AVIAN POPULATIONS IN HERBICIDE TREATED BRUSH FIELDS

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THE effects of habitat alteration on populations of breeding birds have been documented by various workers. The most striking effects are the dramatic increases in bird populations that result from the creation of gardenlike habitats (Pitelka 1942, Johnston 1970, Emlen 1974) and the nearly complete disappearance of birds following destruction of habitat by fires (although see Emlen 1970, Kilgore 1971) or agriculture (Graber and Graber 1963).

In recent years selective habitat alteration through the use of herbicides has occurred over wide acreages where undesirable plants restrict grazing by livestock or prevent the growth of more desirable plants (Alley 1956). The effects of this type of habitat alteration on avian populations have been the subject of few studies (Best 1972, Dwernychuk and Boag 1973).

Within the timber zone of the Sierra Nevada, one frequently finds extensive brush fields. In most places these fields develop after fire or logging has destroyed the conifer forest that was the dominant vegetation. Thus most workers considered Sierran brush fields as an early stage in secondary forest succession (Sampson and Jesperson 1963, Bock and Bock 1969). In many of these brush fields, the growth is so dense that conifer establishment and growth is retarded or even prevented (Wilkens 1967). As a result, the U.S. Forest Service conducts programs of brush control on sites where reforestation by planting is being attempted. In most cases brush control is accomplished by spraying with selective herbicides (J. A. Kennedy, pers. comm.). The brush is killed or retarded in growth whereas conifer seedlings are not affected.

Almost all the species of birds occurring in brush fields are restricted to the use of bushes for feeding and nesting (Beaver 1972). The dependence of birds on these bushes led me to predict initially that the herbicide treatment of brush fields would greatly decrease the population size and number of species of breeding birds, but this did not occur. This paper details the changes that did occur following herbicide treatment and examines the possible causes.

In this study I compare avian populations in two areas of a brush field before and after herbicide treatment. Unfortunately the study was not planned. Detailed work on avian populations was in progress when the first plot was sprayed in the fall of 1970. The decision was made to follow the effects of the herbicide upon learning that the second plot

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was also to be sprayed. This state of affairs does not appear to have compromised the results, but statistical treatment of the data is complicated, as will be seen below.

The species of birds breeding in the brush field were the Fox Sparrow (*Passerella iliaca*), Green-tailed Towhee (*Chlorura chlorura*), Dusky Flycatcher (*Empidonax oberholseri*), Brewer's Sparrow (*Spizella breweri*), Lazuli Bunting (*Passerina amoena*), Yellow Warbler (*Dendroica petechia*), Oregon Junco (*Junco hyemalis oreganus*), Mourning Dove (*Zenaida macroura*), and Mountain Quail (*Oreortyx pictus*).

MATERIALS AND METHODS

The study tract is about 8 km northwest of Truckee, Nevada County, California. The elevation is about 2120 m. The climate is typically cool in the summer with little rainfall, and cold in the winter with heavy snows, frequently more than 2 m.

The large brush field became established after the Donner Ridge fire in 1960 (Bock and Bock 1969). Two 9.7-ha plots that were gridded at 61-m intervals were established in a large brush field in 1969. The plots were about 400 m apart on the same east sloping ridge. The two plots were subjectively judged to be similar in vegetative structure.

The three most important species of brush on each plot are tobacco bush (*Ceanothus velutinus*), green-leaf manzanita (*Arctostaphylos patula*), and current (*Ribes aureum*). The U.S. Forest Service planted Jeffrey pine (*Pinus jeffreyi*) seedlings in both plots in 1964.

The species composition and cover of plants on each study plot was determined by line intersect of plants on 10 randomly chosen 30-m transects (Greig-Smith 1964). The data are presented as total line coverage for each plant species and therefore the percentages for shrubs and grasses and forbs exceed 100%. The plant sample was repeated on each plot on the same lines over the four summers of the study from 1969 to 1972. In addition, the general condition of plants was recorded after spraying.

Bird populations were estimated by the spot map technique of Williams (1936) and by locating nests and making detailed observations of breeding pairs in each summer except 1972, when each plot was censused only in June.

In September 1970 an area of 40 ha in which plot I was approximately centered was sprayed with 0.72 kg per ha of acid equivalent, low volatile, 2,4,5-T with thickener (J. A. Kennedy, pers. comm.). Plot II, approximately centered in an area of 25 ha, was sprayed with the same herbicide at 0.54 kg per ha in September 1971. Application was by helicopter. Nearly all individuals of the birds that nested on these plots had migrated before the time of spraying.

RESULTS

Effects on the vegetation.—The composition and cover of the vegetation during 1969 and 1970 on plot I showed little change prior to spraying, so these data are combined and shown in Table 1. *C. velutinus* was the most abundant bush and comprised 43% of the total brush cover. *R. aureum* was next in total coverage with 40%, and *A. patula* the lowest at 32%. Forbs and grasses had a coverage of 26%, most of which was grass.

TABLE 1
COVERAGE OF THE MOST IMPORTANT PLANT SPECIES ON PLOT I BEFORE AND AFTER HERBICIDE TREATMENT

Plants	Prespray 1969–70 (%)	Postspray 1971 (%)	Postspray 1972 (%)
Shrubs	121	120	118
Ceanothus velutinus	43	43 (0.5)[1]	43 (1)
Arctostaphylos patula	32	32 (0)	30 (5)
Ribes aureum	40	41 (38)	43 (40)
Forbs and grasses	26	30	33
Grass (several spp.)	98	98	98
Forbs	3	2	3
Conifer trees (*Pinus jeffreyi*)	3	4	4
Ground	30	30	30

[1] The figure in parentheses is the percent of the canopy that is living.

P. jeffreyi comprised only 3% of the cover. These trees were about 5 feet tall in 1969. About 30% of the plot had no vegetative cover.

Transects run in the spring of 1971 on plot I one winter after herbicide treatment revealed that little change in vegetative cover had occurred (Table 1), but the herbicide's effect on *C. velutinus* and *A. patula* was striking. The normal green leaves of both of these species of brush had turned a dark reddish brown. No new growth or flowering occurred in either species during the summer. Yet, even though the leaves were obviously dead, very few fell from the plants, which is why the coverage remained the same. It is typical for *C. velutinus* and *A. patula* to retain

TABLE 2
COVERAGE OF THE MOST IMPORTANT PLANT SPECIES ON PLOT II BEFORE AND AFTER HERBICIDE TREATMENT

Plants	Prespray 1969–70–71 (%)	Postspray 1972 (%)
Shrubs	59	59
Ceanothus velutinus	36	36 (0.5)[1]
Arctostaphylos patula	4	4 (0.1)
Ribes aureum	19	19 (18)
Forbs and grasses	39	39
Grasses (several spp.)	33	38
Forbs	10	1
Conifer trees (*Pinus jeffreyi*)	6	5 (4.5)
Ground	45	55

[1] The figure in parentheses is the percent of the canopy that is living.

TABLE 3
ESTIMATED POPULATION SIZE OF BREEDING BIRDS PER 40 HA PRE- AND POSTSPRAYED

	Plot I			
	Prespray		Postspray	
Species	(8)[1] 1969	(9) 1970	(9) 1971	(2)[2] 1972
Fox Sparrow	54.1	69.7	47.9	45.9±4.2
Green-tailed Towhee	18.7	17.7	16.6	11.4±3.1
Dusky Flycatcher	16.6	20.8	20.8	22.9±6.3
Brewer's Sparrow	11.4	8.3	17.7	12.5±5.3
Lazuli Bunting	7.2	6.2	20.8	8.8±1.6
Yellow Warbler	6.2	4.1	8.3	7.2±0.0
Oregon Junco	1.0	3.1	4.1	0.0
Mourning Dove	1.0	1.0	4.1	6.2±1.0
Mountain Quail	0.0	0.0	4.1	0.0
TOTALS	116.2	130.9	144.4	114.9
	Plot II			
	Prespray		Postspray	
	(8) 1969	(9) 1970	(9) 1971	(3)[2] 1972
Fox Sparrow	50.0	73.9	62.5	55.7±2.4
Green-tailed Towhee	14.5	18.7	20.8	16.3±0.3
Dusky Flycatcher	18.7	23.9	9.3	11.4±2.2
Brewer's Sparrow	10.4	7.2	8.3	16.6±0.0
Lazuli Bunting	3.1	5.2	8.3	0.0
Yellow Warbler	8.3	7.2	8.3	8.3±0.0
Oregon Junco	0.0	1.0	2.0	0.0
Mourning Dove	0.0	1.0	2.0	0.0
Mountain Quail	0.0	0.0	4.1	0.0
TOTALS	105.0	138.1	125.6	108.3

[1] The number of 3-h census trips.
[2] Fewer censuses could be taken in 1972. The data are presented as means ± SE.

their leaves overwinter as both are nondeciduous plants (Munz and Keck 1959). Herbicide treatment apparently does not cause leaf drop even though the leaves are dead. Even more remarkable, in view of the heavy snowfall that completely covers these bushes, was the presence of nearly all the dead leaves after the second winter on plot I. *A. patula* had lost more leaves than *C. velutinus* during this time. In the summer of 1972 the coverage of *A. patula* dropped slightly from losing some leaves overwinter, but this was compensated for by an increase in the number of living leaves present as some bushes began to recover from the herbicide's effects.

R. aureum was not affected by the herbicide. This bush is deciduous and the leaves had already dropped when spraying was done in the fall

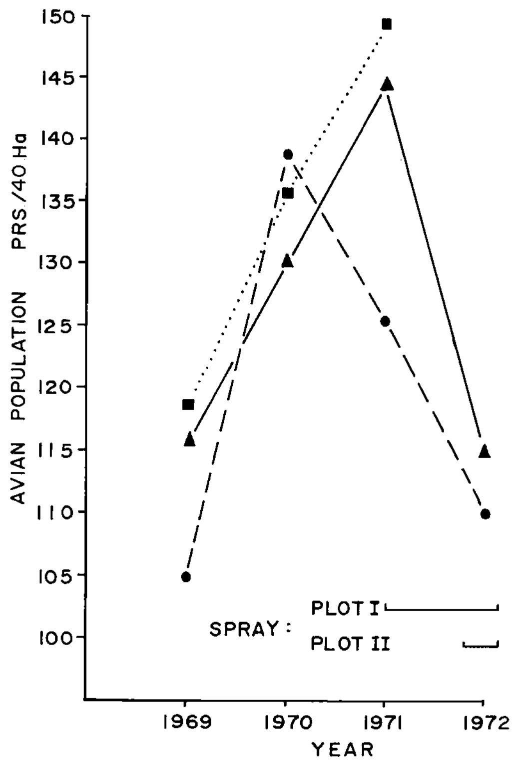

Fig. 1. Population changes of breeding birds over the 4 years of study. Plot I, ●; plot II, ▲; plot in nearby brush field, ■.

of 1970. Leafing and flowering appeared to be normal the following spring and also a year later.

Grasses and forbs as a group increased slightly in coverage (Table 1) in the summers following spraying, but the contribution of grasses relative to forbs remained about the same during this period.

The data on plant coverage on plot II are also combined for the prespray period. Overall the same effects as occurred on plot I were noted for plot II (Table 2). A few of the leaves of *A. patula*, which is much more frequent on plot I than plot II, were still green after spraying. Several *A. patula* and *C. velutinus* plants were even noted to flower. The lighter spray application on plot II may account for the better survival of these bushes. *R. aureum* did not appear to be affected, as was the case on plot I. Forbs decreased in coverage compared to prespray years.

Avian populations.—The abundance of all birds breeding on plots I and II over the 4 years of study are shown in Table 3. Total population size

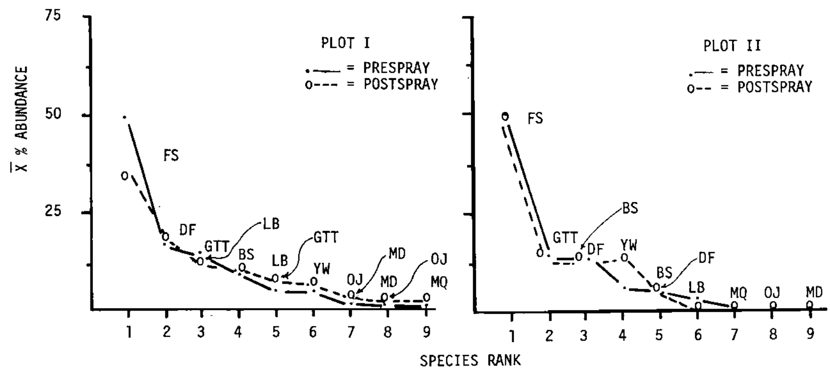

Fig. 2. The relative abundance of avian species before and after herbicide treatment. Abbreviations are: FS, Fox Sparrow; DF, Dusky Flycatcher; GTT, Green-tailed Towhee; LB, Lazuli Bunting; BS, Brewer's Sparrow; YW, Yellow Warbler; OJ, Oregon Junco; MD, Mourning Dove; MQ, Mountain Quail.

increased in 1971 on plot I after spray and then decreased in 1972 to 1969 levels. Populations on plot II increased in 1970, decreased in 1971, and decreased further following herbicide treatment in 1971. Thus plot I showed both an increase and a decrease in population size following spray, whereas plot II continued to decline following spray.

Statistical treatment of these data was difficult because plot II had 3 years pre- and 1 year postspray, whereas plot I had 2 years pre- and postspray. No single statistical design could be found that was suitable for treating both plots and years, so we simply show the total population trends in each plot compared to population trends on a third nearby unsprayed plot 20.2 ha in size (data from Beaver 1972) (Fig. 1). The population trends are not noticeably different from any of the plots in 1969, 1970, or 1971, except plot II, which was about 20 pairs/40 ha lower than the others in 1971. This plot was not yet sprayed whereas plot II had been sprayed the previous year, yet still increased. Plots I and II were near 1969 levels in 1972. We do not have census data for the third plot in 1972, but our impression was that populations were down there as well as elsewhere in the brush field. No clear difference emerges between herbicide sprayed plots and the avian populations on unsprayed brush fields.

The relative abundance of certain species was noted to change between pre- and postspray periods on both plots. Plot I showed the most change in species positions on a relative abundance curve (Fig. 2), but these shifts in relative abundance are slight and were not found to be significant between pre- and postspray periods for either plot (χ^2; $P > 0.20$, plot I;

TABLE 4
PROPORTIONS OF INSECTS AND SEEDS IN THE STOMACHS OF CERTAIN BRUSH FIELD BIRDS[1]

Species		N[2]	% N	mg dry wt[3]	% mg dry wt
Fox Sparrow	Insects	366	29	437.055	10
(N = 63)	Seeds	889	71	3741.351	90
Green-tailed Towhee	Insects	212	28	341.861	40
(N = 27)	Seeds	544	72	512.500	60
Brewer's Sparrow	Insects	92	19	106.284	54
(N = 25)	Seeds	390	81	88.984	46
Oregon Junco	Insects	126	19	118.790	19
(N = 26)	Seeds	548	81	519.066	81

[1] Data from Beaver 1972.
[2] Number of items identified in the stomach.
[3] Determined from samples of whole seeds of the species eaten.

$0.10 > P > 0.05$, plot II, Sokal and Rohlf 1969). In summary, no effect on herbicide treatment was discernable on avian species composition, population size, or relative abundance on plot I with 2-year postspray nor on plot II 1-year postspray.

The breeding biology of the species studied also appeared normal. Nest placement seemed normal in all species; none appeared to avoid nesting under or in dead bushes. While no data on nesting success were obtained, all species were noted to have fledged young in postspray years.

Even though the overall vegetative cover remained nearly unchanged after herbicide treatment, noticeable changes in certain insect and seed abundances were probably related to greatly decreased plant growth. A very abundant, small (4 mm) green-leaf beetle (Coleoptera: Chrysomelidae) that was found mainly on *C. velutinus* was virtually absent after spray. Neither *C. velutinus* or *A. patula* produced seeds after spray.

The green-leaf beetle was eaten by most birds using brush fields (Beaver 1972) except the Mourning Dove and Mountain Quail. The absence of this food produced no noticeable changes in foraging behavior in any of the birds breeding in postspray brush fields.

We do not have dietary information for any species of bird from postspray brush fields, but stomach contents and foraging behavior of most species were obtained in an unsprayed area nearby (Table 4, data from Beaver 1972). For at least one species, the Fox Sparrow, we suspect a significant shift in diet occurred in postspray brush fields. This species eats seeds of *C. velutinus* almost to the exclusion of all other types, especially in the early part of the breeding season when insects are in low numbers. *C. velutinus* seeds are very hard shelled and when a Fox Sparrow crushes one in its bill, the sound is audible up to 30 m on windless days. This snapping sound was heard consistently at about 10-sec intervals when the bird was feeding in unsprayed brush fields. In postspray brush fields we noted many fewer seed-cracks in 1971 and heard none on plot I in 1972 on either censuses or during vegetation sampling 2 years after spray. The Fox Sparrow must have switched to some alternate food source, but no detectable shifts in foraging position or style (i.e. scratch and peck) occurred over this time period.

It is again assumed that alternate food sources were found. Apparently neither of the two noted reductions in food abundance or those that went unnoticed were of sufficient magnitude to produce a decrease in avian populations.

DISCUSSION

Habitat selection by birds is determined by both proximate and ultimate factors (see Hilden 1965 for a review). Over the relatively short time span of this study we expected that only proximate factors would be important in changes in habitat preference of birds in brush fields. Many proximate factors such as foliage profile, nest sites, drinking and feeding sites, and perch sites can elicit settling behavior in birds (Hilden 1965). Ultimate factors for most species of birds are food, requirements imposed by structural and functional characteristics of the species, shelter against weather and enemies, or other factors that determine survival and reproductive success once a bird settles in a habitat. Certain ultimate factors for some species may be proximate releasers for others, such as food (Hilden 1965). In this study, changes in food type and abundance on herbicide sprayed plots resulted in no noticeable short-term population changes. Very little is known concerning how birds identify and respond to habitat stimuli but work by Klopfer (1965, 1972) with Chipping Sparrows (*Spizella passerina*) in the laboratory and the work of MacArthur and MacArthur (1961) and MacArthur et al. (1962) in the field suggest that foliage type and profile (i.e. the distribution and density of leaves and stems) are important factors. This "Gestalt" habitat form-species relationship has been known intuitively by ornithologists for years as "habitat preference." Based on this relationship, the best explanation for the results is that avian population size and species composition did not change with herbicide treatment of the habitat because the essential elements of the habitat in the proximate sense only were not altered for each species. The changes in species abundance and composition that were noted must have been the result of factors operating on the entire brush field avifauna. Patterns of avian populations were similar on both plots within a year, regardless of herbicide treatment. These avian populations were also comparable to other places in brush fields (Beaver 1972).

Two other studies on the effects of herbicides on certain bird populations are interesting for comparison. Best (1972) found that Brewer's Sparrow declined in abundance on plots where sagebrush (*Artemesia tridentata*) was killed by treatment with 2,4-D. Herbicide treatment of sagebrush causes defoliation. Brewer's Sparrows select nest sites with overhead concealment normally present in live sagebrush. Best noted that Brewer's Sparrow compensated for lack of nest concealment by selecting larger sagebrushes with limbs over the nests providing concealment normally provided by foliage. Best also followed populations of Vesper Sparrows (*Pooecetes gramineus*) and noted no change in pre- and posttreatment plots. Vesper Sparrows are ground nesters and apparently were not dependent on sagebrush for nest concealment. Defoliation of sagebrush probably did not result in a significant change in habitat profile for this species.

Insect and seed food found in the stomachs of the Brewer's and Vesper Sparrows taken by Best from total kill plots of sagebrush indicated a possible reduction in variety of foods taken. Both species have similar diets and the information given by Best is not sufficient to implicate food reduction as the cause for the reduction in numbers of Brewer's Sparrows and not in Vesper Sparrows. Interestingly, Best found that neither species' abundance changed on plots with up to 50% sagebrush kill. Apparently nest sites for Brewer's Sparrow were still in sufficient abundance at this level of herbicide effect. Only a total sagebrush kill resulted in a decrease in the numbers of Brewer's Sparrows.

In another study, where herbicide treatment removed a part of the vegetation, similar results were obtained. Dwernychuk and Boag (1973) found that six species of ducks nesting on an island in a lake in Alberta were restricted to those habitats where broad-leafed plants occurred that were not treated with herbicide. Grasses of several species replaced broad-leafed plants killed by the herbicide and ducks avoided using these areas for nesting. Dwernychuk and Boag noted a decline in the number of nesting ducks over the 3 years of their study. They concluded that this decline was due primarily to a reduction in suitable nest sites and was not food related. As feeding was done in aquatic habitats nearby, their conclusion appears justified.

The role of food as a factor important in determining the abundance and guild membership in brush field birds studied here does not appear to be great, at least on a short-term basis.

In summary the brush field birds studied here appear to select a breeding habitat based on vegetative features such as foliage profile and not in relation to the immediate food supply. Many insectivorous and seed-eating birds are very general in the range of foods they will eat, as was the case with the species studied here except for the Fox Sparrow, which appears to be a *C. velutinus* seed specialist, but not obligatorily so. A generalized diet is probably adaptive in that food can be found in temperate regions where wide fluctuations occur in abundance and species of insects, perhaps less so for seed crops, on an annual basis. Choice of a habitat on the basis of profile may be the best strategy to predict the presence of food, nest sites, and shelter.

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