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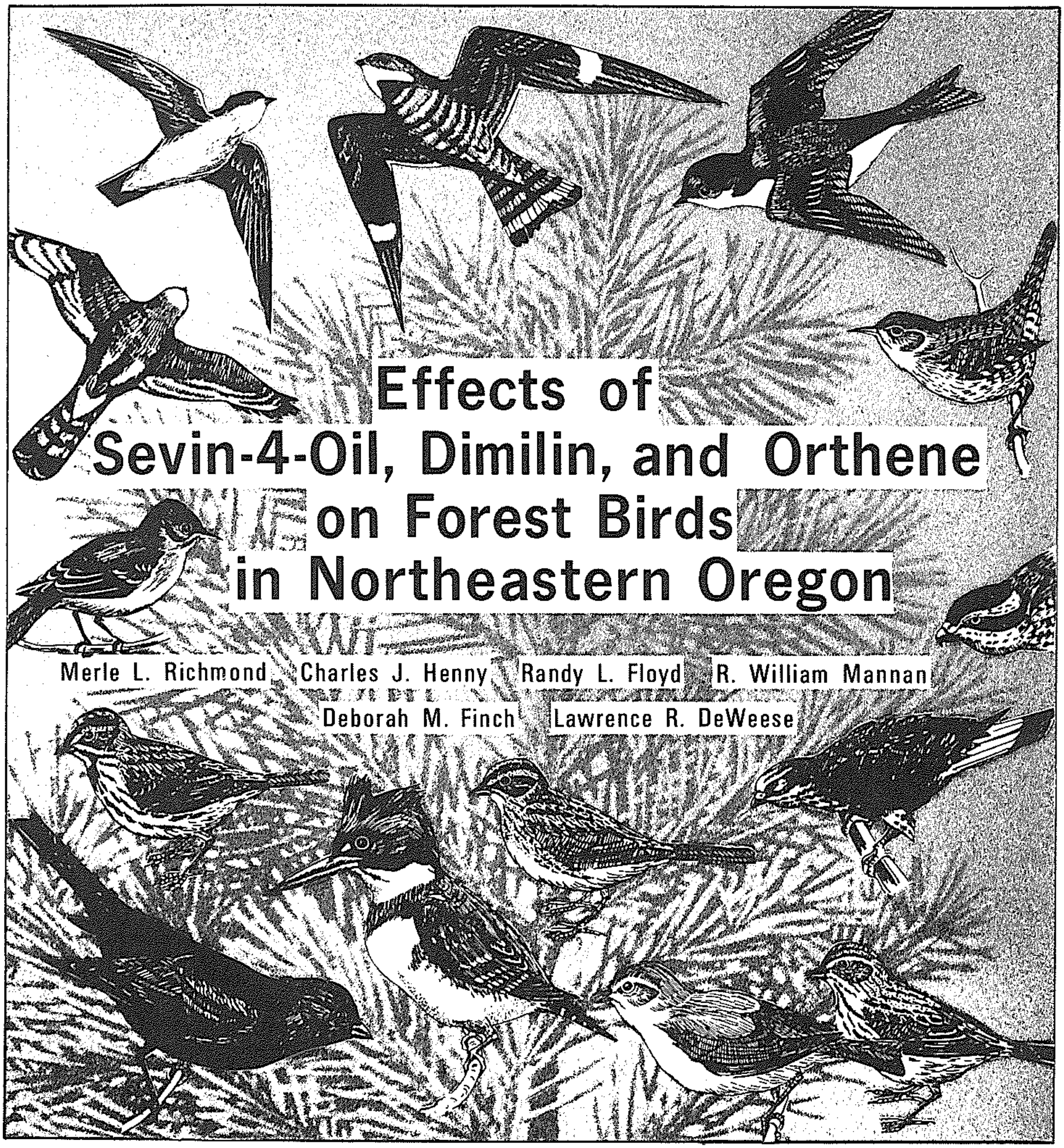

# Effects of Sevin-4-Oil, Dimilin, and Orthene on Forest Birds in Northeastern Oregon

Merle L. Richmond Charles J. Henny Randy L. Floyd R. William Mannan
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RESEARCH PAPER PSW-148

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# IN BRIEF...

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*Retrieval Terms:* Sevin-4-Oil (carbaryl); Orthene (acephate); Dimilin (diflubenzuron); forest birds; brain cholinesterase.

A field study begun in 1975 in the forests of northeastern Oregon was designed to assess the effects of Dimilin (at 0.14 and 0.28 kg/ha), Sevin-4-Oil (at 2.24 kg/ha), and Orthene (at 1.12 and 2.24 kg/ha) on a nontarget nesting bird population. Eleven study plots (six treatment and five control plots) were established in the Wallowa-Whitman National Forest. Breeding bird density, species diversity, nesting success, brain cholinesterase (ChE) activity, and the presence of sick or dead birds were evaluated on control and treatment plots during the study period in the year of spraying (1976) and 1 year after spraying.

Two bird census techniques were used (spot-mapping and fixed station index). Calculations of the probability of success of nest contents were based on nest-days of exposure to allow use of incomplete nest records. Because organophosphate and carbamate insecticides like Orthene and Sevin-4-Oil inhibit cholinesterase enzymes, we measured brain ChE activities of collected birds to determine the extent and magnitude of exposure to the insecticides.

We did not find any sick or dead birds, or observe any abnormal behavior in birds on plots treated with Dimilin or Sevin-4-Oil. Furthermore, cholinesterase tests of birds from plots treated with Sevin-4-Oil showed only 2 of 55 birds with brain ChE depression. However, several observations of abnormal activity in forest birds were made following the application of Orthene. In marked contrast to Sevin-4-Oil, Orthene caused extensive inhibition of brain ChE activity (commonly 30 to 50 percent) for up to at least 33 days for 11 of 12 species collected. The highest frequency of depression (12 out of 13 birds or 92 percent) was noted on the second day following spray. Postspray bird census data suggest that two species of birds may have decreased in numbers following the Orthene treatment. The overall impact of Orthene on the nesting bird population is not fully understood and further testing is necessary. One year postspray, 11 birds (6 species) were collected on the plot treated with Orthene at 1.12 kg/ha and the brain ChE activity from all samples was within the normal range.

The evaluation of bird populations was complicated by (1) movements of birds into and out of the small treated plots, (2) presence of floating surplus individuals, and (3) variability in numbers of birds detected, because bird behavior changed with weather conditions and at different stages of the nesting cycle. Furthermore, since replications of study plots were not feasible, no analysis of variance of the data could be made; consequently interpretation of the results was partly subjective. The absence of an insect outbreak on the study plots may have also influenced the results if the ingestion of sick or dying insects is a major route through which birds encounter pesticides. Some of the difficulties are inherent in most field studies of birds.

The findings from the study were compared with the available literature; other studies differ in evaluation procedures, size of plots, and the presence or absence of insect outbreaks at the time of the investigations. Restraints on funds and manpower require that priorities be established so as to use the most sensitive research methods in determining the insecticide effects on birds. We recommend these research methods should receive priority: (1) studies of brain ChE activity (specific for effects of organophosphate and carbamate insecticides), (2) nesting studies, (3) bird behavior observations, and (4) census of populations.

The possible harmful effect of insecticides on nontarget organisms should be a prominent concern in all attempts to control forest pests. Although all wildlife must be considered, birds are particularly vulnerable. The study reported here was part of the effort to find an environmentally safe method to control one of the major sources of insect damage to forest trees—the Douglas-fir tussock moth (*Orgyia pseudotsugata* [McDunnough]). Its larval stage is an important defoliator of true firs (*Abies* sp.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) in western North America. In Oregon, severe infestations have recurred at intervals of about 10 years since 1936 (Wickman and others 1973).

A tussock moth infestation lasting from 1971 to 1974 covered almost 325,000 ha of forest in northeastern Oregon, southeastern Washington, Idaho, and western Montana (Graham and others 1975). To combat the infestation, DDT, though banned by the U.S. Environmental Protection Agency (EPA) in 1972, was cleared for emergency use against the tussock moth in 1974. During June and July of that year, 172,600 ha of the forest were sprayed. Strong controversy over the use of DDT led to widespread support for finding alternative means of control.

As a result, the U.S. Department of Agriculture began a 4-year effort to find new answers to the problem. The USDA Expanded Douglas-fir Tussock Moth Research and Development Program, begun in October 1974, had two major goals: (1) to put into use methods presently available to reduce damage caused by tussock moth infestations, and (2) to develop new knowledge necessary to prevent or suppress future infestations (Wright 1977).

To meet these broad objectives, the planning group set up a five-phase program. Phase 3 dealt with new or improved materials and methods for suppression with emphasis on new chemical and biological control agents that were both effective and environmentally safe.

As part of this effort, a 3-year field study, begun in 1975 on the Wallowa-Whitman National Forest in northeastern Oregon, assessed the environmental effects of three insecticides—Sevin-4-Oil (carbaryl), Orthene (acephate), and Dimilin (diflubenzuron)—on nontarget organisms. Under contract, the U.S. Fish and Wildlife Service studied the effects of these insecticides on breeding birds.

A specific objective of the study was to determine, by measuring and comparing bird populations before and after treatments, whether the insecticide treatments resulted in the desertion of breeding territories, or in the sickness and death of breeding birds. We also hoped, by studying nesting activities on treated and untreated plots, to determine whether the insecticide treatments jeopardized the survival of eggs or nestlings. In addition, because organophosphate and carbamate insecticides like those being tested inhibit cholinesterase enzymes, we measured brain cholinesterase activities of collected birds to determine the extent and magnitude of exposure to the insecticide.

The methodology for studying the impact of the newer, less persistent insecticides on bird popula-

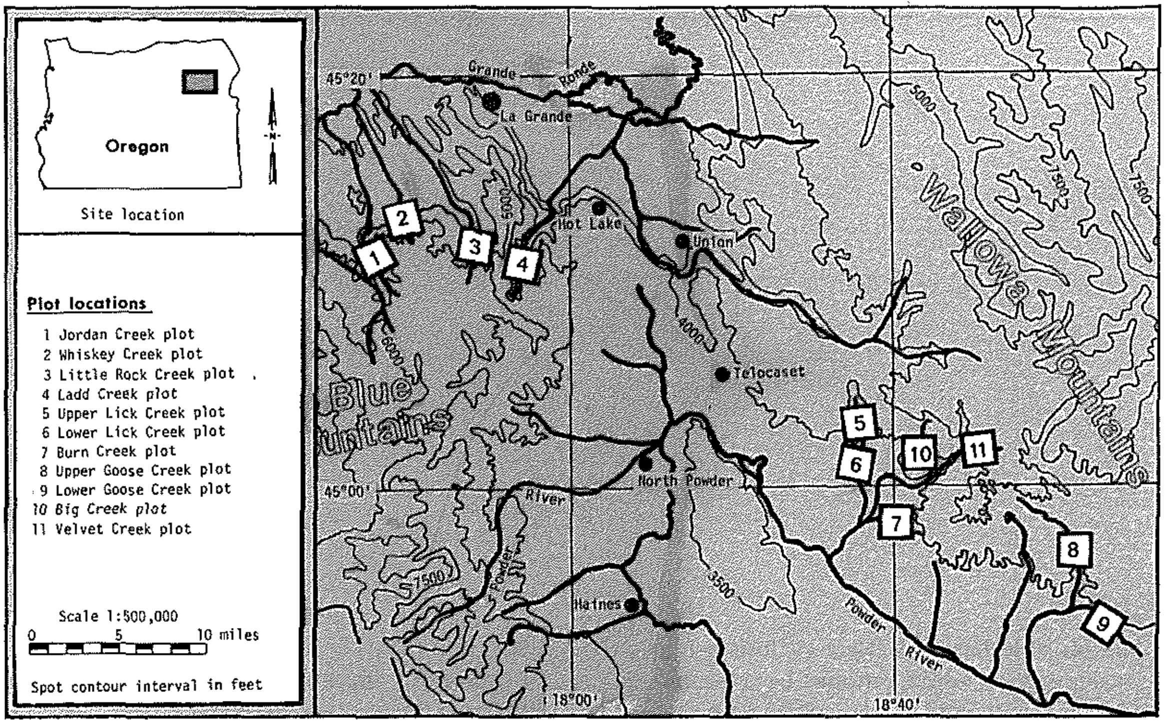

***Figure 1****—Study plots were established in the Wallowa Mountains and Blue Mountains of northeastern Oregon.*

tions is in its early stages of development. Thus, no standard criteria for conducting field studies was available at the time this study was begun. Limitations of this particular study are discussed in detail in the conclusions section. Although some of our findings are partially based upon a subjective assessment, the details presented are important for their description of bird populations and for guidance in future studies. We believe the recommendations section will be useful as a guide for future investigations.

## STUDY AREA

The study plots were established on the Union and La Grande Districts of the Wallowa-Whitman National Forest in northeastern Oregon *(fig. 1)*. Criteria used to select study plots were (1) presence of tussock moth habitat, (2) presence of permanent streams with riparian vegetation (to ensure an adequate diversity of bird species), (3) accessibility by road, (4) no proposed vegetation manipulation until after August 1977, and (5) no previous applications of DDT.

Elevations of the study plots ranged from 1183 m to 1677 m. Although all study plots were in the *Abies grandis* vegetation zone (Franklin and Dyrness 1973), there were noticeable differences between forests on the Union District (Wallowa Mountains) and those on the La Grande District (Blue Mountains).

Forests in the Wallowa Mountains were, in general, open, dry, and composed of a mosaic of plant associations dominated by one of the following: climax stands of grand fir (*Abies grandis* [Dougl.] Lindl.) mixed with western larch (*Larix occidentalis* Nutt.) and Douglas-fir; seral stands of ponderosa pine (*Pinus ponderosa* Dougl. ex Loud.) and Douglas-fir; open, rocky areas with scattered ponderosa pine; or deciduous stands of mountain alder (*Alnus incana* [L.] Moench), red-stemmed maple (*Acer glabrum* Torr.), and black cottonwood

(*Populus trichocarpa* Torr. & Gray). Associations dominated by deciduous trees occurred primarily along streams; those dominated by coniferous species were found upslope.

Forests on study plots in the Blue Mountains were generally more dense and mesic than on plots in the Wallowa Mountains, and consisted of seral stands of ponderosa pine, lodgepole pine (*Pinus contorta* Dougl. ex Loud.), and Douglas-fir, and climax stands of grand fir mixed with Engelmann spruce (*Picea engelmanii* Parry ex Engelm.), subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.), and western larch. Selective logging had occurred on all study plots.

During the data collection periods, June 6 to July 11, 1976, and May 27 to July 18, 1977, daily mean temperatures and ranges (°C) on study plots were as follows:

| | *1976* | *1977* |
|---|---|---|
| Wallowa Mountains: | | |
| Minimum | 7.2<br>(−3.3 to 19.4) | 6.0<br>(1.7 to 12.8) |
| Maximum | 22.8<br>(10.1 to 33.3) | 27.8<br>(7.3 to 32.8) |
| Blue Mountains: | | |
| Minimum | 4.1<br>(−2.8 to 12.2) | 6.2<br>(−2.8 to 13.3) |
| Maximum | 27.8<br>(7.8 to 28.9) | 21.9<br>(7.3 to 31.1) |

Total rainfall on plots in the Wallowa Mountains was 3.5 cm in 1976 and 0.7 cm in 1977. On plots in the Blue Mountains, the rainfall measurements were 4.5 cm in 1976 and 3.7 cm in 1977.

# METHODS

During the summer of 1975 and spring of 1976, we established 11 study plots on the two districts. Each study plot of 129.5 ha consisted of an 80.9-ha square for bird population studies, which included an 8.09-ha subplot in the center, for more intensive research (breeding pair determination); and an adjoining 48.6-ha area for bird collection.

Where possible, for similarity, each treatment plot was assigned a control. Where two plots were established on one stream, the upstream plot was the control *(fig. 1)*.

Table 1—*Treatment allocation of study plots, Wallowa-Whitman National Forest*

| Treatment plot and control | Treatment[1] | Rate | Application date (1976) |
|---|---|---|---|
| | | *kg/ha* | |
| Wallowa Mountains: | | | |
| Lower Goose Creek<br>(Upper Goose Creek)[2] | Sevin-4-Oil | 2.24 | June 27 |
| Lower Lick Creek<br>(Upper Lick Creek)[2] | Sevin-4-Oil | 2.24 | June 27 |
| Big Creek<br>(Burn Creek)[2] | Dimilin | 0.14 | June 26 |
| Velvet Creek | Dimilin | 0.28 | June 26 |
| Blue Mountains: | | | |
| Ladd Creek<br>(Little Rock Creek)[2] | Orthene | 1.12 | June 23 |
| Jordan Creek<br>(Whiskey Creek)[2] | Orthene | 2.24 | June 24 |

[1] All applications were made in 1 gallon total formulation per acre. Solvent for Sevin-4-Oil was No. 2 fuel oil; for Dimilin and Orthene, $H_2O$ + 10 percent ethylene glycol.

[2] Control plots.

## Insecticide Treatments

During the last week of June 1976, the six treatment plots were sprayed with varying rates of Sevin-4-Oil, Dimilin, or Orthene[1] *(table 1)*. The treatments were applied with a conventional nozzle and boom system mounted on a Bell 206B Jet Ranger helicopter. Tee-Jet fan nozzle tips (no. 8002) were used to approximate a drop size of less than 250 microns VMD. All treatments were applied in 22.9 m swaths at 96 km/hr and at pressure of 2.8 kg/cm$^2$.

## Census Techniques

To evaluate the effects of insecticides on breeding birds, we compared bird populations on treated plots with those on control plots. Two independent census techniques were used to assess bird abundance, the spot-mapping technique (Williams 1936, Hall 1964, Robbins 1970) and a fixed-station census. The census procedures used in this study are the same as used by DeWeese and others (1979). Their paper should be consulted for detailed methodology.

Numbers of breeding pairs were estimated on the 8.09-ha subplots by the spot-mapping technique.

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[1] Trade names are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

We conducted at least eight censuses (four before and four after spray) on each subplot between June 7 and July 11, 1976. In 1977, we conducted at least nine censuses on each subplot between May 27 and July 18. Each census was completed in 2 hours, beginning at sunrise. We excluded data for certain birds (calliope hummingbird, brown-headed cowbird, Cassin's finch, pine siskin, and red crossbill) from the estimates of breeding pairs because the territorial behavior of these species cannot be interpreted by the spot-mapping technique. (Note: See Appendix for scientific names of birds mentioned in this report.)

We recognized the weakness of relying on only the breeding-pair estimates for detecting population changes after treatment. Although population reductions can be detected by this technique, critics estimate that at best it uncovers only about one-fourth of an actual reduction (Robbins 1963). Also, repopulations after loss may occur so rapidly that the actual reduction may be masked by immigration of surplus breeders (Stewart and Aldrich 1951). So, since low magnitude population changes may not be detected by the breeding-pair mapping technique alone, we also employed the fixed station census.

The fixed-station census method provided an index of relative abundance—not the density estimate (number of pairs for a given area) obtained from the spot-mapping technique. Using a compass and surveying tape, we established 14 stations, spaced 161 m apart, between the boundaries of the 80.9-ha plot and the 8.09-ha subplot. A standardized route with stops at each of the 14 points was traversed in 2 hours. At each stop the observer rested for 1 minute and then recorded all birds heard or seen for a period of 5 minutes. Care was taken to avoid duplicating counts of an individual that moved from one place to another during the 5-minute period. Fixed-station censuses immediately followed spot-mapping censuses. Results of fixed-station censuses were expressed as the mean number of birds per point. The fixed-station census may be better for detecting short-term population changes immediately postspray.

The plots treated with Orthene were censused by the same observers in 1976 and 1977; however, on the plots treated with Dimilin and Sevin-4-Oil, different observers were used in 1976 and 1977. Therefore, between-year differences in bird populations on the Dimilin and Sevin-4-Oil plots may have been influenced by observer's ability, but any bias would be present also in the control plots, which were evaluated by the same observers as the treatment plots.

To reduce the variance in our analysis, we stratified bird species according to nest type and potential direct exposure to falling spray. Our categories were (1) open-nesters with high, medium, and low exposure to spray, and (2) cavity-nesters. Exposure categories were based on the parts of the habitat a species generally occupies when foraging and nesting (for example, birds of upper canopy, high direct exposure). These categories were also used when evaluating the fixed-station index and the estimates of breeding pairs.

To measure the degree of similarity in species composition between plots, we used data from fixed-station censuses to calculate similarity indexes. They were based on the "coefficient of community" (Bray and Curtis 1957), and express the degree to which two plots shared species. Moulding (1976) described the calculation of the index as it applied to bird populations.

We used data from fixed-station censuses to calculate diversity indexes for prespray and postspray populations. We calculated the indexes using the Shannon-Weaver Information Measure (Shannon and Weaver 1949). An index value was calculated for each census in an attempt to detect changes over time in numbers of species and evenness of distribution. Peterson (1975) reported species diversity indexes from throughout the United States. The values (a 6-year average) ranged from 2.15 in the south Sonoran Desert to 4.19 in the Cascade Mountains.

## Nesting Success Estimates

In 1975 we placed 20 to 22 nest boxes on each of the subplots to increase the number of accessible nests. During the 1976 and 1977 field seasons we found 404 nests on the study plots. Nests were checked periodically to determine clutch size, hatching success, and eventual outcome. Calculations of the probability of success of nest contents were based on nest-days of exposure (Mayfield 1961, 1975). This procedure allows incorporation of incomplete nest records. Green (1977) saw a potential bias in this method; again, however, we feel that if a bias occurs it will be similar in both treatment and control data. Only data from nests that were active at and following treatment were used. To increase the sample size of control tests, we grouped data from control nests into Wallowa

Mountains and Blue Mountains samples for each year. We did not find a sufficient number of nests to allow stratification of the data according to nest type and exposure category. (In the cavity nest category, the majority were mountain chickadees which were utilizing our nest boxes).

The study of nesting success also provided an opportunity to observe bird behavior. Parent birds were observed at the nest for any abnormal behavior following the application of insecticides. A casualty search, which may best be described as a "random walk," was also conducted regularly on all plots in 1976 and 1977; the hours of effort were recorded.

### Brain Cholinesterase Studies

The materials and methods used for the cholinesterase (ChE) studies are described by Zinkl and others (1979).

Brain ChE inhibition of 50 percent was considered diagnostic for cause of death by Ludke and others (1975), although there is some difference of opinion among investigators (Zinkl and others 1977). Following Ludke and others (1975), we have used a 20-percent depression as indicative of exposure, although we believe that more research should be conducted to precisely correlate depression levels with actual mortality. We collected birds for measurement of brain ChE activity on the portion of the spray areas (48.6 ha) where birds were not censused. Recognition of symptoms of ChE inhibition was important for accurate interpretation of bird behavior during the field investigation. Signs of poisoning that would have been noticeable in the field or with trapped birds in hand include miosis, salivation, lacrimation (muscurinic effects), muscle twitching, dyspnea, paralysis, and clonic convulsions (nicotinic effects) (Zinkl and others 1977).

### Plot Comparability Tests

As a means of evaluating comparability between control plots and treated plots, similarity indexes were calculated to compare bird communities. An index value of 1.0 would indicate that two plots shared exactly the same species and that a particular species had the same relative abundance and the same relative frequency in both plots. Although according to Moulding (1976) no objective criterion exists for assessing similarity with this index, we feel that a realistic value for high similarity can be determined. To do this, we divided alternate censuses on a 1977 control plot into two parts and calculated a similarity index to compare these parts. In essence, this index compared the community with itself. The resulting index value was 0.90. On this basis, we judged that the range we found for treatment and control plots, 0.66 to 0.81, was high enough to make the comparisons meaningful.

Similarity indexes were also calculated to compare bird communities on the same plot between the two years. These values ranged from 0.73 to 0.82, suggesting that the basic community structure changed very little between years.

## RESULTS AND DISCUSSION

We did not find any sick or dead birds, or observe any abnormal behavior in birds on the plots treated with Dimilin or Sevin-4-Oil in 1976 or 1977. On plots treated with Orthene, however, several birds showed abnormal activity. One day following application of 1.12 kg/ha, we captured a warbling vireo that was salivating profusely, a symptom of organophosphate poisoning. The bird was collected for measurement of brain cholinesterase activity, which was 38 percent below normal (see ChE discussion later). Three days following application on the same plot, we observed an American robin having difficulty maintaining its balance on perches (incoordination is also a symptom of organophosphate poisoning). The bird fell from its perch several times, and once teetered over until it clung upside down from its perch. It then fell and either flew or glided out of sight where it could not be located. We did not find any dead birds on the plot treated with Orthene at 1.12 kg/ha or its control plot in 1976 or 1977.

On the plot treated with Orthene at 2.24 kg/ha, 20 days following application, we captured an adult male ruffed grouse that was unable to fly. The bird was not emaciated, but showed incoordination. On July 21, an adult male ruffed grouse was found dead about 130 m from the site where the sick grouse had been released 6 days earlier. No sick or dead birds were found on any control plots in 1976, or on any plots in 1977.

## Population Composition

### Breeding Pairs

We examined the estimates of breeding pairs at three levels—individual species, exposure categories, and total species. Detailed findings are presented in the Appendix table.

No major changes in total numbers of breeding pairs occurred immediately following spray on plots treated with Dimilin, Sevin-4-Oil, or Orthene in 1976. Total numbers of breeding pairs, however, did decrease slightly on most subplots—both treatment and control. These decreases were probably due to the completion of nesting cycles of some species. The greatest 1976 postspray decreases in individual species were noted for the warbling vireo and yellow-rumped warbler on the plot treated with Orthene at 1.12 kg/ha.

The warbling vireo is known to sing throughout the breeding season (Sutton 1949), so detectability of the species should not have changed following treatment unless its behavior was affected. Observations of warbling vireo nests on other subplots in 1976 and 1977 indicated that nesting cycles of the species did not terminate until mid-July, 3 weeks after insecticide treatment. Mortality unrelated to the insecticide may have occurred; however, the possibility of treatment effects cannot be excluded. Numbers of warbling vireos were steady or down slightly in other plots.

The apparent decrease observed in the yellow-rumped warbler on the two Orthene-treated plots may also have been related to the insecticide. In the two Orthene plots, the yellow-rumped warbler declined from 7 to 4 breeding pairs, while numbers in the two controls held steady (7 and 7). Furthermore, numbers on the remaining plots also held steady (15 and 16 pairs). Interpretation of recorded detections of this abundant species was very difficult. Territories were not well defined, perhaps because of the presence of surplus males that were not restricted to a given territory (Stewart and Aldrich 1951), wide-ranging movements, a reduction of vocal activity as the breeding season progressed, or inability of observers to detect simultaneous singing. In contrast to the yellow-rumped warbler, the Townsend's warbler showed an increase in the two Orthene plots (8 to 11 pairs) compared to its controls (8 and 8), and decreased slightly in the remaining plots (15 to 12 pairs).

Between 1976 and 1977, on one of the subplots treated with Sevin-4-Oil at 2.24 kg/ha, decreases occurred in the number of breeding pairs of open-nesters with medium exposure to falling spray. The overall reduction (24 or 25 to 17 pairs) was most evident in the western tanager (4 to 0 pairs). Similar reduction also occurred in the golden-crowned kinglet and lazuli bunting on the subplot treated with Dimilin at 0.28 kg/ha, in the Swainson's thrush on several treatment and control subplots, and in the warbling vireo on all subplots.

Increases from 1976 to 1977 in total breeding pairs occurred on both subplots treated with Dimilin (0.14 and 0.28 kg/ha) and their control (Burn Creek). These increases were most evident in the American robin (control), the Townsend's and MacGillivray's warbler (Dimilin 0.14 kg/ha), and the mountain chickadee (Dimilin 0.28 kg/ha). Mountain chickadees also increased on the Whiskey Creek control subplot and the subplots sprayed with Sevin-4-Oil at 2.24 kg/ha (Lower Goose Creek). Increases in mountain chickadees were due primarily to increased use of nest boxes.

Bird populations of western coniferous forests are known to undergo marked fluctuations in density (Wiens 1975). In Utah, Samson (1976) recorded a 16-fold increase in the size of a Cassin's finch population from 1971 to 1972, followed by a 9-fold increase from 1972 to 1973. In a ponderosa pine forest in central Oregon, between-year densities of the mountain chickadee and brown creeper increased 81 and 78 percent, respectively (Gashwiler 1977). Because many of the between-year changes we observed in breeding pairs also occurred on control subplots, we conclude that most such changes probably reflect normal population fluctuations. Another possible source of fluctuations on the plots treated with Dimilin and Sevin-4-Oil, and their control plots, may be the change in observers between years.

### Fixed-Station Bird Count

Trends in mean numbers of birds per station (all species) on treatment plots were similar to those on control plots for each of the three insecticides in both 1976 and 1977 (see Appendix for graphs of these data). However, comparisons based on all species may not be valid, because counts for species not common to both treatment and control plots could mask a decline in one, or even several species on treated plots. Therefore we compared trends in mean numbers of birds per station based on species common to both treatment and control plots. Results were essentially the same as those derived from comparisons of all species.

A confidence interval (95 percent level) was calculated for each census as a method of comparing data means from the 14 stations (*fig. 2,* Appendix). We attributed most of the within-census variation to lack of homogeneity in habitat from station to station. There were also fluctuations in mean numbers of birds per station between censuses on the same study plots. Changes in bird behavior at different stages of the nesting cycle and variations in bird activity due to changing weather conditions accounted for much of the between-census variation.

Trends in the mean numbers of birds per station were also examined for each nest-type and exposure category. We found no major differences, on either treatment or control plots, between mean numbers of open-nesters with high exposure to spray, for any of the three insecticides in either 1976 or 1977 (see Appendix). Trends of other nest-types and exposure categories were similar to those obtained for open-nesters with high exposure to spray.

Although numbers of individuals of most species were too few for separate evaluation, we examined several of the more abundant species and found no apparent differences in numbers between treatment and control plots following application of any of the three insecticides. Species examined on the plots treated with Dimilin and Sevin-4-Oil were *Empidonax* sp. (dusky and Hammond's flycatchers, combined because they are sibling species difficult to separate), mountain chickadee, western tanager, pine siskin, dark-eyed junco, and chipping sparrow. Species examined on the plots treated with Orthene were mountain chickadee, yellow-rumped warbler, Townsend's warbler, pine siskin, and dark-eyed junco.

Mean numbers of birds per station (all species) were generally greater in 1977 than in 1976 on each of the plots treated with Dimilin and Sevin-4-Oil. We believe that these increases were due to slight variations in observer methodology. To determine if any changes in bird abundance were real, we calculated a ratio (treatment plot/control plots) of mean numbers of birds per station (all species) for postspray census periods in each year *(table 2).* The greatest percentage change in ratios between years on any plot was 13 percent. We believe these changes represented small fluctuations in bird abundance and could easily be attributed to normal yearly variations in bird populations. Plots treated with Orthene were censused by the same observers in 1976 and 1977; no large fluctuations in bird abundance were noted between years.

Table 2—*Ratio[1] of bird population on treatment plots to that on control plots, for postspray census periods, 1976 and 1977[2]*

| Treatment | Population ratio 1976 | Population ratio 1977 | Percent difference |
|---|---|---|---|
| Sevin-4-Oil | | | |
| Lower Goose Creek | 0.95 | 1.00 | +5 |
| Sevin-4-Oil | | | |
| Lower Lick Creek | 0.86 | 0.77 | −10 |
| Dimilin | | | |
| 0.14 kg/ha | 1.14 | 0.99 | −13 |
| 0.28 kg/ha | 1.02 | 1.01 | −1 |

[1] Based on mean number of birds per station (treatment/control).
[2] Period extended from late June through mid-July for both years.

### Species Diversity

Trends in species diversity on treatment plots were similar to those on control plots for all three insecticides in both pre- and postspray periods, 1976, and in the census period of 1977 (Appendix). Diversity index values were generally stable throughout each field season and ranged between 2.5 and 3.0. These data indicated that no large changes in species diversity occurred following the application of any of the three insecticides.

## Nesting Success

In northeastern Oregon, insecticides for control of the Douglas-fir tussock moth are most effective when applied in late June. In the present study, treatment plots were sprayed at this time to simulate conditions of an actual control program. The spray period coincided with the peak of hatching of young birds on all study plots *(fig. 4).* Lack (1968, p. 303) stated that for many birds "breeding is timed in relation to the availability of food for the young." Consequently, insecticides applied at the peak of hatching potentially affect the ultimate success of nests by (1) reducing the number of insects during a period when they are in great demand as a source of food, and (2) contaminating food (primarily insects) ingested by parent birds and nestlings. If insecticide particles remain suspended in the air for any length of time, then they also are potentially hazardous, by inhalation, to parent birds and nestlings. In short, the optimum time for insecticide treatment is also a period of great vulnerability for forest birds (DeWeese and others 1979).

The calculations of overall probabilities of success of all nest contents (see Methods section)

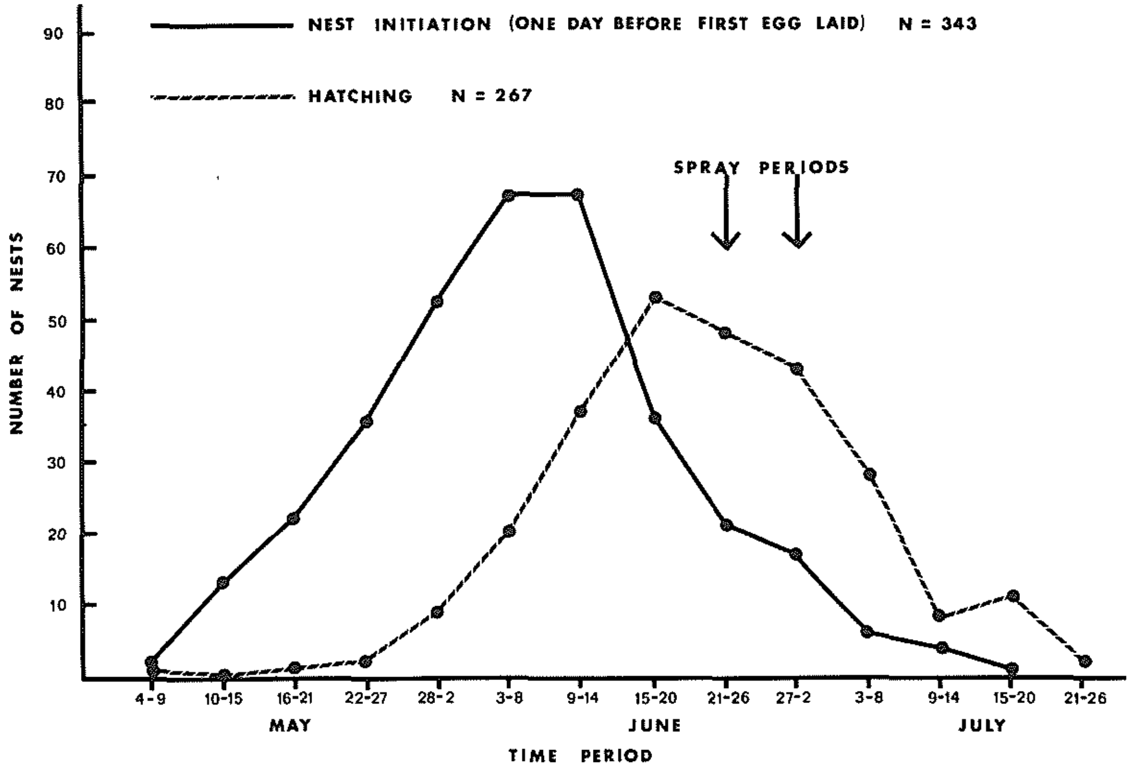

**Figure 4**—Phenology of nests located on all study plots in 1976 and 1977 is shown in relation to dates of spraying with Sevin-4-Oil, Dimilin, and Orthene.

showed that in 1976 nesting success on the plot treated with Dimilin (0.28 kg/ha) and the plots treated with Sevin-4-Oil (2.24 kg/ha) was 16 and 14 percent less likely, respectively, than on the combined Wallowa Mountains control plots *(table 3)*. Success of nest contents on the plot treated with Orthene (1.12 kg/ha) was 7 percent less likely than on the combined Blue Mountains control plots. We do not know if these differences represent actual changes or if they merely reflect variations resulting from insufficient sample sizes of nests, or variable species composition of the samples. Nice (1957) showed that nesting success varied among species, especially between cavity- and open-nesting species.

In 1977, overall likelihood of success *(table 3)* on the Wallowa Mountains control plots decreased 10 percent from 1976; on the plot treated with Dimilin (0.28 kg/ha) and plots treated with Sevin-4-Oil it increased 17 and 23 percent, respectively. Probability of success on the Blue Mountains control plots increased 9 percent from 1976 to 1977; on plots treated with Orthene (1.12 or 2.24 kg/ha) it either remained the same or decreased by 15 percent. These fluctuations tend to support the view that changes of 10 to 15 percent may reflect normal biological variability rather than insecticide effects.

Because nest records were few for individual species, calculation of probability of success was based on a combination of all species. Species composition was similar between treatment and control plots, however.

## Brain Cholinesterase

Depression of brain cholinesterase (ChE) activity has been used previously as an indicator of organophosphate and carbamate poisoning in birds (Stickel 1974, Ludke and others 1975, Zinkl and others 1977). Fifteen species (134 birds) were collected in unsprayed areas for use as controls. No birds were collected on plots treated with Dimilin because, *to our knowledge, it does not inhibit* ChE. Results of the ChE analyses are reported by Zinkl and others (1979), and will be discussed only briefly here.

Table 3—*Probability of success for nests active during postspray census periods, 1976 and 1977*[1]

| Treatment | Probability of success | Nests | 1976 Total nest days | Nest type Open | Nest type Cavity | Probability of success | Nests | 1977 Total nest days | Nest type Open | Nest type Cavity |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Percent* | | | *Percent* | | *Percent* | | | *Percent* | |
| Sevin-4-Oil[2] (2.24 kg/ha) | 45 | 30 | 435.5 | 80 | 20 | 68 | 34 | 632.5 | 61.8 | 38.2 |
| Dimilin (0.14 kg/ha) | 69 | 11 | 158 | 81.8 | 18.2 | 66 | 24 | 274.5 | 87.5 | 12.5 |
| Dimilin (0.28 kg/ha) | 43 | 15 | 183 | 80 | 20 | 60 | 15 | 290 | 66.7 | 33.3 |
| Wallowa Mtns. control plots | 59 | 27 | 392.5 | 77.8 | 22.2 | 49 | 34 | 524.5 | 70.6 | 29.4 |
| Orthene (1.12 kg/ha) | 44 | 8 | 101 | 87.5 | 12.5 | 44 | 12 | 185 | 75 | 25 |
| Orthene (2.24 kg/ha) | 52 | 8 | 101 | 100 | 0 | 37 | 13 | 212 | 76.9 | 23.1 |
| Blue Mtns. control plots | 51 | 11 | 167 | 72.7 | 27.3 | 60 | 25 | 519 | 60 | 40 |

[1] Period extended from late June through mid-July for both years.

[2] Nests from the Lower Goose Creek plot and the Lower Lick plot were combined.

### Sevin-4-Oil

During the summer of 1976, we collected nine passerine species from plots treated with Sevin-4-Oil. The only birds showing ChE inhibition were two Cassin's finches collected 1 day following spray; their ChE activities were depressed 23 and 27 percent. No birds collected on succeeding days showed depression. These findings might be attributed to the rapidly reversible action of carbamates on cholinesterase activity. Carpenter and others (1961) reported that rat brain cholinesterase returned to near-normal levels 24 hours after carbaryl treatments. For a general discussion of the reversible action of carbamates on cholinesterase activity see Matsumura (1975, p. 153-154).

### Orthene

In marked contrast, Orthene caused extensive depression of brain ChE activity. Depression levels of 30 to 50 percent were commonly recorded for 11 of 12 species collected after insecticide treatment. On the plot treated with 1.12 kg/ha, 45 of 65 birds collected 1 to 33 days following spray displayed the ChE inhibition. The highest frequency of depression (12 out of 13 birds or 92 percent) was noted on the second day following spray. The greatest depression for any birds on the plot treated with 1.12 kg/ha was 65 percent. All birds collected 1 to 6 days postspray on the plot treated with 2.24 kg/ha showed ChE inhibition; the greatest reduction was 54 percent. Thus, some birds on plots treated with Orthene may have been subject to fatal organophosphate poisoning.

During the summer of 1977 (1 year postspray), 11 birds (6 species) were collected on the plot treated with Orthene at 1.12 kg/ha. The brain ChE activities from all samples were within the normal range.

## CONCLUSIONS

Our study was a necessary step in testing the effects of Dimilin, Sevin-4-Oil, and Orthene on forest birds in a field situation. Certain limitations of the study affected our ability to interpret the data, however. Comparisons of bird populations between pre- and postspray periods were complicated by (1) movements of birds into and out of the small treated plots, (2) the presence of floating surplus individuals within the study plots, and (3) variability in numbers of birds detected, because bird behavior changed with weather conditions and at different stages of the nesting cycle. The fact that the same observers could not be used in both 1976 and 1977 on several plots affected comparisons of bird populations between years. Because replications of study plots were not possible, no analysis of variance of our data could be made; consequently, interpretation of the results was partly subjective. Because of these limitations, our census methods may not have been sensitive enough to detect subtle changes.

Timing of insecticide applications simulated that of an actual control program; however, our study area was not infested with tussock moth. If ingestion of sick or dying tussock moths is one route through which birds encounter pesticides, then the low abundance or absence of moths on the study plots may have influenced our findings.

Some of the problems we encountered are inherent initial difficulties in most field studies of birds. Solutions to some of these are discussed under "Recommendations." Our findings as compared to those of other investigators will now be examined.

### Dimilin

From the results of our population censuses, nesting studies, and observations of bird behavior, we did not detect any adverse effects of Dimilin (at 0.14 and 0.28 kg/ha) on forest birds in our study. Buckner and others (1975) and Bart (1975) reported similar findings.

### Sevin-4-Oil

We detected no major effects on forest birds from applications of Sevin-4-Oil at 2.24 kg/ha. Our population findings are in agreement with those of Connor (1960), Doane and Schaeffer (1971), and McEwen and others (1972), but conflict with those of Moulding (1976). Moulding detected a 55-percent decrease in bird populations following two applications of Sevin (at 1.12 kg/ha) on a 2000-ha spray block in a New Jersey deciduous forest. There were important differences, however, between our study and Moulding's:

1. His study coincided with a gypsy moth outbreak, whereas ours had no insect outbreak.
2. His study was associated with a large spray block (2000 ha), whereas ours was only 129.5 ha.
3. His spray was applied at two different times, whereas ours was a single application.

Moulding's spray treatment thus may have been considerably more effective than ours in altering avian foods and exposing birds to pesticides. It may not have been possible for birds to get out of his sprayed area on a temporary basis. In other words, birds left permanently if they were avoiding food shortage or insecticide exposure, whereas in our study, they could have utilized unsprayed surrounding areas for feeding while maintaining territories or nests within the sprayed plots. This line of investigation deserves further study.

DeWeese and others (1979) also conducted an investigation during an actual infestation and suppression program (spruce budworm). They detected no major effects on bird populations resulting from an application of Sevin-4-Oil at 1.12 kg/ha (one-half the rate used in Moulding's study), but the plots were somewhat smaller (350 to 500 ha).

### Orthene

The admittedly limited census data suggest that a decrease in the number of breeding pairs of the warbling vireo and yellow-rumped warbler may have occurred following application of Orthene at 1.12 kg/ha. Because warbling vireos were not nesting in the 2.24 kg/ha plot, we have no related data; however, we know that the yellow-rumped warbler numbers also decreased in the 2.24 kg/ha plot. These decreases cannot be attributed to variations in the known breeding habits and behaviors of the two species.

Our findings on brain ChE activity for plots treated with Orthene, and our observations of abnormal behavior, symptomatic of organophosphate poisoning, are of interest here. Location of a dead grouse on the plot treated with 2.24 kg/ha may be indicative of greater overall mortality, considering the rapidity with which carcasses disappear due to heat, predators, or scavengers (Davis 1970). In a study of quail remains, Rosene and Lay (1963) concluded that the location of even a small number of carcasses is reason to suspect a rather heavy mortality.

Our observations thus indicate that the application of Orthene at 1.12 kg/ha and 2.24 kg/ha can cause sickness and possibly death in forest birds. Our findings differ from those of Buckner and McLeod (1975) who reported that applications of 0.56 kg/ha and 1.4 kg/ha had no detectable effect on forest birds in Ontario. However, Buckner and McLeod's study was limited by the small size of the study areas (4 ha), the single census method (spot-mapping), the short period of censusing (5 days before and 5 days after spray), and the absence of ChE analyses. We believe that further tests, especially for Orthene, must be made on larger study areas, with an insect outbreak, and with a replicated design.

# RECOMMENDATIONS

Before an insecticide can be registered for use, initial laboratory screening and safety tests, field tests, and pilot control studies must take place. Our field tests represent the second step in the process, and the first stage of study of the effects on nontarget organisms in an actual forest environment. In further testing, because funds and manpower are limited, priority must be given to the most sensitive research methods, as described below.

## *Field Tests*

### Studies of Brain Cholinesterase Activity

(Specific for effects of organophosphate and carbamate insecticides.) This is the most sensitive and most easily obtained indicator of effects of certain insecticides. Additional work is critically needed, however, to relate ChE depression to the mortality of wild birds. Because ChE depression may result from ingestion of poisoned target insects, we believe priority should be given to conducting field tests in areas with insect outbreaks. Additionally, the spray areas should be as large as possible to minimize edge effects.

### Nesting Studies

These can provide a sensitive measure of pesticide effects, given sufficient sample sizes of nests and replications of treatments. Location of as many nests as possible is important to ensure adequate sample size. Laughlin and Lundy (1976), in a study of pesticide effects on hatchability, provide an equation that relates a difference between treatments to the sample size of eggs required to detect that difference. Once nests are found, standarized techniques should be used by all observers to ensure that the same kinds of information are recorded for all nests. Nests should be checked regularly to provide adequate coverage of all phases of the nesting cycle, and nest contents should not be unnecessarily handled or disturbed when checked. Certain nests, particularly ground nests, are much more vulnerable to predation as a result of human visits (Bart 1977), and should be approached in such a way as to minimize disturbance of the immediate area. Studies of nesting activities also afford an excellent opportunity to make behavioral observations of adult forest birds. In future studies covering larger areas, more effort should be made to obtain meaningful information at the species level. We believe nesting success information is probably the most meaningful biological field data that can be collected: if a parent bird is sick or dead and therefore cannot care for its eggs or young, obviously nesting success will be reduced. Also, nesting success may be reduced by the direct effects of the sprays on the young. Thus, the possible adverse reactions of the adults and/or the young to forest sprays may be detected with nesting studies.

### Observations of Bird Behavior

These can be effective indicators of the effects of insecticides. A knowledge of symptoms of poisoning caused by the insecticides under investigation is valuable for accurate interpretation of bird behavior. Incoordination and salivation were both observed during our study. A regular schedule of casualty searches should also be followed on both treatment and control plots to obtain an index of mortality (for example, casualties per hour of search).

### Censuses of Populations

If sufficient time remains, these should be conducted on both treatment and control plots. If standard census methods for determining avian abundance (spot-mapping, line transects, fixed station censuses) are selected, the advantages and disadvantages of the methods should be considered. However, we believe potential problems with repopulation from the "floating surplus" limit the value of all live bird census techniques.

Two approaches were explored in this study and a discussion of the spot-map method as opposed to the fixed-station census seems warranted here.

Advantages

- Allows more familiarity with individual birds and therefore may detect subtle changes in behavior or the loss of an individual bird. (Losses of birds in the Orthene plot were detected by the spot-map method.)
- May detect replacement birds because a new bird probably will not take the exact territory of the bird it replaced (it may, however, if only one bird of the pair was lost).

Disadvantages

- The analytical procedure is somewhat subjective and provides only one population estimate for a period of interest, and no statistics, to our knowledge, can be applied to the data. A short-term loss is difficult to detect by the procedures used (counts over a period of days or weeks are used to make one population estimate).

- Requires a considerable amount of lead time to establish the plots and at least eight censuses per plot are recommended.

We found one major disadvantage of both methods —because we were unable to recognize individual birds, we could not detect the replacement of local breeding birds by the "floating surplus" birds. Ideally, a study designed to capture, mark, and observe individual birds of several species might be an effective way to determine effects of a spray project, but practical difficulties must be considered:

Handling of birds during early stages of the nesting season may adversely influence their nesting activities.

If the effects of insecticides are species-specific (related to species tolerance and exposure to falling spray), then the examination of a few select species (usually the most numerous and most trappable) may lead to erroneous conclusions.

The number of manhours required to capture and monitor reasonably large numbers of individually marked birds may be prohibitive.

Because of these limitations, we do not recommend an individual marking study in the initial attempts to evaluate a spray project. After problems have been detected with an individual species, this approach may provide the refinement needed. Perhaps a more meaningful approach would be a mass marking of the breeding birds on the study area by aerially applied fluorescent particles or dye at the time of spraying. Then, the birds in the area at the time of spray would be recognizable. Recognition is particularly important in studies of mobile birds on small areas. Basic research on this subject is underway at the Denver Wildlife Research Center of the U.S. Fish and Wildlife Service.

For initial field testing, ideally both spot-mapping and fixed-station indexes of relative abundance can be used. If plot replications are not feasible, we believe more useful information would be obtained from the spot-map method. We do not plan to conduct additional field studies, however, without at least three replications of both treatments and controls. In conclusion, it should be noted that live bird censuses have received the lowest priority among our recommendations for future investigations—primarily because of the repopulation problems.

## *Pilot Control Study*

The same priorities described for field tests should be followed in designing a pilot control study of the effects of insecticides on forest birds. Because the size of the treated area in the pilot control study is usually larger than it is in a field test, there is less likelihood of edge effect. A larger study area can also cover more habitat types, thus expanding coverage of species and providing more opportunity to stratify a data-gathering program according to similar avian communities.

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# APPENDIX

## *Species Check List*

Common and scientific names of all species recorded on each study plot are given here. Species are grouped by nest type and exposure category and are listed in taxonomic order. Taxonomic nomenclature for all bird species follows that of the American Ornithologists' Union (1957, 1973, 1976).

### Open-Nest Species With High Potential Exposure to Spray

| | |
|---|---|
| Spotted sandpiper | *Actitis macularis* |
| Blue grouse | *Dendragapus obscurus* |
| Mourning dove | *Zenaida macroura* |
| Turkey vulture | *Cathartes aura* |
| Red-tailed hawk | *Buteo jamaicensis* |
| Golden eagle | *Aquila chrysaetos* |
| Common nighthawk | *Chordeiles minor* |
| Vaux's swift | *Chaetura vauxi* |
| Calliope hummingbird | *Stellula calliope* |
| Olive-sided flycatcher | *Nuttalornis borealis* |
| Western wood pewee | *Contopus sordidulus* |
| Willow flycatcher | *Empidonax traillii* |
| Dusky flycatcher | *Empidonax oberholseri* |
| Steller's jay | *Cyanocitta stelleri* |
| Gray jay | *Perisoreus canadensis* |
| Common raven | *Corvus corax* |
| Clark's nutcracker | *Nucifraga columbiana* |
| Brown-headed cowbird | *Molothrus ater* |
| Brewer's blackbird | *Euphagus cyanocephalus* |
| Evening grosbeak | *Hesperiphona vespertina* |
| Cassin's finch | *Carpodacus cassinii* |
| Red crossbill | *Loxia curvirostra* |
| Pine siskin | *Carduelis pinus* |
| Vesper sparrow | *Pooecetes gramineus* |
| Chipping sparrow | *Spizella passerina* |
| Dark-eyed junco | *Junco hyemalis* |
| Lincoln's sparrow | *Melospiza lincolnii* |
| Black-headed grosbeak | *Pheucticus melanocephalus* |
| Lazuli bunting | *Passerina amoena* |
| Cedar waxwing | *Bombycilla cedrorum* |
| Warbling vireo | *Vireo gilvus* |
| Orange-crowned warbler | *Vermivora celata* |
| Yellow warbler | *Dendroica petechia* |
| American redstart | *Setophaga ruticilla* |
| Ruby-crowned kinglet | *Regulus calendula* |
| Townsend's solitaire | *Myadestes townsendi* |
| American robin | *Turdus migratorius* |

### Open-Nest Species With Medium Potential Exposure to Spray

| | |
|---|---|
| Sharp-shinned hawk | *Accipiter striatus* |
| Cooper's hawk | *Accipiter cooperii* |
| Goshawk | *Accipiter gentilis* |
| Great horned owl | *Bubo virginianus* |
| Hammond's flycatcher | *Empidonax hammondii* |
| Song sparrow | *Melospiza melodia* |
| Fox sparrow | *Passerella iliaca* |
| Western tanager | *Piranga ludoviciana* |
| Solitary vireo | *Vireo solitarius* |
| Yellow-rumped warbler | *Dendroica coronata* |
| Townsend's warbler | *Dendroica townsendi* |
| MacGillivray's warbler | *Oporornis tolmiei* |
| Golden-crowned kinglet | *Regulus satrapa* |
| Veery | *Catharus fuscescens* |

### Open-Nest Species With Low Potential Exposure to Spray

| | |
|---|---|
| Ruffed grouse | *Bonasa umbellus* |
| Swainson's thrush | *Catharus ustulatus* |
| Hermit thrush | *Catharus guttatus* |
| Varied thrush | *Ixoreus naevius* |

### Cavity-Nest Species

| | |
|---|---|
| American kestrel | *Falco sparverius* |
| Pygmy owl | *Glaucidium gnoma* |
| Belted kingfisher | *Megaceryle alcyon* |
| Hairy woodpecker | *Picoides villosus* |
| White-headed woodpecker | *Picoides albolarvatus* |
| Black-backed three-toed woodpecker | *Picoides arcticus* |
| Northern three-toed woodpecker | *Picoides tridactylus* |
| Yellow-bellied sapsucker | *Sphyrapicus varius* |
| William's sapsucker | *Sphyrapicus thyroideus* |
| Pileated woodpecker | *Dryocopus pileatus* |
| Common flicker | *Colaptes auratus* |
| Cliff swallow | *Petrochelidon pyrrhonota* |
| Dipper | *Cinclus mexicanus* |
| Rock wren | *Salpinctes obsoletus* |
| House wren | *Troglodytes aedon* |
| Winter wren | *Troglodytes troglodytes* |
| Brown creeper | *Certhia familiaris* |
| White-breasted nuthatch | *Sitta carolinensis* |
| Red-breasted nuthatch | *Sitta canadensis* |
| Pygmy nuthatch | *Sitta pygmaea* |
| Black-capped chickadee | *Parus atricapillus* |
| Mountain chickadee | *Parus gambeli* |
| Western bluebird | *Sialia mexicana* |
| Mountain bluebird | *Sialia currucoides* |

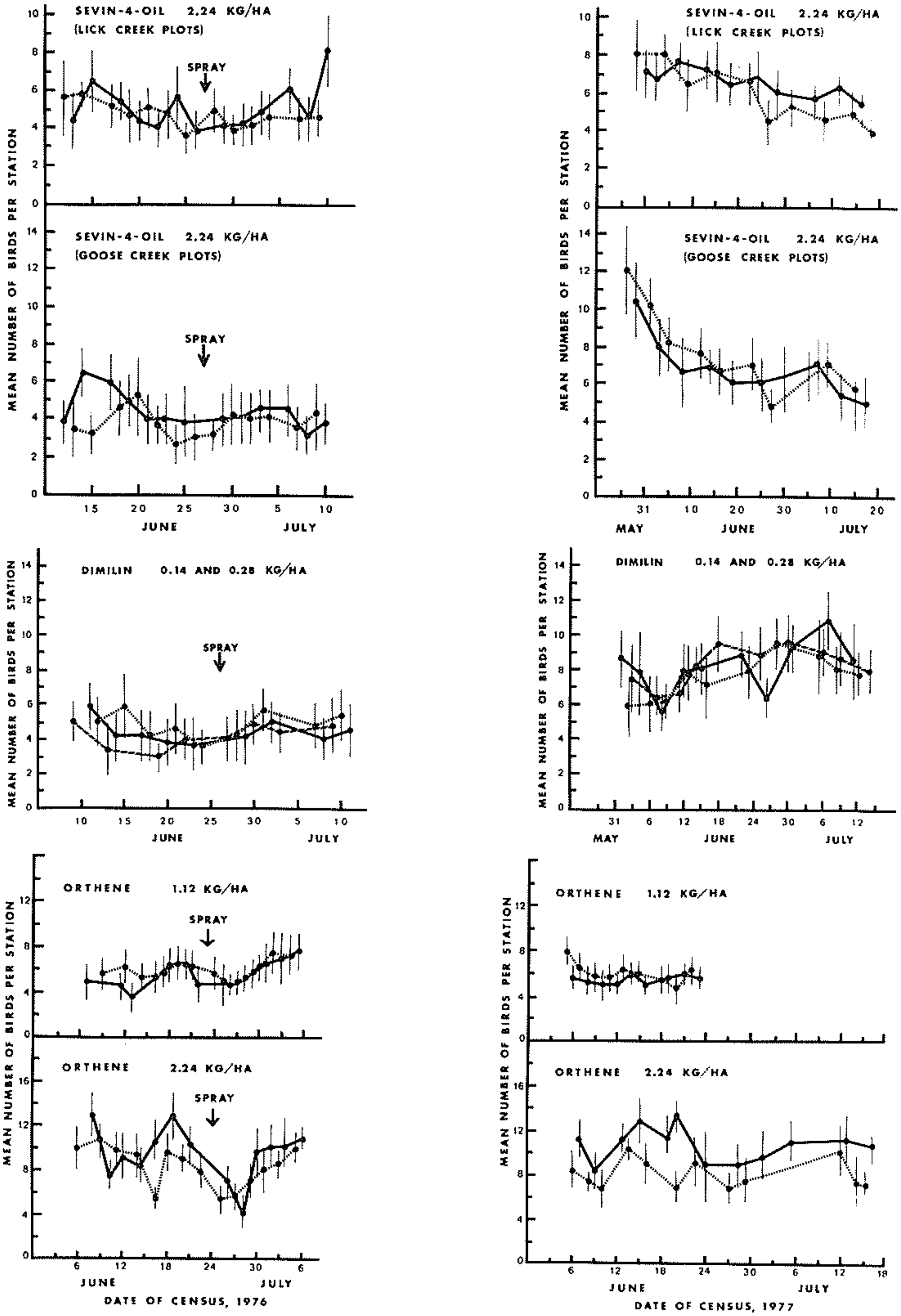

**Figure 2**—Trends in mean numbers of birds per station (all species) for all study plots during the 1976 (left) and 1977 (right) breeding seasons. Short-dashed lines apply to plots treated with Sevin-4-Oil, Orthene, and Dimilin (0.14 kg/ha); long-dashed lines, Dimilin (0.28 kg/ha); and solid lines, controls. The vertical line at each census date represents a confidence interval (95 percent level).

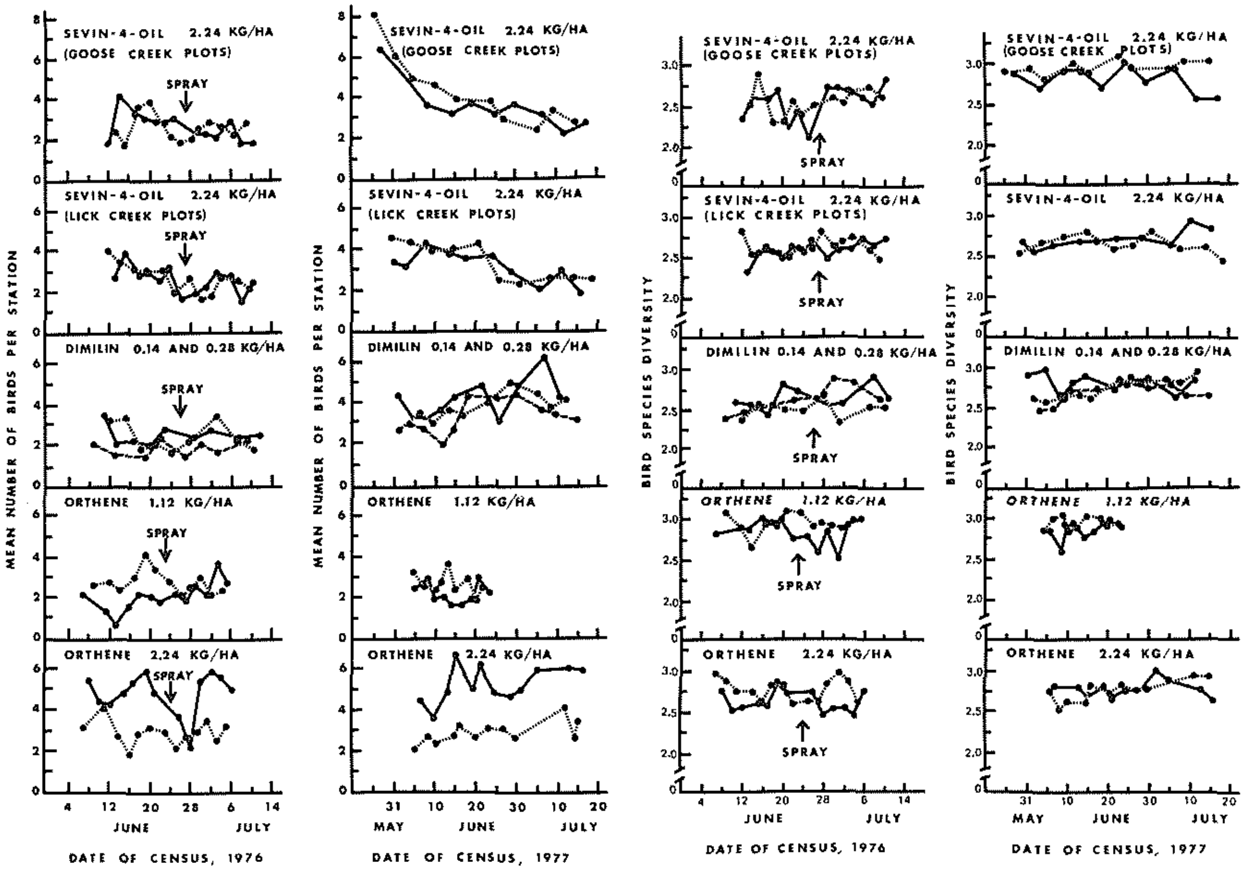

**Figure 3**—Trends in (left) mean numbers of birds per station (open-nesters with high exposure to spray) and (right) bird species diversity are shown for all study plots in the 1976 and 1977 breeding seasons. Short-dashed lines apply to plots treated with Sevin-4-Oil, Orthene, and Dimilin (0.14 kg/ha); long-dashed lines, Dimilin (0.28 kg/ha); and solid lines, controls. Bird species diversity is expressed as an index (see text).

Table 4—*Estimated numbers of breeding pairs,*[1, 2] *by category of potential exposure*

| Species, by exposure category | Dimilin 0.28 kg/ha | | | Dimilin 0.14 kg/ha | | | Control Burn Cr. | | | Sevin-4-Oil 2.24 kg/ha | | | Control Upper Goose Cr. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 |
| | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | |
| ***Open-nesting — high exposure*** | | | | | | | | | | | | | | | |
| Spotted sandpiper | | | | | | | | | | 1 | 1 | 0 | | | |
| Mourning dove | | | | | | | P | 0 | 1+ | 0 | P | P | | | |
| Willow flycatcher | | | | | | | | | | 1 | 1 | 2 | | | |
| *Empidonax* sp. | | | | | | | | | | 7 | 7 | 10 | 8 | 7 | 10 |
| Western wood pewee | | | | | | | | | | P | 0 | P | | | |
| Olive-sided flycatcher | | | | | | | | | | | | | | | |
| Gray jay | | | | | | | | | | | | | | | |
| Steller's jay | P | 0 | P | | | | P | P | P | P | 0 | P | | | |
| American robin | 1+ | P | 1+ | 1+ | P | 2+ | 1+ | 1 | 4 | 5 | 5 | 4 | 4 | 3 | 3+ |
| Townsend's solitaire | 0 | 0 | 2 | P | 0 | 1+ | P | 0 | 1 | | | | 0 | 0 | P |
| Ruby-crowned kinglet | 0 | 0 | P | 0 | 0 | P | | | | 0 | 0 | P | | | |
| Warbling vireo | 3 | 3 | 3+ | 3 | 3 | 1+ | 1 | 0 | 1 | 2+ | 2 | 1 | 1 | 1 | 0 |
| Orange-crowned warbler | | | | | | | 0 | 0 | 1 | 0 | 0 | P | | | |
| Yellow warbler | | | | | | | | | | 6 | 5 | 6 | 2 | 2 | 1 |
| American redstart | | | | | | | | | | 1 | 1 | 1 | | | |
| Black-headed grosbeak | P | 0 | 0 | | | | | | | 3 | 3 | 2 | 1+ | 0 | P |
| Lazuli bunting | 3 | 3 | 0 | 1 | 1 | 1+ | | | | 2 | 1 | 0 | P | 0 | 0 |
| Dark-eyed junco | 3 | 3 | 4+ | 4 | 4 | 5 | 4 | 3 | 5+ | 2+ | 2 | 1 | 5 | 5 | 3+ |
| Chipping sparrow | 3 | 3 | 4 | 3 | 3 | 5+ | 3+ | 3+ | 5 | 5+ | 5 | 4 | 5 | 5 | 4 |
| Lincoln's sparrow | | | | | | | | | | | | | | | |
| Subtotal pairs | 13 | 12 | 14 | 12 | 11 | 15 | 9 | 7 | 18 | 35 | 33 | 31 | 26 | 23 | 21 |
| ***Open-nesting — medium exposure*** | | | | | | | | | | | | | | | |
| Goshawk | | | | | | | | | | | | | | | |
| Sharp-shinned hawk | | | | | | | | | | 0 | P | 0 | | | |
| Hammond's flycatcher | 6 | 6 | 6+ | 6 | 6 | 8 | 1+ | 1 | 3+ | | | | | | |
| Veery | | | | | | | | | | 3+ | 3 | 3 | 1 | 1 | 2 |
| Golden-crowned kinglet | 3 | 3 | P | 1 | 1 | 1+ | P | P | P | 1 | 1 | 1 | 2 | 1 | 1+ |
| Solitary vireo | 0 | 0 | 2 | 1 | 1 | 3+ | 1 | 1 | 3 | 2+ | 2+ | 1 | 2 | 2 | 1 |
| Yellow-rumped warbler | 3 | 3 | 3+ | 2 | 3 | 3 | P | P | 2 | 2+ | 2+ | 4 | 4 | 4 | 4 |
| Townsend's warbler | 2 | 2 | 5 | P | 0 | 3 | 3 | 3 | 1 | 1+ | 1 | P | 2+ | 0 | 1 |
| MacGillivray's warbler | 2 | 2 | 4+ | 2 | 2 | 5 | 2 | 3 | 2 | 4 | 5 | 2 | 2 | 2 | 3 |
| Western tanager | 4 | 3 | 4 | 2 | 2 | 2 | 1 | 1 | P | 4 | 3 | P | 1 | 1 | 1 |
| Fox sparrow | | | | | | | | | | 2 | 3 | 3 | 1 | 1 | P |
| Song sparrow | | | | | | | | | | 5 | 5 | 3+ | 1 | 0 | 1 |
| Subtotal pairs | 20 | 19 | 24 | 14 | 15 | 25 | 8 | 9 | 11 | 24 | 25 | 17 | 16 | 12 | 14 |
| ***Open-nesting — low exposure*** | | | | | | | | | | | | | | | |
| Varied thrush | | | | 1 | 0 | 0 | | | | | | | P | P | 0 |
| Hermit thrush | 0 | 0 | 1+ | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | P | 1 | 1 | P |
| Swainson's thrush | 1 | 3 | 3 | 2 | 3 | 2+ | 1 | 1 | 1 | 2 | 2 | P | 2+ | 2 | 2 |
| Subtotal pairs | 1 | 3 | 4 | 3 | 3 | 3 | 1 | 1 | 3 | 2 | 2 | 0 | 3 | 3 | 2 |
| ***Cavity-nesting*** | | | | | | | | | | | | | | | |
| American kestrel | | | | 0 | 0 | P | 0 | 0 | 1 | | | | 0 | P | P |
| Belted kingfisher | | | | 0 | 1 | P | | | | 0 | P | 0 | | | |
| Common flicker | 0 | 0 | P | 0 | 0 | P | 0 | 0 | 1 | 1 | 1 | P | | | |
| Yellow-bellied sapsucker | 0 | 0 | P | 0 | 0 | P | | | | 1 | 1 | 1 | | | |
| Williamson's sapsucker | | | | | | | 0 | 0 | P | | | | | | |
| Hairy woodpecker | 0 | 0 | P | 0 | 0 | P | 0 | P | 1 | 0 | P | P | 0 | 0 | P |
| Mountain chickadee | 3 | 3 | 6+ | 2 | 1 | 3 | 3 | 3 | 3 | 2 | 2 | 7 | 3 | 2 | 4 |
| Red-breasted nuthatch | | | | | | | 1 | 1 | 1+ | 0 | 1 | P | 0 | P | 1 |
| Brown creeper | | | | 0 | 1 | 0 | | | | | | | | | |
| House wren | | | | | | | | | | 1 | 1 | 4 | | | |
| Winter wren | | | | | | | | | | | | | | | |
| Rock wren | | | | | | | 2 | 2 | 3 | | | | | | |
| Subtotal pairs | 3 | 3 | 6 | 2 | 3 | 3 | 6 | 6 | 10 | 5 | 6 | 12 | 3 | 2 | 5 |
| TOTAL PAIRS | 37 | 37 | 48 | 31 | 32 | 46 | 24 | 23 | 42 | 66 | 66 | 60 | 48 | 40 | 42 |

[1] P = One or more adults observed but no identifiable pairs.
[2] Species not listed unless at least one identifiable pair detected.
[3] See text for explanation of study methods.
+ = Additional adults observed but no identifiable pairs.

*to falling spray, on plots treated with three insecticides, and on control plots*[3]

| Sevin-4-Oil 2.24 kg/ha | | | Control Upper Lick Cr. | | | Orthene 1.12 kg/ha | | | Control Little Rock Cr. | | | Orthene 2.24 kg/ha | | | Control Whiskey Cr. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 | 1976 | | 1977 |
| Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | | Pre-spray | Post-spray | |
| P | 0 | 0 | | | | | | | | | | | | | | | |
| 6+ | 5 | 9+ | 4+ | 4 | 5 | 6 | 5 | 5 | | | | | | | | | |
| | | | | | | P | 0 | 0 | 1 | 1 | 1 | | | | | | |
| | | | | | | 2 | 2 | 2 | 0 | 0 | 1 | P | P | 0 | 1 | 1 | 1 |
| | | | | | | 0 | 0 | P | P | 0 | 0 | P | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | P | | | | | | | P | 0 | 0 | | | | 1 | 1 | 0 |
| 1+ | 1+ | P | 2 | 2 | 0 | 2+ | 1+ | 1+ | 1+ | 1+ | 1+ | 1 | 1 | 1+ | 1+ | 1 | 2 |
| P | P | 1 | P | P | P | P | P | P | P | 0 | 0 | | | | | | |
| 0 | 0 | P | 1+ | 1 | 3+ | 0 | 1+ | 1+ | 0 | 0 | 1+ | | | | | | |
| 2 | 2 | 0 | 3 | 2+ | P | 5 | 3 | 4+ | | | | P | 0 | 0 | 2 | 1 | 1 |
| 0 | 0 | P | | | | | | | | | | | | | | | |
| | | | | | | 0 | 0 | P | | | | | | | | | |
| 4 | 3+ | 4 | 3 | 2+ | 2+ | 2+ | 2 | 3 | 3 | 5 | 4+ | 4 | 3 | 4 | 7 | 6 | 8 |
| 4 | 4 | 3+ | 3+ | 2+ | 3 | 2 | 2 | 1+ | 0 | 1 | 1+ | 0 | 0 | 2 | 2+ | 2 | 4+ |
| | | | | | | P | 0 | P | 1 | 0 | 1 | | | | | | |
| 18 | 16 | 17 | 16 | 13 | 13 | 19 | 16 | 17 | 6 | 8 | 10 | 5 | 4 | 7 | 15 | 12 | 16 |
| | | | 1 | 1 | 0 | | | | | | | | | | | | |
| 0 | 0 | 1 | | | | | | | | | | | | | | | |
| | | | | | | | | | 3 | 3 | 2+ | 2+ | 2 | 0 | 1 | 1 | 2 |
| | | | 0 | 0 | 2 | | | | | | | | | | | | |
| 2+ | 2+ | 2 | 2 | 2 | 2+ | 5+ | 6 | 5 | 2+ | 2 | 4 | 3 | 3 | 3+ | 2 | 2 | 1+ |
| 3+ | 3+ | 1+ | 2 | 2 | 2 | 1 | 1 | 1+ | 2 | 2 | P | 1 | 1 | 0 | 1 | 2 | 3 |
| 1+ | 1+ | 1 | 3 | 3 | 3+ | 4 | 2 | 6+ | 3 | 3 | 4 | 3 | 2+ | 3+ | 4+ | 4+ | 5+ |
| 3+ | 2 | 3+ | 4+ | 4+ | 6+ | 5+ | 9 | 7+ | 6 | 7 | 4+ | 3 | 2 | 4 | 2 | 1 | 3 |
| 2+ | 2 | 2 | 2 | 2 | P | 4 | 4 | 4+ | 0 | P | 1 | 2 | 2 | P | | | |
| 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 1+ | 1+ | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| 14 | 13 | 12 | 16 | 16 | 18 | 22 | 25 | 24 | 17 | 18 | 16 | 15 | 13 | 11 | 12 | 12 | 17 |
| P | 0 | 0 | 0 | 0 | P | 2 | 2 | 2 | 0 | P | 1+ | 2 | 2 | 2 | | | |
| P | 0 | 2 | 3 | 3 | 0 | | | | 0 | 0 | P | 2 | 2 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 3 | 3 | 1+ | 4 | 4 | 1+ | 3+ | 3 | 1+ | 3 | 3 | 3 | 1 | 1 | 1 |
| 2 | 2 | 4 | 6 | 6 | 1 | 6 | 6 | 3 | 3 | 3 | 2 | 7 | 7 | 6 | 2 | 2 | 2 |
| | | | | | | | | | P | 0 | 0 | | | | | | |
| | | | | | | 0 | 0 | P | 1 | 1 | 1 | | | | | | |
| | | | 0 | P | 0 | | | | P | 0 | 0 | | | | 0 | 0 | 1 |
| | | | 0 | P | 1+ | | | | 1 | 1 | 1 | | | | 1 | 1 | 0 |
| | | | P | P | P | P | P | 0 | P | P | P | P | 0 | 0 | | | |
| 5 | 5 | 6 | 6 | 6 | 5 | 2+ | 2+ | 2 | 4 | 4 | 3 | 2 | 1+ | 2 | 2 | 2 | 6 |
| 2 | 1 | 0 | 2 | 2 | 2 | 1 | 0 | 1 | 1+ | 1 | 1+ | 1 | P | 1+ | 1 | 1 | 3 |
| | | | 1 | 1 | 1 | | | | P | P | 1 | P | 0 | 1 | 1 | 0 | 1 |
| | | | 0 | 0 | 1 | 2 | 2 | 2+ | 4 | 4 | 4 | 0 | 0 | 1 | 1 | 1 | P |
| 7 | 6 | 6 | 9 | 9 | 10 | 5 | 4 | 5 | 11 | 11 | 11 | 3 | 1 | 5 | 6 | 5 | 11 |
| 41 | 37 | 39 | 47 | 44 | 42 | 52 | 51 | 49 | 37 | 40 | 39 | 30 | 25 | 29 | 35 | 31 | 46 |

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**The Pacific Southwest Forest and Range Experiment Station**

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Richmond, Merle L., Charles J. Henny, Randy L. Floyd, R. William Mannan, Deborah M. Finch, and Lawrence R. DeWeese.
1979. **Effects of Sevin-4-Oil, Dimilin, and Orthene on forest birds in Northeastern Oregon.** Res. Paper PSW-148, 19 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Service, U.S. Dep. Agric., Berkeley, Calif.

A field study begun in 1975 was designed to assess the effects of three insecticides on nontarget nesting birds. Breeding bird density, species diversity, nesting success, brain cholinesterase activity, and presence of sick or dead birds were evaluated on control and treatment plots during the year of spraying and 1 year after. No adverse effects were detected in the Dimilin plots, and no major effects in the Sevin-4-Oil plots, although 2 of 55 birds showed brain cholinesterase depression. In the Orthene plots, however, studies of brain cholinesterase activity showed severe and prolonged depression (commonly 30 to 50 percent) for up to at least 33 days. Abnormal behavior symptomatic of organophosphate poisoning was also observed in the field, although the overall impact on the nesting bird population is not fully understood.

*Retrieval Terms:* Sevin-4-Oil (carbaryl); Orthene (acephate); Dimilin (diflubenzuron); forest birds; brain cholinesterase.

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