AN ABSTRACT OF THE THESIS OF

Daniel Calvin McCluskey for the degree of Master of Science in Department of Fisheries and Wildlife presented on November 30, 1976

Title: DDT and Reproductive Success of Bluebirds and House Wrens in Northeastern Oregon.

Abstract approved: E. Charles Meslow

Mountain bluebirds (Sialia currucoides), western bluebirds (S. mexicana) and house wrens (Troglodytes aedon) utilizing nest boxes in northeast Oregon were studied for two breeding seasons following aerial applications of DDT at a rate of 0.84 kg per ha (0.75 lbs per acre) in June 1974. Eggs laid, eggs hatched and young fledged were compared between sprayed and control areas each year. In 1975, additional data on weight gains and nestling development time were collected for mountain and western bluebirds. Population indices on both sprayed and control areas were made for flying insects in 1974 and 1975 and grasshoppers in 1975.

No significant differences (P ≥ 0.05) between sprayed and control areas for clutch size, hatching success, or fledging success were observed for mountain bluebirds in 1974. There was a significant difference (P ≤ 0.05) in clutch size for house wrens in 1974, but the difference was not attributed to DDT since spray application took place after egg laying was complete. There were no significant differences (P ≥ 0.05) in hatching or fledging success between sprayed and control areas for house wrens in 1974. Due to the small sample of western bluebird nests in sprayed areas, no statistical comparisons were made in 1974.

In 1975, there were no significant differences (P ≥ 0.05) between
sprayed and control areas in clutch size for all three species. There were no significant differences \( (P > 0.05) \) in hatching or fledging success between sprayed and control areas for mountain bluebirds in 1975; there were significant differences in these parameters for western bluebirds and house wrens.

Comparisons of clutch size, hatching and fledging success between years for mountain bluebirds revealed significantly \( (P \leq 0.05) \) lower hatching and fledging success in 1975. The difference was not attributed to DDT since greater hatching success occurred in sprayed areas.

There were no observed differences in nestling development time or nestling weight gains for mountain or western bluebirds between sprayed and control areas. Unseasonably cold weather and increased predation were believed responsible for lower hatching and fledging success in 1975.
DDT and Reproductive Success of Bluebirds and House Wrens in Northeastern Oregon

by

Daniel C. McCluskey

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Dean of Graduate School

Date thesis is presented November 30, 1976

Typed by Janet D. McCluskey for Daniel Calvin McCluskey
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I am especially grateful to Dr. E. Charles Meslow who was a major driving force behind this project. His guidance, encouragement, supervision, and criticism aided me considerably.

This project would not have been possible without the moral and financial support of Dr. Jack W. Thomas, Project Leader, U. S. Forest Service Range and Wildlife Habitat Laboratory, who provided me with the necessary equipment and facilities during the field work. In addition, he contributed a substantial amount of expertise in study design, data analysis, and collection. His encouragement and guidance throughout this study is sincerely appreciated.

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Acknowledgment is given to Britt W. Thomas and Jon Kell for their technical assistance in the field. Christine Barton provided help and suggestions in data analysis. Dr. B. J. Verts' critical review of the manuscript is appreciated.

Last but certainly not least, I would like to thank my wife Jan, who did everything from nailing up nest boxes during snow storms to critically reviewing the text and typing the manuscript. No one could ask for a better companion or helper.
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This is a report on an investigation of the effects of aerial applications of 0.84 kg per ha (0.75 lbs per acre) technical grade DDT (dichlorodiphenyltrichloro-ethane) on clutch size, hatching success, and survival to fledging success of mountain bluebirds (Sialia currucoides) western bluebirds (S. mexicana), and house wrens (Troglodytes aedon). The advent of an operational DDT spray program to control an outbreak of Douglas-fir tussock moth (Orygia pseudotsugata McDonnough) on 426,159 acres of forest land in northeast Oregon prompted this study.

Extensive use of DDT after World War II resulted in widespread contamination of the biosphere (Dustman and Stickel 1966). Residues of DDT were recorded in thousands of species, and in such remote areas as Antarctica (Tatton and Ruzicka 1967). DDT is a persistent chlorinated hydrocarbon insecticide which lasts an average of 4 years in the environment when applied at a rate of 0.56 to 0.84 kg per ha (0.5 to 0.75 lbs per acre); applications of 1.8 to 2.3 kg per ha (4.0 to 5.0 lbs per acre) may persist 8-12 years (Kearney et al. 1969). In addition to its persistence, DDT, its analogs and some of its metabolites are fat soluble allowing them to accumulate and concentrate in fatty tissues of organisms (Macek 1970).

An immediate and obvious effect of DDT application on nesting success of birds can be death of nestlings (Hotchkiss and Pough 1946, Adams et al. 1949, Mitchell et al. 1953, Ratcliffe 1965, Wurster et al. 1965). Effects of DDT on avian reproduction include reduced clutch size (Rubin et al. 1947), reduced hatching success (Hickey and Anderson 1968,
Heath et al. 1969). Factors such as sex (Wurster 1969) and physical condition (Gish and Chura 1970, Stickel et al. 1965, Wurster 1969) were shown to be important variables that influence the susceptibility of birds to the toxic effects of DDT.

I monitored selected insect populations to determine if insect numbers responded to DDT application. For the same reason I monitored growth rates and development of nestlings.

Mountain bluebirds, western bluebirds, and house wrens were studied for the following reason:

a) All were common summer residents of the grasslands included within the study areas (Gabrielson and Jewett 1940).

b) They were predominantly insectivorous during summer months (Martin et al. 1951, Beal 1915, Bent 1948, 1949, Knowlton and Harmston 1946).

c) All readily accepted nest boxes (Headstrom 1970, Gabrielson and Jewett 1940).

d) They nested at 1-2 meters, allowing observations of nests and handling of their contents with minimum effort (Headstrom 1970, Powers 1966).

STUDY AREAS

Two study areas (Graham et al. 1975) were selected (Fig. 1): the La Grande Unit, centered 15 km northeast of the city of La Grande, Union County, Oregon, and the Wallowa Unit, centered approximately 20 km north of the city of Wallowa, Wallowa County, Oregon. Nest boxes were placed in both sprayed and control areas within the boundaries of the two units (Fig. 1, Appendix 1).
Figure 1. Location of La Grande (left) and Wallowa (right) study areas, 1974-1975 in northeast Oregon.

- Areas treated with DDT
- Control areas

Legend:
- Dotted areas: La Grande
- Solid areas: Wallowa

Scale: 9.6 km

La Grande

Elgin

Minam
Specific areas for nest box placement were delineated from topographic maps and aerial photographs insuring that the following criteria applied:

a) The amount of nesting habitat for bluebirds and house wrens was comparable between areas.

b) Comparable numbers of the three study species were present.

c) Areas were accessible by truck during the nesting period.

MATERIALS AND METHODS

Bluebird nest boxes were similar to those described by Schutz (1974). In spring 1974, 250 nest boxes were placed in areas proposed for treatment; 300 boxes were placed as controls in proposed untreated areas. Changes in boundaries of areas proposed for spray treatment combined with low occupancy rates during the 1974 breeding season caused me to relocate 150 of 239 unoccupied nest boxes from areas not sprayed to sprayed areas for the 1975 breeding season.

Measures of Reproduction and Nesting Success

Nest boxes were examined during the 1974 breeding season at 2- to 21-day intervals. In 1975, with more personnel available, nest boxes were examined at 2- to 6-day intervals. Boxes were opened on each visit and the contents examined.

The number of eggs present at the onset of incubation was defined as clutch size. The proportion of eggs laid (clutch size) that hatched was defined as hatching success; fledging success was the proportion of young hatched that fledged. Because intervals between observations were 2-21 days in 1974 and 2-6 days in 1975, fledging in many cases was
derived circumstantially. Criteria used to determine fledging were similar to those used by Powers (1966) in Montana:

a) age and condition of young at the previous examination;
b) a well-matted nest with an abundance of fecal material, indicating fledgling-aged nestlings had been in the nest box;
c) no evidence of nest disturbance or predation.

Measures of Insect Numbers

I used the capture rate in 13 Malaise net traps (Butler 1965) as an index to density of flying insects in 1974 and 1975. Seven traps were located in sprayed areas and six in control areas. Contents were collected at 3- to 8-day intervals. The air-dry weight of each sample was recorded and used to calculate the capture rate (mg/day) of insect biomass.

An index to grasshopper numbers was obtained during 1975 using a technique suggested by K. Gaden, Union County Extension Specialist (Personal communication). Ten 100-m transects were established in similar habitats in sprayed and control areas. Three 100-m long sweeps with an 46.2-cm (18-inch) diameter sweep net were made along each transect and the number of grasshoppers captured were recorded.

Measures of Nestling Development

I compared the mean number of days to fledging between 15 mountain bluebird and 10 western bluebird nests in control areas and 31 mountain bluebird and 24 western bluebird nests in sprayed areas. No comparisons were made for house wrens because of small sample sizes.
Measures of Nestling Growth Rates

To monitor possible differences in growth rates between control and sprayed areas, nestling weights were recorded from the time of hatching to fledging. Nestlings from 8 mountain bluebird and 10 western bluebird nests from control areas and 20 mountain bluebird and 25 western bluebird nests from sprayed areas were weighed at 1- to 3-day intervals and compared using an F-test (Snedecor and Cochran 1967:125).

Measures of Nestling Mortality

Numbers of dead nestlings were recorded each time a nest box was examined. In the event nestlings were missing before fledging age they were considered fatalities. The cause of death in each case was assigned either to predation or "other causes." Criteria used to determine predator kills were as follows:

a) absence of pre-fledgling nestlings;

b) obvious signs of nest disturbance or destruction accompanied by dead or missing nestlings;

c) remains of nestlings.

All other nestling losses were assigned to "other causes."

Measures of DDT Application

DDT reaching ground level was measured using three 10.2-x 12.7-cm (4x 5-inch) oil sensitive cards (White 1959) placed near each nest box. Because bluebirds and house wrens commonly nest at the forest edge adjacent to grassland, I measured DDT applications at three different points near each nest box. One card was placed beside the box, one card
20 m from the box into the adjacent clearing, and one card 20 m into the wooded areas. Each card was stapled to a wooden stake and placed at ground level. The cards were placed in the field 12-24 hours before DDT was applied.

The number and size of spray droplets on each oil sensitive card were visually compared with the "Standards for Estimating Airplane Spray Deposits on Oil Sensitive Cards" (Maksymiuk 1963a, Davis and Elliot 1953). The mean value of the amounts indicated by the three cards was considered to be the amount of DDT deposited at that box.

Because of personnel shortages and logistics the control areas were not monitored for DDT drift. However, David Graham, Director, U.S. Forest Service Tussock Moth Control Project in Portland, Oregon (Personal communication), stated..."the oil sensitive cards (White 1959) placed along streams and meadows by other Forest Service monitoring groups recorded negligible DDT spray drift 200 feet (66m) from the spray boundaries." Graham further stated "It would be safe to say that there was no spray recorded 400 m from the spray boundaries." Graham's statement was supported experimentally by T. Torgerson (Personal communication), a U.S. Forest Service researcher with the Forest and Range Experiment Station, Corvallis, Oregon, who placed caged adult sarcophagid flies (Agria housei) in treated and untreated areas prior to the DDT applications. All of Torgerson's flies in treated areas died, while none of those in control areas 400-800 m from the treated areas died.

It should be noted, however, that the study areas were exposed to DDT prior to the 1974 applications. Between 1950-1955 the U.S. Forest Service sprayed DDT at a rate of 1.2 kg per ha (1.0 lbs per acre) on six
different areas in northeastern Oregon. These applications accomplished total coverage of both control and treated areas. Because DDT persists an average of 4 years in the environment when applied at 1.2 kg per ha, there was little chance the DDT residues from the 1950-1955 spray projects would still be present in significant amounts (Kearney et al. 1969).
RESULTS

DDT Levels in Sprayed Areas

Average amounts of DDT recorded at ground level were 0.081 kg per ha (0.072 lbs per acre) at the nest box, 0.075 kg per ha (0.067 lbs per acre) in the forest and 0.175 kg per ha (0.156 lbs per acre) in the open (Table 1). U.S. Forest Service monitoring teams made available data from 419 additional cards placed in a stratified manner across treated areas. These revealed an average of 0.202 kg per ha (0.18 lbs per acre) at ground level.

There were several reasons for the large difference between the applied amount and the quantity measured on the ground:

a) Trees and shrubs intercepted spray and thus lowered amounts recorded at ground level (Maksymiuk 1963b).

b) A portion of the DDT spray volatilized before reaching ground level (Maksymiuk 1963b).

c) Helicopter pilots were instructed to avoid spraying when crossing grasslands larger than 0.81 ha. This led to the spray being shutoff and turned on at or near nest boxes on the edge of clearings. Variable amounts of DDT thus reached the ground near nest boxes (Thomas and McCluskey 1974), (Table 1).

Insect Response to DDT Applications

Malaise traps captured only flying insects, which reportedly comprised a large portion of insects eaten by bluebirds (Criddle 1927, Powers 1966:361) but only a minor portion of the insect food of house wrens (Knowlton and Harmston 1946, Bent 1948). Although these traps
Table 1. Mean DDT reaching ground level (kg per ha) at three locations around nest boxes after application of 0.84 kg per ha in sprayed areas in northeast Oregon, 1974.

<table>
<thead>
<tr>
<th>CARD LOCATION</th>
<th>MEAN DDT (kg/ha)</th>
<th>RANGE(^a)</th>
<th>VARIANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest(^b)</td>
<td>0.075</td>
<td>0.051-0.126</td>
<td>0.001</td>
</tr>
<tr>
<td>Nest Box</td>
<td>0.081</td>
<td>0.071-0.095</td>
<td>0.001</td>
</tr>
<tr>
<td>Open(^c)</td>
<td>0.175</td>
<td>0.081-0.233</td>
<td>0.002</td>
</tr>
</tbody>
</table>

\(^a\) Range and variance based on differences between various locations within sprayed areas.

\(^b\) 20 m from nest box into forested area.

\(^c\) 20 m from nest box into adjacent clearing.
have limitations when used for studying food supplies of bluebirds and house wrens, they were the most effective tools available after considerations were made for expense, time and personnel availability.

In 1974, the capture rate of insects (mg/day) generally declined on both sprayed and control areas prior to DDT applications (June 23-24) (Fig. 2). However, capture rates for insects decreased significantly ($P \leq 0.05, F=16.16, D.F.13$) on treated areas immediately following DDT applications. Capture rates on sprayed areas declined by 80.7 percent compared with a decline of 41.9 percent on untreated areas.

Rates captured of insects in 1975 were similar for both sprayed and control areas ($P \geq 0.05, F=0.466, D.F.=11$), (Fig. 2).

Grasshoppers collected in August, 1975 served as an index to the abundance of ground dwelling insects. Mean numbers of grasshopper captures per transect was 5.1 (range 2-9) in sprayed areas and 4.9 (range 1-9) in control areas. A $t$-test indicated no significant differences ($P \geq 0.05, t=0.190$) in mean numbers captured between sprayed and control areas.

**Clutch Size**

In 1974 a $t$-test indicated no significant ($P > 0.05, t=0.584$) differences in clutch sizes between sprayed and control areas for mountain bluebirds. There was a significant ($P \leq 0.05, t=2.401$) difference in mean clutch sizes for house wrens. Because there was only a single western bluebird nest in sprayed areas no statistical comparisons were made for this species. During 1975 similar comparisons revealed no significant ($P \geq 0.05$) differences in mean clutch sizes for the three
Figure 2. Mean capture rates for flying insects in sprayed and control areas in northeast Oregon 1974-75.
species ($t=0.680$, mountain bluebirds; $t=0.220$, western bluebirds; $t=0.398$, house wrens).

**Hatching Success**

In 1974, hatching success was similar on sprayed and control areas. A chi-square test for independence (Snedecor and Cochran 1967:125) revealed no significant ($P \geq 0.05$, $X^2=0.65$) differences in hatching success between sprayed and control areas for mountain bluebirds or house wrens.

A chi-square comparison of hatching success in 1975 between sprayed and control areas revealed no significant ($P \geq 0.05$, $X^2=3.27$) difference for mountain bluebirds. Comparisons between sprayed and control areas of hatching success for western bluebirds and house wrens indicated significant ($P \leq 0.05$) differences ($X^2=10.54$, western bluebirds; $X^2=4.36$, house wrens). Western bluebirds hatched an average of 4.3 eggs in sprayed areas and 3.6 in control areas. House wrens nesting in sprayed areas had an average hatch of 6.0 while control area birds hatched 4.0 eggs per clutch (Table 2).

**Fledging Success**

Because DDT was applied on the study areas during June 23-25, 1974 after clutch establishment in the majority of nests studied, the pesticide only could have affected nestling survival. However, fledging success for mountain and western bluebirds living on both sprayed and control areas in 1974 was 100 percent (Table 2). House wrens nesting in sprayed areas averaged 5.9 young per nest for 100 percent success and those
Table 2. Clutch size, hatching success and fledging success for mountain bluebirds, western bluebirds, and house wrens nesting in control areas and areas treated with DDT in northeast Oregon, 1974 and 1975. Standard errors in parenthesis.

<table>
<thead>
<tr>
<th>Species</th>
<th>1974</th>
<th>1975</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample size (eggs)</td>
<td>Mean clutch size</td>
</tr>
<tr>
<td>Mountain bluebird</td>
<td>63</td>
<td>5.3 (0.16)</td>
</tr>
<tr>
<td>(sprayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain bluebird</td>
<td>246</td>
<td>5.2 (0.10)</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western bluebird</td>
<td>6*</td>
<td>6.0 (0.15)</td>
</tr>
<tr>
<td>(sprayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western bluebird</td>
<td>44</td>
<td>4.9</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House wren</td>
<td>60</td>
<td>6.7 (0.34)</td>
</tr>
<tr>
<td>(sprayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House wren</td>
<td>27</td>
<td>5.4 (0.50)</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant differences (P \leq 0.05) between sprayed and control areas (see text).

a No comparisons of clutch size were made.
nesting in control areas averaged 4.0 young per nest for a success rate of 72.7 percent. DDT apparently had no detectable effect on fledging success for the three species in the year that it was applied.

In 1975, there were no significant ($P > 0.05, \chi^2=1.45$) differences in fledging success for mountain bluebirds between sprayed and control areas (Table 2). Western bluebirds in sprayed areas fledged an average of 2.8 young per nest for 65.9 percent success compared with 2.1 young per nest for 56.5 percent success in control areas. House wrens nesting in sprayed areas averaged 4.0 young fledged per nest for 66.6 percent success compared with 1.5 young per nest for 37.5 percent success in control areas. A chi-square test indicated that the greater fledging success exhibited by western bluebirds and house wrens from sprayed areas was significantly ($P < 0.05$) different from that of control area birds ($\chi^2=4.53$, western bluebirds; $\chi^2=4.36$, house wrens).

Nestling Mortality

There were no nestling losses for all three species in sprayed areas in 1974. A complete brood of six house wrens nestlings from a control area failed to fledge.

In comparison with 1974, nestling mortality in 1975 increased for all three species in sprayed and control areas (Table 3). Fifty-nine percent of the mountain bluebird mortality, 82 percent of all western bluebird mortality and 83 percent of all house wren losses were caused by predators. The remainder of the mortality was attributed to "other causes."

Further comparisons of nestling mortality to "other causes" revealed that 36 percent of the mountain bluebird nestlings lost were from
Table 3. Nestling mortality of mountain bluebirds, western bluebirds, and house wrens attributed to predation and "other causes" on combined sprayed and control areas in northeastern Oregon, 1975.

<table>
<thead>
<tr>
<th>Species</th>
<th>NESTLING MORTALITY FROM PREDATION</th>
<th>NESTLING MORTALITY FROM &quot;OTHER CAUSES&quot;</th>
<th>TOTAL NESTLINGS AVAILABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no.</td>
<td>percent</td>
<td>no.</td>
</tr>
<tr>
<td>mountain bluebirds</td>
<td>51</td>
<td>59</td>
<td>36</td>
</tr>
<tr>
<td>western bluebirds</td>
<td>102</td>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td>house wrens</td>
<td>10</td>
<td>83</td>
<td>2</td>
</tr>
</tbody>
</table>
control areas compared with 64 percent from sprayed areas. Eighty-four percent of the western bluebird nestlings which died from "other causes" were from sprayed areas. In contrast 17 percent of the house wrens which died from "other causes" were from sprayed areas.

Between-Year Comparisons

Because tests indicated no statistical differences between sprayed and control areas for clutch size, hatching success, and fledging success of mountain bluebirds in 1974 and 1975, I could have concluded that DDT had no effect upon those parameters. However, it could be argued that lower reproductive and recruitment rates observed in 1975 over 1974 were caused by DDT contamination. Therefore, I made between-year comparisons and tested for differences in reproductive success between 1974 and 1975 (Table 4).

Mountain bluebirds averaged 5.2 eggs per clutch in 1974 compared with 4.9 in 1975 (Table 4). A t-test indicated no significant (P > 0.05), t=1.46) differences in clutch sizes between years for this species. Hatching success for mountain bluebirds was 93.8 percent in 1974 compared with 82.3 percent in 1975 this was a significant difference (P < 0.05, χ²=21.10). Fledging success between years for mountain bluebirds declined from 100 percent (4.9 young per nest) in 1974 to 73.1 percent (2.9 young per nest) in 1975; this also was a significant difference (P < 0.05, χ²=90.87).

Rate of Nestling Development

A t-test indicated that the mean number of days to fledging for
Table 4. Clutch size, hatching success, and fledging success of mountain bluebirds, sprayed and control areas combined, in northeast Oregon, 1974 and 1975.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample size (eggs)</th>
<th>Mean clutch size</th>
<th>Mean no. hatched</th>
<th>Percent hatched</th>
<th>Mean no. fledged</th>
<th>Percent fledged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>309</td>
<td>5.2</td>
<td>4.9</td>
<td>93.8</td>
<td>4.9</td>
<td>100</td>
</tr>
<tr>
<td>1975</td>
<td>434</td>
<td>4.9</td>
<td>4.0</td>
<td>82.3</td>
<td>2.9</td>
<td>73.1</td>
</tr>
</tbody>
</table>
mountain bluebirds and western bluebirds was not significantly different 
(P > 0.05, t=1.12, mountain bluebirds; t=0.68, western bluebirds) 
between sprayed and control areas (Table 5).

Nestling Growth Rates

An analysis of variance comparison of mean daily nestling weights 
between sprayed and control areas for both species indicated no significant 
(P > 0.05) differences (F=0.004, d.f.=35, mountain bluebirds; F=0.008, 
d.f.=35, western bluebirds) (Table 6).
Table 5. Mean number of days (+ 95% confidence limits) from hatching to fledging of nestling mountain bluebirds and western bluebirds in sprayed and control areas, northeast Oregon, 1975.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of nests examined</th>
<th>Mean no. days to fledging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain bluebirds</td>
<td>31</td>
<td>18.2 ± 0.60</td>
</tr>
<tr>
<td>(sprayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain bluebirds</td>
<td>15</td>
<td>17.5 ± 0.80</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western bluebirds</td>
<td>24</td>
<td>19.3 ± 1.0</td>
</tr>
<tr>
<td>(sprayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western bluebirds</td>
<td>10</td>
<td>18.8 ± 0.90</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6. Mean body weights in grams of known-age nestling mountain bluebirds and western bluebirds in northeast Oregon sprayed and control areas, 1975 1./

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Mountain bluebird</th>
<th>Sample size</th>
<th>Variance</th>
<th>Western bluebird</th>
<th>Sample size</th>
<th>Variance</th>
</tr>
</thead>
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1/ 8 mountain bluebird, 10 western bluebird nests from control areas and 20 mountain bluebird and 25 western bluebird nests from sprayed areas.
DISCUSSION

Because DDT was applied in 1974 after nearly all clutches were completed, these applications could not have affected clutch size or egg viability for the three species being investigated. It could have affected hatching success by altering adult survival or behavior.

The observed lower clutch size for house wrens on control areas in 1974 (Table 2) was probably related to predation of one or more eggs from clutches early in the nesting season. While I observed no predation on eggs in 1974, more frequent observations in 1975 indicated some egg losses to predators could have occurred before the first visit with little or no obvious sign of nest predation.

If bluebird and house wren populations were affected by DDT in 1974 it would have been expressed in terms of adult or nestling mortality. Fledging success of all three species in nest boxes was 100 percent (Table 2). Also, no dead house wrens or bluebirds were found on either sprayed or control areas during the 1974 field season.

Observations of mountain and western bluebirds 1 year after application of DDT were designed to disclose longer-term impacts of DDT on clutch size, hatching or fledging success. Clutch sizes for all three species in 1975 were not significantly different \((P > 0.05)\) between sprayed and control areas, again indicating that DDT apparently had not affected egg production.

The significant difference \((P < 0.05)\) in hatching success between sprayed and control areas in 1975 for western bluebirds and house wrens probably were not related to DDT because hatching success was greater in sprayed areas (Table 2). Likewise, the significant differences in
fledging success for western bluebirds and house wrens in 1975 resulted from greater success in sprayed rather than control areas. It could be argued that the superior production from nests in sprayed areas may have resulted from DDT enhancing reproduction (Heath et al. 1969). However, if this were the case then fledging success for birds in sprayed areas in 1974 also should have been enhanced.

The observed significant difference ($P < 0.05$) in fledging success for house wrens in 1974 was caused by the loss of one complete brood from a control area and not greater fledging success by sprayed area birds. The observed difference for house wrens and western bluebirds in 1975 was attributed to a type 1 error (Snedecor and Cochran 1967:27). One entire clutch of six house wren eggs failed and five nestlings in the only remaining nest were preyed upon. This left only three nestlings to fledge from a sample of eight nestlings. The loss of 54 nestlings to predators in control areas compared with 48 in sprayed areas accounted for the observed difference in fledging success for western bluebirds.

Adult and Nestling Homing Behavior

To monitor longer-term impacts of DDT on reproduction for mountain and western bluebirds and house wrens 1 year after spray application it was necessary that the living adults and nestlings demonstrate reasonable fidelity to breeding areas. Fidelity to former breeding areas was not well documented for mountain bluebirds or western bluebirds. Passerine species in general, however, show a marked tendency to return to the same locality in successive breeding seasons (Farner 1945, Uchida 1932). Powers (1966:364) determined that three (42.8 percent) of seven adult
mountain bluebirds banded during the first year of his study returned to
breed on his 136-ha study area the following year. Power's second year
of banding yielded a return of 3 of 12 adults. These included one adult
female which returned to breed for the second consecutive year. Powers
(1966:364) commented "three of the five returning adults, one male and
two females, nested in the boxes they had previously occupied, and the
others nested very close to their former nesting territories indicating
strong fidelity to the nesting areas." Several investigators (Laskey
1940, Krug 1941, Thomas 1946) determined that 36-60 percent of adult
eastern bluebirds returned to former breeding areas. This rate of
return would be much greater if corrected for annual mortality. Annual
mortality of adults was estimated at about 50 percent by Lack (1954).

Homing for birds banded as nestlings reportedly occurs with less
precision than for adults, but frequently they return to the same
general area (Nice 1937). Observations on starlings (Sturnus vulgaris)
(Kluijver 1933), tree swallows (Iridoprocne bicolor) (Low 1934), barn
swallows (Hirundo rustica) (Uchida 1932), and song sparrows
(Melospiza melodia) (Nice 1937:189) indicated that 1.5 to 12.6 percent
of the birds banded as nestlings returned to former nesting areas to
breed. Farner (1945) and Hickey (1943) concluded that homing for first
year breeding robins (Turdus migratorius), a species closely related to
bluebirds, was definitely not random, but that 70 to 74 percent of the
surviving young returned to breed within a 16 to 40 km radius of the
place where they hatched. Similar statistics were reported for bank
swallows (Riparia riparia) and song sparrows (Bergstrom 1951, Nice
1937).

Kendeigh (1941) estimated that 19 percent of the adult house wrens
banded returned to breed 1 year later and that 10 percent of the birds banded as nestlings returned to breed within a 3.2 km radius of their natal nest.

Again, these figures did not account for annual mortality which may be as high as 75 percent for first year birds (Nice 1957). Although specific data on nest site fidelity are lacking for bluebirds banded as nestlings, the information available on related species and adult bluebirds indicates that first year breeding bluebirds might be expected to demonstrate reasonable nest site fidelity. Therefore, it is not unreasonable to assume that the birds observed breeding on study areas in 1975 were associated with the areas in 1974.

Between-Year Comparisons

Hatching Success

The significant difference \( (P < 0.05) \) in hatching success between years for mountain bluebirds probably was not caused by DDT because hatching success was greater in sprayed rather than control areas. The reason for the difference in hatching success in 1975 could be attributed to higher densities of nesting birds on both sprayed and control areas. White and Wolfenden (1973), reporting on eastern bluebirds, observed significantly lower occupancy rates but greater reproductive success during the first year nest boxes were erected than during the second. They attributed the decline in reproductive success during the second year of study to greater social pressure caused by increased density. I compared hatching success in 1975 with that of other studies of bluebirds and house wrens using nest boxes. Hatching success observed in north-
eastern Oregon in 1975 was usually greater for all three species than previously reported (Tables 2 and 7). For instance, the 11.5 percent decrease in hatching success observed between 1974 and 1975 for mountain bluebirds in this study was considerably less than the 32.4 percent between-year difference observed by Powers (1966:359).

Weather also may have been an important factor affecting hatching success in 1975. A comparison of weather conditions for June, the principal month of clutch establishment and hatching for the three species, indicated that June 1975 was colder and wetter than June 1974 (Table 8). Data collected at Meacham, Umatilla County, Oregon, an area representative of the study areas, indicated that the mean monthly temperature for June, 1975 was 1.4 C lower and precipitation 0.97 cm above the 30-year average (Table 8). Further comparisons of mean daily temperatures for June, 1975 revealed that the mean temperature for the second half of the month was 3.3 C colder than the first half. Reports by Criddle (1927), Musselman (1939), Miller (1970), and Pinkowski (1975) revealed that cold, wet weather often caused adult female bluebirds to leave their eggs for long periods resulting in partial or total nest failures. Scott and Lane (1974) reported that 80 percent of the first nests of mountain bluebirds failed following a 2-day period when mean daily temperatures of 7.2 C and 12.7 C were accompanied by 4.4 cm precipitation.

Fledging Success

Both inclement weather and increased predation possibly were involved in the lower fledging success observed in 1975.
Table 7. Clutch size, hatching success, and fledging success of mountain bluebirds, western bluebirds, and house wrens reported in other nest box studies.

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<th>Percent hatched</th>
<th>Mean no. fledged</th>
<th>Percent fledged</th>
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<td>House wrens</td>
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<td>5.3</td>
<td>82.3</td>
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Table 8. Total precipitation and mean monthly temperature for June, 1974 and 1975 at Meacham, Oregon compared with the 30-year average (1940-70) 1/.

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<th>TEMPERATURE (monthly mean)</th>
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<td>1975</td>
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<tr>
<td>30-year avg. (1940-1970)</td>
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1/ Weather data derived from National Oceanic and Atmospheric Administration, Meacham, Oregon station.
Mortality associated with colder than normal weather between 15 June and 29 June 1975 was evident (Fig. 3). Of 60 nestlings lost to causes other than predation, 53 or 84.1 percent died when mean daily temperatures were below the 30-year mean (Fig. 4). A period of below normal temperatures coincided with hatching of most nests on the study areas. Passerine young are most susceptible to adverse weather conditions when less than 9-10 days old (O'Connor 1975). Scott and Lane (1974) noted that nearly all dead nestlings discovered following a severe storm were 17 days old. In addition, Lane and Burton (1974) and Scott (1974) estimated that cold and wet weather conditions resulted in a 50 to 83 percent reduction in young fledged per nest.

Predation was a major contributor to the decreased fledging success for all three species in 1974 (Table 3). Fifty-one mountain bluebird nestlings, 59 percent of nestlings, were taken by predators. Western bluebird losses were greater: 102 nestlings, 82 percent of nestlings, succumbed to predation. House wren mortality attributable to predation accounted for 10 (83 percent) of the nestlings that died.

I attributed increased predation in 1975 partially to more frequent examinations of nest boxes and partially to a larger available number of occupied nest boxes. Examining nest boxes at the more frequent (26 day) intervals in 1975 increased the frequency of disturbance of adults at the nest. Wilson (1966) suggested that frequent human activity around nests was responsible for low nesting success in 17 species he studied. Studies of egg predation in waterfowl indicated that many predators apparently keyed on movements of adults to locate nests (Hammond and Forward 1956). A greater number of occupied nest boxes increased the
Figure 3. Mean daily temperature, 30-year monthly mean temperature, and combined nestling mortality from sprayed and control areas in northeast Oregon, 1975.
Figure 4. Nestling bluebird and house wren mortality from "other causes" in northeast Oregon in 1975 in relation to deviation of the daily mean temperature for June and July from 30-year monthly mean temperature.

- Nestlings on sprayed areas
- Nestlings on control areas
probability that predators searching nest boxes for either food or nest-
sites would encounter nestlings or eggs. Such a food reward would
reinforce a search pattern of predators. In several cases, two or three
occupied nest boxes in sequence were preyed upon indicating that predators
may have associated the nest box with food and learned to search them
systematically.

Four mammal species were observed preying on bluebirds and house
wrens during this study: yellow-pine chipmunks (Eutamius amoenus),
red squirrels (Tamiasciurus hudsonicus), and weasels
(Mustela frenata, and M. erminae).

Egg and nestling losses attributed to squirrels and chipmunks
appeared related to cavity investigations for possible nest sites.
Subsequent observations of destroyed nests revealed many had additional
nesting material added to the box by squirrels and chipmunks. In
several cases sciurid litters were reared in nest boxes.

Based on the methods used, this study indicated that DDT applied at
0.83 kg per ha (0.75 lbs per acre) had neither an immediate affect upon
nestling survival nor a second year impact on clutch size, hatching or
fledging success for mountain bluebirds, western bluebirds, and house
wrens. These results should not, however, be used to assign DDT a role
as a harmless contaminent of the environment. Applications of DDT at
dosage levels which apparently did not disrupt nesting success of
bluebirds and house wrens still contribute to DDT residues in the
environment and can be passed on through food webs (Macek 1970, Henny
1977).
Literature Cited


_________. 1963b. Screening effect of the nearest tree on aerial spray deposits recovered at ground level. J. For. 61(2):143-144.


Appendix 1. Legal description and local names of ridges where sprayed and control area boxes were located.

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Control Areas

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