Responses of songbirds to aerial spraying of the microbial insecticide *Bacillus thuringiensis* var. *kurstaki* (Foray 48B®) in Garry Oak habitat on Vancouver Island, 1999-2000

Final report

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EXECUTIVE SUMMARY

As part of ecological monitoring by the Ministry of Forests associated with the Gypsy Moth (*Lymantria dispar*) eradication program conducted in spring 1999, we investigated the responses of songbirds to a reduced food supply resulting from aerial spraying of the microbial, lepidopteran-specific insecticide *Bacillus thuringiensis* var. *kurstaki* (Btk; Foray 48B) over a 12,803 ha area in and around Victoria on southern Vancouver Island, British Columbia. The insecticide was applied on three occasions in 1999 (on 9–10 and 19–21 May and 8–9 June) and resulted in a significant reduction in caterpillar abundance in Garry Oaks (*Quercus garryana*), according to a separate, concurrent study. We examined the hypotheses that (a) densities of breeding songbirds, particularly leaf-gleaning, insectivorous species, would be depressed in sprayed areas in relation to pre-treatment densities and when compared to densities in unsprayed areas, and that (b) the incidence of renesting and second broods, as reflected by numbers of singing males in late spring, and (c) numbers of broods produced would be lower in sprayed than unsprayed areas due to high energetic costs associated with reproduction. To test these hypotheses, we conducted standard songbird point-count surveys on 41 study plots at 14 sites in Btk-sprayed areas and the same number in unsprayed areas in Garry Oak-dominated habitats in 1999 and, one year after Btk-application, in 2000. In 1999, one point-count survey was in April before spraying and three were after spraying in May-June. There were four point-count surveys in April-June 2000. In June of both years, we also conducted two intensive searches of the plots to obtain an index of the number of broods produced and additional information on the relative abundance of adult birds in sprayed and unsprayed areas (a total of 58 plots in 1999 and 60 plots in 2000 were searched).

We detected a total of 61 species of songbirds, 44 of which were considered to include caterpillars in their diet during the breeding season. Sufficient sample sizes existed for 10 species that have a moderate to high proportion of caterpillars in their diet to compare total counts of adult birds and singing males per survey between sprayed and

unsprayed areas. These species were the Bewick's Wren, Chipping Sparrow, Dark-eyed Junco, House Wren, Red-breasted Nuthatch, Spotted Towhee, White-crowned Sparrow, Chestnut-backed Chickadee, Bushtit (brood-survey data only), and Orange-crowned Warbler. Additionally, sufficient sample sizes permitted a more detailed analysis of the pattern of abundance (mean number of birds per plot) across surveys for five of these species (Bewick's Wren, Chipping Sparrow, White-crowned Sparrow, Spotted Towhee, Orange-crowned Warbler). The remaining species were analyzed in groups of species having similar foraging behaviour.

The point-count surveys in 1999 and 2000 revealed no patterns consistent with adverse effects of the treatment on the relative abundance of adults or singing males for any of the species examined individually or when combined into foraging guilds. An exception was the Spotted Towhee, which in 1999 occurred at significantly lower numbers in sprayed than unsprayed plots after Btk-treatment when compared to corresponding values during the pre-spraying period. The number of singing males of this species showed a similar decline in sprayed plots in 1999. This reduction occurred prior to the main decline in the abundance by lepidopteran prey in June, but adverse short-term effects of the spraying on this species remain a possibility. No differences in the relative abundance of the Spotted Towhee were found in 2000, indicating that the possible effects of the Btk-spraying in 1999 did not affect breeding numbers the following year.

During intensive, post-spraying surveys in 1999 and 2000, we found consistently fewer adult Bushtits on the sprayed than unsprayed plots. However, differences in habitat suitability and flocking habits of these birds (the presence of a few flocks inflated the total counts on the unsprayed areas) most likely accounted for this pattern. Few Bushtits were detected during point-count surveys, precluding comparisons with pre-spraying densities.

We located a total of 127 songbird broods (fledged, dependent young with adults) in 1999 and 179 broods in 2000 during post-spraying surveys. We detected no significant differences in numbers of broods between sprayed and unsprayed areas for any of the

species examined in either year but did not examine more subtle effects on productivity, such as the number of young per brood. These data, together with comparisons of the relative abundance of singing males suggest that the Btk-application had no detectable effects on the pattern of territory maintenance or frequency of renesting by songbirds in 1999 and 2000.

The results of this 2-year study indicate that the use of Btk to control Gypsy Moth populations had few or no detectable effects on songbird abundance. However, as a precaution to prevent any potential minor effects on songbirds, particularly on rare species, future spray-programs should target only areas known to harbour Gypsy Moths or their eggs to minimize the size of continuous areas with depressed caterpillar prey.

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1.0 INTRODUCTION

Microbial insecticides provide a potentially safe and environmentally-friendly alternative to chemical pesticides and are gaining increasing popularity for large-scale, aerial applications to control insect pests (Lambert and Peferoen 1992; Bernhard and Utz 1993; van Frankenhuyzen 1995). Preparations of *Bacillus thuringiensis* var. *kurstaki* (Btk) are specific in their action against lepidopteran larvae and have few or no direct effects on other organisms (reviewed in Otvos and Vanderveen 1993). However, more subtle, indirect effects on non-target organisms can easily remain undetected. For example, large-scale application of Btk-preparations may reduce the available food supply for insectivorous animals, such as songbirds, potentially resulting in decreased productivity (Burgess et al. 1995). Elucidating the nature and magnitude of these unintended effects in a variety of ecosystems is essential for informed management decisions and for the responsible use of Btk-based insecticides as an efficient management tool.

Across Canada, large-scale applications of Btk to control a variety of pest organisms coincides with the spring breeding season of insectivorous birds, when the effects of an artificially reduced food supply can be expected to be most pronounced (Burgess et al. 1995). Many neotropical migrants, such as wood-warblers (Parulidae) and vireos (Vireonidae), time their arrival on northern breeding grounds with the emergence of caterpillar prey. In addition to insectivorous species, many omnivorous species, such as towhees, juncos, and sparrows (Emberizidae), switch to a largely insectivorous diet when laying eggs and feeding young and thus are also vulnerable.

Aerial spraying of Foray 48B®, a Btk-preparation, over a 12,803 ha area in Victoria and surroundings on southern Vancouver Island, British Columbia, in spring 1999 provided us with an opportunity to examine the responses of songbirds to the pesticide application. The spraying was undertaken to prevent the establishment and spread of the European Gypsy Moth (*Lymantria dispar*), a potentially serious pest of native deciduous trees and nursery products. We sampled birds in Garry Oak (*Quercus*

garryana)-dominated habitats in and around Victoria. These habitats are scattered, limited in extent, and often confined to rocky outcrops, where trees are typically gnarled and small (<10 m in height). In British Columbia, Garry Oak habitats have undergone extreme shrinkage and fragmentation since European settlement (Erickson 1996) and are presently listed as an endangered ecosystem by the provincial government (Red List, Conservation Data Centre, Victoria, British Columbia). We chose to survey birds in Garry Oak habitats because of the thorough penetration of Btk-spray in these relatively open, low-canopy areas, the comparative ease by which birds can be sampled in these stands, and increasing concerns of human impacts from various sources on these rare ecosystems. Garry Oak habitats are significant for resident and migrating songbirds because they provide islands of refuges within an urban setting and within more extensive but relatively homogeneous coniferous stands. A concurrent study addressing effects of the pesticide treatment on non-target lepidopterans provided us with an index of the abundance of caterpillar prey for birds in these habitats (Boulton et al. 1999).

By surveying birds immediately before spraying in 1999 and at intervals after spraying in both treated and adjacent, untreated areas in 1999 and 2000, we attempted to elucidate effects of the pesticide application on species richness, relative abundance, and territory maintenance. Surveys in 2000 were designed to examine the longer-term effects, 12-14 months after the treatment. Although most pronounced effects are expected during the first breeding season following treatment, longer-term effects on songbirds over subsequent breeding seasons are possible. For example, if prey abundance were reduced for more than one year as a result of Btk-application, as observed in some studies in Garry Oak habitats in Oregon (Miller 1990), songbird abundance and productivity could be depressed.

We predicted that densities of insectivorous birds would be depressed in sprayed areas in relation to pre-treatment densities and when compared to unsprayed areas. This pattern could result from fewer birds settling on territories, movements of birds away from sprayed areas, or maintenance of larger territories at sites with a reduced food supply. We further predicted that the incidence of renesting and second broods, as

reflected by numbers of singing males late in spring, would be lower in sprayed than unsprayed areas due to high energetic costs associated with reproduction. Decreased nesting attempts have been reported previously as a result of an artificially reduced prey-supply associated with Btk-application (Black-throated Blue Warbler, *Dendroica caerulescens*: Rodenhouse and Holmes 1992). We also predicted that the number of newly-fledged broods, reflecting productivity, would be lower in sprayed than unsprayed sites as a result of reduced food supply.

2.0 METHODS

2.1 Study sites

We surveyed songbirds in Garry Oak-dominated habitats at 14 sprayed treatment sites and 14 unsprayed control sites in and around Victoria, Vancouver Island, British Columbia (Figure 1; Appendix A). Thirteen stands (referred to as sites) were within a larger (12,203 ha) Greater Victoria spray-zone and one was within a smaller (602 ha), separate Brentwood Bay spray-zone. The two spray-zones were about 15 km apart at their nearest points. Within these spray-zones we sampled all Garry Oak-dominated stands that were large enough to accommodate at least one 50-m-radius study plot (i.e., > 1 ha) and where a shrub layer was present ($\geq$ 25% ground coverage by shrubs/plot; Appendix A). For control sites we selected 13 similar stands adjacent to the Greater Victoria spray-zone and one stand adjacent to the Brentwood Bay spray-zone. At most sites Douglas-fir (*Pseudotsuga menziesii*) and Arbutus (*Arbutus menziesii*) were interspersed with oaks, and a fringe of Douglas-fir and Grand Fir (*Abies grandis*) was usually present at the circumference of the oak stands. Understory shrubs included Common Snowberry (*Symphoricarpus albus*), Ocean Spray (*Holodiscus discolor*), and Indian Plum (*Oemleria cerasiformis*). Introduced Scotch Broom (*Cytisus scoparius*) and blackberries (*Rubus* spp.) were present at more disturbed sites. The Btk-sprayed and unsprayed plots were similar with respect to elevation, percentage of canopy coverage by Garry Oak and by all trees combined, and percentage of ground covered by native shrubs and all shrubs combined. The mean percentage of canopy

Fig. 1

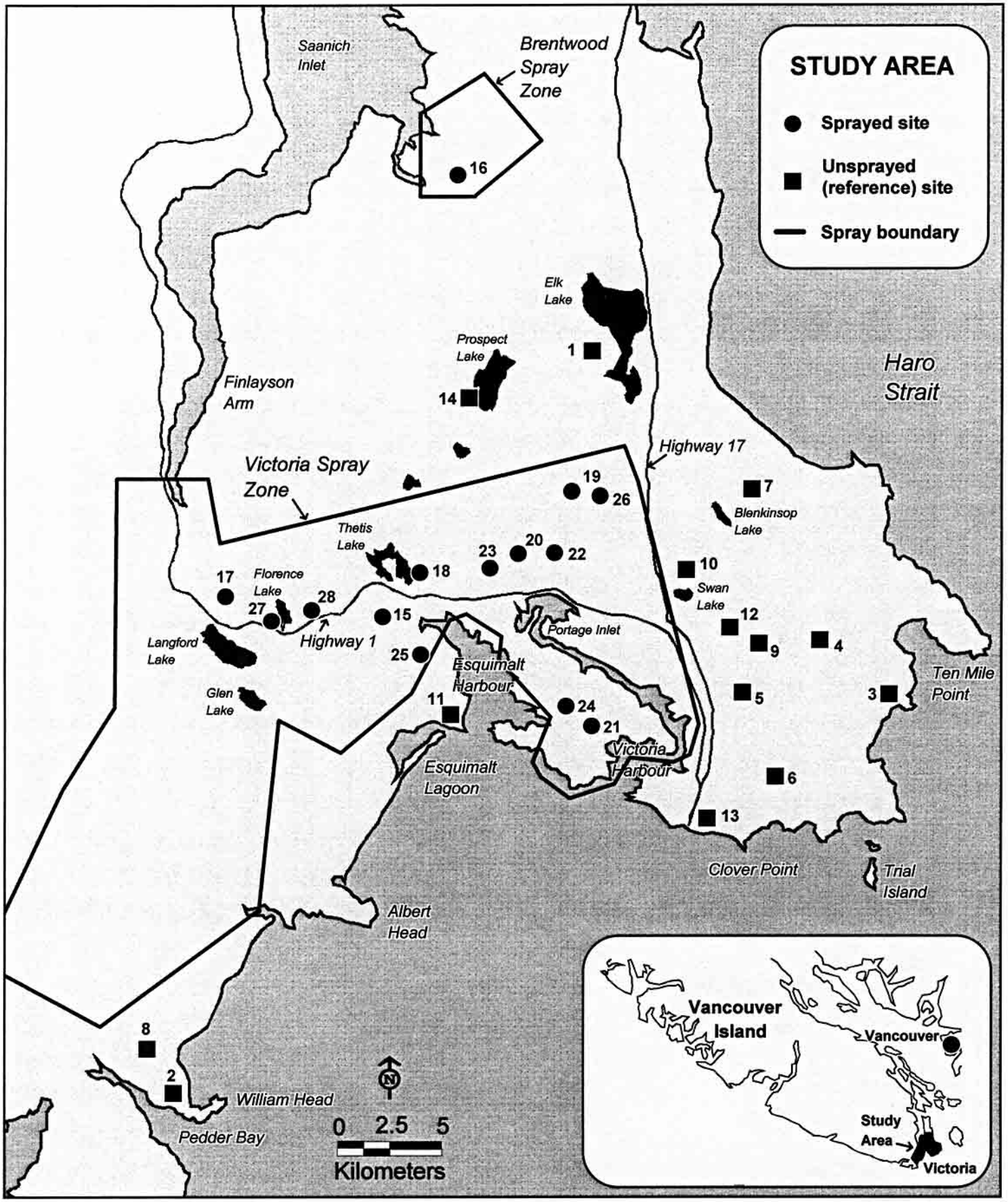


Figure 1. Location of songbird study sites in relation to Btk spray zones, spring 1999 and 2000. See Appendix A for a detailed description of each numbered site.

coverage by Douglas-fir was somewhat greater on the Btk-sprayed than unsprayed plots, but the absolute difference was small (mean of 8.0% versus 4.5% in the two areas, respectively).

The number of study plots per site ranged from 1 to 6, reflecting the relative size of the oak stands. Their distribution was similar in the sprayed and unsprayed areas: In each area 1 site had 6 plots, 2 sites had 5 plots, 1 site had 4 plots, 4 sites had 3 plots, 3 sites had 2 plots, and 3 sites had 1 plot. At the smaller sites, we systematically placed the plots with their edges 25 m apart in a configuration that maximized the number of plots. At the larger stands we placed the centers of plots with their edges 50-m apart along parallel transects, the starting points of which were located at a random distance from the stand edge.

2.2 Pesticide application and effectiveness

A commercial preparation of Foray 48B® was used for each of three aerial pesticide-applications at a rate of 50 BIU in 4 liters/ha. Spraying occurred in 1999; the first application took place on 9–10 May, the second on 19–21 May, and the third on 8–9 June. Spray penetration to ground level occurred at all treatment sites, based on the presence of spray-droplets on Kromakote® cards (2–4 cards per site set up each evening before spray application). None of the cards placed at unsprayed sites closest to the spray-zone received spray-droplets.

A concurrent investigation of non-target lepidopterans, using 21 of 28 of the sites where we surveyed for songbirds, showed that total caterpillar abundance on Garry Oak foliage, including abundance of nine of 13 most common species, was significantly lower in Btk-sprayed than unsprayed sites in 1999 (Boulton et al. 1999). The reduction was more severe after the third than the first two spray applications. At the end of the sampling period on 2-6 July, the total caterpillar abundance in the treatment sites was approximately one third of that in the unsprayed sites, although pre-spraying densities had been similar. In 2000, caterpillar abundance continued to be lower on areas that

were sprayed in 1999, both in Garry Oak foliage and in the Snowberry-dominant understory (Tim Boulton. pers. comm.). The final report of the year 2000 lepidopteran study was not available to us at the writing of this report.

2.3 Point-count surveys

We sampled birds in the study plots using standard point-count surveys (Ralph et al. 1995; RIC 1999). To eliminate inconsistencies due to observer bias, the same experienced person conducted all surveys in 1999 and 2000. The method consisted of an observer counting all birds seen or heard from the center of a 50 m-radius plot in 10 minutes. When necessary, the observer used a laser range-finder (Bushnell™ Yardage Pro 400) to confirm the boundaries of the plot. In addition to the number and location of birds, the observer recorded the type of detection (auditory, visual), the activity of each bird (singing, calling, carrying food or nesting material, feeding young, flying over plot above or below the level of tree-tops), and, when possible, the sex and relative age (adult, juvenile) of the bird. The number of singing males observed during each survey was used as an index of territory maintenance over the breeding season.

In 1999, we conducted point-count surveys at each site during one pre-spraying period (Survey 1: 20–29 April) and three post-spraying periods (Survey 2: 18–25 May; Survey 3: 2–9 June; Survey 4: 20–29 June). In 2000, four surveys were again conducted at each site (Survey 1: 19-29 April; Survey 2: 11-19 May; Survey 3: 25 May-1 June; Survey 4: 15-23 June). Each survey was conducted several days earlier in 2000 because of mild spring weather and the earlier arrival of migrant songbirds compared to that observed in 1999 (B. Whittington, pers. comm.). We randomly selected the sites to be surveyed within each period but began each day by alternately surveying either a Btk-sprayed or unsprayed site. We surveyed all plots within 4–5 hours of sunrise and avoided surveys on windy or rainy days.

2.4 Intensive surveys for broods and adult birds

To obtain an index of breeding success, we surveyed a subset of the study plots for songbird broods (1999: 29 plots each in Btk-sprayed and unsprayed areas, 58 plots in total; 2000: 30 plots each in Btk-sprayed and unsprayed areas, 60 plots in total). To reduce the number of plots for a manageable survey effort, we randomly selected three plots from each of the larger sites for these surveys. To survey the plots two observers (rarely one) slowly walked through the entire plot in a zigzag pattern and observed birds from vantage points. We recorded the species and number of broods located on each plot, and whether the young were fed or accompanied by adults. We counted the young in each brood but did not use these data in the analyses because obtaining an accurate count of the secretive young was often not possible. We refer to these surveys as brood-surveys, because of their primary focus. However, in addition to broods, we recorded the total number of adults and whether they were singing, indicating continued maintenance of breeding territories.

In 1999, we carried out two brood-surveys during the post-spraying period: Survey 1: 2–9 June and Survey 2: 20–29 June. In 2000, Survey 1 was conducted from 25 May–5 June and Survey 2 from 16–23 June. The surveys were several days earlier in 2000 because of the earlier appearance of young broods and adults carrying food in that year based on observations during point-count surveys. Within each period we surveyed the plots on the same day as the point-count surveys but after their completion or on the following day. On average, we spent 67 $\pm$ 16.9 person-minutes on each plot in 1999 and 71 $\pm$ 13 person-minutes in 2000 (mean $\pm$ 1 SD). In 1999, we spent a total of 63.9 person-hours in the unsprayed and 65.3 person-hours in the Btk-sprayed plots. In 2000, the corresponding totals were 68.8 and 73.0 person-hours.

2.5 Foraging guilds

Based on summary information on diets and foraging habits of individual species (Ehrlich et al. 1988; Peterson 1995), we divided birds detected during the surveys into three foraging guilds: Guild 1 (omnivores and seed-eaters), Guild 2 (omnivores-

insectivores), and Guild 3 (leaf-gleaning insectivores). In general, we expected species in Guild 3 to be more vulnerable to Btk-application than those in Guild 2, although the latter might differ in their vulnerability according to the frequency that a particular species feeds caterpillars to their young during the nestling period. We expected species in Guild 1 to be unaffected by the spray-application.

The categories consisted of the following species: Guild 1: American Robin, Cedar Waxwing, European Starling, Brown-headed Cowbird, American Goldfinch, House Finch, Pine Siskin, Purple Finch, House Sparrow; Guild 2: Bewick's Wren, House Wren, Winter Wren, Red-breasted Nuthatch, Hermit Thrush, Swainson's Thrush, Townsend's Solitaire, Varied Thrush, Black-headed Grosbeak, Chipping Sparrow, Dark-eyed Junco, Golden-crowned Sparrow, Lincoln's Sparrow, Savannah Sparrow, Song Sparrow, Spotted Towhee, White-crowned Sparrow, Red-winged Blackbird, Evening Grosbeak; Guild 3: Bushtit, Chestnut-backed Chickadee, Golden-crowned Kinglet, Ruby-crowned Kinglet, Cassin's Vireo, Warbling Vireo, Hutton's Vireo, Black-throated Gray Warbler, Common Yellowthroat, Orange-crowned Warbler, Townsend's Warbler, Wilson's Warbler, Yellow Warbler, Yellow-rumped Warbler, MacGillivray's Warbler, Western Tanager (see Appendix B for scientific names; nomenclature according to Check-list of North American Birds, American Ornithologists' Union 1998). Of the above species, the Hermit Thrush, Golden-crowned Sparrow, Lincoln's Sparrow, and Ruby-crowned Kinglet do not usually breed in the Victoria area.

2.6 Data analysis

To examine responses of individual species to the Btk-treatment, we used contingency tables (χ^2-test) to compare the total number of birds, singing males (an index of territoriality), and broods between sprayed and unsprayed areas. Because the same birds may have been counted during more than one period, we performed separate tests for each survey. We used the Bonferroni-correction to reduce alpha by 1/4, to 0.0125, to achieve an overall significance level of 0.05 for each species (Zar 1996). An exception was the number of broods, for which we combined the counts from both

surveys. Because the period of dependency on adults by fledged young is short for most of the species observed, we postulated that the probability of finding the same brood in a cohesive group during both surveys was small. We used the Yate's correction for continuity when df = 1 (Zar 1996).

We used the analysis of variance to compare the number of birds and singing males (index of territories) per study plot between Btk-sprayed and unsprayed areas. This analysis allowed a more detailed investigation of the pattern of relative abundance across surveys than the χ^2- tests described above, as well as the testing of specific models. Sufficient data for this analysis existed for five individual species (Bewick's Wren, Chipping Sparrow, Spotted Towhee, White-crowned Sparrow, and Orange-crowned Warbler) and for groupings of other species (remaining Guild 2 species, Bushtits and Chestnut-backed Chickadees, and remaining Guild 3 species). The Bushtit and Chestnut-backed Chickadee are year-round residents in the study area and have similar foraging behaviour, whereas the remaining Guild 3 species (warblers with Orange-crowned Warbler omitted, vireos, and the Western Tanager) are seasonal migrants with similar leaf-gleaning foraging behaviour.

We tested the following models*:* Model 1a: Comparison of the pre-spray survey with the three post-spray surveys in 1999 [effect variables: "spray-status" (unsprayed, Btk-sprayed) and "site" (study sites, nested within "spray-status"), response variables: numbers of birds or singing males/plot during each of the four surveys]; Model 1b: Comparison of linear trends within post-spraying surveys in 1999 (variables as above for Model 1a); Model 2: Comparison of sprayed versus unsprayed plots in 2000 (repeated measures analysis of variance with "spray-status" and "site" as effect variables, numbers of birds or singing males/plot as response variables, and "time" as the repeated measure); Model 3: Comparison of sprayed versus unsprayed plots in 1999 and 2000 combined, with the first survey of each year omitted (repeated measures analysis of variance with "spray-status", "year", and "site" as effect variables, numbers of birds or singing males/plot as response variables, and "time" as the repeated measure).

In the above analyses, we included data for only those plots where a particular species was found during at least one survey in 1999 or 2000; we omitted plots where a species was never found to eliminate potential bias resulting from unsuitability of the habitat for a particular species and to increase the likelihood of detecting an effect due to spray-status. Because the data did not conform with the assumption of normality required by parametric statistical procedures, we performed those analyses where "spray-status" was significant also on ranked data. Congruency of the results from actual and ranked data would indicate robustness of the results (Zar 1996, pp. 269–270). We used the statistical package Jmp In (Version 3.2.1, 1989–1997, SAS Institute Inc.) for analyses of variance and set alpha = 0.05 in all tests.

3.0 RESULTS

3.1 Distribution and abundance

During point-count and brood-surveys in May-June 1999 and 2000, we observed a total of 61 species of songbirds, 44 of which were considered to include caterpillars in their diet during the breeding season (Appendix B). Of the latter 44 species, the most frequently observed species during point-count surveys were the American Robin (15.9% of 4505 observations in 1999 and 2000), Spotted Towhee (14.5%), Pine Siskin (13.6%), Orange-crowned Warbler (8.0%), Bewick's Wren (7.6%), House Finch (5.1%), Chipping Sparrow (3.7%), Dark-eyed Junco (3.5%), European Starling (3.3%), Brown-headed Cowbird (3.1%), and White-crowned Sparrow (3.1%; Tables 1a, b). During brood-surveys of the same plots (4432 observations of adult birds in total), the general pattern of relative abundance was similar, with the exception of the Bushtit and Chestnut-backed Chickadee, which were observed more frequently during brood- than point-count surveys (Bushtit: 7.1% versus 0.5%; Chestnut-backed Chickadee: 12.3% versus 2.4% of observations during brood- and point-count surveys, respectively). Brood-surveys, where the observers covered the entire plot, were more effective for locating these birds than were point-counts, where the observer remained in the center of the plot.

Table 1a. Number of adult songbirds encountered on Btk-sprayed and unsprayed study plots during point-count surveys in April-June 1999. See Appendix B for explanations of species codes. Letters denote values that are significantly different at alpha = 0.0125 (0.05/4); sprayed<unsprayed (upper case); sprayed>unsprayed (lower case).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	CEWA	EUST	HOFI	HOSP	PISI	PUFI	Total	# of species
Unsprayed	1	0	48	6	0	3	21	1	14	4	97	7
Sprayed	1	1	54	17	0	6	15	0	6	7	106	7
Unsprayed	2	6	48	13	1	13	12	3	5	0	101	8
Sprayed	2	1	45	9	0	22	6	0	2	6	91	7
Unsprayed	3	6	56	10	0	11	29^{A}	5	2	1	120	8
Sprayed	3	3	55	11	2	12	6^{A}	3	1	1	94	9
Unsprayed	4	6	37	5	0	8	24^{B}	5	5	1	91^{C}	8
Sprayed	4	3	25	6	0	4	8^{B}	1	1	3	51^{C}	9
Total		26	368	77	3	79	121	18	36	23	751	9

B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	BHGR	CHSP	DEJU	GCSP	HETH	HOWR	RBNU	LISP	RWBL	SAVS	SOSP	SPTO	SWTH	TOSO	VATH	WCSP	WIWR	Total
Unsprayed	1	34	0	7	10	4	1	1	4	3	2	2	1	44	0	0	3	14	2	132
Sprayed	1	23	0	9	10	1	3	2	9	0	0	2	2	57	0	3	4	11	0	136
Unsprayed	2	20	1	13	5	8	0	5	3	0	0	0	2	46	2	0	0	1	0	106
Sprayed	2	23	1	16	8	0	0	15	10	0	3	0	1	37	0	0	1	5	0	120
Unsprayed	3	25	1	13	14	0	0	6	6	0	0	0	0	51	1	0	0	11	1	129
Sprayed	3	15	0	16	7	0	0	7	6	0	0	0	0	37	6	0	0	6	1	101
Unsprayed	4	15	0	8	2	0	0	3	4	0	0	0	1	41	0	0	0	10	0	84
Sprayed	4	13	0	6	9	0	0	7	6	0	0	0	0	30	0	0	0	3	1	75
Total		168	3	88	65	13	4	46	48	3	5	4	7	343	9	3	8	61	5	883

C. Guild 3 (high proportion of caterpillars in diet)

Spray status	Survey #	BUSH	CAVI	CBCH	COYE	GCKI	OCWA	RCKI	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	8	2	9	0	0	41	9	0	0	0	0	0	9	78	50	2
Sprayed	1	2	1	5	1	1	52	0	0	0	0	0	0	10	72	63	1
Unsprayed	2	2	4	11	0	0	25	0	2	4	7	6	1	3	65	37	8
Sprayed	2	0	2	4	0	0	31	0	5	2	4	3	1	1	53	41	4
Unsprayed	3	9	0	3	0	0	18	0	0	1	2	0	2	0	35	20	1
Sprayed	3	2	1	5	0	0	28	0	1	0	0	0	0	0	37	29	1
Unsprayed	4	0	1	1	0	0	13	0	1	1	1	0	0	0	18	14	2
Sprayed	4	0	0	5	0	3	16	0	0	0	0	0	0	3	27	19	0
Total		11	23	43	1	4	224	9	9	8	14	9	4	26	385	273	19

Table 1b. Number of adult songbirds encountered on Btk-sprayed and unsprayed study plots during point-count surveys in April-June 2000. See Appendix B for explanations of species codes. Letters denote values that are significantly different at alpha = 0.0125 (0.05/4); sprayed<unsprayed (upper case); sprayed>unsprayed (lower case).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	CEWA	EUST	HOFI	HOSP	PISI	PUFI	Total	# species
Unsprayed	1	2	37	10	0	4	23	3	15[b]	6	100	8
Sprayed	1	0	53	3	0	7	11	0	38[b]	5	117	6
Unsprayed	2	1	27[a]	11	0	2	12	10	34	0	97[e]	7
Sprayed	2	8	56[a]	7	0	11	10	1	36	15	144[e]	8
Unsprayed	3	9	38	10	0	3	12	1	13[c]	2	88	8
Sprayed	3	2	48	7	0	10	5	1	337[c]	4	*114	8
Unsprayed	4	6	34	8	2	17	22	1	100[D]	10	*128	9
Sprayed	4	4	53	8	3	14	13	0	3[D]	4	102	8
Total		32	346	64	5	68	108	17	576	46	*890	9

*3 large flocks of PISI (300 birds during Survey 3; 32 and 40 birds during Surveys 4) were omitted from the total count

B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	BHGR	CHSP	DEJU	EVGR	GCSP	HETH	HOWR	RBNU	LISP	RWBL	SAVS	SOSP	SPTO	SWTH	WCSP	WIWR	Total
Unsprayed	1	22	0	7	4	0	1	0	1	5	0	0	2	3	30	0	8	0	83
Sprayed	1	25	0	5	13	1	7	0	4	6	1	0	0	1	36	0	11	0	110
Unsprayed	2	28	0	10	8	0	0	0	2	3	0	0	0	2	47	2	5	0	107
Sprayed	2	18	0	14	18	0	0	0	10	6	0	1	0	1	33	0	11	1	113
Unsprayed	3	24	1	11	9	0	0	0	4	7	0	0	0	1	38	0	3[f]	0	98[g]
Sprayed	3	25	0	10	24	0	1	0	13	3	0	0	0	0	46	8	16[f]	0	146[g]
Unsprayed	4	18	0	6	9	0	0	0	3	19	0	0	0	2	48	1	6	1	113
Sprayed	4	16	0	16	8	0	0	0	8	25	0	0	0	0	33	4	17	0	127
Total		176	1	79	93	1	9	0	45	74	1	1	2	10	311	15	77	2	895

C. Guild 3 (high proportion of caterpillars in diet)

Spray status	Survey #	BUSH	CAVI	CBCH	COYE	GCKI	HUVI	OCWA	RCKI	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total (Guild 3)	All warblers	All Vireos
Unsprayed	1	3	3	6	0	0	0	23	1	2	0	0	0	0	6	44	31	3
Sprayed	1	0	0	9	0	0	0	37	0	0	0	0	1	0	9	56	47	0
Unsprayed	2	2	1	4	0	0	0	14	0	1	1	7	2	2	3	37	22	2
Sprayed	2	0	0	3	0	0	0	15	0	1	3	7	1	0	5	35	22	3
Unsprayed	3	0	2	7	0	0	0	9	0	1	3	10	0	0	3	35	13	5
Sprayed	3	1	0	13	0	0	1	11	0	2	5	5	1	2	6	47	22	6
Unsprayed	4	6	3	18	0	0	0	9	0	0	1	3	0	0	3	43	12	4
Sprayed	4	0	1	5	0	0	0	19	0	0	1	1	0	0	3	30	22	2
Total		12	10	65	0	0	1	137	1	7	14	33	5	4	38	315	191	25

During the point-count surveys, we detected a total of 9 species in Foraging Guild 1 (low proportion of caterpillars in the diet; all year-round residents), 19 species in Guild 2 (moderate proportion of caterpillars in the diet; 8 residents and 11 seasonal migrants), and 14 species in Guild 3 (high proportion of caterpillars in diet; 3 residents and 11 seasonal migrants; Figure 2a, b). The species diversity was similar in Btk-sprayed and unsprayed areas during each of the surveys.

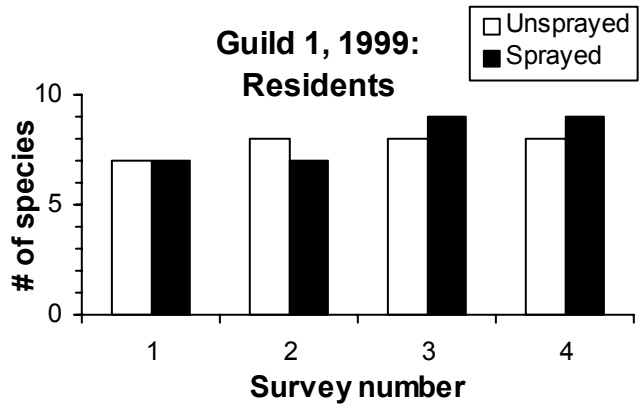
The American Robin, Spotted Towhee, and Orange-crowned Warbler occurred on most plots and at all sites, whereas the distribution of many other commonly observed species, such as the White-Crowned Sparrow, Dark-eyed Junco, and Bushtit, appeared to be more restricted. Figure 3a-h shows distribution maps for selected species in Foraging Guilds 2 and 3 at our study sites in relation to the Btk-spray zones.

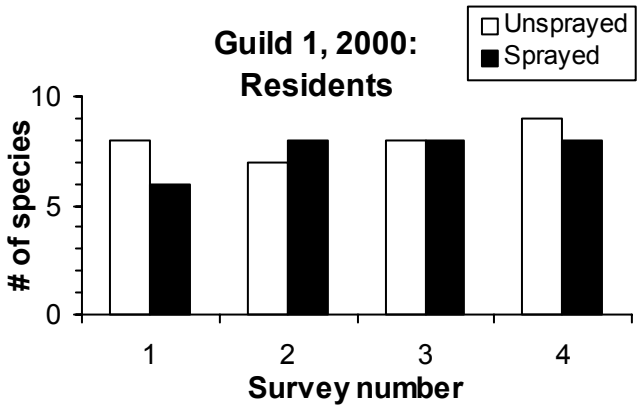
3.2 Relative abundance of adults in relation to Btk-treatment

Comparisons of total counts of adult birds observed in Btk-sprayed and unsprayed plots during each of the four point-count surveys revealed no patterns consistent with adverse effects of the Btk-treatment (Table 1a, b). Significantly fewer House Finches occurred during the last two post-spraying surveys in 1999 in sprayed than unsprayed areas (χ^2 = 13.8 for Survey 3 and 7.0 for Survey 4, *df* = 1, *P* < 0.01). The difference can be attributed to three flocks of 6–15 birds observed on the unsprayed plots, which inflated the numbers of this species and also the totals for Guild 1. The House Finch is omnivorous and rarely consumes caterpillars or feeds insects to its young (Ehrlich et al. 1988). Of those species considered to include a moderate (Guild 2) or high (Guild 3) proportion of caterpillars in their diets, no comparisons were significant either when individual species were considered separately or when combined into foraging guilds (Table 1a, b; Figure 4a-f). However, a trend towards lower numbers of Spotted Towhees existed in Btk-sprayed than unsprayed plots during the three post-spraying surveys in 1999, although these comparisons with total counts were not statistically significant. Such a trend towards reduced numbers in sprayed areas was absent from the point-count data for Spotted Towhees in 2000 (Figure 4b).

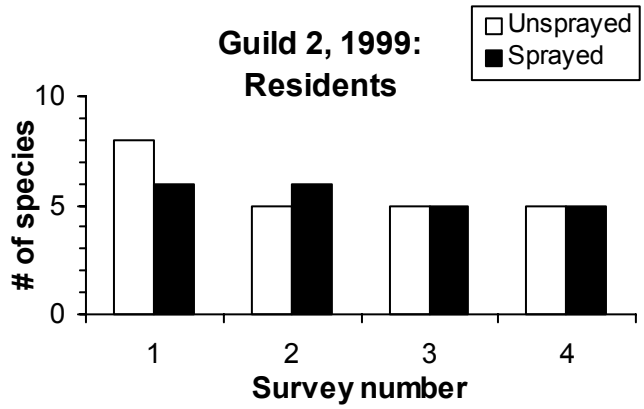
Figure 2a. Species diversity of songbirds detected in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Total number of plots = 41 both in unsprayed and sprayed areas. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

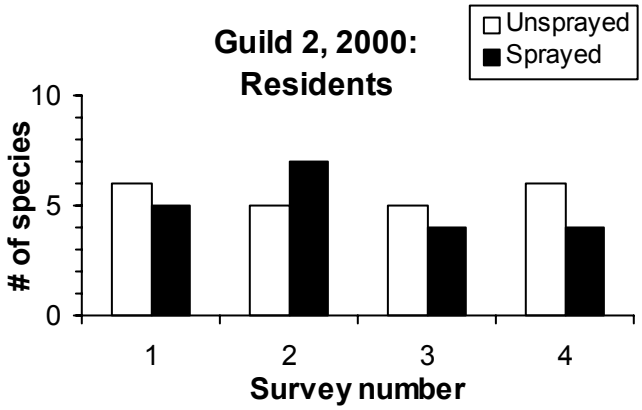
A. Species with a low proportion of caterpillars in the diet

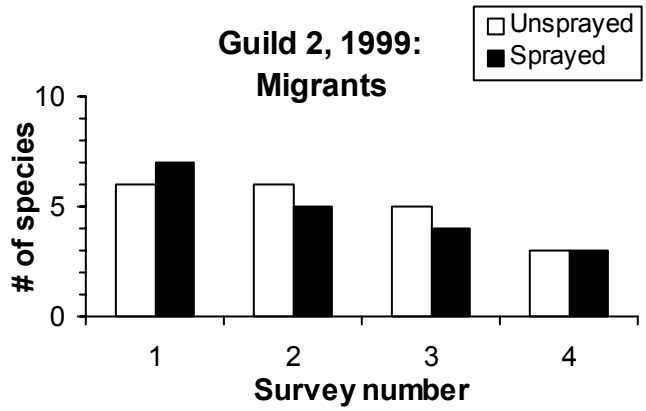




B. Species with a moderate proportion of caterpillars in the diet







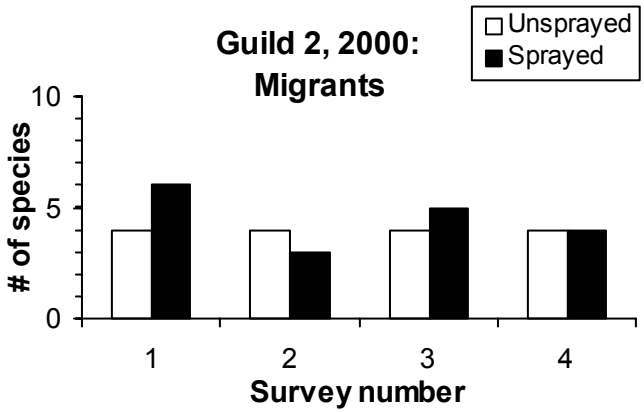
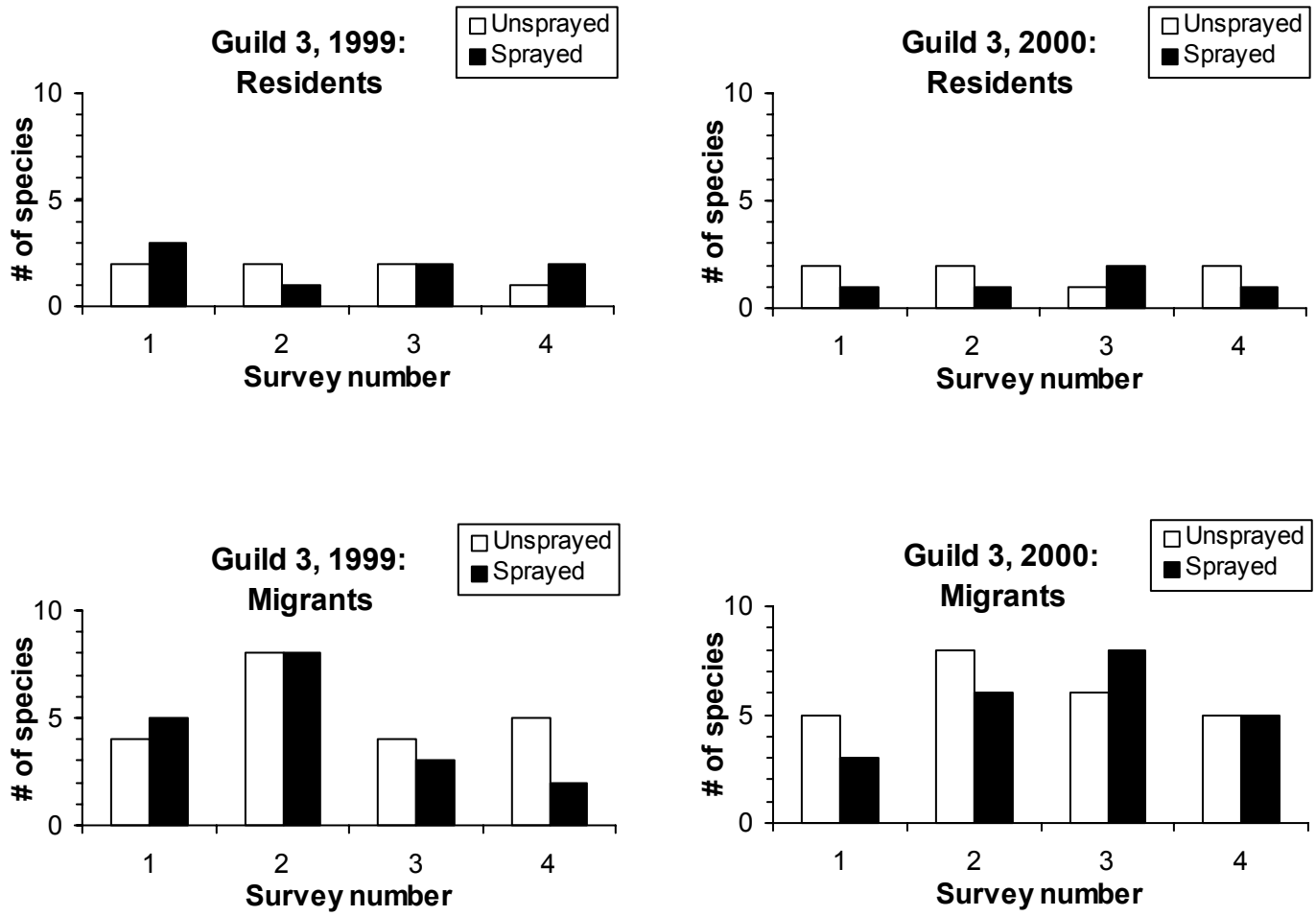
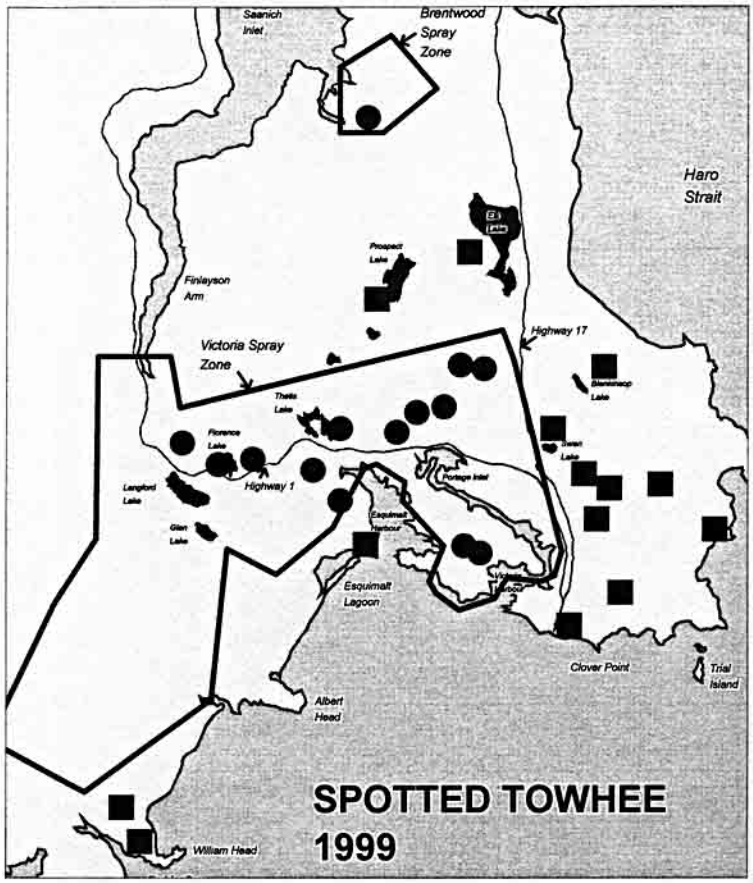
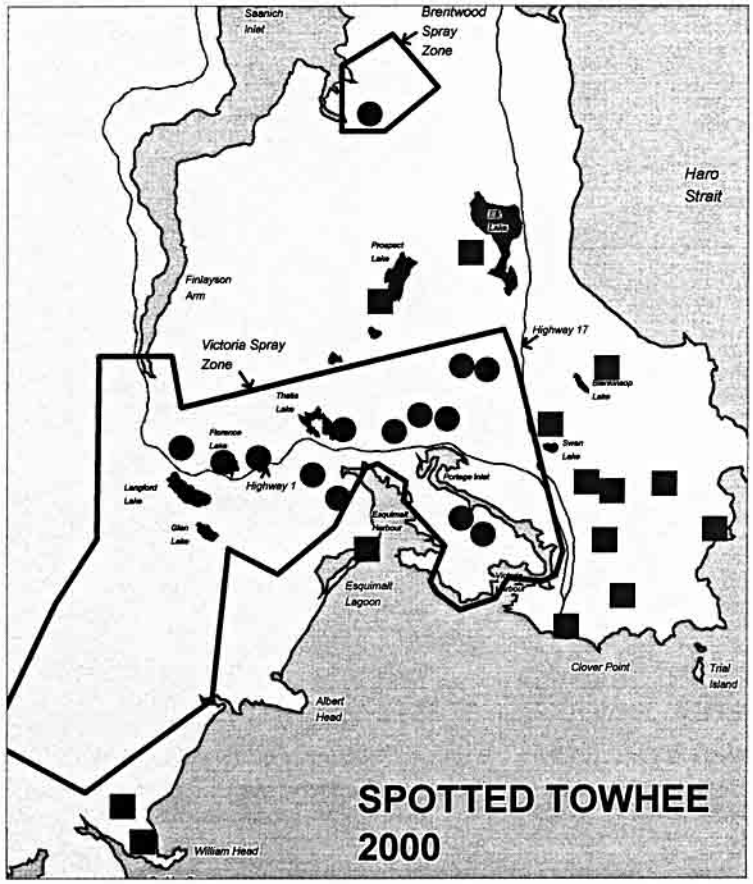


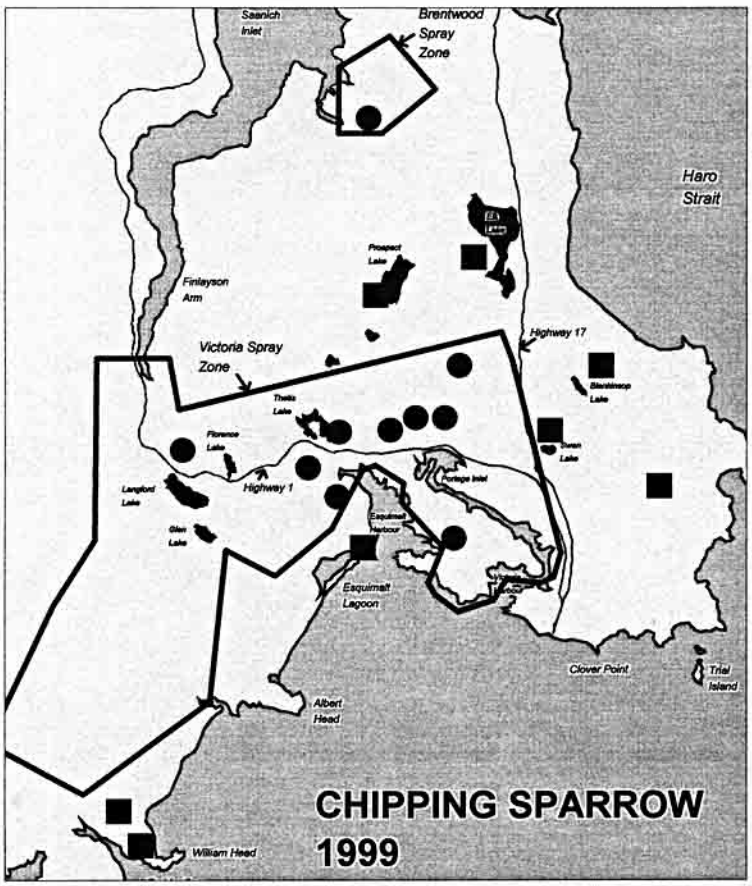
Figure 2b. Species diversity of songbirds detected in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Total number of plots = 41 both in unsprayed and sprayed areas. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

A. Species with a high proportion of caterpillars in the diet









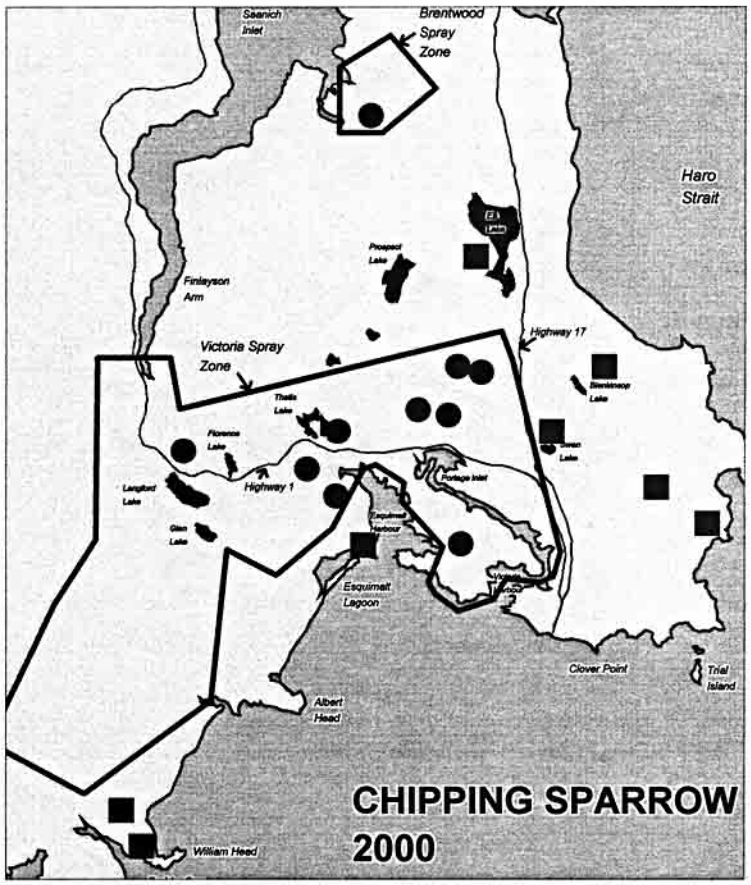
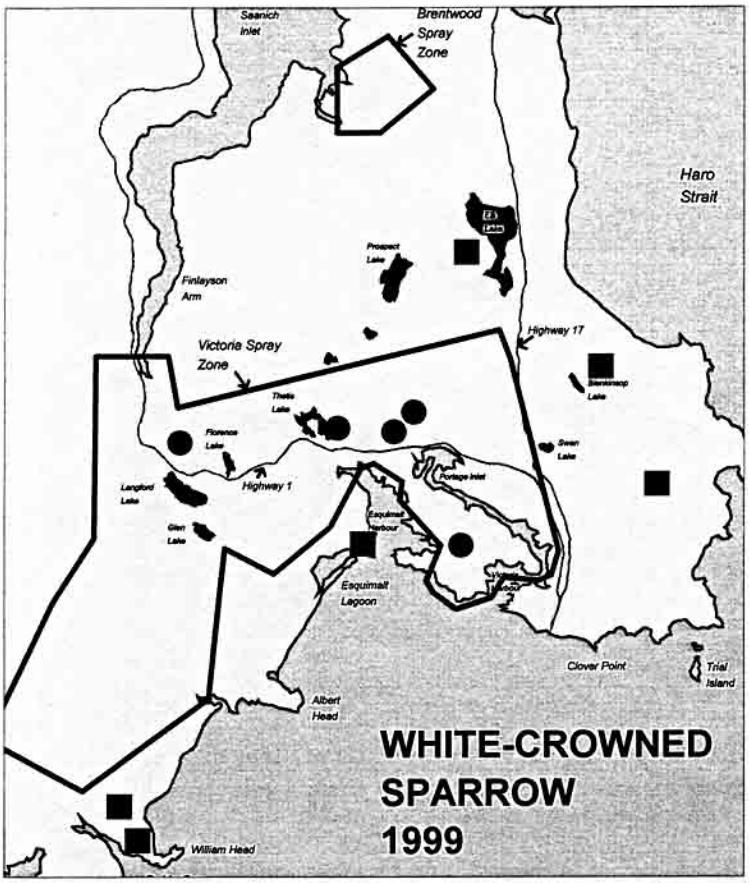
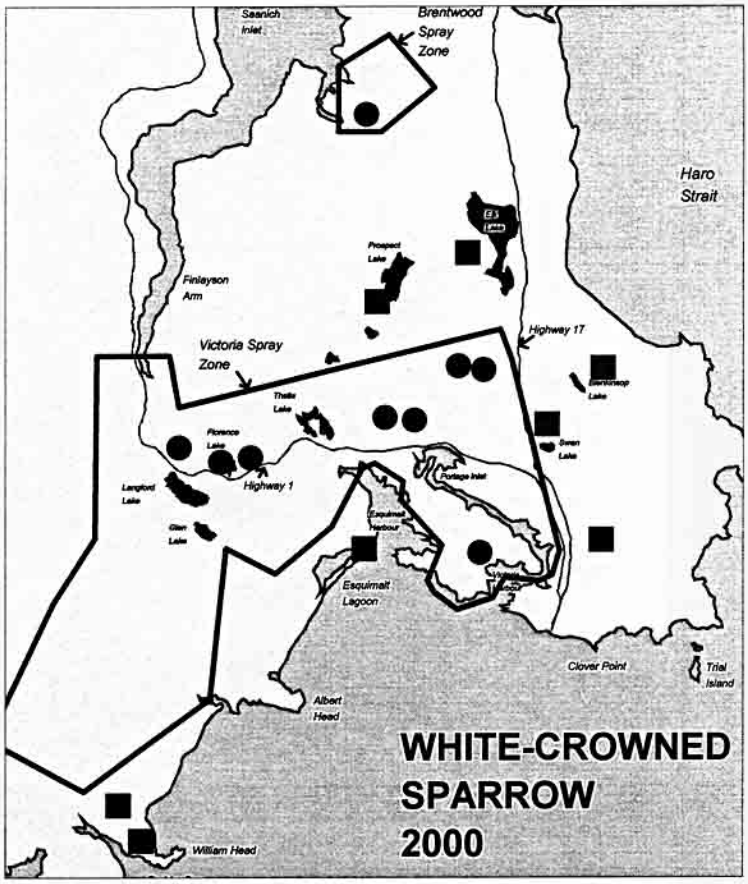
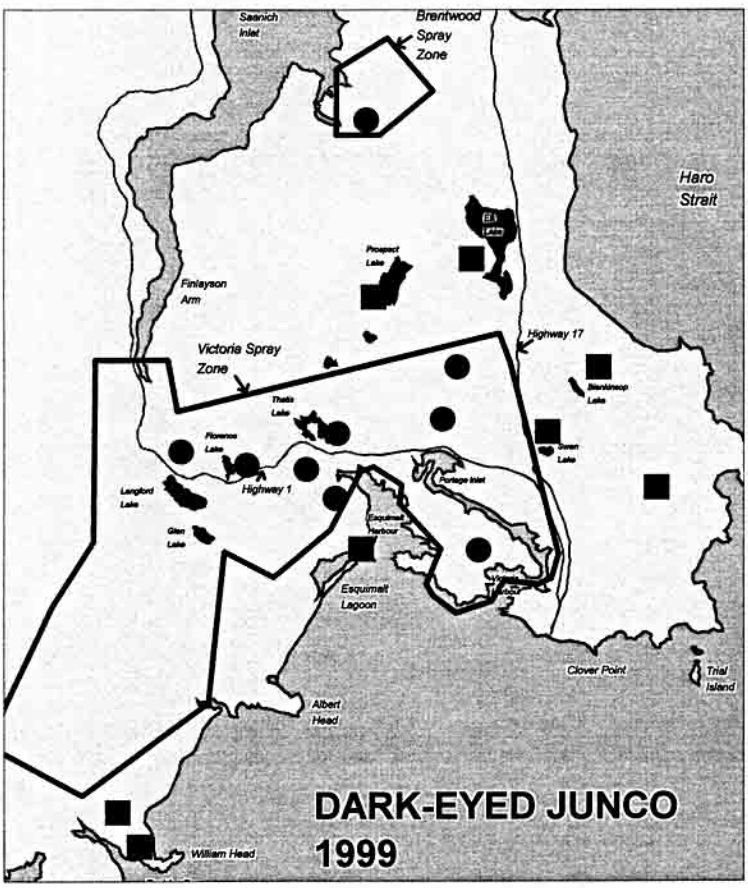


Figure 3a. Distribution of Spotted Towhee and Chipping Sparrow in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







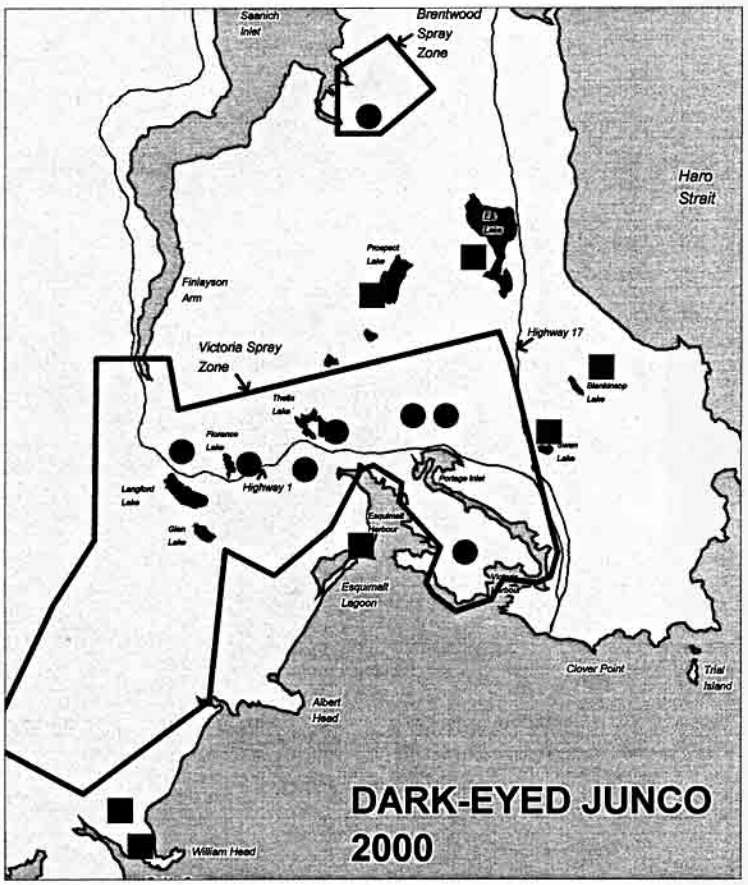
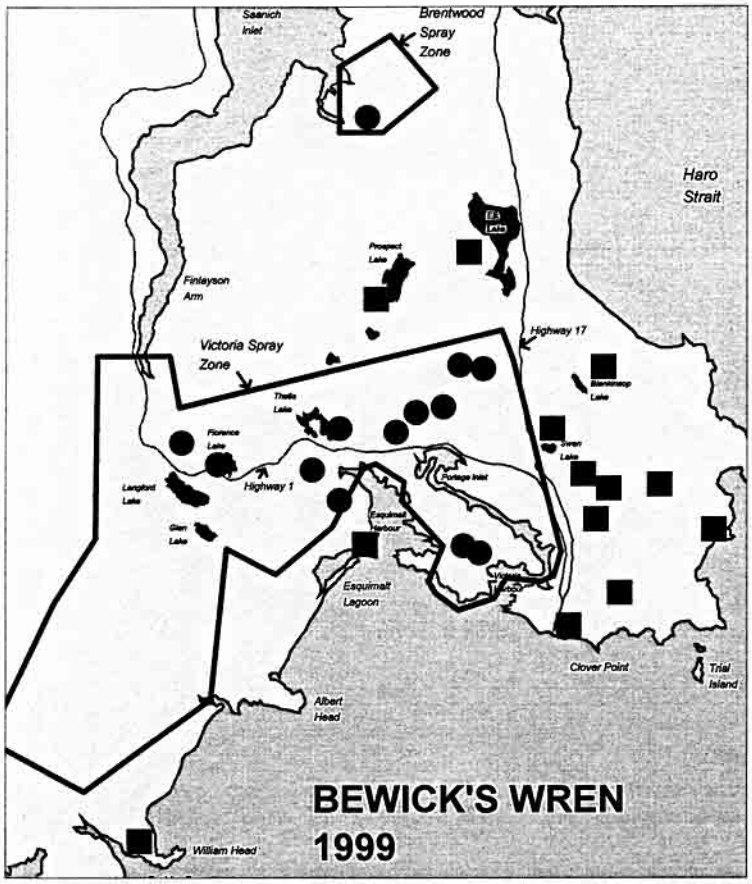
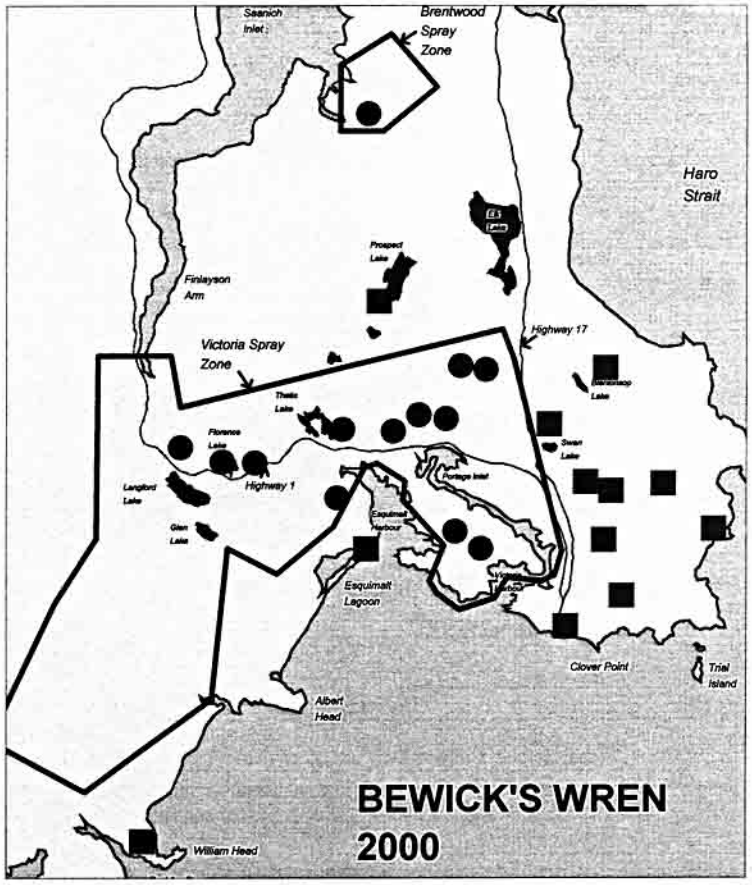
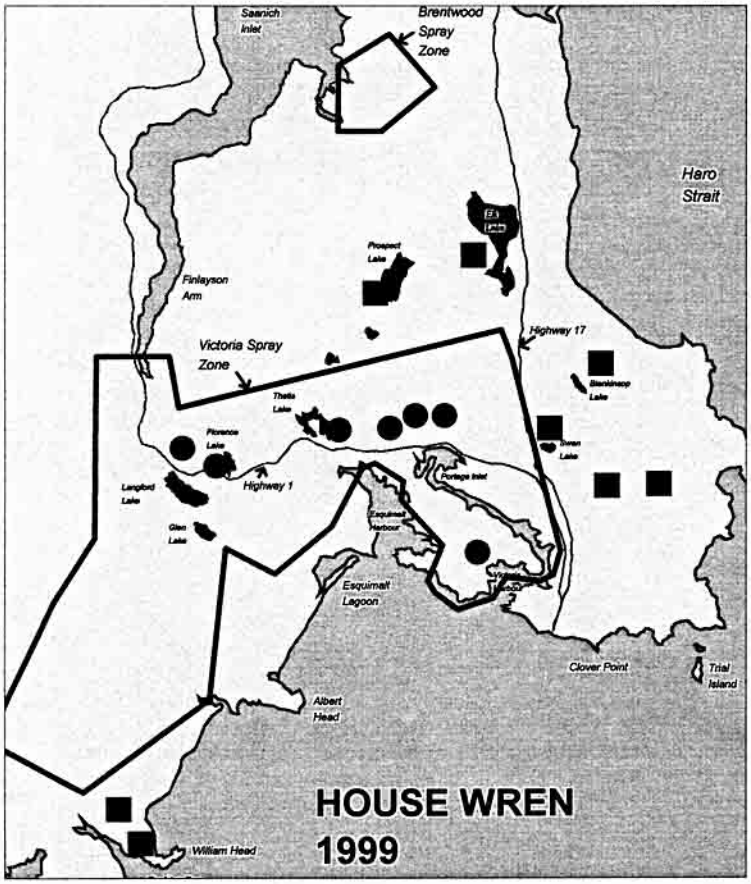


Figure 3b. Distribution of White-crowned sparrow and Dark-eyed junco in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







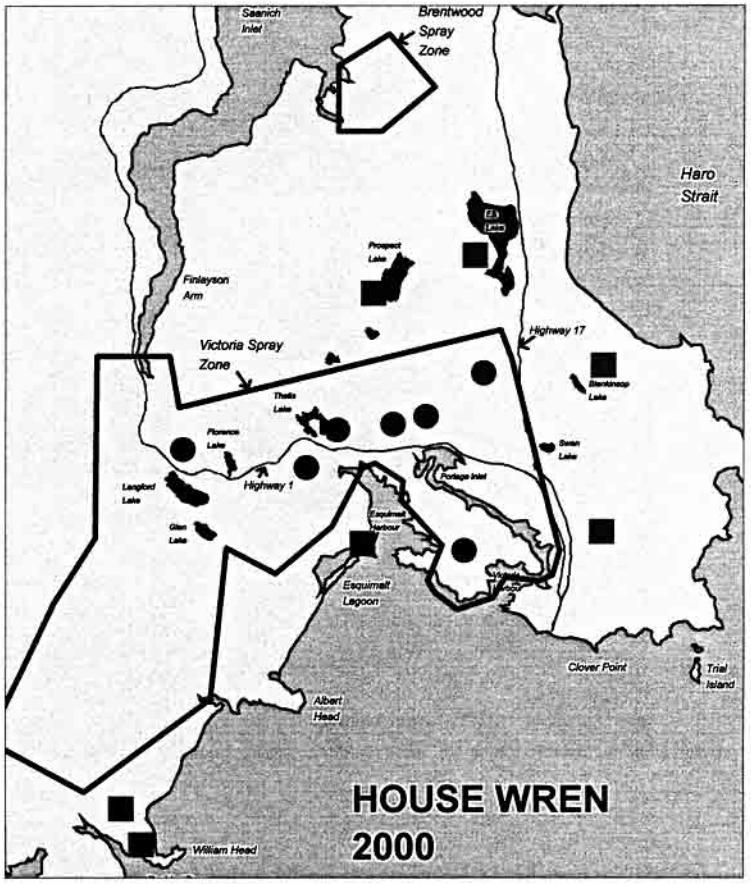
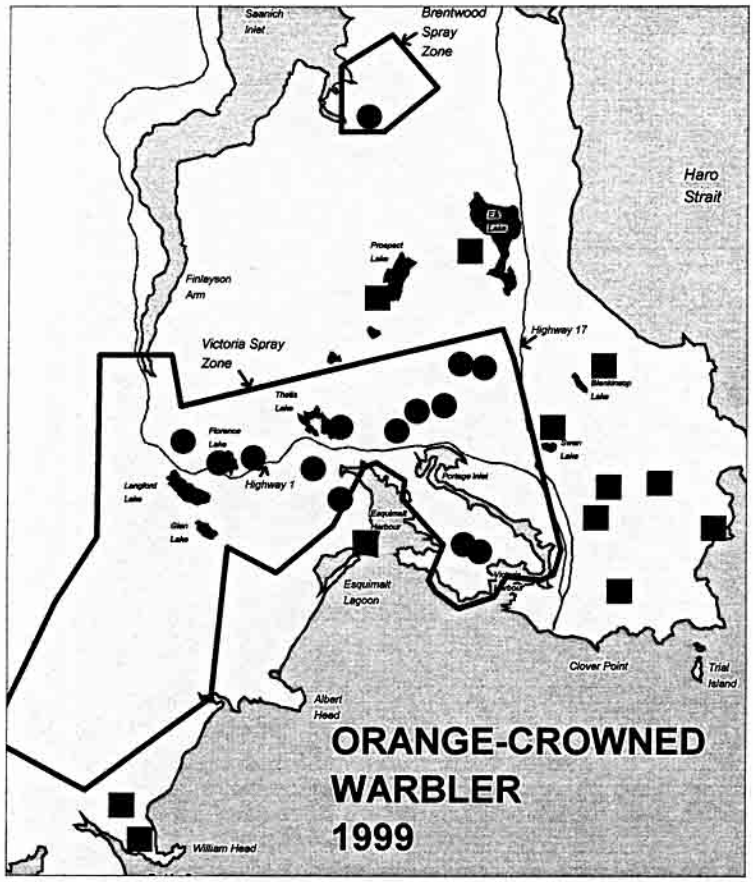
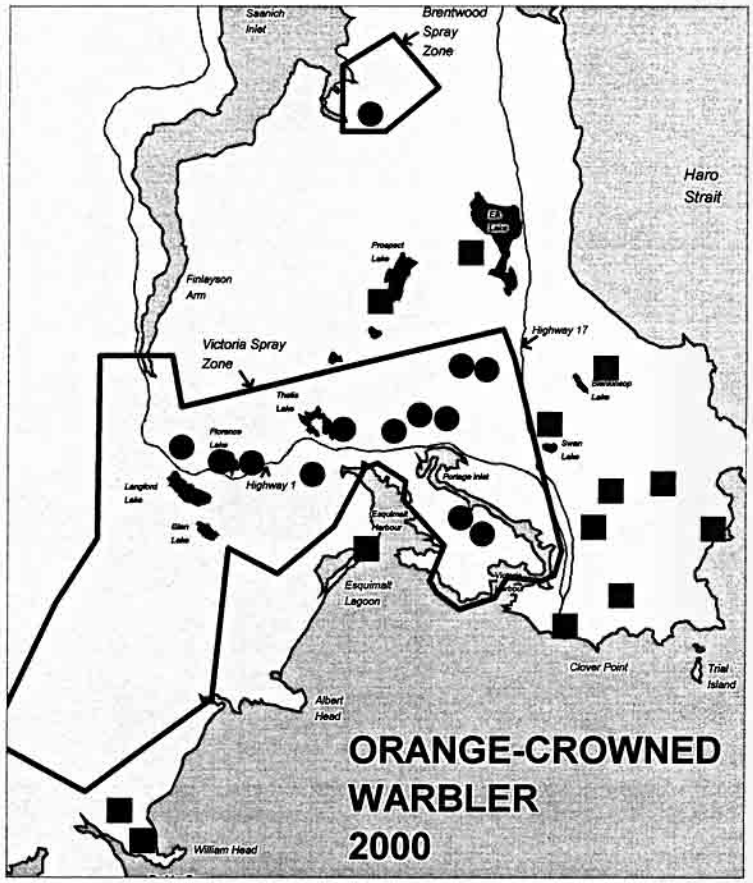
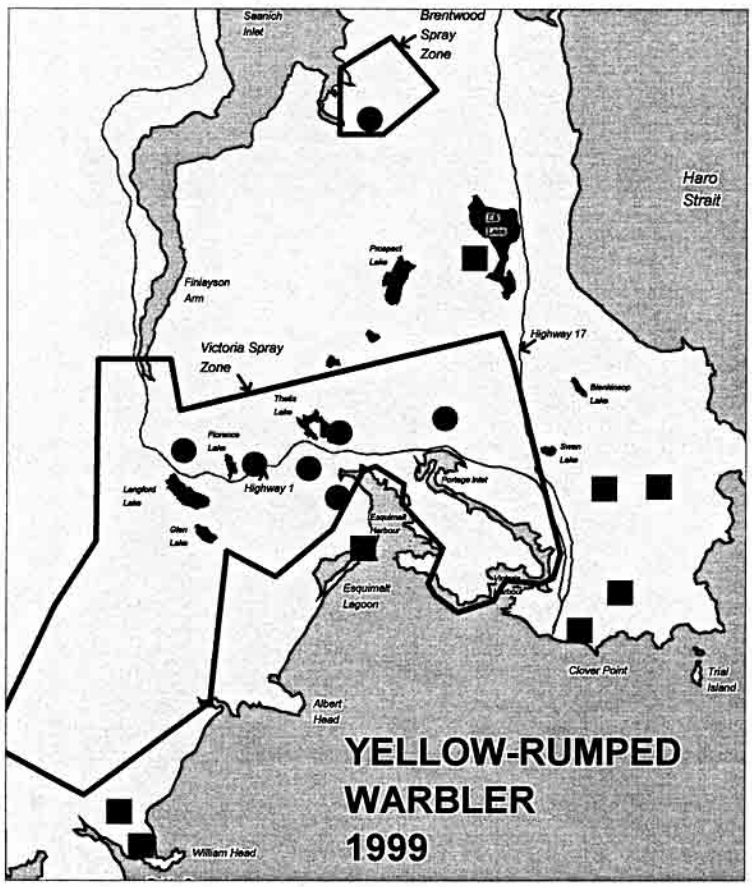


Figure 3c. Distribution of Bewick's Wren and House Wren in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







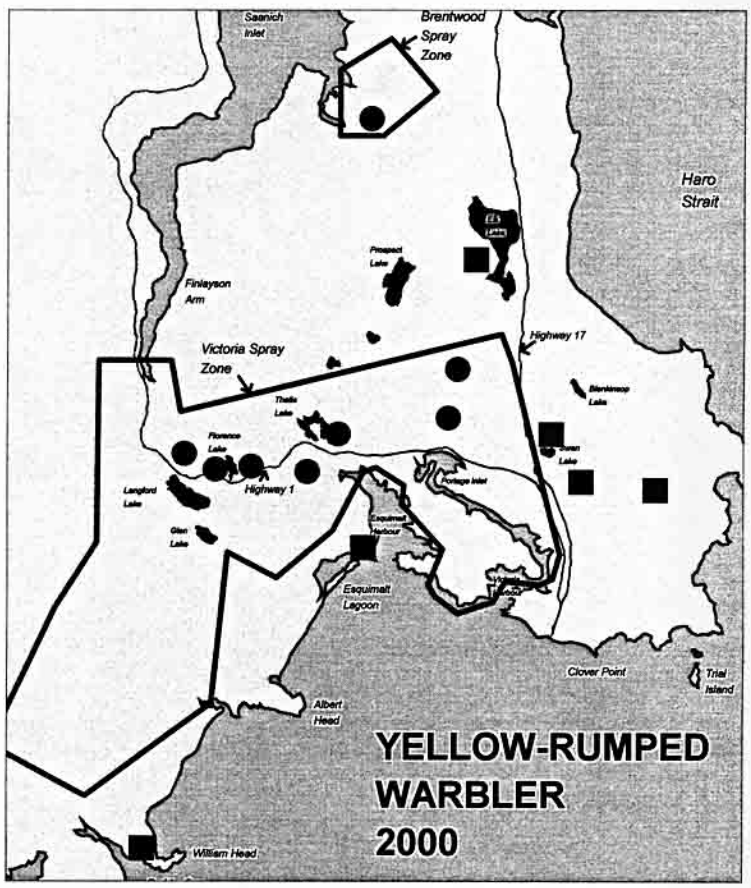
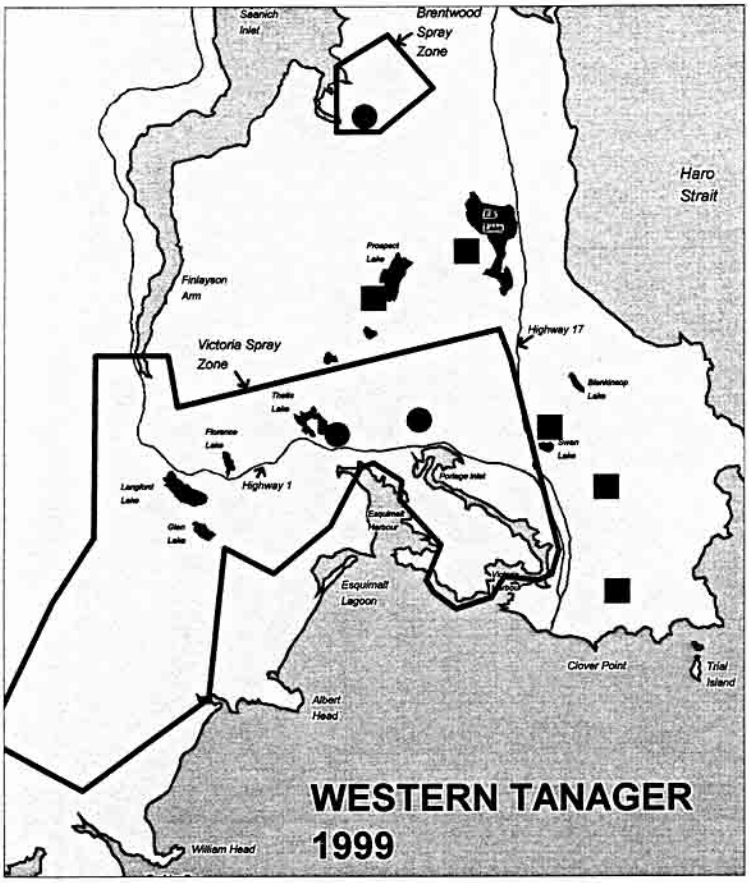
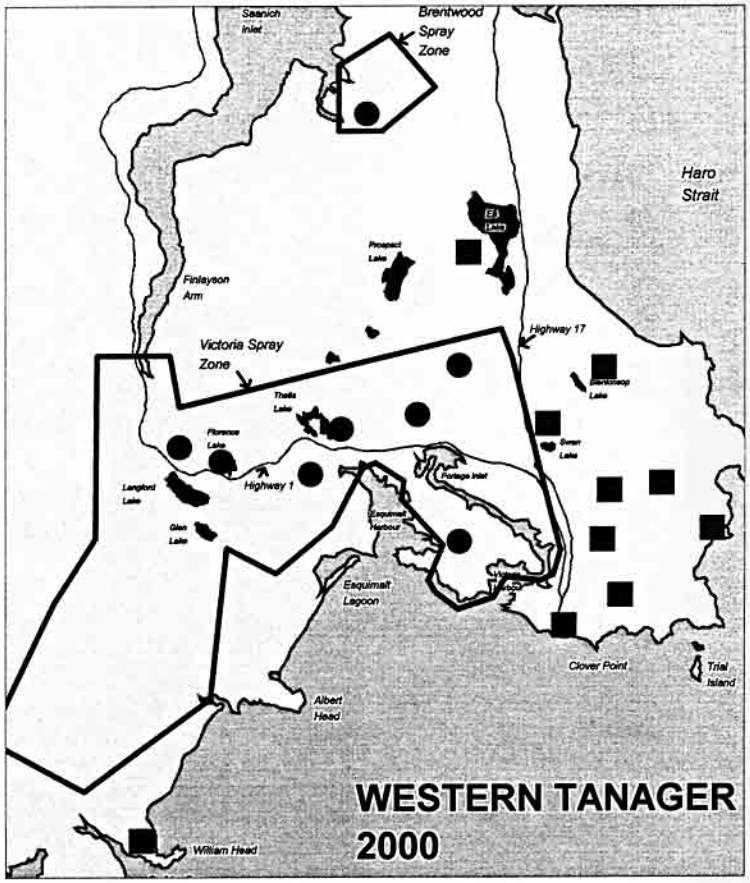
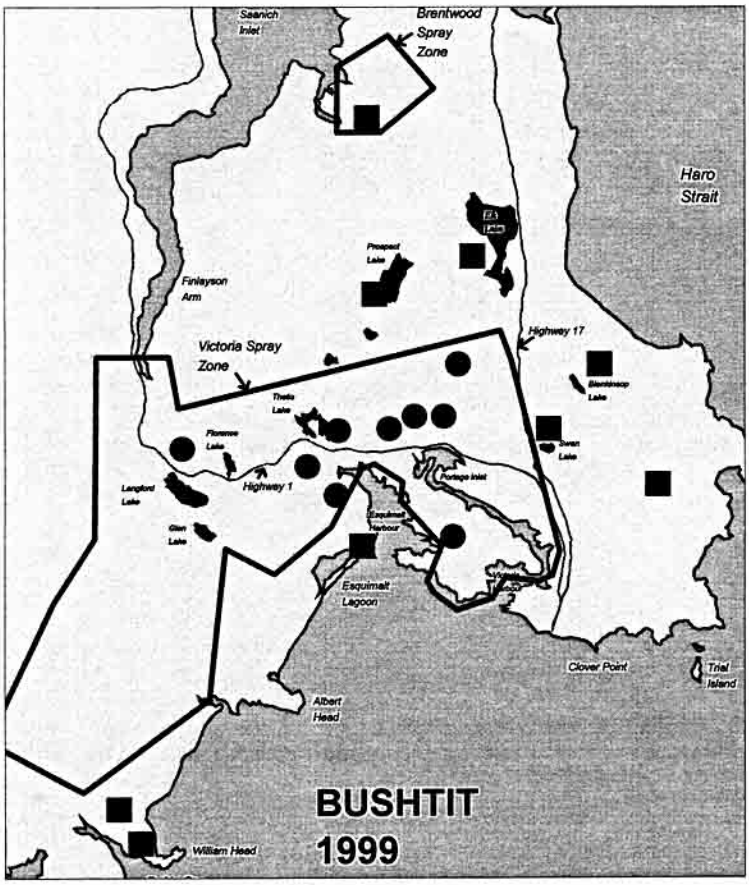


Figure 3d. Distribution of Orange-crowned and Yellow-rumped Warblers in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







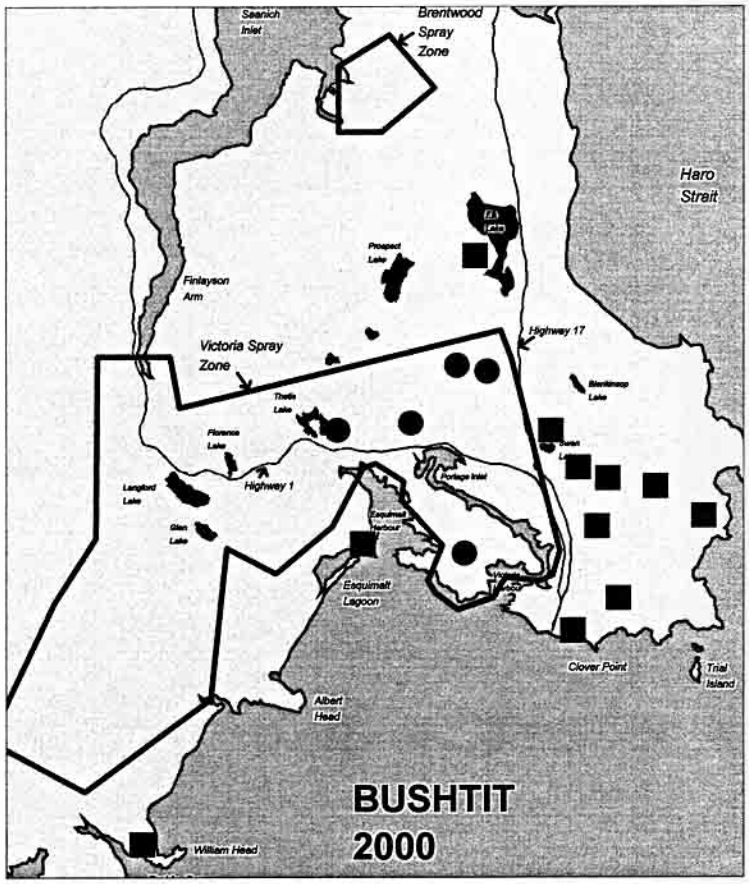
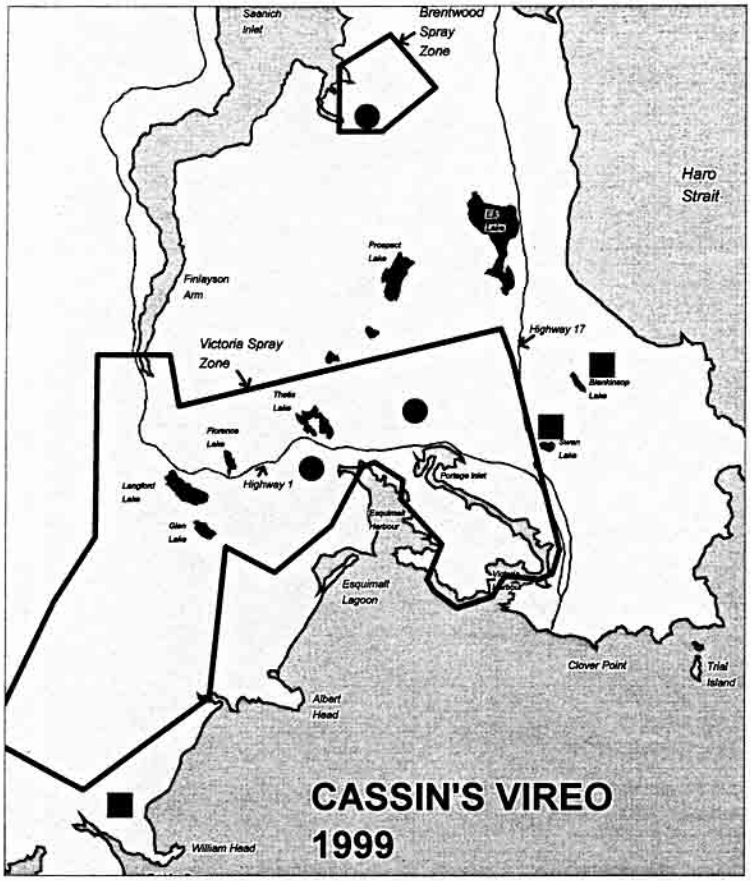
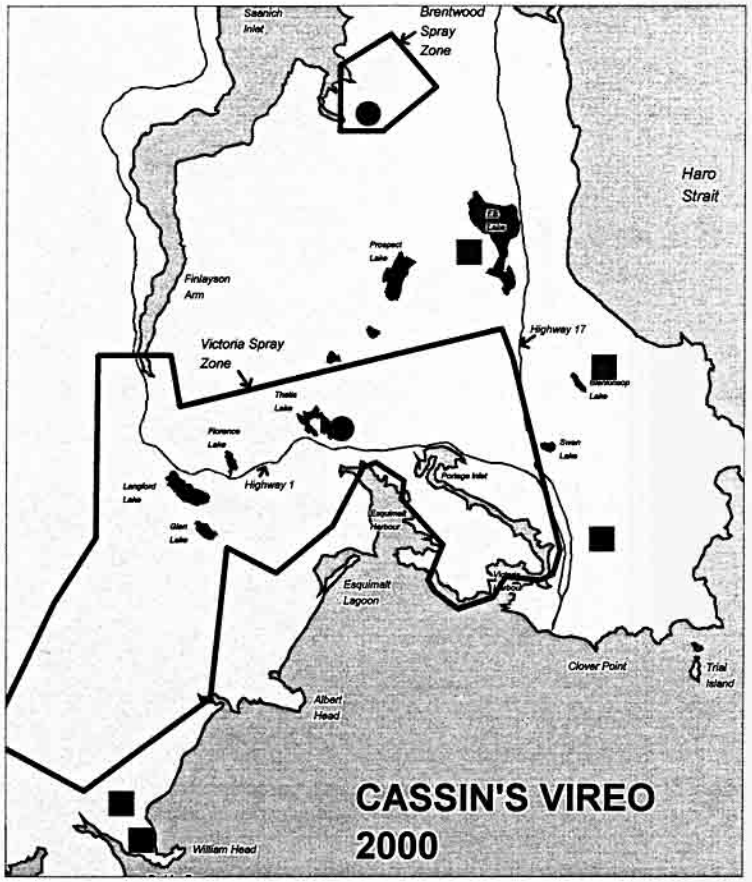
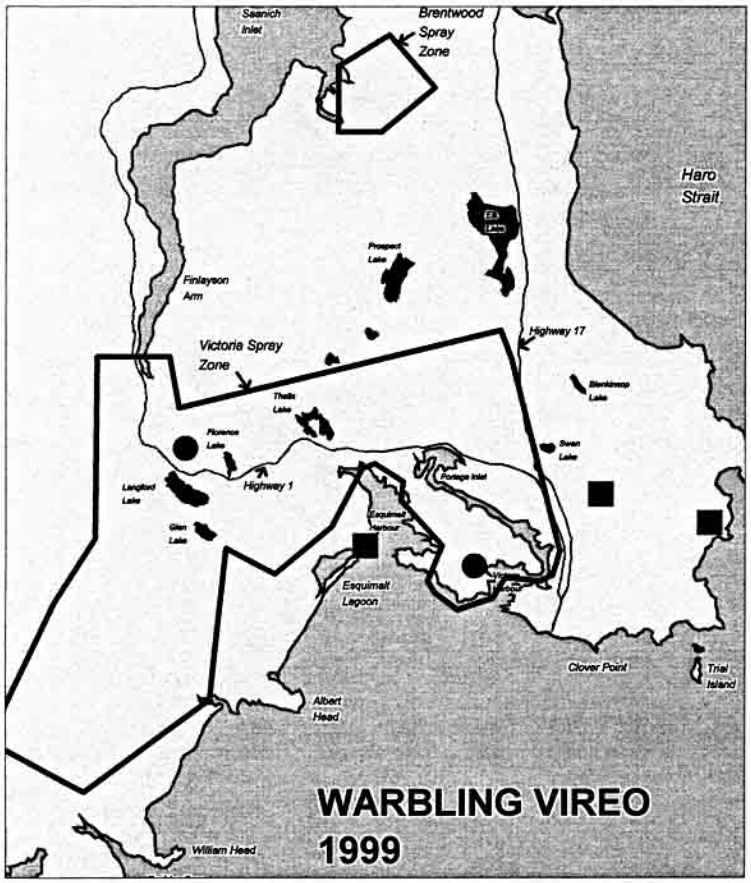


Figure 3e. Distribution of Western Tanager and Bushtit in relation to Btk spray zones, spring 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







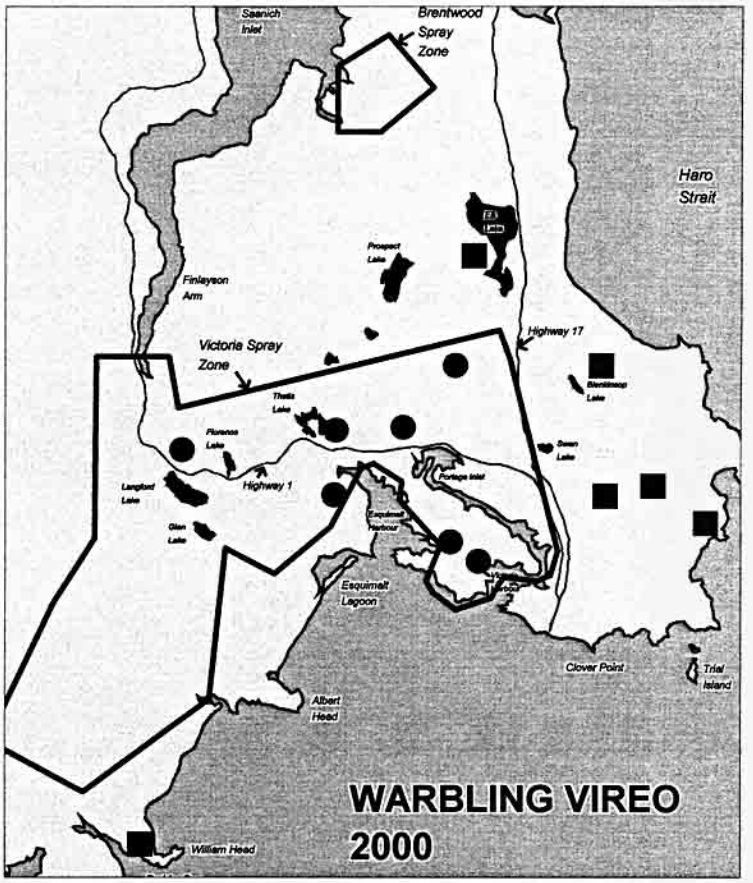
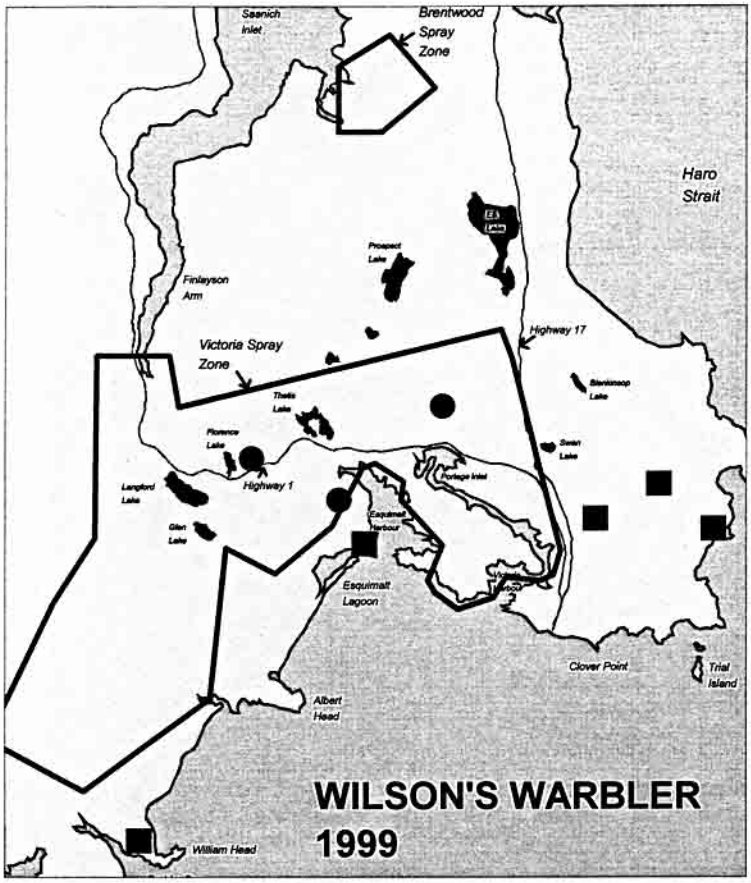
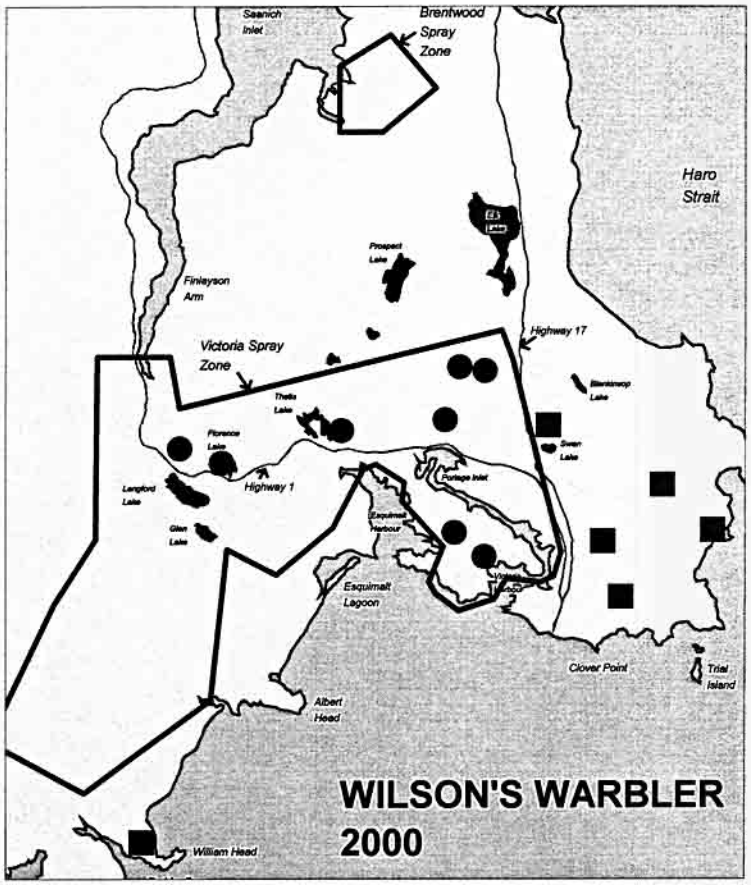
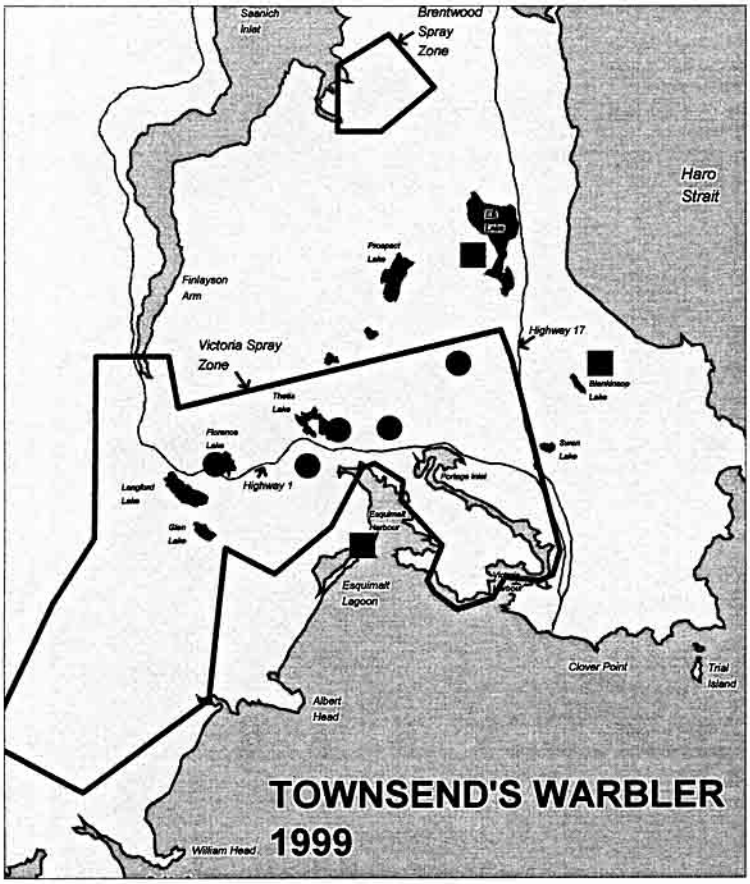


Figure 3f. Distribution of Cassin's and Warbling Vireos in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







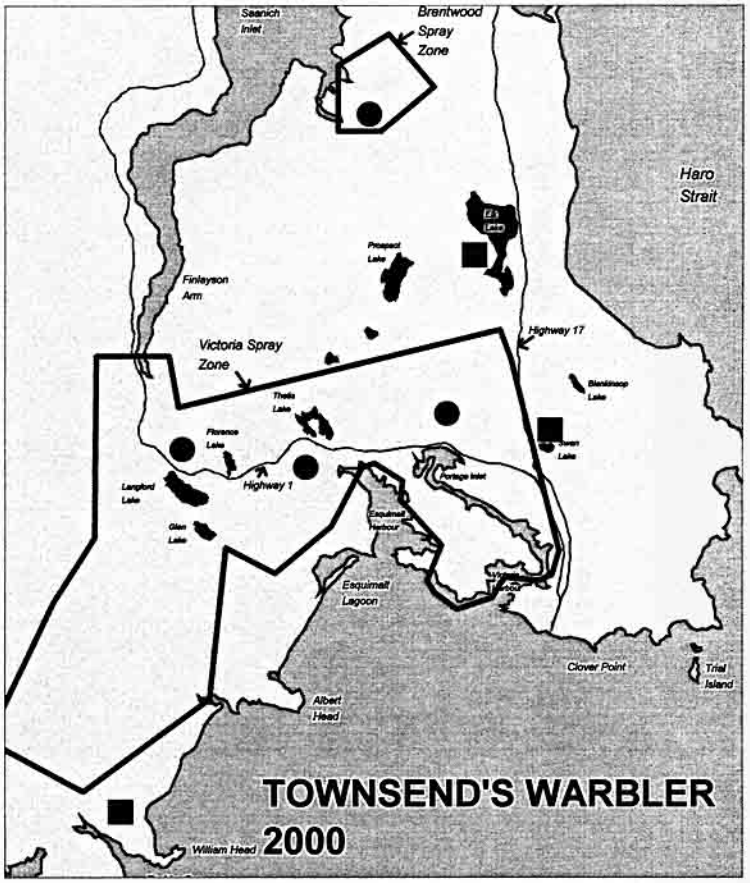
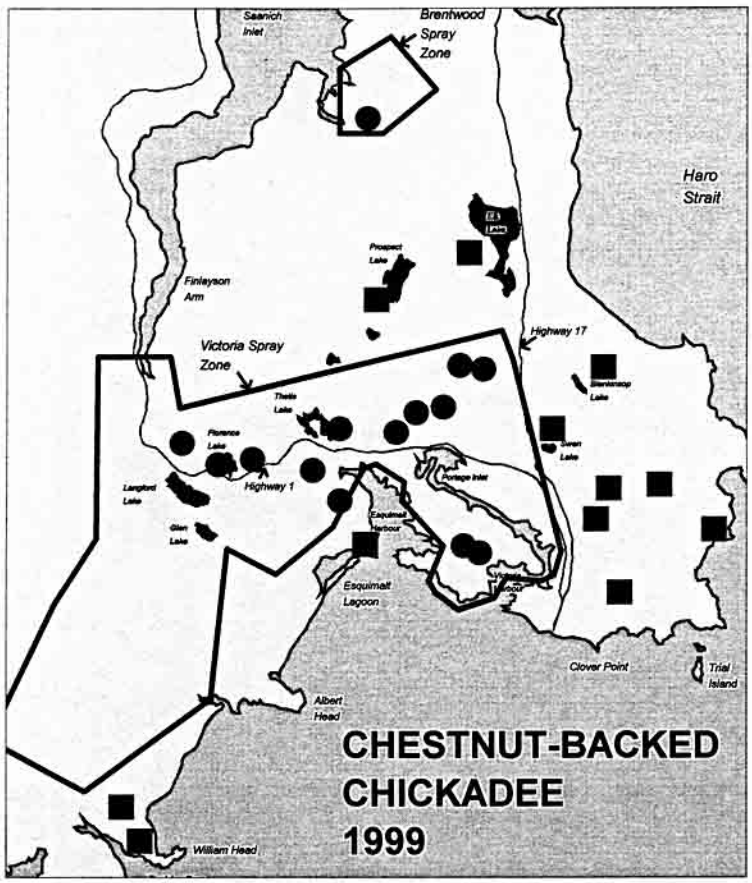
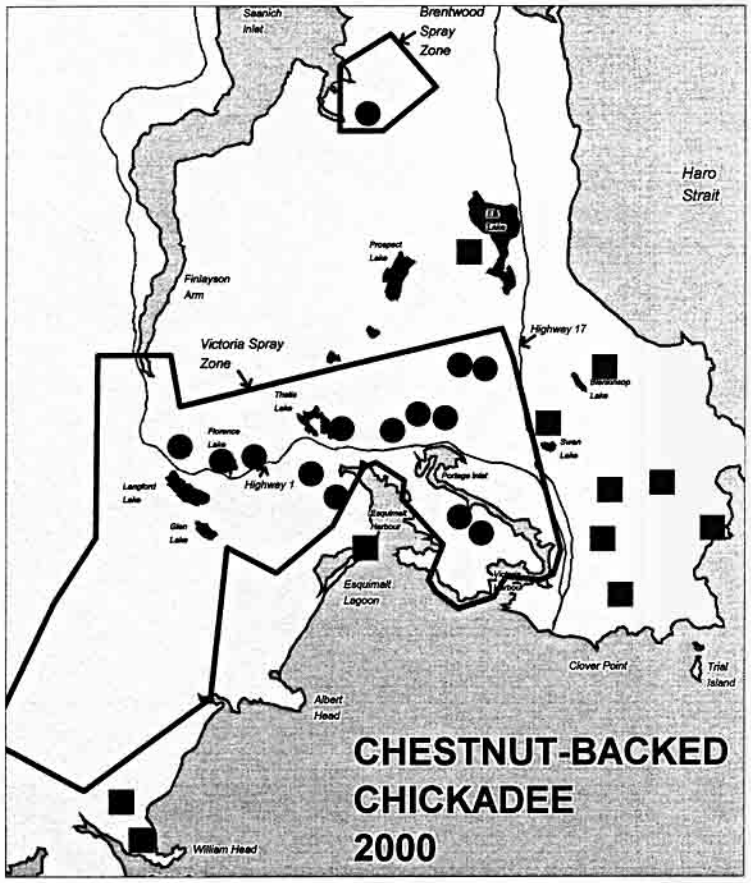
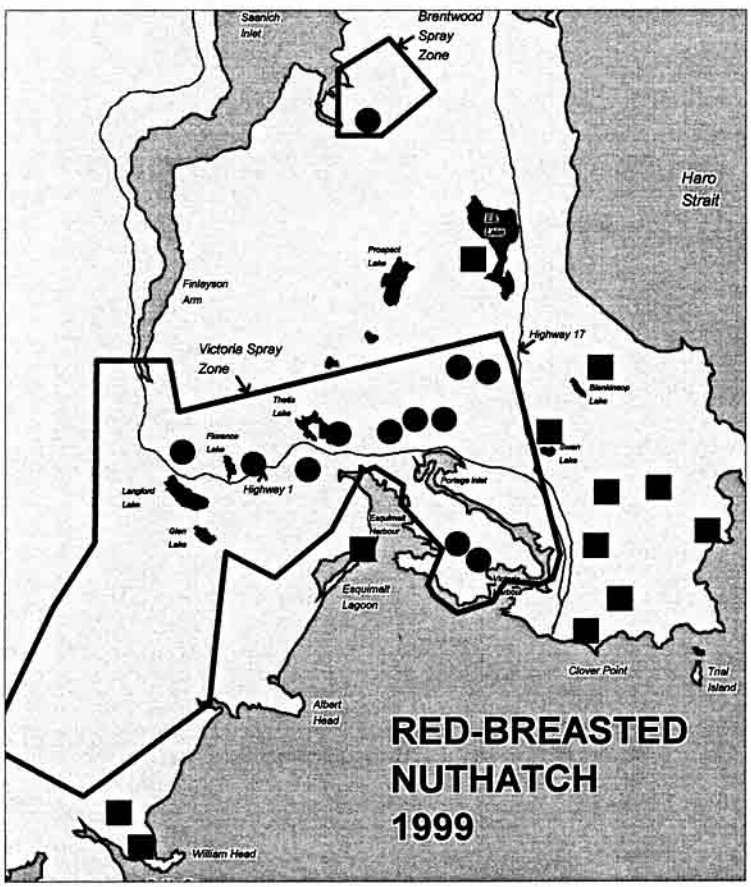


Figure 3g. Distribution of Wilson's and Townsend's Warblers in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square (unsprayed areas) symbols.







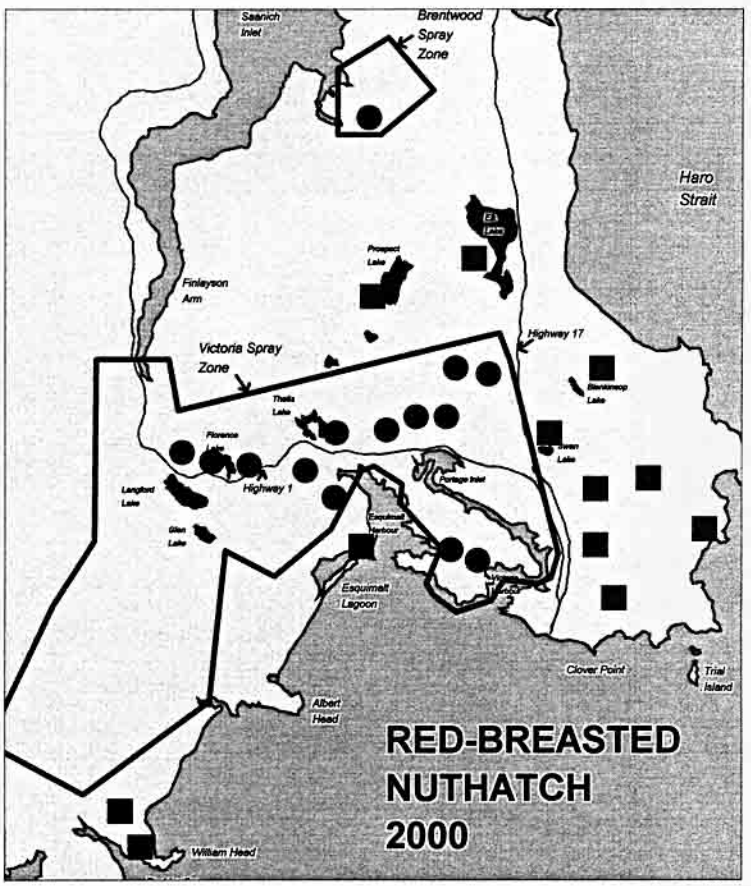


Figure 3h. Distribution of Chestnut-backed Chickadee and Red-breasted Nuthatch in relation to Btk spray zones, 1999 and 2000. Sites where species was present during any point-count or brood survey are shown by round (sprayed areas) and square symbols.

Figure 4a. Total number of adult songbirds detected on Btk-sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

A. Species with a moderate proportion of caterpillars in the diet.

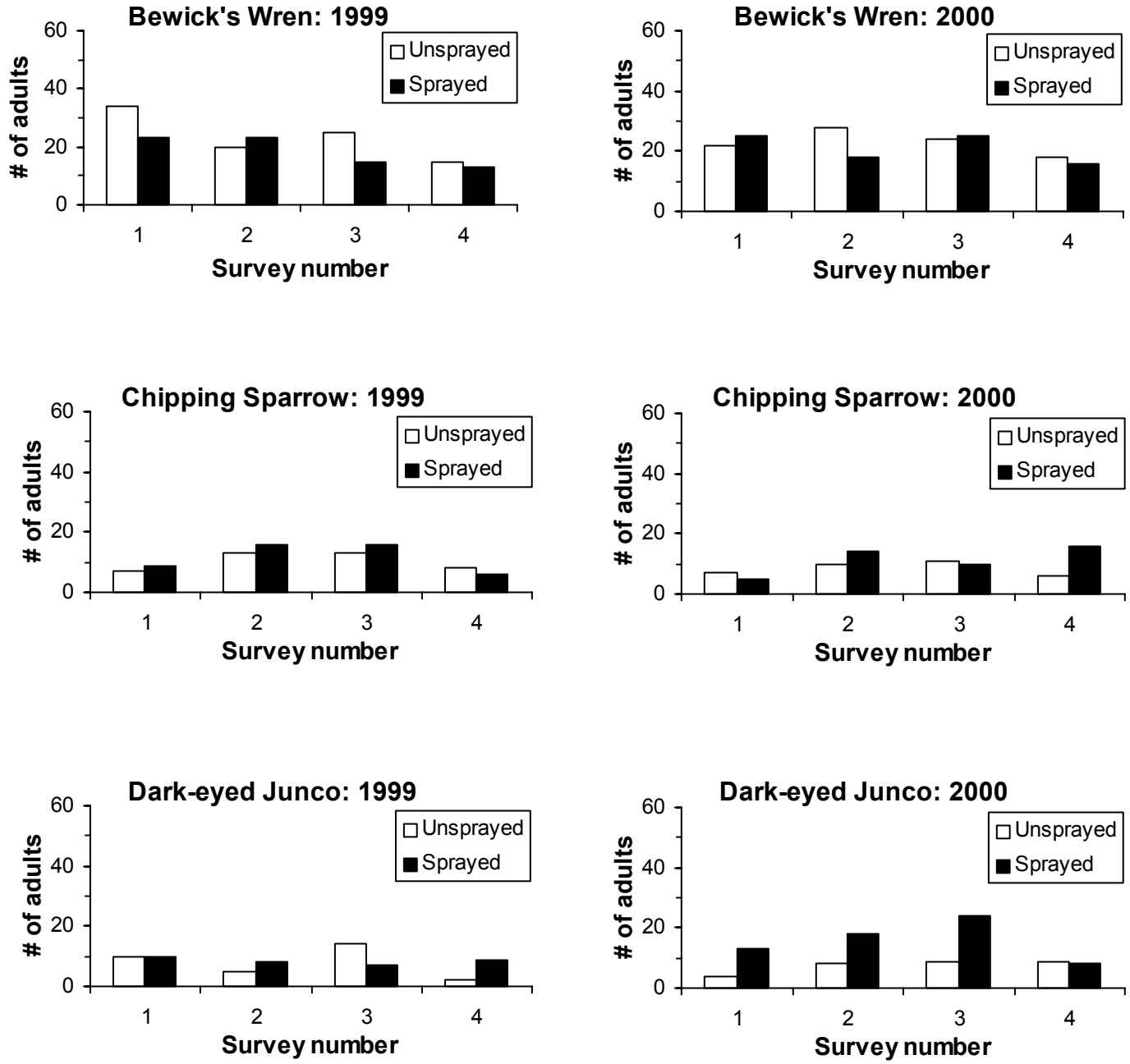
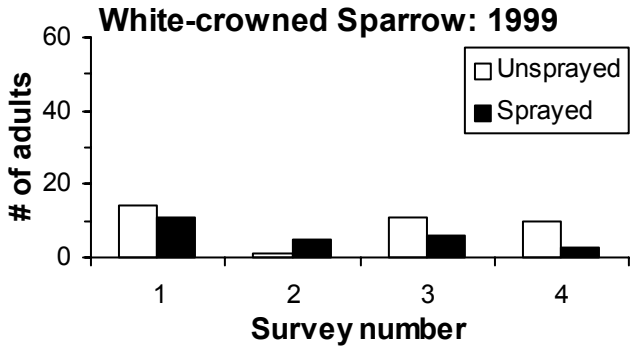
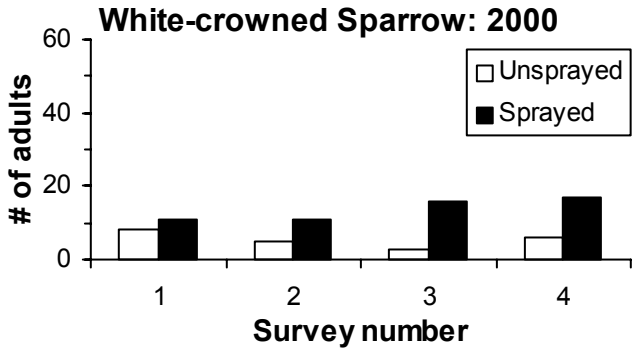
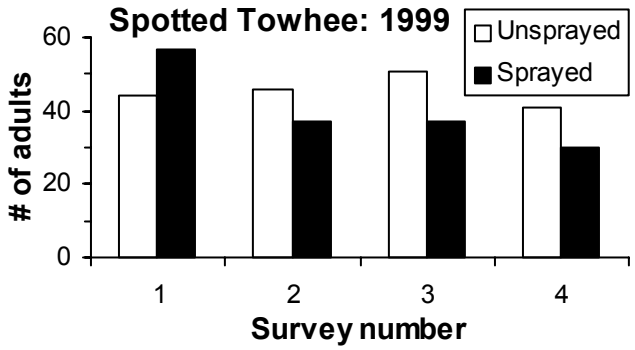


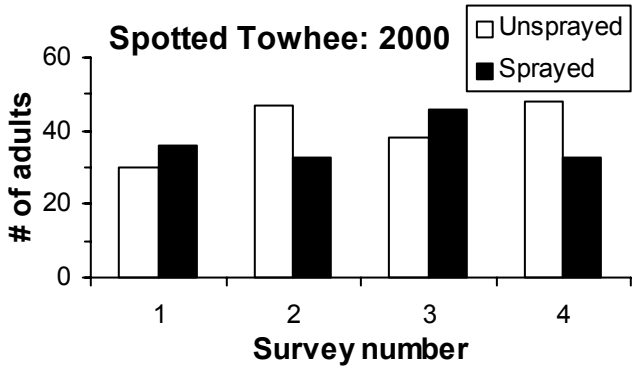
Figure 4b. Total number of adult songbirds detected on Btk-sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

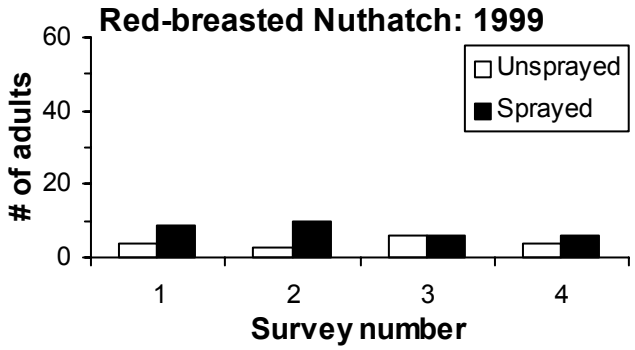
A. Species with a moderate proportion of caterpillars in the diet (continued)











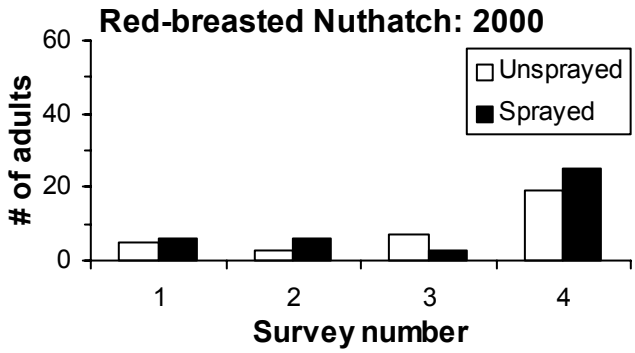
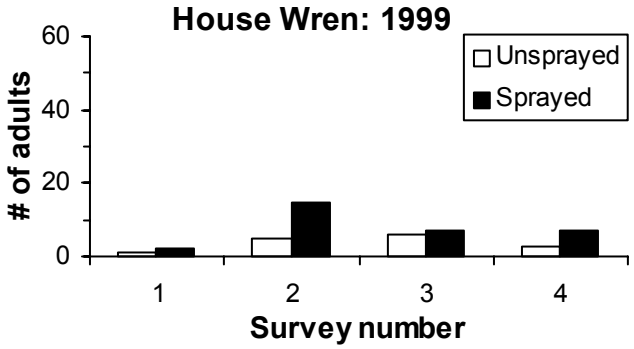
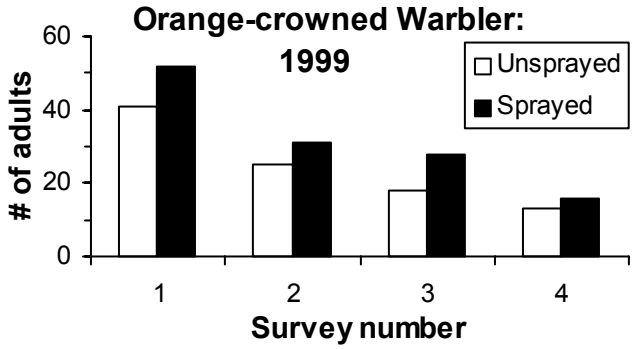


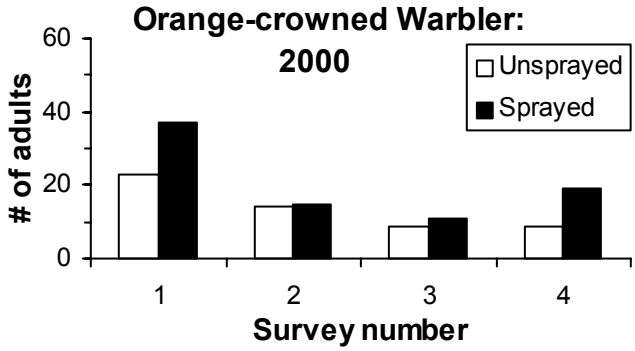
Figure 4c. Total number of adult songbirds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

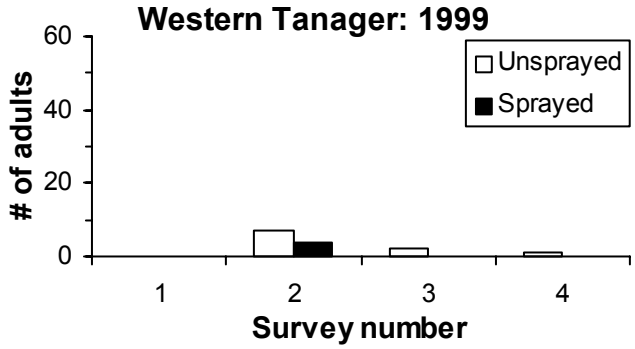
A. Species with a moderate proportion of caterpillars in the diet (continued)



B. Species with a high proportion of caterpillars in the diet







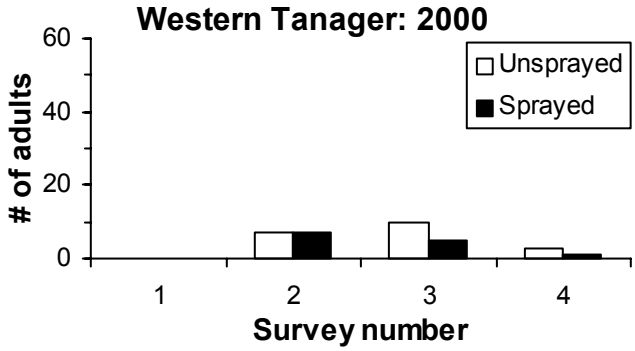
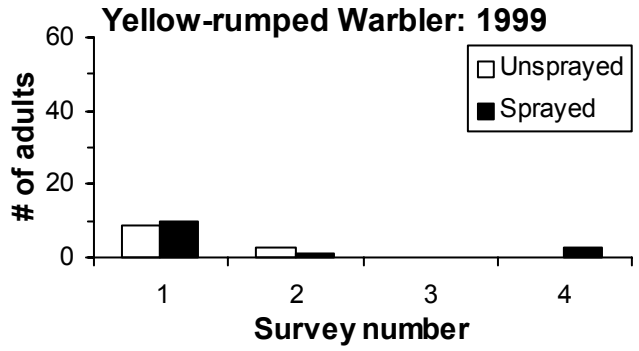
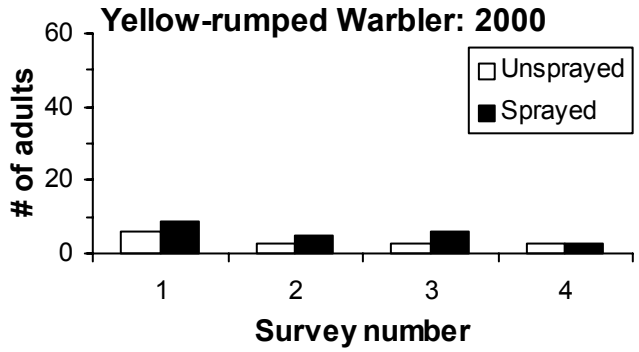
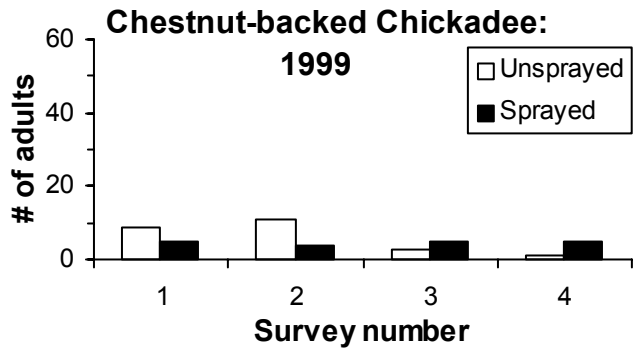


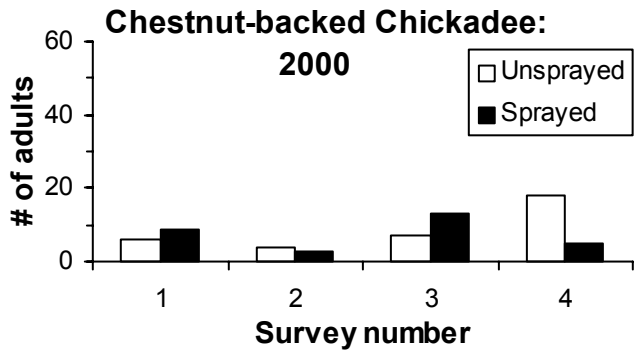
Figure 4d. Total number of adult songbirds detected on Btk-sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

B. Species with a high proportion of caterpillars in the diet (continued)

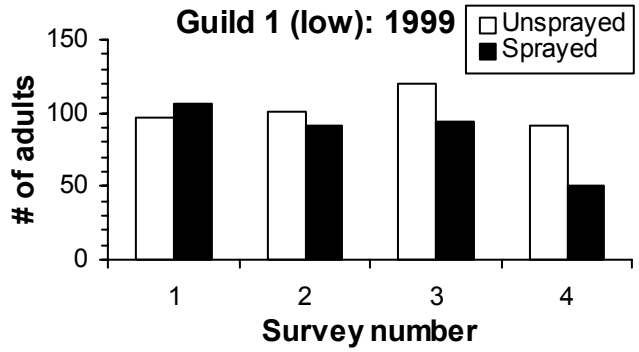








C. Totals for Guild 1 (Species with a low proportion of caterpillars in the diet)



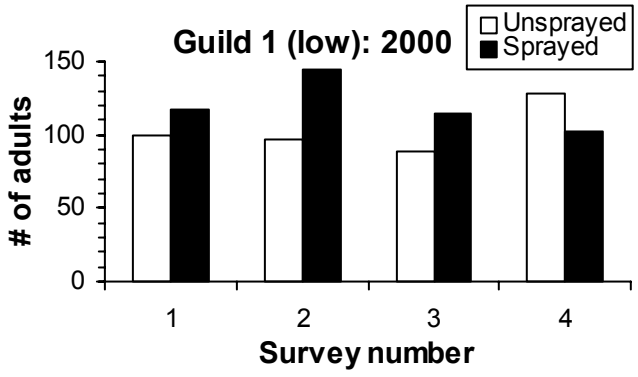
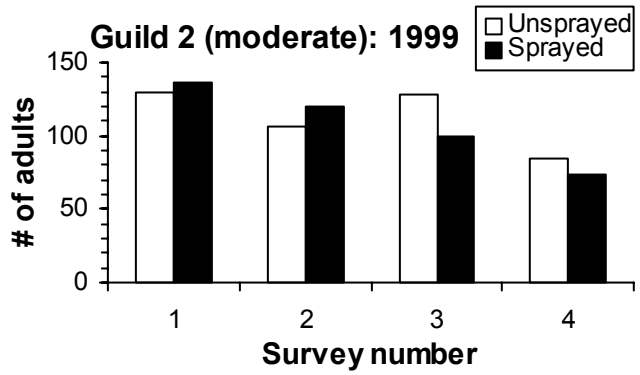
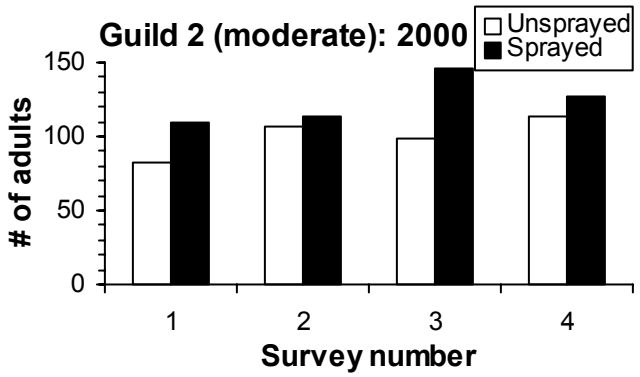


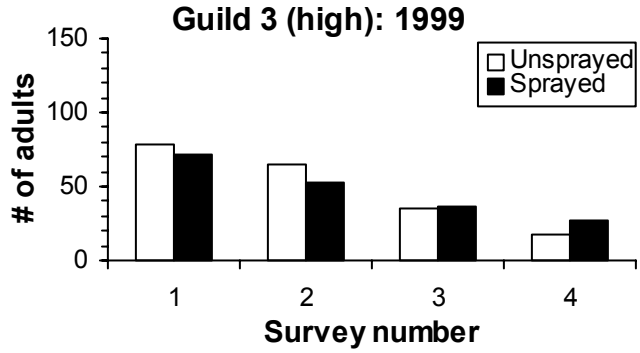
Figure 4e. Total number of adult songbirds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

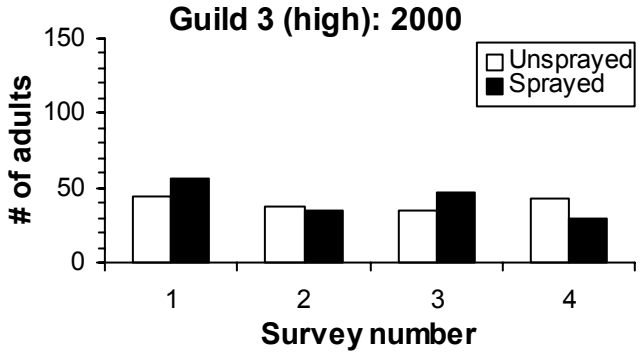
C. Totals for Guild 2 (Species with a moderate proportion of caterpillars in the diet)



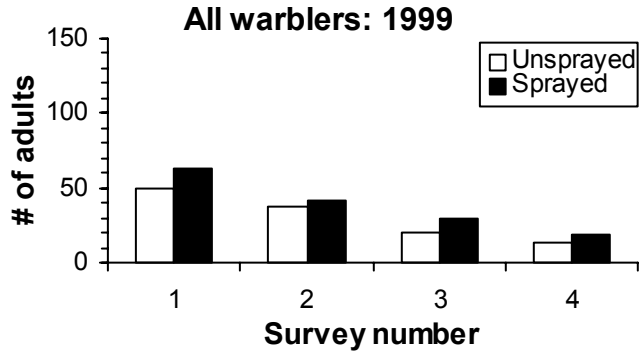


D. Totals for Guild 3 (Species with a high proportion of caterpillars in the diet)





E. Totals for all warbler species within Guild 3



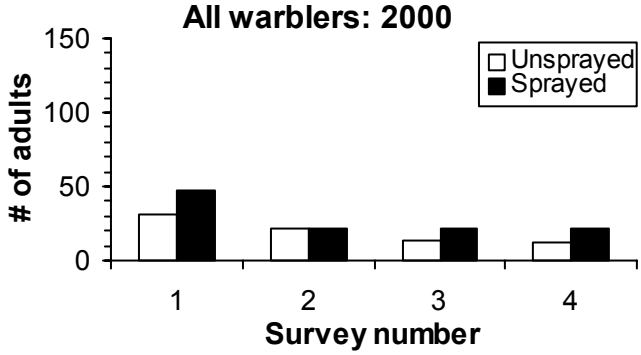
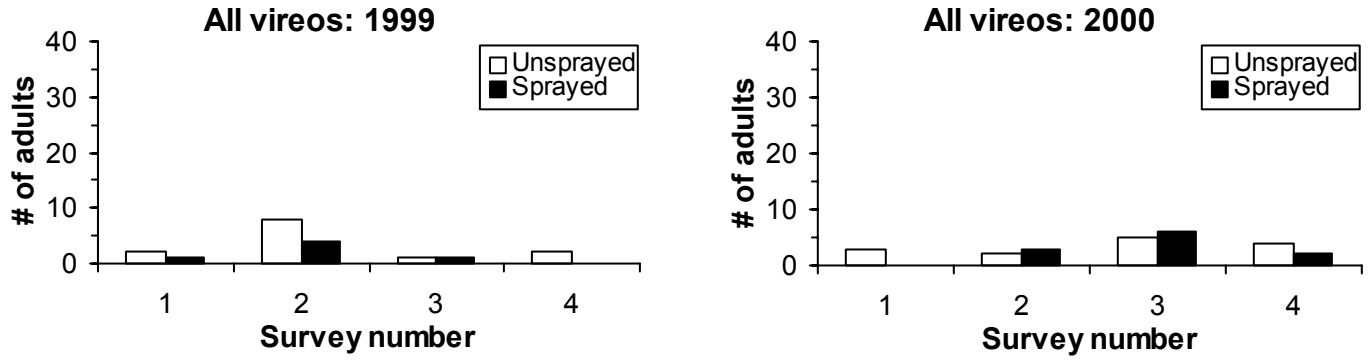


Figure 4f. Total number of adult songbirds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. The first survey in 1999 was before spraying, which took place May-June 1999. See methods for survey dates.

F. Totals for all vireo species within Guild 3



During brood-surveys in 1999 and 2000, we observed consistently lower total numbers of adult (or independent juvenile) Bushtits in the Btk-sprayed than unsprayed plots (Table 2a, b). Bushtits often occurred in flocks, and we observed nine flocks of $\geq$10 birds in the unsprayed areas during the brood-surveys in 1999 and 2000; we saw no flocks of this size in the sprayed areas during the surveys. These larger flocks inflated the total counts for the sprayed areas and resulted in high variance among plots. A comparison of the mean number of Bushtits per plot detected during brood surveys showed no differences that could be accounted to spray-status (Anova with repeated measures for 1999 and 2000 combined: $F_{1,13} = 2.54$, $P = 0.12$; only those plots where the species was found during any of the 4 brood-surveys, 19 unsprayed and 9 Btk-sprayed, were included in the analyses). We observed fewer Chestnut-backed Chickadees on sprayed than unsprayed plots during the first brood-survey in 1999, but the difference was not consistent among surveys. The data obtained during brood surveys showed no other differences in numbers of adults for the species in Foraging Guilds 2 or 3 that would suggest adverse effects of the Btk-treatment.

From the point-count data, sufficient numbers of observations existed for five individual species from Guilds 2 and 3 (Spotted Towhee, Bewick's Wren, White-crowned Sparrow, Chipping Sparrow, Orange-crowned Warbler) and for groupings of other species (other Guild 2 species, other Guild 3 migrants, Bushtit and Chestnut-backed Chickadee combined) to compare the mean number of adult birds per plot across surveys between Btk-sprayed and unsprayed areas. This allowed a detailed analysis of patterns in the data across surveys.

During the post-spraying surveys in 2000, we detected fewer Orange-crowned Warblers but more other Guild 3 migrants (other warblers, vireos, and the Western Tanager grouped together) per plot than during the corresponding period in 1999 (Figure 5b, c; significant "Year" effect in Appendix C). The numbers of these birds per plot also declined as the season progressed (significant "Time" effect in Appendix C). However, these annual and seasonal trends were similar in both sprayed and unsprayed areas. For most species, the number of birds per plot varied among sites within both sprayed

Table 2a. Number of adult songbirds encountered on Btk-sprayed and unsprayed study plots during brood-surveys in June 1999. # of plots = 29 sprayed and 29 unsprayed. See Appendix B for explanations of species codes. Letters denote values that are significantly different at alpha = 0.025 (0.05/2); sprayed<unsprayed (upper case).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	CEWA	EUST	HOFI	HOSP	PISI	PUFI	Total
Unsprayed	1	3	62	24	6	25	7	11	6	5	149
Sprayed	1	5	68	20	6	17	6	9	8	0	139
Unsprayed	2	2	67	8	8	49	29[A]	8	5	0	176[B]
Sprayed	2	1	50	14	5	40	5[A]	7	2	0	124[B]
Total		11	247	66	25	131	47	35	21	5	588

B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	CHSP	DEJU	HOWR	RBNU	RWBL	SPTO	SWTH	WCSP	Total
Unsprayed	1	29	48	22	4	15[C]	0	75	1	31[D]	225[F]
Sprayed	1	28	30	21	5	3[C]	2	57	3	7[D]	156[F]
Unsprayed	2	18	26	19	5	9	0	64	0	23[E]	164
Sprayed	2	30	38	31	12	14	2	54	2	2[E]	185
Total		105	142	93	26	41	4	250	6	63	730

C. Guild 3 (high proportion of caterpillars in diet)

Spray status	Survey #	BUSH	BGWA	CAVI	CBCH	OCWA	TOWA	WIWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	35[G]	0	2	56[I]	54	0	2	2	151[J]	58	2
Sprayed	1	1[G]	1	0	32[I]	42	1	0	3	80[J]	47	0
Unsprayed	2	92[H]	0	1	58	31	0	2	0	184[K]	33	1
Sprayed	2	22[H]	0	0	74	28	0	0	5	129[K]	33	0
Total		150	1	3	220	155	1	4	10	544	171	3

Table 2b. Number of adult songbirds encountered on Btk-sprayed and unsprayed study plots during brood-surveys in May-June 2000. # of plots = 30 sprayed and 30 unsprayed. See Appendix B for explanations of species codes. Letters denote values that are significantly different at alpha = 0.025 (0.05/2); sprayed<unsprayed (upper case); sprayed>unsprayed (lower case).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	CEWA	EUST	HOFI	HOSP	PISI	PUFI	Total
Unsprayed	1	8	48	22	2	11[b]	27	18[D]	49[e]	1	186[g]
Sprayed	1	2	71	33	2	35[b]	14	1[D]	142[e]	0	300[g]
Unsprayed	2	2	55	26	2[a]	17	31[C]	14	160[F]	0	*207
Sprayed	2	3	68	31	12[a]	16	10[C]	6	36[F]	0	182
Total		15	242	112	18	79	82	39	387	1	*875

* A flock of 100 PISI was excluded from the guild total

B. Guild 2 (moderate proportion of caterpillars in diet)

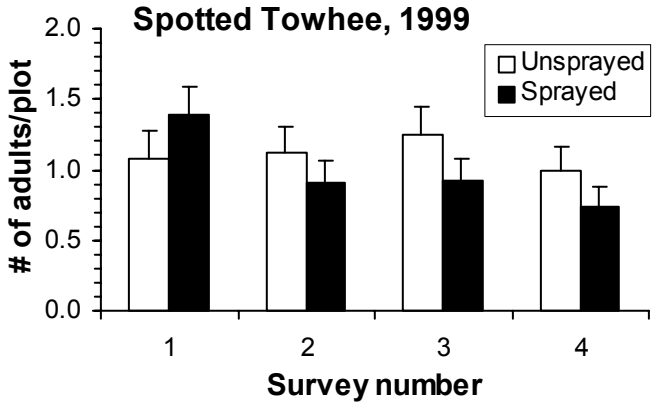
Spray status	Survey #	BEWR	CHSP	DEJU	HOWR	RBNU	RWBL	SOSP	SPTO	SWTH	WCSP	WIWR	Total
Unsprayed	1	32	37	23[h]	2	21	0	0	58	2	25	1	201
Sprayed	1	26	53	43[h]	10	18	1	1	69	3	17	0	241
Unsprayed	2	39	27	20[i]	5	20	0	0	61	0	13	0	185[j]
Sprayed	2	34	32	42[i]	13	25	1	2	59	1	25	0	234[j]
Total		131	149	128	30	84	2	3	247	6	80	1	861

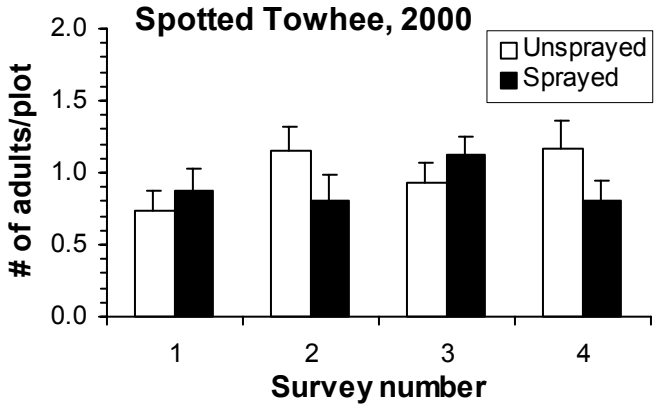
C. Guild 3 (high proportion of caterpillars in diet)

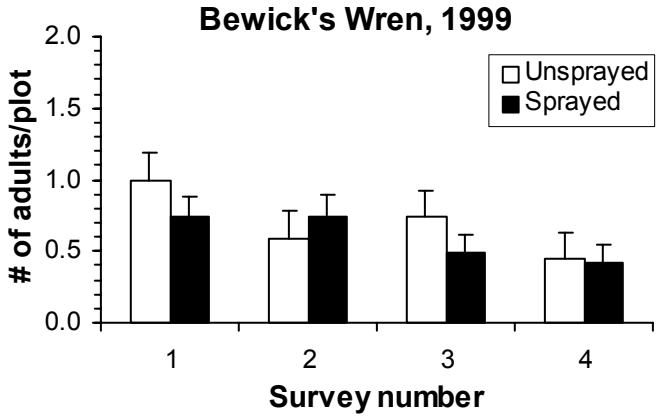
Spray status	Survey #	BUSH	CAVI	CBCH	GCKI	MGWA	OCWA	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	64[K]	1	62	1	0	40	3	2	3	5	9	3	193	60	3
Sprayed	1	17[K]	1	75	0	2	48	2	0	3	8	0	6	162	66	1
Unsprayed	2	71[L]	2	88	0	0	33	0	1	0	1	0	3	199	37[m]	3
Sprayed	2	12[L]	3	100	0	0	51	4	3	0	1	0	6	180	62[m]	6
Total		164	7	325	1	2	172	9	6	6	15	9	18	734	225	13

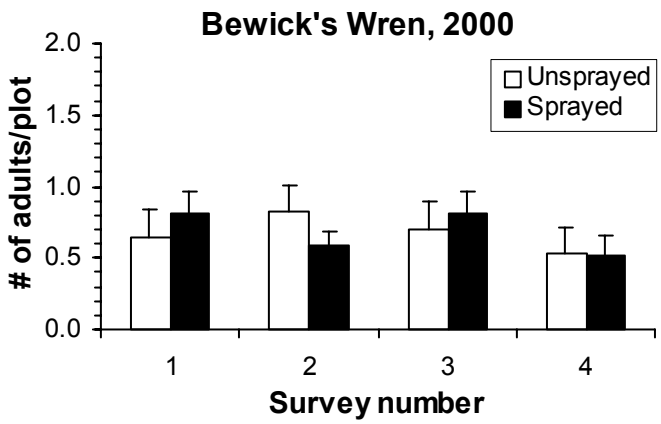
Figure 5a. Mean number of adults per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

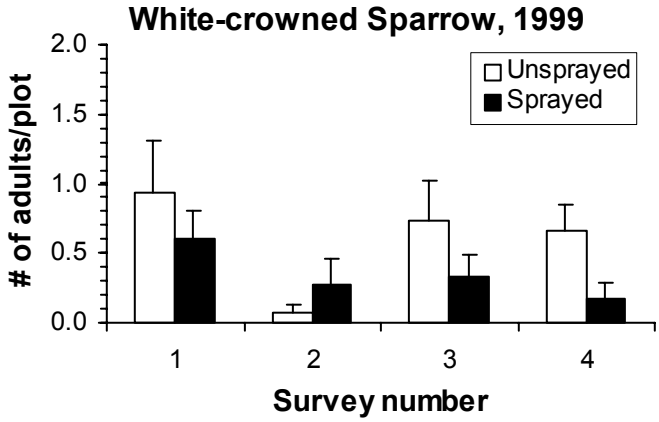
A. Species with a moderate proportion of caterpillars in the diet











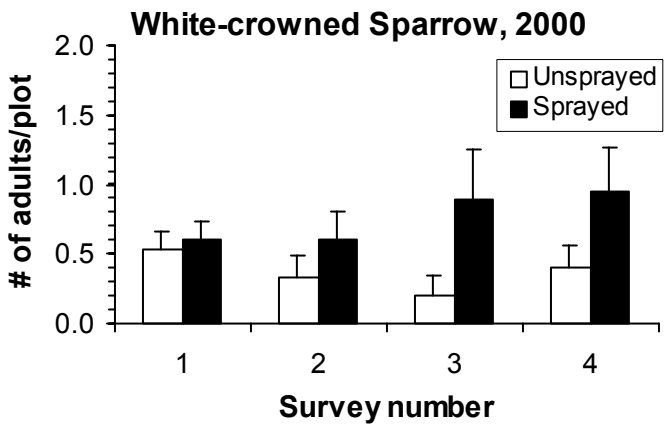
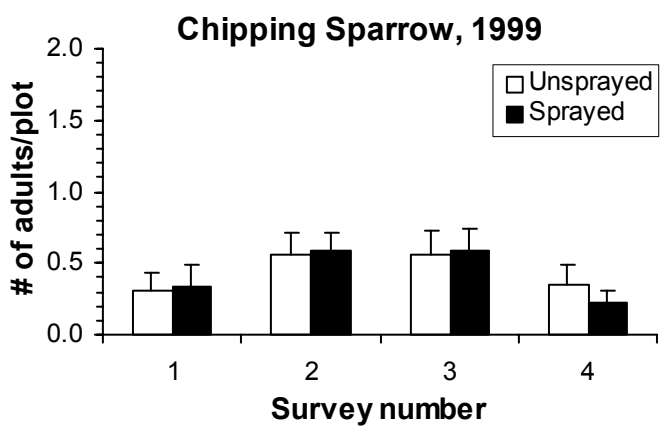
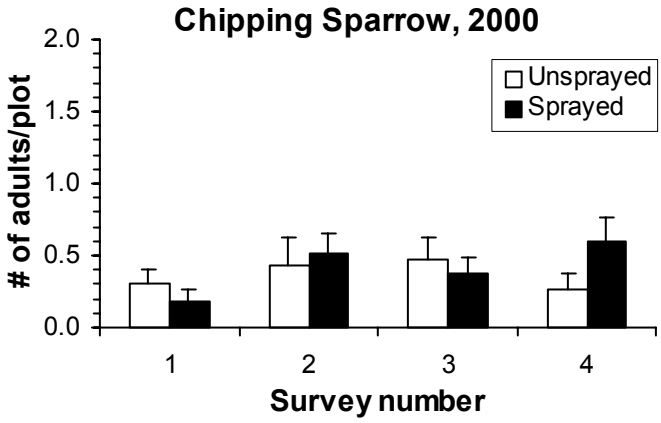


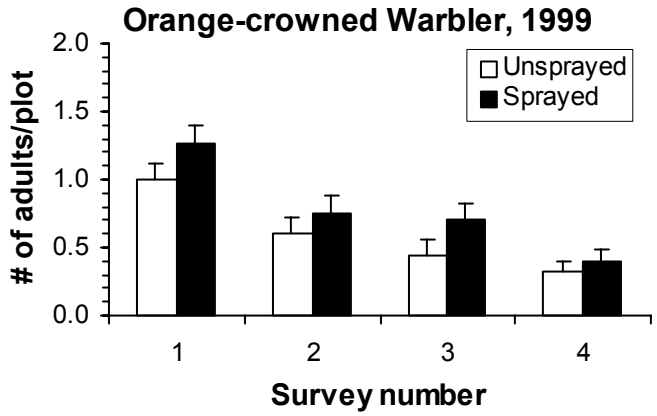
Figure 5b. Mean number of adults per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

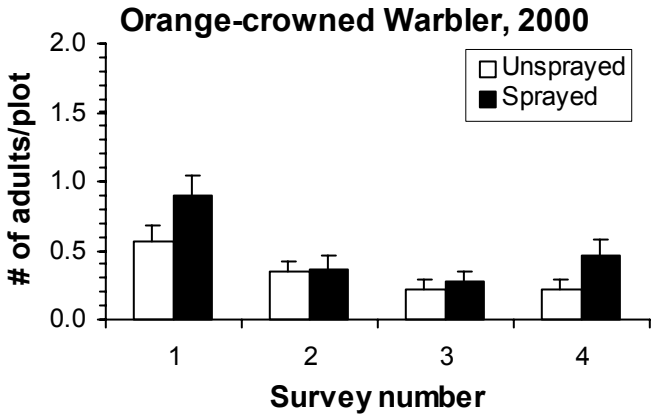
A. Species with a moderate proportion of caterpillars in the diet (continued)



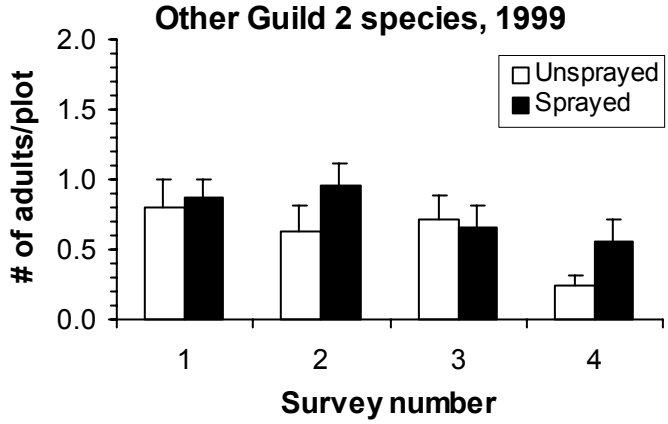


B. Species with a high proportion of caterpillars in the diet





C. Totals for remaining Guild 2 species (moderate proportion of caterpillars in the diet)



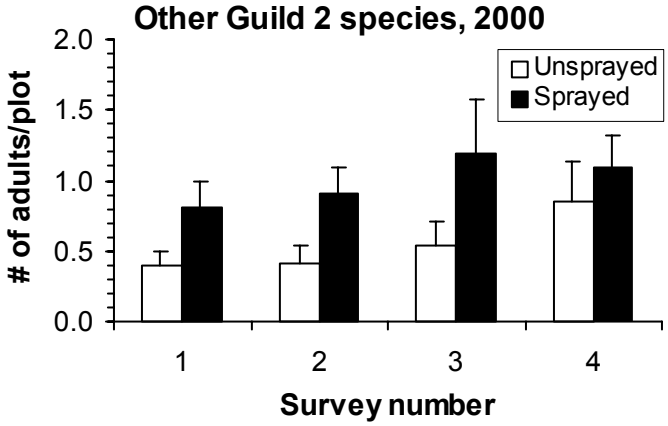
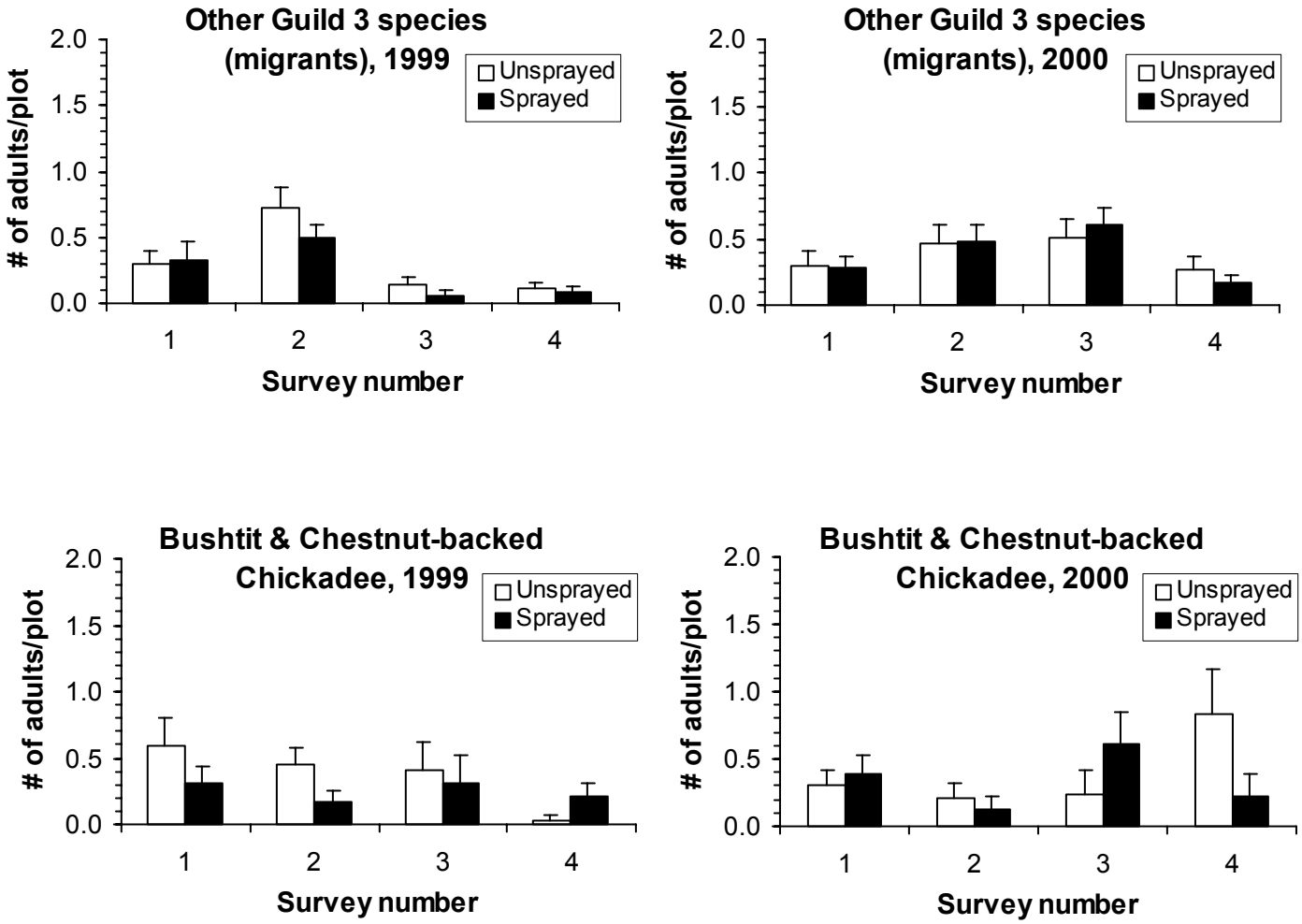


Figure 5c. Mean number of adults per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

D. Totals for other Guild 3 species (high proportion of caterpillars in the diet)



and unsprayed areas, possibly as a result of subtle differences in habitat suitability (significant "Site" effect in Appendix C).

With respect to spray-status, there were no significant differences in the mean number of birds per plot for four of the five species examined (Bewick's Wren, White-crowned Sparrow, Chipping Sparrow, and Orange-crowned Warbler) or for groupings of the remaining Guild 2 or 3 species in either 1999 or 2000 or when the three post-spraying surveys in the two years were considered together (Figure 5a-c; see Appendix C for statistical values). A significant difference in the linear trend among post-spraying surveys in 1999 existed for the group consisting of the Bushtit and Chestnut-backed Chickadee (Appendix C), but the pattern was not consistent with adverse effects of the Btk-treatment (a decline over time on unsprayed plots only; Figure 5c). The Spotted Towhee was an exception, and the mean number of adult birds per plot in 1999 was lower in the Btk-sprayed than unsprayed plots after Btk-application when compared to corresponding values during the pre-spraying survey (Figure 5a; Appendix C). The comparison was significant both when actual and ranked values of the data were used, indicating robustness of the result ($F_{1,54}$ = 8.40, P = 0.005 with actual values; $F_{1,54}$ = 9.71, P = 0.003 with ranked values). In 2000, however, we detected no differences between sprayed and unsprayed plots for the Spotted Towhee; nor could we detect any differences attributable to spray-status when we compared the three post-spraying surveys in the two years together (Figure 5a; Appendix C).

3.2 Patterns of territory maintenance

The total numbers of singing birds detected during each point-count survey showed no differences consistent with adverse effects of the Btk-treatment for any individual species examined or for species grouped into foraging guilds (Table 3a, b; Figure 6a-e). However, as for all adult birds, the numbers of singing Spotted Towhees were somewhat lower in the sprayed than unsprayed areas during each of the three post-spraying surveys in 1999 but not in 2000 (Figure 6b). The data from the two post-spraying brood-surveys showed a similar, but also statistically non-significant pattern for

Table 3a. Number of singing males encountered on Btk-sprayed and unsprayed study plots during point-count surveys in April-June 1999. See Appendix B for explanations of species codes. None of the comparisons between sprayed and unsprayed areas were significant at alpha = 0.0125 (0.05/4).

A. Guild 1 (low proportion of caterpillars in diet)

Spray status	Survey #	AMGO	AMRO	BHCO	EUST	HOFI	PUFI	HOSP	Total
Unsprayed	1	0	18	2	0	16	1	0	37
Sprayed	1	0	24	6	3	8	7	0	48
Unsprayed	2	5	19	3	0	10	0	1	38
Sprayed	2	1	19	0	2	5	6	0	33
Unsprayed	3	2	18	2	0	10	1	1	34
Sprayed	3	0	21	1	1	6	1	0	30
Unsprayed	4	0	5	1	0	8	1	0	15
Sprayed	4	1	7	4	1	6	3	0	22
Total		9	131	19	7	69	20	2	257

B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	BHGR	CHSP	DEJU	GCSP	HOWR	RWBL	SOSP	SPTO	SWTH	VATH	WCSP	WIWR	Total
Unsprayed	1	30	0	6	4	0	0	0	0	14	0	2	13	2	71
Sprayed	1	20	0	7	3	0	1	1	1	30	0	2	11	2	78
Unsprayed	2	20	1	9	2	1	5	0	2	27	1	0	1	0	69
Sprayed	2	23	1	14	3	0	13	0	1	22	0	1	5	0	83
Unsprayed	3	24	1	9	4	0	6	0	0	34	0	0	6	1	85
Sprayed	3	13	0	9	3	0	5	0	0	24	6	0	2	1	63
Unsprayed	4	15	0	7	1	0	3	0	1	33	0	0	6	0	66
Sprayed	4	12	0	5	7	0	7	0	0	24	4	0	3	0	62
Total		157	3	66	27	1	40	1	5	208	11	5	47	6	577

C. Guild 3 (high proportion of caterpillars in diet)

Spray status	Survey #	CAVI	COYE	OCWA	RCKI	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	1	0	33	8	0	0	0	0	0	4	46	37	1
Sprayed	1	1	1	46	0	0	0	0	0	0	8	56	55	1
Unsprayed	2	2	0	22	0	1	4	0	0	5	0	34	28	6
Sprayed	2	2	0	25	0	5	2	2	3	0	1	40	34	4
Unsprayed	3	0	0	16	0	0	1	0	0	0	0	17	16	1
Sprayed	3	1	0	21	0	1	0	0	0	0	0	23	22	1
Unsprayed	4	1	0	11	0	1	1	0	0	0	0	14	12	2
Sprayed	4	0	0	12	0	0	0	0	0	0	3	15	15	0
Total		8	1	186	8	8	8	2	3	5	16	245	219	16

Table 3b. Number of singing males encountered on Btk-sprayed and unsprayed study plots during point-count surveys in April-June 2000. See Appendix B for explanations of species codes. Letters denote values that are significantly different at alpha = 0.0125 (0.05/4); sprayed>unsprayed (lower case).

A. Guild 1 (low proportion of caterpillars in diet)

Spray status	Survey #	AMGO	AMRO	BHCO	CEWA	EUST	HOFI	HOSP	PISI	PUFI	Total
Unsprayed	1	1	17	1	0	0	15	1	1	6	42
Sprayed	1	0	16	0	0	2	7	0	1	5	31
Unsprayed	2	0	13	2	0	0	10	1	1	0[a]	27[b]
Sprayed	2	2	31	2	0	3	5	0	0	11[a]	54[b]
Unsprayed	3	0	18	2	0	0	10	0	0	2	32
Sprayed	3	0	19	1	0	1	3	0	0	4	28
Unsprayed	4	1	8	0	0	0	6	0	0	5	20
Sprayed	4	1	16	3	0	0	6	0	0	3	29
Total		5	138	11	0	6	62	2	3	36	263

B. Guild 2 (moderate proportion of caterpillars in diet)

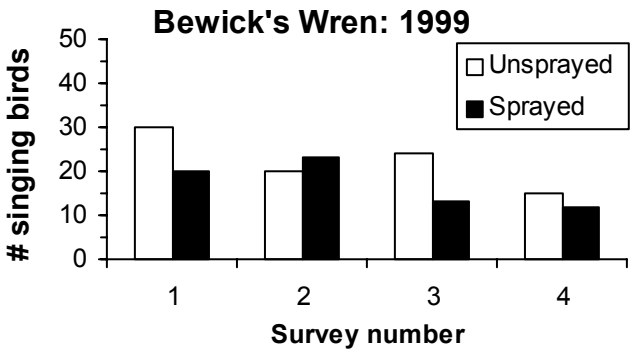
Spray status	Survey #	BEWR	CHSP	DEJU	GCSP	HETH	HOWR	RWBL	SAVS	SOSP	SPTO	SWTH	WCSP	WIWR	Total
Unsprayed	1	18	6	1	1	0	1	0	0	3	14	0	7	0	51
Sprayed	1	19	5	4	0	0	4	0	0	1	17	0	10	0	60
Unsprayed	2	23	6	3	0	0	2	0	0	2	34	0	4	0	74
Sprayed	2	17	10	3	0	0	10	1	0	1	23	0	6	1	72
Unsprayed	3	24	4	6	0	0	4	0	0	1	28	0	3	0	70
Sprayed	3	20	3	4	0	0	12	0	0	0	36	2	6	0	83
Unsprayed	4	17	5	2	0	0	2	0	0	2	32	1	6	1	68
Sprayed	4	12	6	3	0	0	6	0	0	0	22	4	8	0	61
Total		150	45	26	1	0	41	1	0	10	206	7	50	2	539

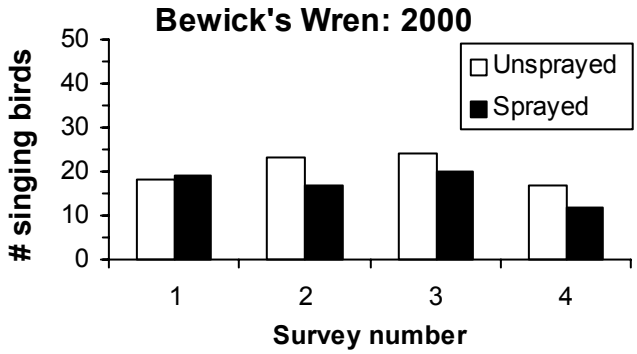
C. Guild 3 (high proportion of caterpillars in diet)

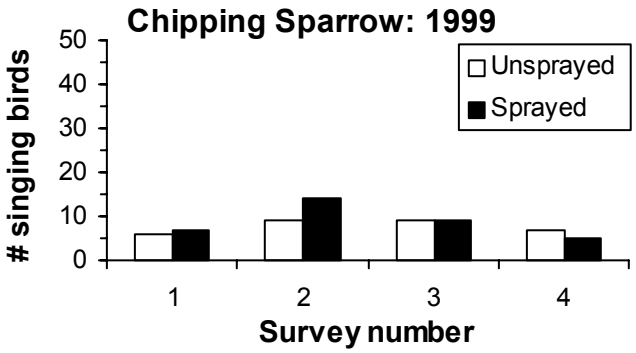
Spray status	Survey #	CAVI	HUVI	OCWA	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total	All warbler	All vireos
Unsprayed	1	3	0	22	2	0	0	0	0	2	29	26	3
Sprayed	1	0	0	30	0	0	0	0	0	9	39	39	0
Unsprayed	2	1	0	9	1	0	3	0	2	2	18	14	1
Sprayed	2	0	0	10	1	2	4	1	0	5	23	17	2
Unsprayed	3	2	0	5	1	3	5	0	0	1	17	7	5
Sprayed	3	0	1	8	2	4	3	2	1	4	25	17	5
Unsprayed	4	3	0	7	0	1	1	0	0	3	15	10	4
Sprayed	4	1	0	16	0	1	1	0	0	3	22	19	2
Total		10	1	107	7	11	17	3	3	29	188	149	22

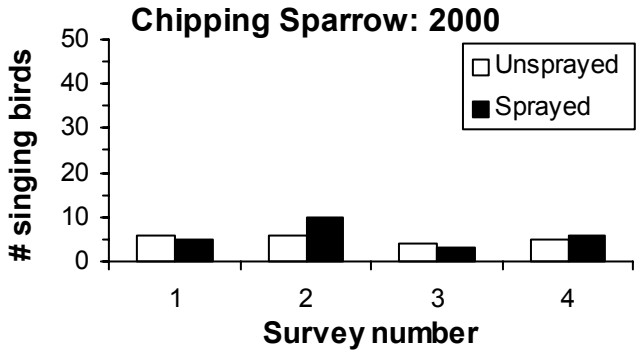
Figure 6a. Total number of singing birds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999. See methods for survey dates.

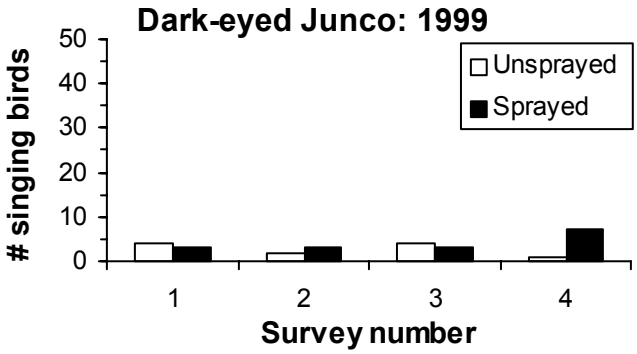
A. Species with a moderate proportion of caterpillars in the diet











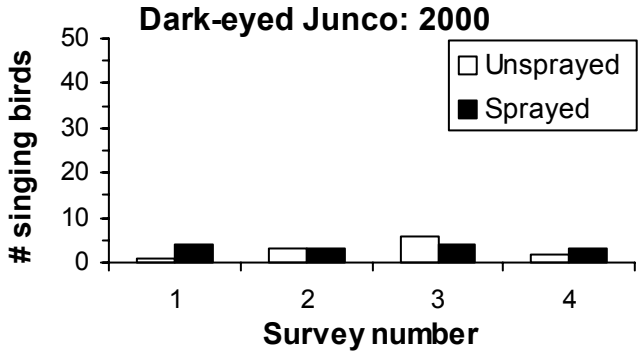


Figure 6b. Total number of singing birds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999. See methods for survey dates.

A. Species with a moderate proportion of caterpillars in the diet

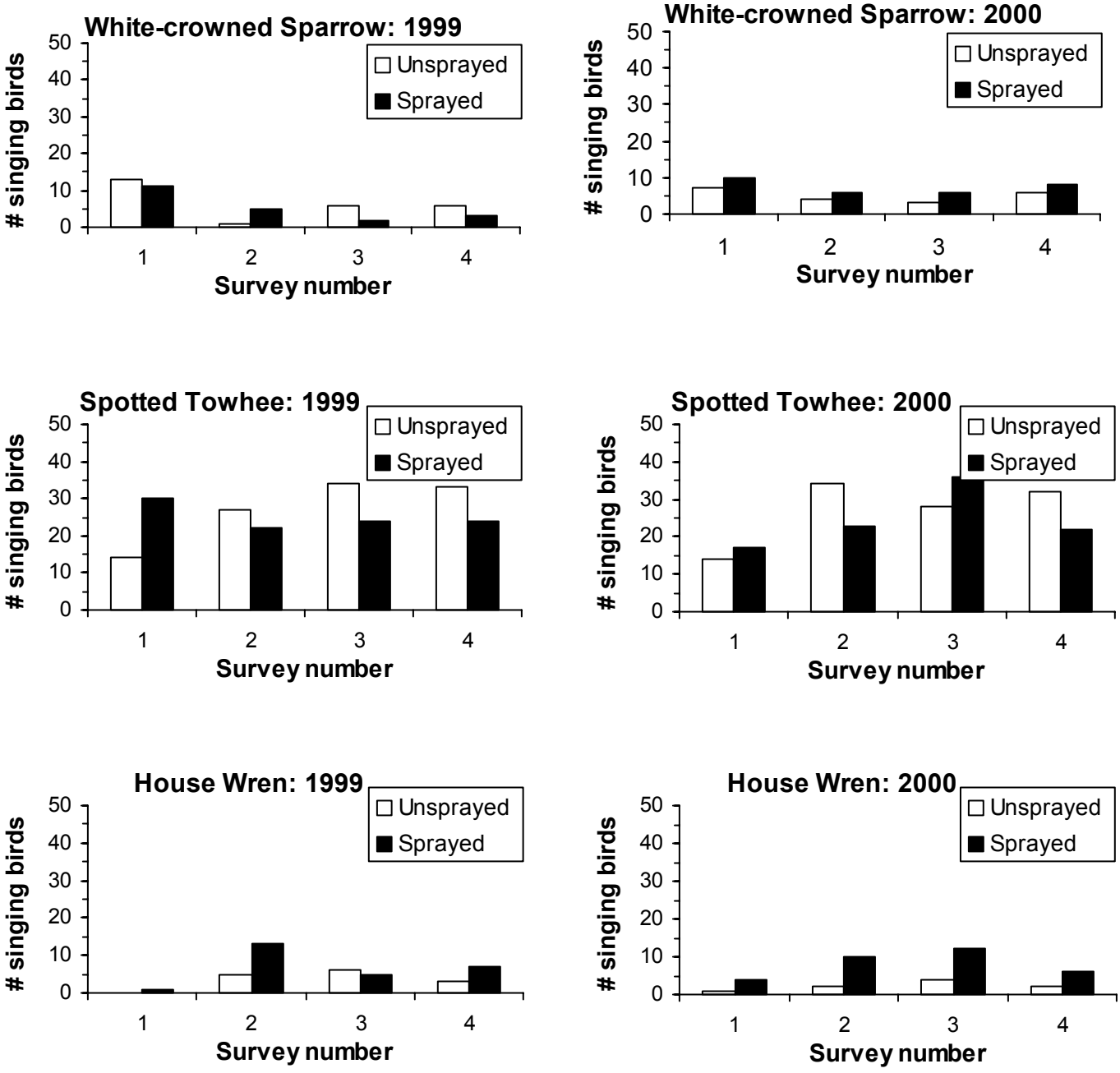


Figure 6c. Total number of singing birds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999. See methods for survey dates

B. Species with a high proportion of caterpillars in the diet

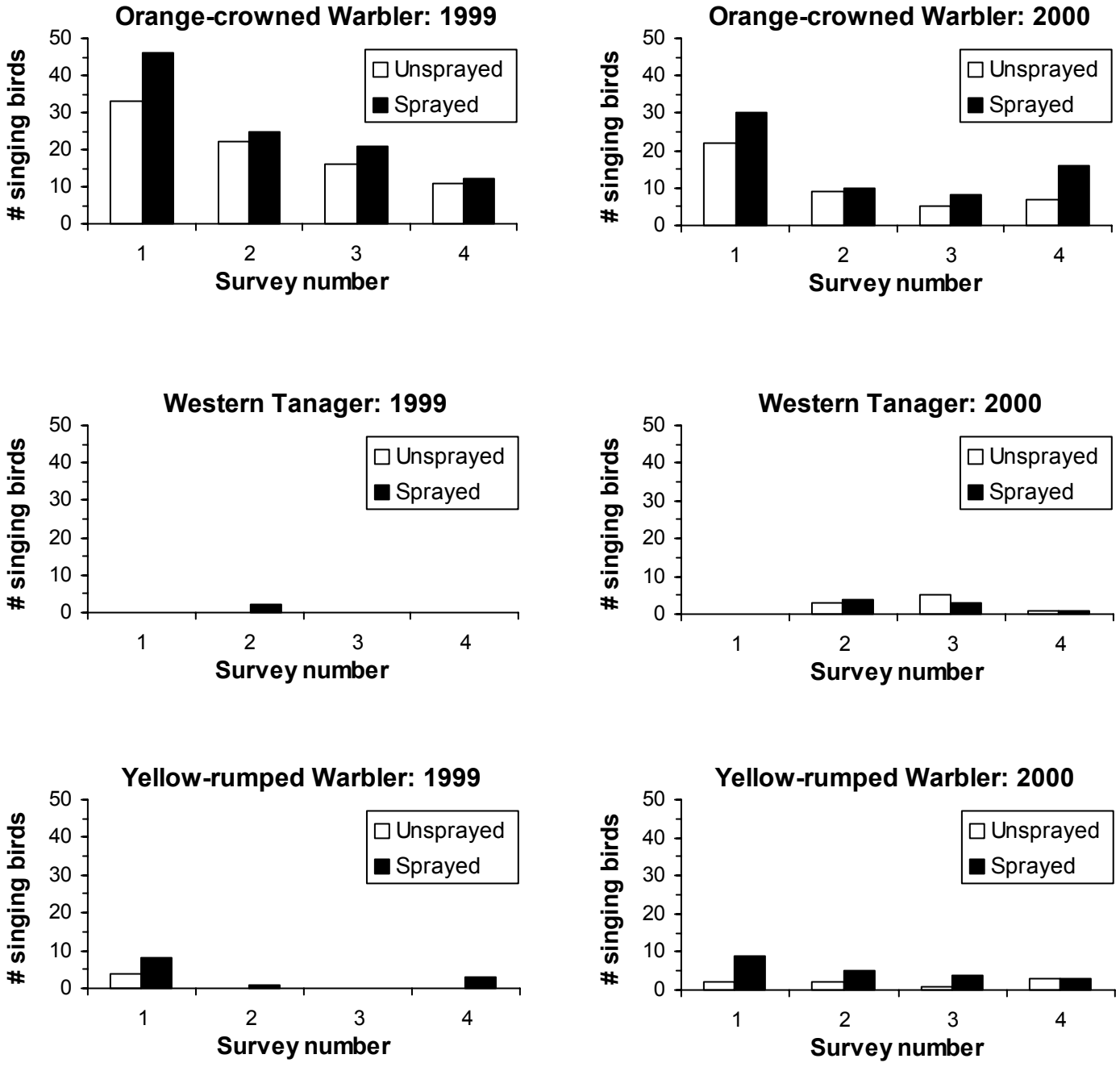
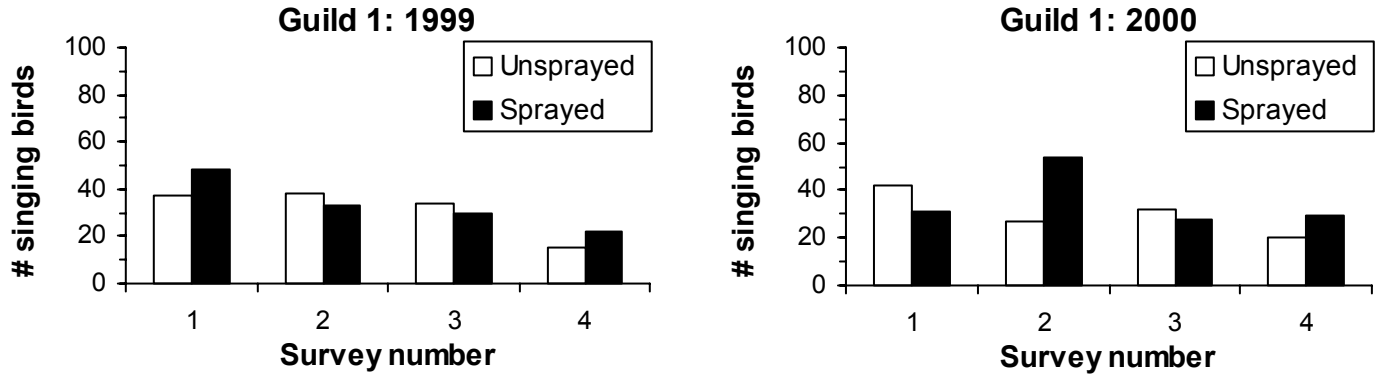
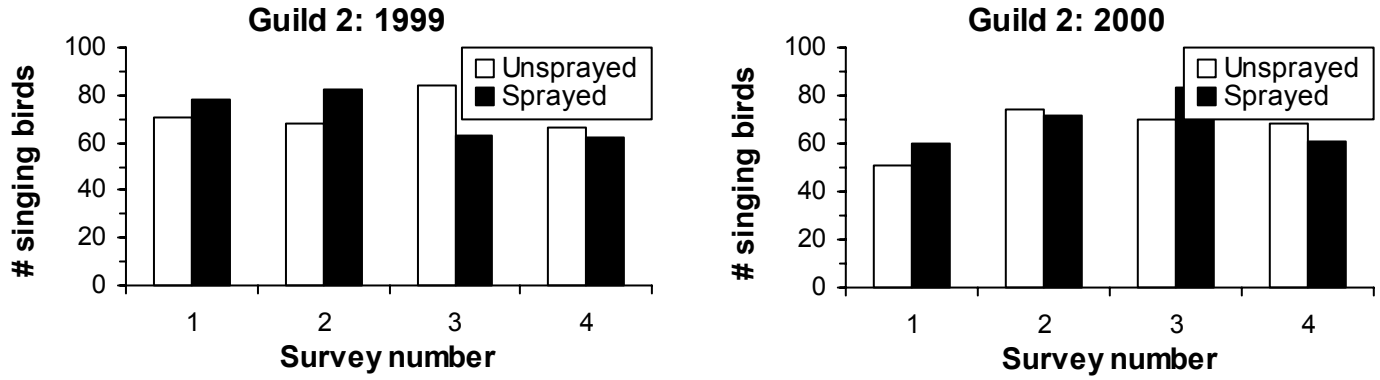


Figure 6d. Total number of singing birds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999. See methods for survey dates

C. Totals for Guild 1 (low proportion of caterpillars in the diet)



D. Totals for Guild 2 (moderate proportion of caterpillars in the diet)



E. Totals for Guild 3 (high proportion of caterpillars in the diet)

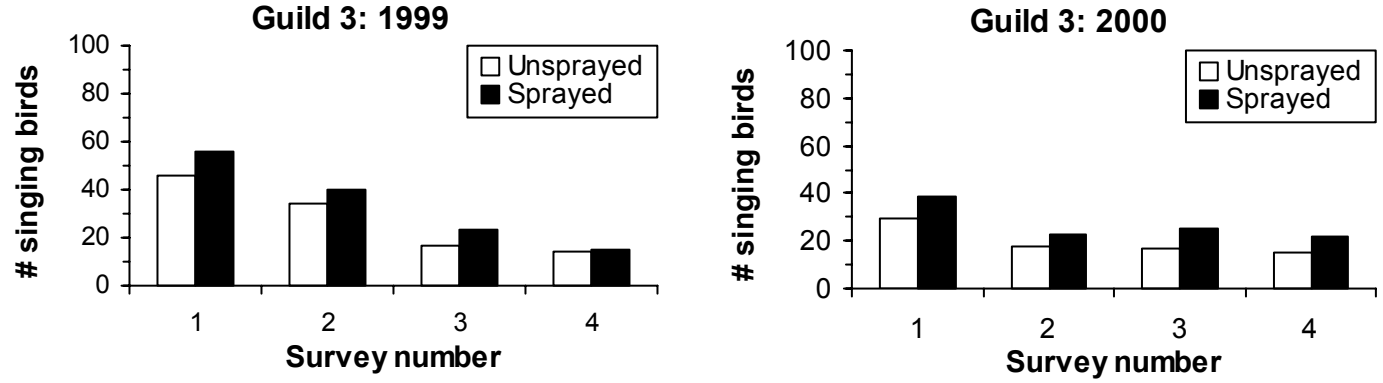
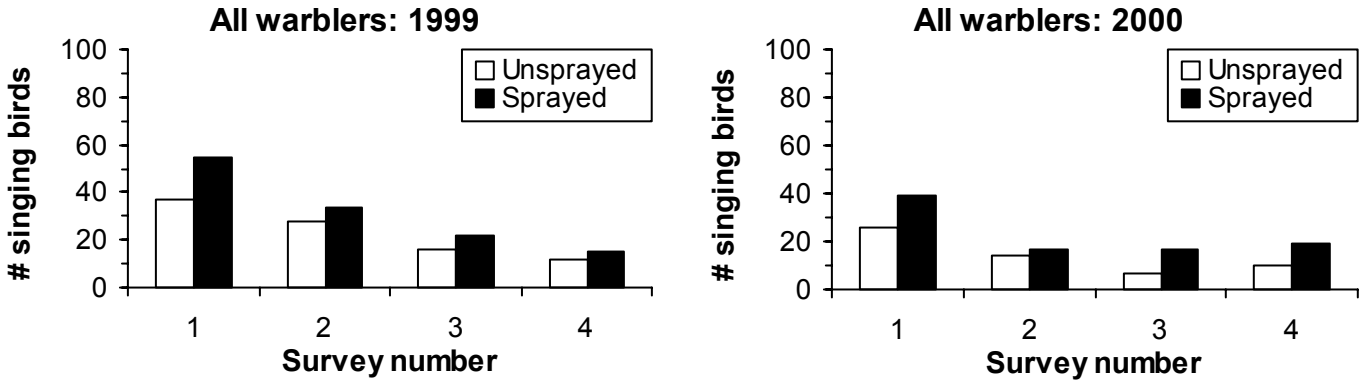
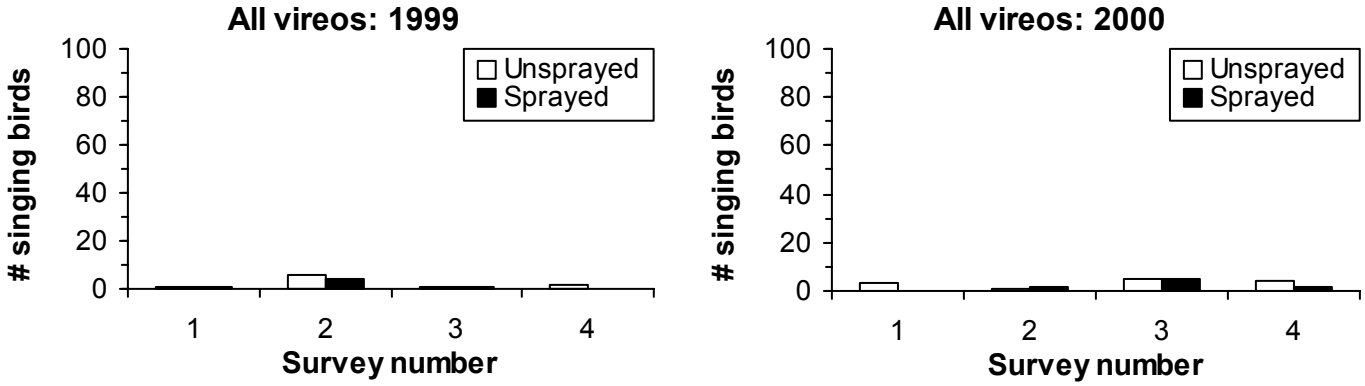


Figure 6e. Total number of singing birds detected on sprayed and unsprayed plots during point-count surveys in spring 1999 and 2000. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999. See methods for survey dates.

F. Totals for all warblers within Guild 3



G. Totals for all Vireos within Guild 3



the number of singing Spotted Towhees (Table 4a, b). In the brood-survey data, there were no other consistent trends towards lower numbers in sprayed than unsprayed areas for singing males of other species (Table 4, b).

The more detailed comparisons using the mean number of singing birds per plot revealed that the patterns across point-count surveys were similar in Btk-sprayed and unsprayed areas for four of the five species examined and for other Guild 3 species combined. Also, there were more other Guild 2 species in Btk-sprayed than unsprayed areas during the three post-spraying surveys, which is not consistent with adverse effects of Btk-treatment (Figure 7a-c; see Appendix D for statistical values). Again, the exception was that the number of Spotted Towhees per plot was depressed in the Btk-sprayed areas in 1999 after spraying in relation to pre-spraying densities (Figure 7a; Appendix D). The comparison was significant both when actual ($F_{1,54}$ = 9.46 P = 0.003) and ranked ($F_{1,54}$ = 7.94, P = 0.007) values of the data were used. Parallel to the results for total numbers of adults per plot, there were no differences in numbers of singing Spotted Towhees between sprayed and unsprayed areas in 2000 (Figure 7a; Appendix D).

3.3 Index of productivity

We observed a total of 127 songbird-broods (fledged, dependent young with adults) in 1999 and 179 broods in 2000 during post-spraying surveys (Table 8a, b). In 1999, the number of Spotted Towhee broods was lower on the Btk-sprayed than unsprayed plots (8 versus 16 broods, respectively), but the difference was not statistically significant (Fig. 8a; χ^2 = 2.04, df = 1, P > 0.5). In 2000, the numbers of Spotted Towhee broods were similar in both sprayed and unsprayed plots (17 versus 19 broods on sprayed and unsprayed plots, respectively). In 2000, we detected more broods of the Dark-eyed Junco on the sprayed than unsprayed plots, which is not consistent with adverse effects of Btk-application (22 versus 8 on sprayed and unsprayed plots, respectively; χ^2 = 5.63, df = 1, P > 0.025). There were no other differences in either year between sprayed and

Figure 7a. Mean number of singing birds per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

A. Species with a moderate proportion of caterpillars in the diet.

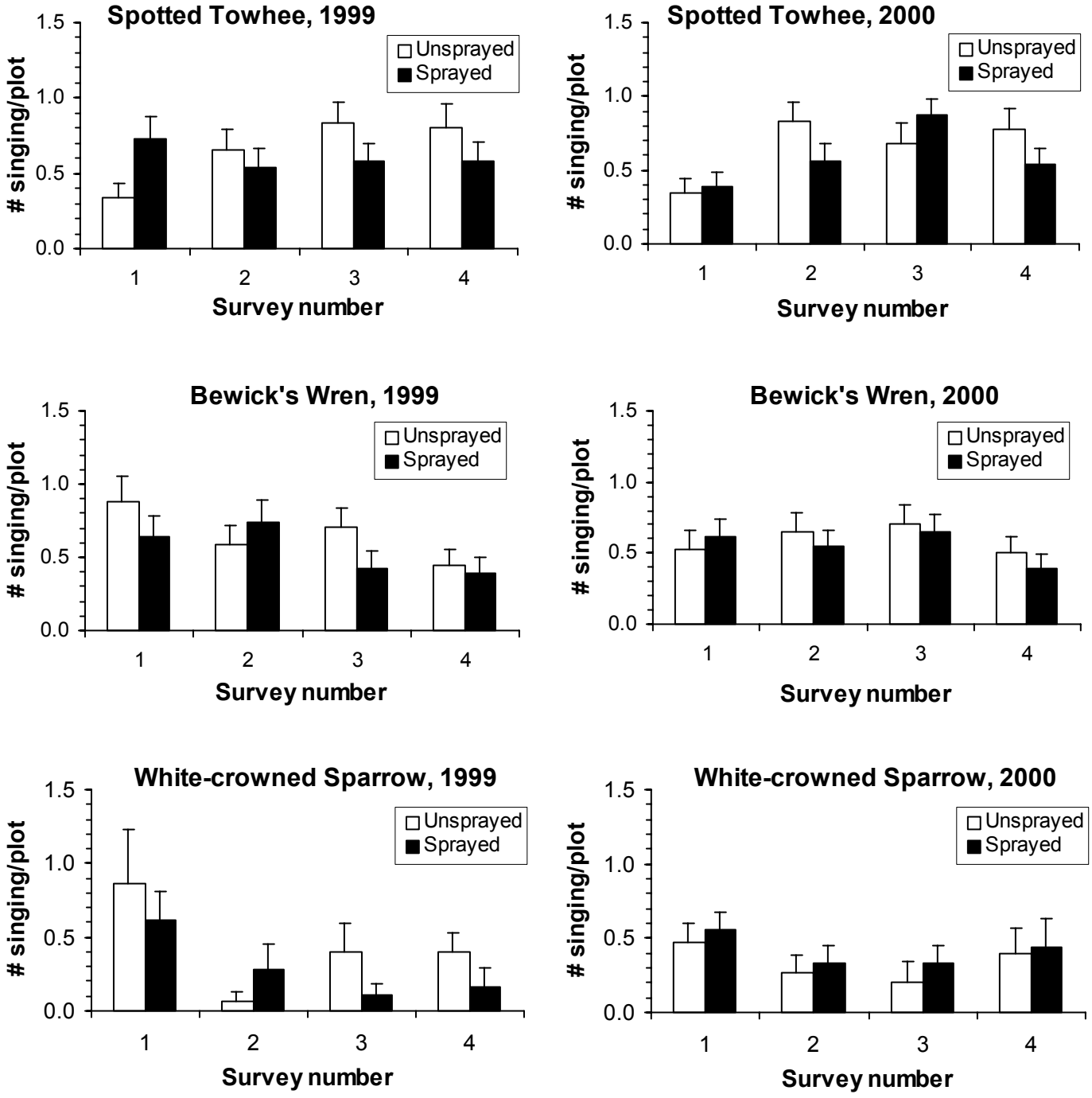
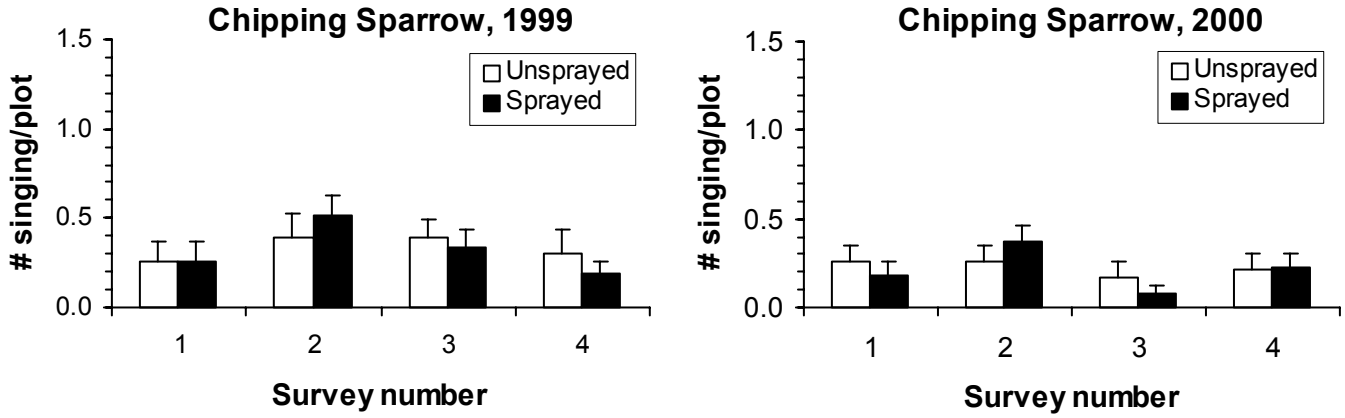
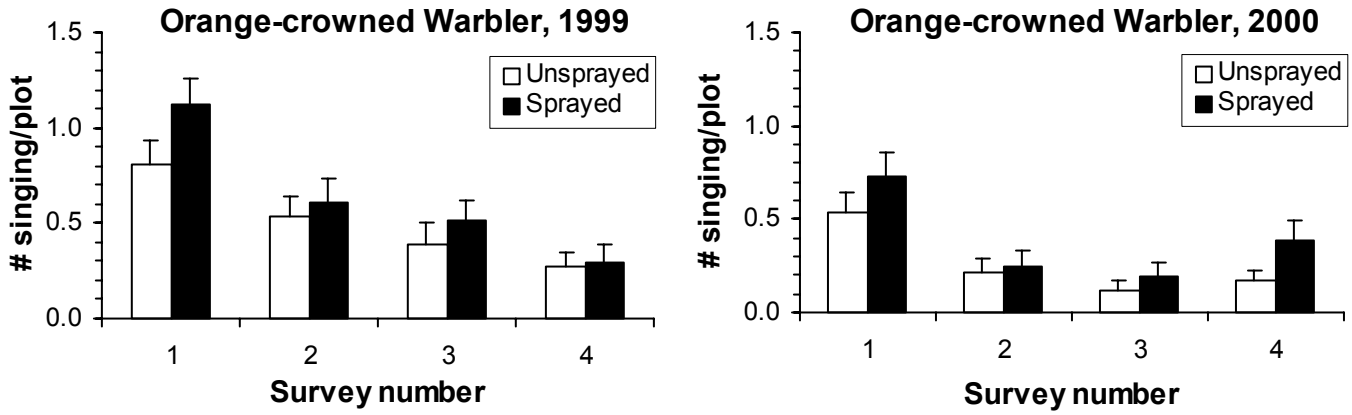


Figure 7b. Mean number of singing birds per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

A. Species with a moderate proportion of caterpillars in the diet.



B. Species with a high proportion of caterpillars in the diet



C. Totals for remaining Guild 2 species (Moderate proportion of caterpillars in the diet)

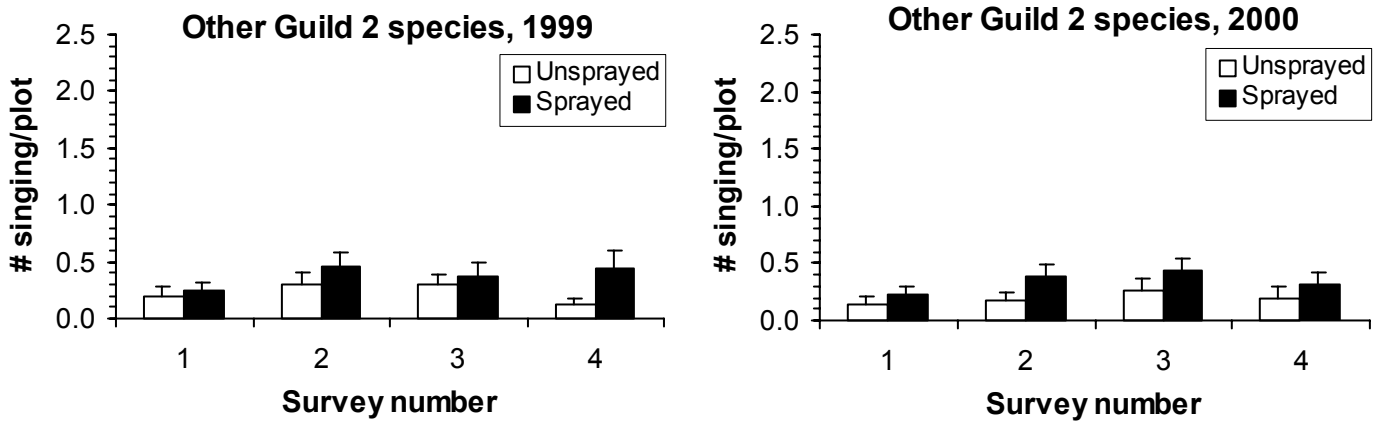


Figure 7c. Mean number of singing birds per study plot in unsprayed and Btk-sprayed areas during point-count surveys in 1999 and 2000. Top of bars - means, whiskers - 1 SE. Survey 1 in 1999 took place before spraying, which was conducted in May-June 1999.

D. Totals for other Guild 3 species (High proportion of caterpillars in the diet)

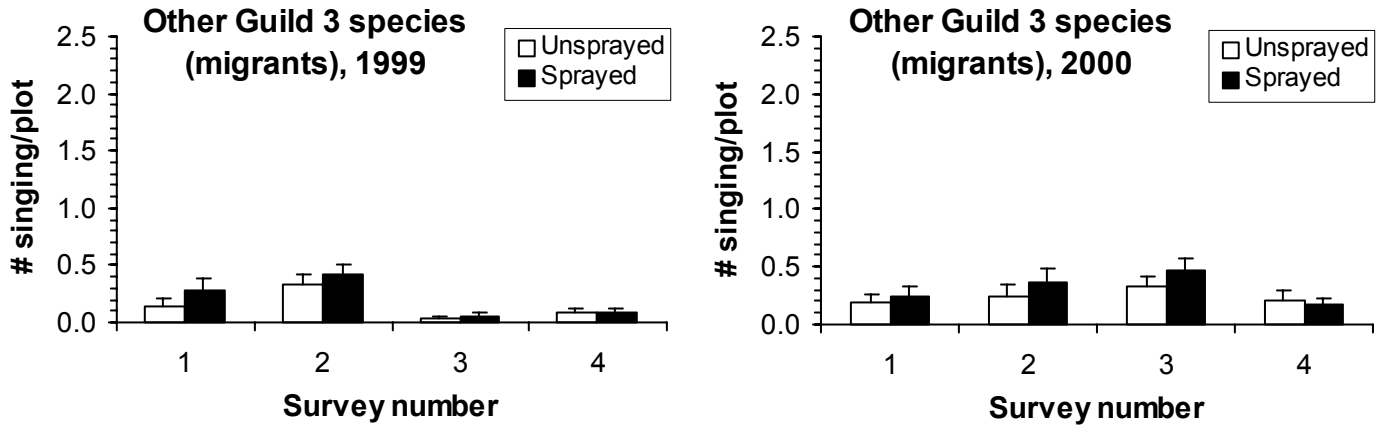


Table 4a. Number of singing birds encountered on Btk-sprayed and unsprayed study plots during brood-surveys in June 1999. # of plots = 29 sprayed and 29 unsprayed. See Appendix B for explanations of species codes. All comparisons between sprayed and unsprayed areas were non-significant at alpha = 0.025 (0.05/2).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	HOFI	HOSP	PUFI	Total
Unsprayed	1	1	5	7	0	1	2	16
Sprayed	1	0	4	10	2	1	0	17
Unsprayed	2	0	3	1	6	1	0	11
Sprayed	2	0	5	3	1	0	0	9
Total		1	17	21	9	3	2	53

B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	CHSP	DEJU	HOWR	SPTO	SWTH	WCSP	WIWR	Total
Unsprayed	1	18	16	4	4	17	1	5	0	65
Sprayed	1	15	9	4	4	9	3	0	0	44
Unsprayed	2	4	7	4	3	19	0	4	1	42
Sprayed	2	11	11	6	3	8	1	1	0	41
Total		48	43	18	14	53	5	10	1	192

C. Guild 3 (high proportion of caterpillars in diet)

Spray status	Survey #	CAVI	BGWA	OCWA	WIWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	1	0	19	2	0	22	21	1
Sprayed	1	0	0	11	0	0	11	11	0
Unsprayed	2	1	0	15	1	0	17	16	1
Sprayed	2	0	1	15	0	2	18	18	0
Total		2	1	60	3	2	68	66	2

Table 4b. Number of singing birds encountered on Btk-sprayed and unsprayed study plots during brood-surveys in May-June 2000. # of plots = 30 sprayed and 30 unsprayed areas. See Appendix B for explanations of species codes. All comparisons between sprayed and unsprayed areas were non-significant at alpha = 0.025 (0.05/2).

A. Guild 1 (low proportion of caterpillars in diet; all year-round residents)

Spray status	Survey #	AMGO	AMRO	BHCO	EUST	HOFI	HOSP	PUFI	Total
Unsprayed	1	0	6	3	0	9	3	1	22
Sprayed	1	1	7	7	1	5	0	0	21
Unsprayed	2	1	1	8	0	10	3	0	23
Sprayed	2	1	2	3	0	5	1	0	12
Total		3	16	21	1	29	7	1	78

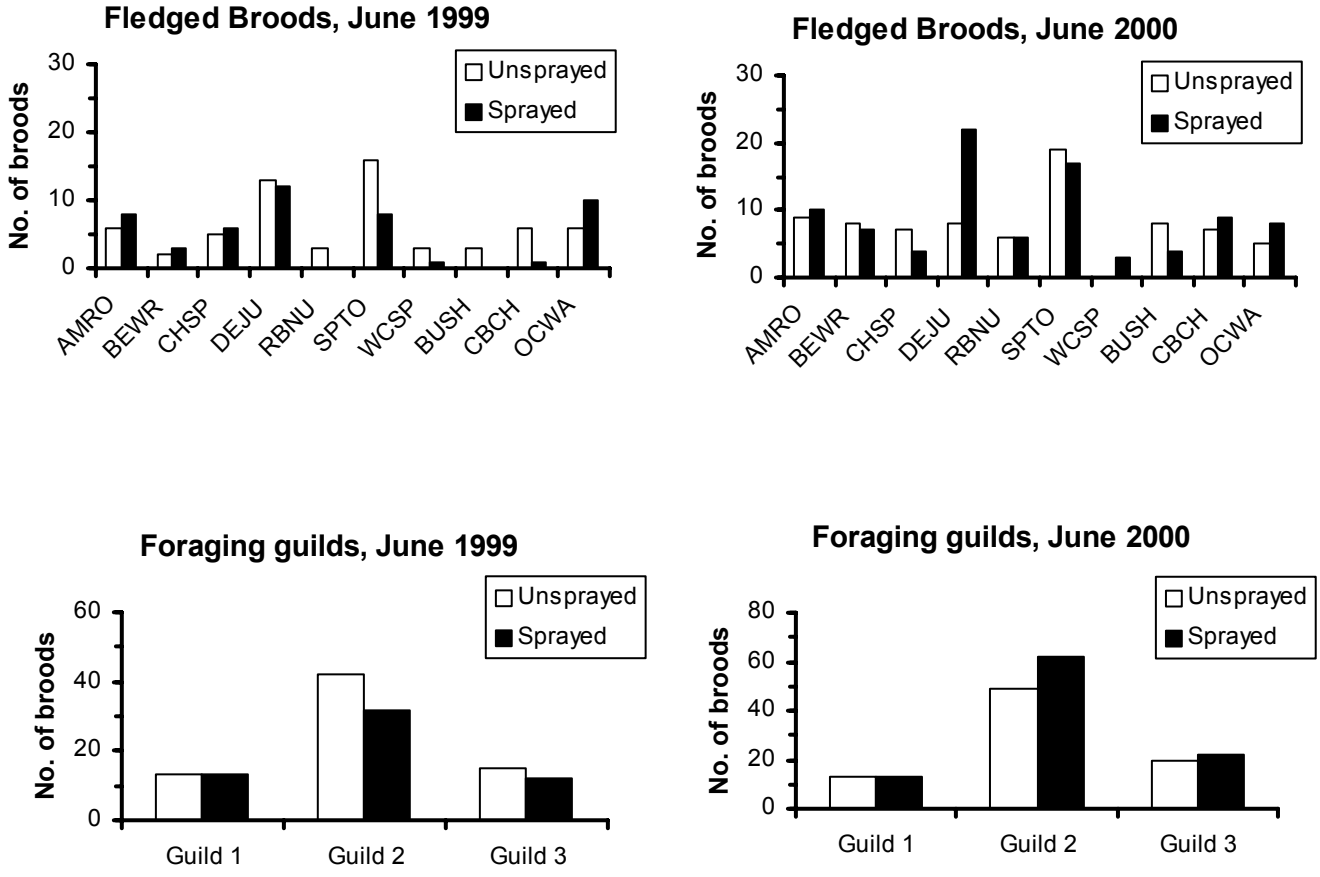
B. Guild 2 (moderate proportion of caterpillars in diet)

Spray status	Survey #	BEWR	CHSP	DEJU	HOWR	SOSP	SPTO	SWTH	WCSP	WIWR	Total
Unsprayed	1	22	13	11	2	0	29	2	14	1	94
Sprayed	1	20	21	12	8	0	39	0	5	0	105
Unsprayed	2	25	12	4	3	0	23	0	8	0	75
Sprayed	2	11	14	10	5	0	32	1	12	0	85
Total		78	60	37	18	0	123	3	39	1	359

C. Guild 3 (high proportion of caterpillars in diet)

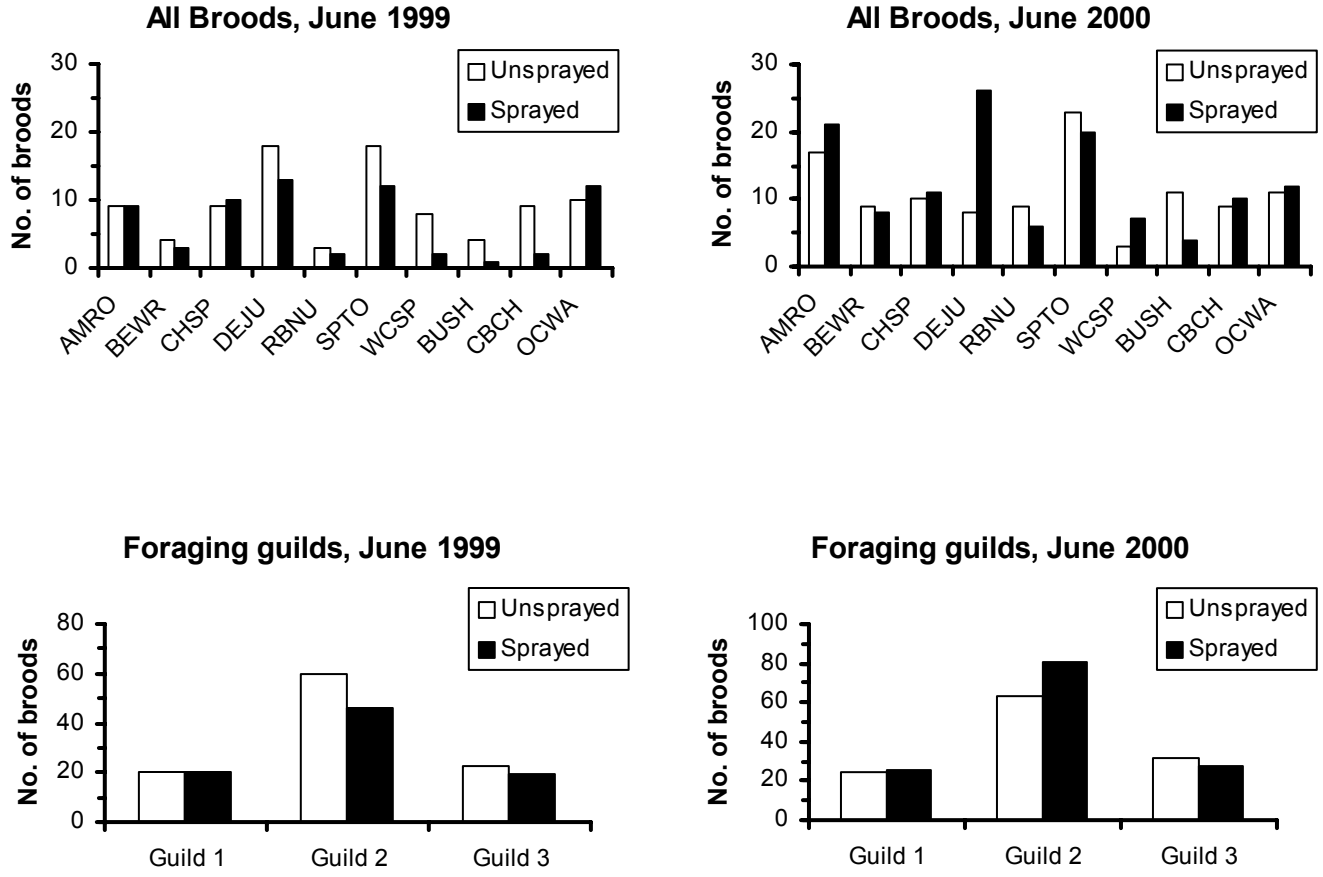
Spray status	Survey #	CAVI	MGWA	OCWA	TOWA	WAVI	WETA	WIWA	YEWA	YRWA	Total	All warblers	All vireos
Unsprayed	1	1	0	18	3	2	1	3	3	2	33	30	3
Sprayed	1	0	1	19	1	0	1	5	0	5	32	32	0
Unsprayed	2	2	0	22	0	1	0	1	0	2	28	25	3
Sprayed	2	2	0	25	2	3	0	1	0	4	37	32	5
Total		5	1	84	6	6	2	10	3	13	130	119	11

Figure 8a. Number of songbird broods with fledged, dependent young observed during surveys on Btk-sprayed and unsprayed study plots in June 1999 and May-June 2000.



Key to species abbreviations: *AMRO*-American Robin, *BEWR*-Bewick's Wren, *CHSP*-Chipping Sparrow, *DEJU*-Dark-eyed Junco, *RBNU*-Red-breasted Nuthatch, *SPTO*-Spotted Towhee, *WCSP*-White-crowned Sparrow, *BUSH*-Bushtit, *CBCH*-Chestnut-backed Chickadee, *OCWA*-Orange-crowned Warbler.

Figure 8b. Number of songbird broods with fledged, dependent young combined with inferred broods based on adults carrying food during surveys on Btk-sprayed and unsprayed study plots in June 1999 and May-June 2000.



Key to species abbreviations: *AMRO*-American Robin, *BEWR*-Bewick's Wren, *CHSP*-Chipping Sparrow, *DEJU*-Dark-eyed Junco, *RBNU*-Red-breasted Nuthatch, *SPTO*-Spotted Towhee, *WCSP*-White-crowned Sparrow, *BUSH*-Bushtit, *CBCH*-Chestnut-backed Chickadee, *OCWA*-Orange-crowned Warbler.

unsprayed areas for individual species or when species were combined into foraging guilds (Table 8a; Figure 8a, b).

In addition to brood sightings, we made 61 observations in 1999 and 76 observations in 2000 of adults carrying food, indicating the presence of undetected broods (fledged or still in the nest) on the study plots. These observations support the patterns between sprayed and unsprayed areas shown by the brood data (Table 8a, b; Figure 8b).

3.5 Foraging observations

In total, we observed 27 species of birds foraging for caterpillars in Garry Oak habitats, and birds of 18 species feeding them to young or carrying them in their beak (Appendix F). As expected, the Chestnut-backed Chickadee, Bushtit, and Orange-crowned Warbler frequently foraged on caterpillars and fed them to their young. Omnivorous species, such as the Dark-eyed Junco, Spotted Towhee, and Chipping Sparrow also frequently fed their young with caterpillars. On several occasions in 1999, we observed adults of these species feeding caterpillars to fledged young or nestlings at rates up to 5 prey taken per minute. In addition to caterpillars, all of the above species also fed winged insects and unidentified non-caterpillar prey to young. We also observed species that are not usual inhabitants of Garry Oaks, such as the Townsend's Warbler, or consumers of caterpillars, such as the Northwestern Crow and Downy Woodpecker, feeding on these prey.

4.0 DISCUSSION

4.1 Relative abundance and territory maintenance

We detected no patterns in the point-count data consistent with adverse effects of the Btk-treatment on the relative abundance and territory maintenance of four of the five Guild 2 and 3 species examined separately and when data for the remaining species were combined into foraging guilds. The species examined individually differed in their foraging mode and diet. We expected the Orange-crowned Warbler to be particularly

sensitive to a reduction in caterpillar abundance because of its leaf-gleaning foraging behavior and insectivorous diet, but detected no effects that could be attributed to the Btk-treatment.

An exception was the Spotted Towhee, the relative abundance of which declined in a pattern consistent with adverse effects of the Btk-treatment in 1999. This difference was not present in 2000. In 1999, the sudden decrease in numbers after the first spray-application in the treatment plots (35% reduction in sprayed versus 5% reduction in unsprayed areas from the pre-survey counts), followed by similar numbers in both Btk-sprayed and unsprayed plots in subsequent surveys, was unexpected, because a marked reduction in caterpillar abundance did not occur until after the third spray-application (Boulton et al. 1999). This result is also somewhat surprising, because the diet of the Spotted Towhee includes surface-litter invertebrates and vegetable matter (Ehrlich et al. 1988). Consequently, the birds potentially can compensate for a reduced caterpillar supply by foraging on the ground for non-caterpillar prey unaffected by Btk. Furthermore, previous studies suggest that food availability is not a proximate factor in determining territory size of the Spotted Towhee (Franzblau and Collins 1980). However, caterpillars may form a readily-available protein source for nestlings and newly fledged young, and we frequently observed towhees carrying caterpillars. The observed reduction in abundance may have resulted from factors other than the Btk-treatment, or it may have been a spurious artifact of our single pre-spraying survey. However, the possibility cannot be ruled out that the treatment was responsible for the observed reduction in abundance of this species in 1999. The adverse affects of btk treatment on this species, if any, were not present in 2000.

Lower number of Bushtits observed in sprayed areas during brood-surveys in both 1999 and 2000 suggest that this species might have been adversely affected by the Btk-treatment. However, the Bushtit had a patchy distribution within our study sites favouring low elevation sites in the eastern part of the study area, and differences in habitat suitability could have accounted for this pattern. The Bushtit is an early breeder and forms large family groups in June that move widely as the juveniles begin to feed

independently. During the brood-surveys in June, several large groups of Bushtits with independent juveniles (which cannot easily be distinguished from adults) were observed, resulting in large numbers of adults being recorded on just a few plots. An analysis using average numbers of adult bushtits per plot, which reduces the influence of occasional large flocks, did not show differences between sprayed and unsprayed areas.

4.2 Index of productivity

An estimate of productivity is desirable to accurately document the effects of artificially reduced food supply on songbird populations (Burgess et al. 1995). Because of practical difficulties associated with locating and monitoring nests of secretive songbirds, particularly warblers, few studies have examined nesting success and productivity in relation to Btk-application (but see Rodenhouse and Holmes 1992). Intensive searches for broods on our study plots in 1999 and 2000 failed to detect differences in numbers of broods between Btk-sprayed and unsprayed sites for any of the species examined, including the Spotted Towhee. However, we did not examine more subtle effects on productivity, such as a reduction in brood size, as we did not monitor individual nests and were unable to obtain an accurate count of newly fledged young.

Although several studies have shown that Lepidoptera-specific insecticides, including Btk, Tebufenozide, and Dimilin, can alter diets, behavior, or energy expenditures of songbirds (Cooper et al. 1990; Rodenhouse and Holmes 1992; Sample et al. 1993; Holmes 1998), no studies have yet demonstrated an effect on productivity. Rodenhouse and Holmes (1992) showed that individual Black-throated Blue Warblers (*Dendroica caerulescens*) made fewer nesting attempts and that nestlings were fed fewer caterpillars in Btk-treated than untreated control areas. Unexpectedly, however, the decreased number of nesting attempts did not result in significantly lower productivity, as measured by the number of fledged young per pair, in the single year examined. The study was continued for two additional years, but weather-induced

reductions of caterpillar abundance on both treated and control sites confounded the results.

4.3 Factors affecting responses of birds to Btk-application

Several factors could account for the lack of detected effects of Btk-application on songbirds during our study. Although total caterpillar abundance was significantly lower in the treatment than control sites following spray-applications, some caterpillars (estimated 30%) remained within Garry Oak foliage in the sprayed area in 1999 (Boulton et al. 1999). Furthermore, caterpillar abundance in the shrub layer may have been less affected by the treatment in 1999. The observed reduction in prey abundance might have been insufficient to produce detectable differences on bird populations. Alternatively, birds could have switched from caterpillars to other prey or increased their foraging time following pesticide treatment, as observed in previous studies. Six of eight songbird species studied by Sample et al. (1993) switched to other arthropod prey after plots were sprayed with Dimilin, an insecticide that kills mostly lepidopteran larvae. However, these alternative prey may have been inferior in quality to caterpillars, as indicated by reduced levels of body fat in birds from sprayed areas (Whitmore et al. 1993). Broad-spectrum insecticides that affect a wide range of arthropods are much more likely to have negative effects on songbird populations through reduced food supply than are Lepidoptera-specific insecticides (Moulding 1976; Cooper et al. 1990; Pascual and Peris 1992). For example, Pascual and Peris (1992) reported up to a 83% reduction in fledging success of the Blue Tit (*Parus caeruleus*) after the application of Cypermethrin, which reduced the abundance of all arthropods by 95%.

Songbirds could also compensate for reduced numbers of caterpillar prey by enlarging their foraging areas or by increasing the time spent foraging. Changes in foraging time, in particular, would not have been detected during our study. Cooper et al. (1990) reported that individual Red-eyed Vireos (*Vireo olivaceus*) at least doubled the size of their foraging areas in sites with low caterpillar abundance after Dimilin application. However, increased energetic costs of this behavior apparently did not affect overall

densities, which were similar in treatment and control areas over a 2-year period. Holmes et al. (1997) found that individual Tennessee Warblers (*Vermivora peregrina*) and Bay-breasted Warblers (*Dendroica castanea*) spent more time foraging on spruce budworm host trees in areas treated with a Lepidoptera-specific insecticide (Tebufenozide) than in control areas, resulting in similar proportion of caterpillars in the diets of nestlings found in both treated and control areas despite vastly reduced numbers of caterpillars in the treated areas. Increased searching activity and enlarged foraging areas in locations sprayed by Fenitrothion (a broad-spectrum insecticide) was reported for the Chestnut-sided Warbler (*Dendroica pensylvanica*) in Ontario (Millikin and Smith 1990). The warblers did not abandon their territories in response to pesticide treatment.

4.4 Limitations and potential biases

Our study design was limited by the established boundaries of the spray-zone and the timing of the Btk-treatment, which permitted only one pre-treatment survey; these parameters were governed by the distribution and phenology of the Gypsy Moth. Base-line, pre-treatment data are important, because comparisons between pre- and post-spraying periods from the same sites are not affected by possible habitat biases and other factors that can affect comparisons among sites.

We distributed study sites widely over the larger spray-zone to minimize bias due to pseudo-replication, but other, site-specific factors might have been responsible for some of the observed patterns. In addition, we were limited in our ability to address possible effects on rarer bird species, such as vireos, individually because of low densities and insufficient numbers of observations. However, we were able to perform comparisons by grouping these species. Despite of these potential biases, studies of non-target organisms conducted within limitations imposed by pest-management programs contribute to a growing database on ecological effects of different pest-control strategies in different ecosystems and habitats. This information is useful for evaluating various

pest-control options in the future and facilitates the adaptive management of ecosystems.

4.5 Management implications

The results of this and previous studies indicate that the use of Btk to control Gypsy Moth populations has few, if any, effects on songbird abundance. Btk-spray is much preferable to broad-spectrum insecticides because arthropod-prey other than caterpillars remain available for birds. Possible impacts on songbirds, especially rarer species, can be minimized by focusing Btk-applications to areas of high pest concentrations, thus providing birds with a mosaic of refuges containing caterpillar prey.

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Appendix A. Locations and habitat descriptions of study plots used for songbird surveys in April-June 1999 and 2000.

Site #	Spray-status	Site name	Plot ID #	Latitude[1]	Longitude[1]	Elevation (m)	% cover: Oak[2]	% cover: DF[2]	Total canopy[3] (%)	% cover: shrubs (native spp)	% cover: shrubs (all	% cover: herbs/grass
1	No	Observatory Hill	1	48 31.317	123 25.364	200	25	5	15	8	40	45
1	No	Observatory Hill	2	48 31.305	123 25.295	220	12	3	30	5	35	40
1	No	Observatory Hill	3	48 31.165	123 25.230	200	45	0	46	4	30	50
1	No	Observatory Hill	4	48 31.123	123 25.131	200	50	0	50	3	30	45
1	No	Observatory Hill	5	48 31.103	123 24.949	200	45	6	51	4	35	45
1	No	Observatory Hill	6	48 31.157	123 24.885	200	10	2	17	10	50	30
2	No	Mary Hill (DND lands)	1	48 20.473	123 33.145	30	25	10	40	0	35	25
2	No	Mary Hill (DND lands)	2	48 20.444	123 32.991	30	30	20	55	0	30	35
2	No	Mary Hill (DND lands)	3	48 20.476	123 32.937	30	60	10	70	0	35	50
2	No	Mary Hill (DND lands)	4	48 20.547	123 33.003	40	30	5	45	0	55	35
2	No	Mary Hill (DND lands)	5	48 20.626	123 32.945	55	15	3	20	0	30	35
3	No	Uplands Park	1	48 26.472	123 18.012	20	30	0	30	18	35	35
3	No	Uplands Park	2	48 26.531	123 17.889	20	60	0	60	43	55	45
3	No	Uplands Park	3	48 26.479	123 17.789	20	60	0	70	59	80	15
3	No	Uplands Park	4	48 26.360	123 17.792	20	60	0	60	50	80	20
3	No	Uplands Park	5	48 26.448	123 17.875	20	25	0	25	10	60	30
4	No	Mount Tolmie	1	48 27.410	123 19.346	110	65	5	70	69	75	15
4	No	Mount Tolmie	2	48 27.462	123 19.324	100	30	0	30	34	40	50
4	No	Mount Tolmie	3	48 27.555	123 19.358	90	35	0	35	29	35	50
4	No	Mount Tolmie	4	48 27.526	123 19.425	100	40	0	40	13	45	35
5	No	Summit Park	1	48 26.625	123 21.175	70	60	0	60	48	70	15
5	No	Summit Park	2	48 26.724	123 21.243	70	40	0	40	33	35	55
5	No	Summit Park	3	48 26.765	123 21.314	70	25	0	25	23	30	60
6	No	Government House	1	48 25.035	123 20.374	30	45	0	55	36	40	50
6	No	Government House	2	48 24.989	123 20.521	25	20	5	25	39	40	40
6	No	Government House	3	48 25.081	123 20.653	35	45	5	60	69	70	20
7	No	Mount Douglas	1	48 29.351	123 21.174	120	20	15	36	16	40	45
7	No	Mount Douglas	2	48 29.419	123 21.163	135	25	0	25	10	40	35
7	No	Mount Douglas	3	48 29.497	123 21.024	180	18	1	25	21	45	40
8	No	Galloping Goose	1	48 21.228	123 33.680	80	15	15	30	0	35	25
8	No	Galloping Goose	2	48 21.308	123 33.642	85	40	10	50	0	50	35
8	No	Galloping Goose	3	48 21.334	123 33.488	90	25	20	50	0	40	35
9	No	Cedar Hill Park	1	48 27.527	123 20.845	75	20	0	20	12	30	20
9	No	Cedar Hill Park	2	48 27.437	123 20.852	65	75	0	75	79	90	5
10	No	Christmas Hill	1	48 28.439	123 22.496	80	35	5	40	17	35	40
10	No	Christmas Hill	2	48 28.469	123 22.586	95	25	5	30	14	20	30
11	No	Fort Rodd Hill	1	48 26.188	123 27.067	45	20	5	45	18	50	40
11	No	Fort Rodd Hill	2	48 26.109	123 27.252	50	40	15	60	18	60	30
12	No	Playfair Park	1	48 27.661	123 21.320	75	70	0	70	68	70	20
13	No	Beaconhill Park	1	48 24.656	123 21.840	30	65	5	75	75	80	20
14	No	Prospect Lake	1	48 30.488	123 26.829	70	15	10	40	24	40	30
15	Yes	Mill Hill	1	48 27.406	123 28.804	190	30	<1	60	0	50	30
15	Yes	Mill Hill	2	48 27.448	123 28.671	170	25	5	60	5	35	40

Site #	Spray-status	Site name	Plot ID #	Latitude[1]	Longitude[1]	Elevation (m)	% cover: Oak[2]	% cover: DF[2]	Total canopy[3] (%)	% cover: shrubs (native spp)	% cover: shrubs (all	% cover: herbs/grass
15	Yes	Mill Hill	3	48 27.385	123 28.723	160	30	5	60	5	60	35
15	Yes	Mill Hill	3	48 27.512	123 28.655	170	30	10	60	0	50	25
15	Yes	Mill Hill	4	48 27.607	123 28.720	190	20	5	40	20	35	35
15	Yes	Mill Hill	5	48 27.604	123 28.672	130	45	15	75	5	60	25
16	Yes	Fama Lands	1	48 33.897	123 26.984	100	20	5	25	35	55	30
16	Yes	Fama Lands	1	48 33.855	123 26.854	110	18	8	27	49	45	45
16	Yes	Fama Lands	2	48 33.882	123 26.727	120	35	1	37	28	60	35
16	Yes	Fama Lands	3	48 33.808	123 26.680	130	20	8	28	22	40	44
16	Yes	Fama Lands	4	48 33.795	123 26.807	100	35	12	51	15	25	61
17	Yes	Skirt Mountain	1	48 27.370	123 31.968	190	35	5	40	0	70	20
17	Yes	Skirt Mountain	2	48 27.446	123 32.031	190	55	5	60	10	55	30
17	Yes	Skirt Mountain	3	48 27.513	123 32.126	180	50	5	60	0	60	30
17	Yes	Skirt Mountain	4	48 27.484	123 31.944	240	25	4	30	5	60	20
17	Yes	Skirt Mountain	5	48 27.526	123 31.820	280	25	10	40	0	40	45
18	Yes	Thetis Lake Park	1	48 27.863	123 27.908	120	10	10	30	4	40	35
18	Yes	Thetis Lake Park	2	48 27.915	123 27.781	130	10	10	40	10	60	25
18	Yes	Thetis Lake Park	3	48 28.020	123 27.821	70	10	10	25	6	35	40
18	Yes	Thetis Lake Park	4	48 28.094	123 27.958	140	15	15	45	9	35	30
19	Yes	Layritz Park	1	48 29.406	123 24.772	80	27	5	32	22	80	18
19	Yes	Layritz Park	2	48 29.439	123 24.804	80	10	5	16	69	24	46
19	Yes	Layritz Park	2	48 29.466	123 24.728	80	10	3	14	5	40	35
20	Yes	Charleton/Woods End Rds	1	48 28.571	123 26.651	40	50	15	65	45	50	50
20	Yes	Charleton/Woods End Rds	1	48 28.672	123 26.191	55	20	10	60	30	20	50
20	Yes	Charleton/Woods End Rds	2	48 28.596	123 26.201	40	30	10	40	40	50	40
21	Yes	Cairn Park	1	48 26.097	123 24.383	65	23	5	30	39	50	20
21	Yes	Cairn Park	2	48 26.030	123 24.359	55	30	20	50	39	70	15
21	Yes	Cairn Park	3	48 25.982	123 24.432	60	30	10	40	38	50	25
22	Yes	Knockan Hill	1	48 28.188	123 24.957	85	20	5	25	19	35	40
22	Yes	Knockan Hill	1	48 28.196	123 25.053	80	20	15	35	5	30	50
23	Yes	West Burnside Rd	1	48 28.215	123 26.446	35	45	5	50	24	40	40
23	Yes	West Burnside Rd	2	48 28.284	123 26.448	30	55	5	60	68	70	25
24	Yes	Naden Hospital	1	48 26.442	123 24.880	55	30	20	50	10	40	25
24	Yes	Naden Hospital	6	48 27.276	123 28.746	45	30	<1	30	24	40	40
25	Yes	Juan de Fuca Rec. Centre	1	48 26.920	123 27.877	45	50	10	60	49	55	40
25	Yes	Juan de Fuca Rec. Centre	2	48 26.870	123 27.810	40	50	10	60	10	50	45
26	Yes	Wilkinson Rd	1	48 29.094	123 24.685	30	18	8	27	20	75	15
26	Yes	Wilkinson Rd	2	48 29.079	123 24.785	35	30	3	35	40	60	30
27	Yes	Florence Lake	5	48 27.263	123 30.873	82	55	5	60	55	70	0
28	Yes	Costco, Millstream Rd.	3	48 27.440	123 30.213	100	55	10	70	37	50	20

[1]Latitude/Longitude: Degrees/minutes at plot centre (measured in June 1999 using a handheld Garmin GPS-unit)

[2]Canopy coverage by Garry Oak and Douglas-fir, respectively

[3]Total canopy coverage by trees > 2 m in height

Appendix B. List of bird species encountered in Garry Oak habitats during point-count and brood surveys, April-June 1999 and 2000. Nomenclature is according to Field Guide to the Birds of North America (National Geographic, third edition, 1999). Foraging guilds are based on foraging mode and predominant prey type in the diet during spring and early summer. Relative proportion of caterpillars in the diet in spring and early summer: N-none/occasional, L-low, M-moderate, H-high.

Common name	Scientific name	Abbreviation	Foraging guild	Caterpillars in diet
Hummingbirds:				
Anna's Hummingbird	*Calypte anna*	ANHU	Nectarivore	N
Rufous Hummingbird	*Selasphorus rufus*	RUHU	Nectarivore	N
Woodpeckers:				
Downy Woodpecker	*Picoides pubescens*	DOWO	Bark-gleaning insectivore	N
Hairy Woodpecker	*Picoides villosus*	HAWO	Bark-gleaning insectivore	N
Northern Flicker	*Colaptes auratus*	NOFL	Ground/bark-gleaning insectivore	N
Pileated Woodpecker	*Dryocopus pileatus*	PIWO	Bark-gleaning insectivore	N
Red-breasted Sapsucker	*Sphyrapicus ruber*	RBSA	Bark-gleaning insectivore	N
Raptors:				
Turkey Vulture	*Cathartes aura*	TUVU	Scavenger/vertebrate predator	N
Osprey	*Pandion haliaetus*	OSPR	Piscivore	N
Bald Eagle	*Haliaeetus leucocephalus*	BAEA	Piscivore/vertebrate predator	N
Cooper's Hawk	*Accipiter cooperii*	COHA	Avian predator	N
Peregrine Falcon	*Falco peregrinus*	PEFA	Avian predator	N
Merlin	*Falco columbarius*	MERL	Avian predator	N
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	Mammalian/avian predator	N
Barred Owl	*Strix varia*	BAOW	Mammalian predator	N
Great-horned Owl	*Bubo virginianus*	GHOW	Mammalian predator	N
Flycatchers:				
Olive-sided Flycatcher	*Contopus cooperi*	OSFL	Aerial insectivore	N
Western Wood-Peewee	*Contopus sordidulas*	WWPE	Aerial insectivore	N
Western Kingbird	*Tyrannus verticalis*	WEKI	Aerial insectivore	N
Hammond's Flycatcher	*Empidonax hammondii*	HAFL	Aerial insectivore	N
Pacific-slope Flycatcher	*Empidonax difficilis*	PSFL	Aerial insectivore	N
Willow Flycatcher	*Empidonax traillii*	WIFL	Aerial insectivore	N
Swifts and swallows:				
Barn Swallow	*Hirundo rustica*	BASW	Aerial insectivore	N
Cliff Swallow	*Petrochelidon pyrrhonota*	CLSW	Aerial insectivore	N
Purple Martin	*Progne subis*	PUMA	Aerial insectivore	N
Violet-green Swallow	*Tachycineta thalassina*	VGSW	Aerial insectivore	N
Vaux's Swift	*Chaetura vauxi*	VASW	Aerial insectivore	N
Corvids:				
Common Raven	*Corvus corax*	CORA	Omnivore/scavenger	N
Northwestern Crow	*Corvus caurinus*	NWCR	Omnivore/scavenger	N
Steller's Jay	*Cyanocitta stelleri*	STJA	Omnivore/scavenger	N
Bushtits and Chickadees:				
Bushtit	*Psaltriparus minimus*	BUSH	Foliage/bark-gleaning insectivore	H
Chestnut-backed Chickadee	*Poecile rufescens*	CBCH	Foliage/bark-gleaning insectivore	H
Creepers and Nutchatches				
Brown Creeper	*Certhia americana*	BRCR	Bark-gleaning insectivore	N
Red-breasted Nuthatch	*Sitta canadensis*	RBNU	Foliage/bark-gleaning insectivore	L
Wrens:				
Bewick's Wren	*Thryomanes bewickii*	BEWR	Foliage/bark-gleaning insectivore	M
House Wren	*Troglodytes aedon*	HOWR	Foliage/bark-gleaning insectivore	M
Winter Wren	*Troglodytes troglodytes*	WIWR	Foliage/bark-gleaning insectivore	M
Kinglets:				
Golden-crowned Kinglet	*Regulus satrapa*	GCKI	Foliage-gleaning insectivore	H
Ruby-crowned Kinglet	*Regulus calendula*	RCKI	Foliage-gleaning insectivore	H
Thrushes:				
American Robin	*Turdus migratorius*	AMRO	Ground/foliage-gleaning omnivore	L
Hermit Thrush	*Catharus guttatus*	HETH	Ground/foliage-gleaning omnivore	M
Swainson's Thrush	*Catharus ustulatus*	SWTH	Ground/foliage-gleaning omnivore	M
Townsend's Solitaire	*Myadestes townsendi*	TOSO	Ground/foliage-gleaning omnivore	M
Varied Thrush	*Ixoreus naevius*	VATH	Ground/foliage-gleaning omnivore	M
Waxwings:				
Cedar Waxwing	*Bombycilla cedrorum*	CEWA	Herbivore/aerial insectivore	L
Starlings:				
European Starling	*Sturnus vulgaris*	EUST	Ground/foliage-gleaning omnivore	L
Vireos:				
Cassin's Vireo	*Vireo cassinii*	CAVI	Foliage-gleaning insectivore	H
Hutton's Vireo	*Vireo huttoni*	HUVI	Foliage-gleaning insectivore	H
Warbling Vireo	*Vireo gilvus*	WAVI	Foliage-gleaning insectivore	H

Common name	Scientific name	Abbreviation	Foraging guild	Caterpillars in diet
Warblers:				
Black-throated Gray Warbler	*Dendroica nigrescens*	BGWA	Foliage-gleaning insectivore	H
Common Yellowthroat	*Geothlypis trichas*	COYE	Foliage-gleaning insectivore	H
MacGillivray's Warbler	*Oporornis tolmiei*	MGWA	Foliage-gleaning insectivore	H
Orange-crowned Warbler	*Vermivora celata*	OCWA	Foliage-gleaning insectivore	H
Townsend's Warbler	*Dendroica townsendi*	TOWA	Foliage-gleaning insectivore	H
Wilson's Warbler	*Wilsonia pusilla*	WIWA	Foliage-gleaning insectivore	H
Yellow Warbler	*Dendroica petechia*	YEWA	Foliage-gleaning insectivore	H
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	Foliage-gleaning insectivore	H
Grossbeaks and Sparrows:				
Black-headed Grosbeak	*Pheucticus melanocephalus*	BHGR	Foliage-gleaning omnivore	M
Chipping Sparrow	*Spizella passerina*	CHSP	Foliage/ground-gleaning omnivore	M
Dark-eyed Junco	*Junco hyemalis*	DEJU	Foliage/ground-gleaning omnivore	M
Golden-crowned Sparrow	*Zonotrichia atricapilla*	GCSP	Foliage/ground-gleaning omnivore	M
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	Foliage/ground-gleaning omnivore	M
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	Foliage/ground-gleaning omnivore	M
Song Sparrow	*Melospiza melodia*	SOSP	Foliage/ground-gleaning omnivore	M
Spotted Towhee	*Pipilo maculatus*	SPTO	Foliage/ground-gleaning omnivore	M
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	Foliage/ground-gleaning omnivore	M
Blackbirds:				
Brown-headed Cowbird	*Molothrus ater*	BHCO	Foliage/ground-gleaning omnivore	L
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	Foliage/ground gleaning omnivore	M
Western Tanager	*Piranga ludoviciana*	WETA	Foliage-gleaning insectivore	H
Finches:				
American Goldfinch	*Carduelis tristis*	AMGO	Foliage/ground-gleaning omnivore	L
House Finch	*Carpodacus mexicanus*	HOFI	Foliage/ground-gleaning omnivore	L
Pine Siskin	*Carduelis pinus*	PISI	Foliage-gleaning omnivore	L
Purple Finch	*Carpodacus purpureus*	PUFI	Ground/foliage-gleaning omnivore	L
Evening Grosbeak	*Coccothraustes vespertinus*	EVGR	Foliage-gleaning herbivore/insectivore	M
Pine Grossbeak	*Pinicola enucleator*	PIGR	Foliage-gleaning herbivore	N
Red Crossbill	*Loxia curvirostra*	RECR	Foliage-gleaning herbivore/insectivore	N
Weaver finches:				
House Sparrow	*Passer domesticus*	HOSP	Ground/foliage-gleaning omnivore	L
Kingfishers:				
Belted Kingfisher	*Ceryle alcyon*	BEKI	Piscivore	N
Doves and Pigeons:				
Band-tailed Pigeon	*Columba fasciata*	BTPI	Ground/foliage-gleaning herbivore/omnivore	N
Rock Dove	*Columbra livia*	RODO	Ground/foliage-gleaning herbivore/omnivore	N
Mourning Dove	*Zenaida macroura*	MODO	Ground/foliage-gleaning herbivore/omnivore	N
Quails, Pheasants, and Grouse:				
California Quail	*Callipepla californica*	CAQU	Ground-gleaning herbivore/omnivore	L
Ring-necked Pheasant	*Phasianus colchicus*	RNPH	Ground-gleaning herbivore/omnivore	L
Blue Grouse	*Dendragapus obscurus*	BLGR	Ground-gleaning herbivore/omnivore	L
Ruffed Grouse	*Bonasa umbellus*	RUGR	Ground-gleaning herbivore/omnivore	L
Herons, shorebirds:				
Great-blue Heron	*Ardea herodias*	GBHE	Piscivore/vertebrate predator	N
Green Heron	*Butorides virescens*	GRHE	Piscivore/vertebrate predator	N
Greater Yellowlegs	*Tringa melanoleuca*	GRYE	Predator of shoreline invertebrates	N
Whimbrel	*Numenius phaeopus*	WHIM	Predator of shoreline invertebrates	N
Black Oyestercatcher		BLOY	Predator of shoreline invertebrates	N
Waterfowl:				
Hooded Merganser	*Lophodytes cucullatus*	HOME	Piscivore	N
Common Loon	*Gavia immer*	COLO	Piscivore	N
Greater White-fronted Goose	*Anser albifrons*	GWFG	Aquatic herbivore/omnivore	N
Canada Goose	*Branta canadensis*	CAGO	Aquatic herbivore/omnivore	N
Mallard	*Anas platyrhynchos*	MALL	Aquatic herbivore/omnivore	N
Gulls:				
Glaucous-winged Gull	*Larus glaucescens*	GWGU	Omnivore/piscivore	N

Appendix C. Statistical values for analysis of variance for numbers of adult songbirds observed during 4 point-count surveys in April-June 1999 and 2000 on Btk sprayed and unsprayed study plots. Survey 1 in April 1999 took place before spraying, which was conducted in May-June 1999. Wilk's lambda was used as a test statistics in all comparisons.

1. Year 1999** (analysis of variance with specified contrast)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp[1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]			Bushtit & Chickadee[3]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
a) 1 pre- versus 3 post-spraying surveys (contrast vector: -3. 1, 1, 1)																								
Spray-status	0.771	1/38	0.385	0.129	1/31	0.722	8.400	1/54	0.005	0.023	1/18	0.882	0.269	1/54	0.606	0.442	1/53	0.509	2.559	1/45	0.117	0.215	1/25	0.647
Site (within spray-status)	0.988	25/38	0.504	1.230	17/31	0.299	1.305	26/53	0.202	0.446	13/18	0.929	0.896	26/54	0.610	0.746	26/53	0.789	1.954	26/45	0.024	0.802	25/25	0.707
b) linear trend among 3 post-spraying surveys (contrast vector: 0, -1, 0, 1)																								
Spray-status	1.930	1/38	0.173	1.477	1/31	0.233	0.034	1/54	0.855	4.091	1/18	0.058	0.050	1/54	0.825	1.188	1/53	0.281	3.061	1/45	0.087	4.511	1/25	0.044
Site (within spray-status)	0.884	25/38	0.621	2.254	17/31	0.024	0.775	26/54	0.758	0.593	13/18	0.830	1.089	26/54	0.385	1.303	26/53	0.205	1.173	26/45	0.313	1.415	25/25	0.199

2. Year 2000 (repeated measures analysis of variance with "time" as repeated measure)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp[1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]			Bushtit & Chickadee[3]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
Spray-status	0.0003	1/38	0.987	0.511	1/31	0.480	0.0001	1/54	0.992	1.442	1/18	0.245	2.617	1/54	0.112	1.186	1/54	0.281	0.166	1/45	0.686	0.009	1/25	0.925
Site (within spray-status)	2.857	25/38	0.002	0.981	17/31	0.501	4.076	26/54	<0.0001	5.292	13/18	0.0007	1.964	26/54	0.018	2.277	26/54	0.005	1.502	26/45	0.114	0.994	25/25	0.506
Time	0.697	3/36	0.560	1.643	3/29	0.201	0.282	3/52	0.838	0.588	3/16	0.631	1.519	3/52	0.221	8.843	3/52	<0.0001	5.696	3/43	0.002	1.007	3/23	0.408

3. Years 1999+2000 (repeated measures analysis of variance with "time" as repeated measure)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp [1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]			Bushtit & Chickadee[3]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
a) 3 surveys/year; 1st survey omitted																								
Spray-status	0.519	1/102	0.473	0.307	1/80	0.581	2.362	1/134	0.127	0.027	1/50	0.870	3.995	1/135	0.048*	3.766	1/134	0.054*	0.176	1/117	0.676	0.129	1/76	0.721
Year	1.130	1/102	0.290	0.163	1/80	0.688	0.019	1/134	0.890	3.010	1/50	0.089	3.120	1/135	0.080	16.971	1/134	<0.0001	4.939	1/117	0.028	1.013	1/76	0.317
Site (within spray-status)	2.337	25/102	0.002	1.477	17/80	0.125	5.759	26/134	<0.0001	4.299	13/50	<0.0001	2.625	26/135	0.0002	3.149	26/134	<0.0001	0.968	26/117	0.516	0.903	25/76	0.600
Time	0.963	2/101	0.385	1.424	2/79	0.247	0.438	2/133	0.647	0.482	2/49	0.620	2.874	2/134	0.060	5.499	2/133	0.005	16.178	2/116	<0.0001	1.724	2/75	0.185

*more birds on sprayed than unsprayed plots

** The values presented here differ from those in Ovaska and Sopuck (1999), because the number of plots used for individual species in the analyses were increased reflecting data obtained in year 2000.

[1]Other Guild 2 species category includes a variety species other than those treated individually (i.e., Bewick's Wren, Chipping Sparrow, Spotted Towhee, and White-crowned Sparrow omitted)

[2]Other Guild 3 spp (migrants) category includes warblers other than Orange-crowned Warbler, vireos, and Western Tanager

[3]Bushtit and Chickadee category includes observations of the Bushtit and Chestnut-backed Chickadee combined

# of study plots = 41 unsprayed and 41 sprayed, except for species with patchy distribution, for which only those plots where the species was found during at least 1 survey were used:
Bewick's Wren: 34, 31; Chipping Sparrow: 23, 27; White-crowned Sparrow: 15, 18; Bushtit & Chestnut-backed Chickadee (combined): 29, 23; Other Guild 3 spp (migrants): 37, 36
(# of unsprayed versus sprayed plots, respectively).

Appendix D. Statistical values for analysis of variance for numbers of singing birds observed during 4 point-count surveys in April-June 1999 and 2000 on Btk sprayed and unsprayed study plots. Survey 1 in April 1999 took place before spraying, which was conducted in May-June 1999. Wilk's lambda was used as a test statistics in all comparisons.

1. Year 1999** (analysis of variance with specified contrast)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp[1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
a) 1 pre- versus 3 post-spraying surveys (contrast vector: -3. 1, 1, 1)																					
Spray-status	0.494	1/38	0.487	0.153	1/31	0.698	9.455	1/54	0.003	0.001	1/18	0.979	0.341	1/54	0.562	2.030	1/54	0.160	1.995	1/45	0.165
Site (within spray-status)	0.786	25/38	0.734	1.176	17/31	0.337	0.994	26/54	0.491	0.605	13/18	0.820	2.513	26/54	0.002	0.531	26/54	0.960	1.955	26/45	0.024
b) linear trend among 3 post-spraying surveys (contrast vector: 0, -1, 0, 1)																					
Spray-status	2.299	1/38	0.138	1.770	1/31	0.193	0.219	1/54	0.642	1.774	1/18	0.200	1.460	1/54	0.232	1.152	1/54	0.288	0.014	1/45	0.907
Site (within spray-status)	0.923	25/38	0.576	1.921	17/31	0.056	0.782	26/54	0.750	0.417	13/18	0.944	0.652	26/54	0.882	1.381	26/54	0.158	1.342	26/45	0.190

2. Year 2000 (repeated measures analysis of variance with "time" as repeated measure)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp[1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
Spray-status	0.282	1/38	0.599	0.054	1/31	0.818	0.034	1/54	0.855	0.266	1/18	0.612	1.093	1/54	0.301	0.623	1/54	0.434	2.117	1/45	0.153
Site (within spray-status)	3.319	25/38	0.0004	1.215	17/31	0.310	3.119	26/54	0.0002	3.299	13/18	0.010	6.691	26/54	<0.0001	1.949	26/54	0.020	1.611	26/45	0.079
Time	0.533	3/36	0.663	0.142	3/29	0.934	3.690	3/52	0.018	1.059	3/16	0.394	1.161	3/52	0.333	6.761	3/52	0.0006	1.989	3/43	0.1298

3. Years 1999+2000 (repeated measures analysis of variance with "time" as repeated measure)

	Bewick's Wren			Chipping Sparrow			Spotted Towhee			White-crowned Sparrow			Other Guild 2 spp[1]			Orange-crowned Warbler			Other Guild 3 spp (migrants)[2]		
Effect	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P	F	DF	P
a) 3 surveys/year; 1st survey omitted																					
Spray-status	1.253	1/102	0.266	0.055	1/80	0.815	1.780	1/135	0.184	0.109	1/50	0.743	5.363	1/135	0.022*	2.100	1/135	0.150	2.043	1/117	0.156
Year	0.153	1/102	0.697	5.532	1/80	0.021	0.351	1/135	0.555	1.532	1/50	0.222	0.304	1/135	0.582	16.619	1/135	<0.0001	6.597	1/117	0.012
Site (within spray-status)	2.567	25/102	0.0005	1.397	17/80	0.161	4.088	26/135	<0.0001	2.451	13/50	0.012	5.801	26/135	<0.0001	2.117	26/135	0.003	1.241	26/117	0.217
Time	1.286	2/101	0.281	0.891	2/79	0.414	0.124	2/134	0.884	0.041	2/49	0.960	0.956	2/134	0.3872	4.900	2/134	0.009	10.232	2/116	<0.0001

*more birds on sprayed than unsprayed plots

** The values presented here differ from those in Ovaska and Sopuck (1999), because the number of plots used for individual species in the analyses were increased reflecting data obtained in year 2000.

[1]Other Guild 2 species category includes a variety species other than those treated individually (i.e., Bewick's Wren, Chipping Sparrow, Spotted Towhee, and White-crowned Sparrow omitted)

[2]Other Guild 3 spp (migrants) category includes warblers other than Orange-crowned Warbler, vireos, and Western Tanager

[3]Bushtit and Chickadee category includes observations of the Bushtit and Chestnut-backed Chickadee combined

# of study plots = 41 unsprayed and 41 sprayed, except for species with patchy distribution, for which only those plots where the species was found during at least 1 survey were used: Bewick's Wren: 34, 31; Chipping Sparrow: 23, 27; White-crowned Sparrow: 15, 18; Bushtit & Chestnut-backed Chickadee (combined): 29, 23; Other Guild 3 spp (migrants): 37, 36 (# of unsprayed versus sprayed plots, respectively).

Appendix E-a. Number of broods with newly fledged young or sign of broods (based on adults carrying food) observed during surveys in spring 1999. # of study plots was 29 in Btk-sprayed and 29 in unsprayed areas. Survey 1: 2-11 June 1999; Survey 2: 19-29 June 1999.

Common name	# of broods with fledged young/survey*				Additional broods (fledged or in nest)/survey**				Total # of
	Unsprayed-1	Sprayed-1	Unsprayed-2	Sprayed-2	Unsprayed-1	Sprayed-1	Unsprayed-2	Sprayed-2	broods
A. Caterpillars constitute a low proportion of diet									
American Robin	1	3	5	5	1	1	2	0	18
Cedar Waxwing	0	0	0	2	0	0	0	0	2
European Starling	1	0	1	1	0	1	2	4	10
House Finch	3	1	2	1	0	0	0	0	7
House Sparrow	0	0	0	0	1	1	1	0	3
B. Caterpillars constitute a moderate proportion of diet									
Bewick's Wren	2	3	0	0	0	0	2	0	7
House Wren	0	0	0	1	0	0	0	2	3
Chipping Sparrow	0	0	5	6	2	3	2	1	19
Dark-eyed Junco	9	7	4	5	1	0	4	1	31
Red-breasted Nuthatch	3	0	0	0	0	0	0	2	5
Spotted Towhee	9	5	7	3	1	0	1	4	30
White-crowned Sparrow	2	0	1	1	5	1	0	0	10
Red-winged Blackbird	0	0	0	1	0	0	0	0	1
C. Caterpillars constitute a high proportion of diet									
Bushtit	2	0	1	0	0	0	1	1	5
Chestnut-backed Chickadee	4	1	2	0	2	1	1	0	11
Common Yellowthroat	0	0	0	0	0	0	0	1	1
Orange-crowned Warbler	2	7	4	3	4	1	0	1	22
Townsend's Warbler	0	0	0	0	0	1	0	0	1
Yellow-rumped Warbler	0	0	0	1	0	1	0	0	2

* Dependent young with adults

** Includes observations of young in nest and additional broods (in nest or fledged) inferred from adult(s) carrying food

Appendix E-b. Number of broods with newly fledged young or sign of broods (based on adults carrying food) observed during surveys in spring 2000. # of study plots was 30 in Btk-sprayed and 30 in unsprayed areas. Survey 1: 25 May-5 June 2000; Survey 2: 16-25 June 2000.

Common name	# of broods with fledged young/survey*				Additional broods (fledged or in nest)/survey**				Total # of broods
	Unsprayed-1	Sprayed-1	Unsprayed-2	Sprayed-2	Unsprayed-1	Sprayed-1	Unsprayed-2	Sprayed-2	(actual & inferred)
A. Caterpillars constitute a low proportion of diet									
American Robin	4	1	5	9	4	9	4	2	38
Cedar Waxwing	0	0	0	0	0	0	0	0	0
European Starling	1	0	0	0	1	1	1	1	5
House Finch	0	3	0	0	0	0	0	0	3
House Sparrow	1	0	0	0	1	0	1	0	3
Pine Siskin	1	0	1	0	0	0	0	0	2
B. Caterpillars constitute a moderate proportion of diet									
Bewick's Wren	4	3	4	4	1	0	0	1	17
House Wren	0	0	1	2	0	0	0	0	3
Chipping Sparrow	2	1	5	3	2	3	1	4	21
Dark-eyed Junco	2	14	6	8	0	3	0	1	35
Red-breasted Nuthatch	5	4	1	2	0	0	3	0	15
Spotted Towhee	9	7	10	10	1	3	3	0	43
Song Sparrow	0	1	0	0	0	0	0	0	1
White-crowned Sparrow	0	0	0	3	2	3	1	1	10
C. Caterpillars constitute a high proportion of diet									
Bushtit	7	2	1	2	1	0	2	0	15
Chestnut-backed Chickadee	7	6	0	3	2	1	0	0	18
Orange-crowned Warbler	2	0	3	8	4	2	2	2	23
Townsend's Warbler	0	0	0	0	1	0	0	0	1
Yellow-rumped Warbler	0	1	0	0	0	0	0	1	2

* Dependent young with adults

** Includes observations of young in nest and additional broods (in nest or fledged) inferred from adult(s) carrying food

Appendix F. Birds observed foraging on caterpillars in Garry Oak habitats in in spring 1999 and 2000.

Species	Feeding on caterpillars (# of occasions)*		Feeding caterpillars to young or carrying in beak (# occasions)*	
	1999	2000	1999	2000
Hairy Woodpecker	0	0	1	0
Downy Woodpecker	0	0	0	1
Northwestern Crow	1	0	0	0
American Robin	0	0	2	0
Bewick's Wren	1	0	1	1
Black-throated Gray Warbler	1	0	0	0
Bushtit	4	0	6	3
Cassin's Vireo	0	1	0	0
Chestnut-backed Chickadee	6	3	14	3
Chipping Sparrow	4	1	7	7
Dark-eyed Junco	6	0	11	2
European Starling	1	0	0	0
House Finch	0	0	1	0
House Sparrow	1	0	2	0
House Wren	2	0	0	0
Orange-crowned Warbler	8	2	9	8
Pine Siskin	0	1	0	0
Red-breasted Nuthatch	0	1	0	2
Red-winged Blackbird	1	0	0	0
Spotted Towhee	6	1	5	7
Townsend's Warbler	3	0	2	1
Warbling Vireo	1	0	0	0
Western Tanager	2	0	1	1
White-crowned Sparrow	1	0	4	2
Wilson's Warbler	2	1	0	1
Yellow Warbler	3	1	0	0
Yellow-rumped Warbler	3	0	0	1

* # occasions refers to separate observations either on different days or of different birds. Birds feeding together (as a pair or in a flock) were considered a single observation.