express these changes in economic terms to more realistically describe the impact of wildfire on wildlife resources.

The improvement of habitat, and the subsequent increase in wildlife abundance, can be thought of as flows of benefits over time. The annuities presented in this paper were derived from these flows to help managers evaluate wildlife benefits under a multiple use management concept. Although the specific annuities presented are primarily illustrative, they may be verified and refined as additional information is gathered.

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Common and Scientific Names of Plants and Animals

Common Name	Scientific Name

Plants

Trees	
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Shrubs	
Ceanothus	*Ceanothus fendleri*
Grasses	
Intermediate wheatgrass	*Agropyron intermedium*
Orchardgrass	*Dactylis glomerata*
Smooth brome	*Bromus inermis*
Perennial ryegrass	*Lolium perenne*
Wheatgrasses	*Agropyron*, spp.
Yellow sweetclover	*Melilotus officinalis*

Mammals

Deer	*Odocoileus hemionus*
Deer mouse	*Peromyscus maniculatus*
Elk	*Cervus canadensis*
Golden-mantled ground squirrel	*Spermophilus lateralis*
Grey-collared chipmunk	*Eutamias cinereicollis*
Mexican vole	*Microtus mexicanus*
Mexican woodrat	*Neotoma mexicana*

Birds

Tree-Foliage-Searching Birds
Yellow-rumped warbler — *Dendroica coronata*
Clark's nutcracker — *Nucifraga columbiana*
Grace's warbler — *Dendroica graciae*
Mountain chickadee — *Parus gambeli*
Solitary vireo — *Vireo vicinior*
Steller's jay — *Cyanocitta stelleri*
Virginia's warbler — *Vermivora virginiae*
Western tanager — *Piranga ludoviciana*

Timber-Gleaning Birds
Brown creeper — *Certhia familiaris*
Pygmy nuthatch — *Sitta pygmaea*
White-breasted nuthatch — *Sitta carolinensis*

Ground- and Brush-Foraging Birds
American robin — *Turdus migratorius*
Black-headed grosbeak — *Pheucticus melanocephalus*
Brown-headed cowbird — *Molothrus ater*
Chipping sparrow — *Spizella passerina*
Green-tailed towhee — *Pipilo chlorurus*
Gray-headed junco — *Junco caniceps*
Mountain bluebird — *Sialia currucoides*
Mourning dove — *Zenaida macroura*
Common flicker — *Colaptes cafer*
Vesper sparrow — *Poocetes gramineus*
Western bluebird — *Sialia mexicana*

Flycatching Birds
Empidonax flycatchers — *Empidonax,* spp.
Olive-sided flycatcher — *Nuttallornis borealis*
Western wood pewee — *Contopus sordidulus*

Timber-Drilling Birds
Acorn woodpecker — *Melanerpes formicivorus*
Hairy woodpecker — *Picoides villosus*

Aerial Flycatching Birds
Purple martin — *Progne subis*
Violet-green swallow — *Tachycineta thalassina*

Other Birds
Broad-tailed hummingbird — *Selasphorus platycercus*
American kestrel — *Falco sparverius*

Lowe, Philip O., Peter F. Ffolliott, John H. Dieterich, and David R. Patton. 1978. Determining potential wildlife benefits from wildfire in Arizona ponderosa pine forests. Gen. Tech. Rep. RM-52, 12 p. Rocky Mt. For. and Range Exp. Stn., For. Serv., U.S. Dep. Agric., Fort Collins, Colo. 80521.

Large wildfires are frequently destructive to the timber resource, but wildlife may not be so adversely affected. A study of selected species of wildlife (deer, elk, rodents, and birds) that were present on large burned areas, 1, 3, 7, and 20 years old, indicated population fluctuations and habitat changes that are, for the most part, predictable, and can be expressed in economic terms. An "Index to Benefits" was developed that converts the flows of benefits or losses after fire to annuities. By assuming values for wildlife use, the manager can interpret these changes in terms of dollars in order to describe the total impact of wildfire on the wildlife resource.

Keywords: Fire effects, fire economics, species diversity, wildlife populations, game and nongame animals.