INVESTIGATION OF STARLING POPULATIONS IN BRITISH COLUMBIA

AND

ASSESSMENT OF THE FEASIBILITY OF A TRAPPING PROGRAM IN THE LOWER MAINLAND

A Report Prepared for:
British Columbia Blueberry Council
Abbotsford, British Columbia

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Executive Summary

In British Columbia, starlings have been identified as a significant damaging agent to orchards and vineyards in the Okanagan, and blueberry crops in the Lower Mainland of B.C. As a consequence of this damage, trapping programs have been initiated to reduce abundance of starlings in Whatcom County, Washington and the Okanagan. Given the establishment of these trapping programs north and south of the Lower Mainland, there is interest in initiating a similar trapping program in the Lower Mainland. However, before establishing a trial program, it is important to identify if a trapping program would be effective in reducing the abundance of starlings. This unknown was addressed by reviewing previous reports that examined population reduction of starlings. In addition, a review and analysis of data retrieved from the National Breeding Bird Surveys (BBS) was examined for indications whether the current trapping programs in Whatcom County and Okanagan have been successful in reducing the relative abundance of breeding starlings on routes adjacent to the trapping programs.

A review of the available literature showed that there were no reports that provided a strong scientific assessment of the benefits or weaknesses of control programs to reduce the abundance of starlings. Other than one report, assessment of the effects of control programs were based on number of birds removed and/or qualitative assessment of changes in their abundance or the damage they caused. However, a number of generalizations can be made.

Winter Control Programs: A trapping program aimed at the long-term reduction in abundance of starlings in the Lower Mainland is unlikely to be successful, especially if the emphasis is placed on winter trapping. Although significant short-term reduction in abundance of birds can be obtained during winter (primarily with a starlicide or surfactant), it appears that long-term reduction in either damage or abundance of starlings in winter is not well supported. Those reports that monitored the abundance of starlings following treatments indicated that their abundance quickly returned to pre-removal levels. Previous winter control programs appeared to provide little long-term reduction in abundance of starlings; although, some short-term reductions were noted.

Summer Trapping Programs: Although no reports documented changes in abundance of birds resulting from a summer trapping program, they consistently confirmed that trapping captured primarily juvenile birds, resulting in little change in abundance of adult birds (breeding segment of the population). Data from BBS failed to indicate a consistent decrease in relative abundance of breeding starlings on routes within the effective trapping areas when compared to those outside of the trapping areas. Thus, there was little evidence available to support the idea that a summer trapping program could result in a long-term reduction in the resident population of

starlings in the Lower Mainland. However, a number of reports have found that a summer trapping program was very effective at reducing damage to summer crops, including blueberries in Connecticut. Previous reports had identified flocks of juvenile starlings as causing significant damage to summer crops. Therefore, implementing an intensive trapping program from late May-early June to August, targeting juvenile starlings, may reduce a significant number of juvenile starlings and the damage they cause to summer crops while the program is being conducted. A summer trapping program has merit, if the primary goal is to reduce damage, rather than long-term population reduction of starlings. If a trapping program was implemented, it is strongly recommended that a thorough and reliable monitoring protocol be implemented to evaluate whether the program is being successful and if the level of trapping is sufficient. A monitoring program would permit modification of the program as an adaptive-management approach, enhancing effectiveness and efficiencies of the trapping program.

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Overview

[1]Starlings (*Sturnus vulgaris*) were originally introduced into North America in 1890 and 1891. Although introductions failed in Oregon, eventually individuals introduced into New York survived and started increasing in abundance. By 1942, starlings reached the west coast of North America. From this initial introduction starlings have increased in abundance and currently are among the most abundant bird species in North America (BBS, 2010; Sauer et al., 2008).

Starlings have been identified as one of the 100 World's Worst invades (Lowe et al., 2000). Damage caused by starlings to feed lots, fruit orchards, vineyards, and berry production is well documented around the world. Damage to agricultural crops in the US has been estimated at an annual cost of $800 million, with an additional cost of $800 million in health treatment costs associated with livestock and human disease transmission (Linz et al., 2007). In British Columbia, starlings have been identified as a significant damaging agent to vineyards in the Okanagan Similkameen region with annual crop loss to vineyards estimated at $1.5 million (Bielert and Hol, 2008) and $3 million (Prairie Farm and Ranch, 2010). Similarly, damage to tree fruits in the north and south Okanagan has been estimated at close to $2 million annually (B.C. Fruit Growers Association, 1998) and more recently at close to $0.5 million for cherries and apples (Prairie Farm and Ranch, 2010). In the Lower Mainland, starlings have caused significant damage to blueberry crops and which has been estimated at 10 to 20% (Avery et al., 1992) and 10% (Weber, 1983). Some berry producers have reported losses ranging from 20 to 40% in the Lower Mainland of B.C. (Weber, 1983) and up to 30% in Whatcom County, Washington (Whatcom Farm Friends, 2008).

As a consequence of this damage, control programs have been initiated to reduce abundance of starlings throughout the United States. A pilot control program aimed at reducing starling populations in the Okanagan Similkameen area was initiated in 2003. This program used trapping to capture birds then, following removal of non-target species; starlings were humanly euthanized using CO_2. From 2003 to July 2010, approximately 300,660 birds have been removed (Bielert, pers. comm.). Whatcom County Washington initiated a similar trapping program for starlings in 1997. Their program has removed > 500,000 birds in the northern County since 1997 (H. Bierlink, pers. comm.).

[1] Source for image on the front page: ttp://www.google.ca/imgres?imgurl=http://whatcom.wsu.edu/ag/comhort/nooksack/ipmweb/blue/images/starling.jpg&imgrefurl=http://whatcom.wsu.edu/ag/comhort/nooksack/ipmweb/blue/birds.html&usg=__tmEXduvMBc8_WeoJ2TH7eIAlAfM=&h=264&w=452&sz=21&hl=en&start=30&um=1&itbs=1&tbnid=yvvdTmDHDLx6zM:&tbnh=74&tbnw=127&prev=/images%3Fq%3Dimage%2Bsturnus%2Bwashington%26start%3D18%26um%3D1%26hl%3Den%26sa%3DN%26ndsp%3D18%26tbs%3Disch:1

Given the established starling control programs both north (Okanagan Similkameen) and south (Whatcom County, Washington) of the Lower Mainland, there is interest in initiating a similar control program here. However, before establishing a trial program in the Lower Mainland, a few key uncertainties need to be addressed, namely:

1. What is the effectiveness of trapping to control starlings?
2. Is there evidence (breeding bird surveys or Christmas bird counts) that indicate currently-conducted control programs have reduced the abundance of starlings?
3. Are our starlings primarily composed of resident or migrant birds? Related uncertainties include:
    a. Where are the migrants coming from?
    b. When do the migrants arrive in the Lower Mainland?
4. What is needed to initiate a trial control program and monitoring protocol?

The following literature review addresses uncertainties 1 and 2. Uncertainty 3 is being addressed through UBC Okanagan. Should it be deemed feasible to proceed with a trapping program, a trapping program protocol will be developed (uncertainty # 4).

Starling Biology (sources: Feare, 1984 + cited references)

Description: The European starling is approximately 21 cm long, weighs 75 grams, has a stocky build, and powerful legs (Figure 1). Its bill is long, pointed, and approximately 2.5 cm long. It is well adapted for capturing insects from vegetation and the upper few centimetres of soil. The adult body is often a glossy black with a green, purple, and bluish sheen (Figure 1A). Contour feathers are tipped with white or tan pigment giving adult birds a spotty appearance. However, as winter progresses, these spots slowly wear away, leaving adult birds looking iridescent. Bills in adult birds are typically dark brown for most of the year, but turns bright yellow for the breeding season. Legs and feet change from brown to reddish pink during the breeding season.

Adult male birds can be distinguished from adult female birds by the colour of the bird's bill at its base during their breeding plumage (November through the breeding season). Males have a steely-blue base (rami) while the females have a creamy-pink base (Kessel, 1951: Figure 1C). Outside this period, the bill is completely yellow or yellow at the base in adults. In addition, eye colour (iris) of males is deep brown throughout while the outer edge of the iris of females becomes lighter in colour (yellowish), making a light-coloured conspicuous ring around it; although this criterion is not as reliable as bill colour (Kessel, 1951; Pyle, 2001). Other features that may also be used to indicate genders (although less reliably) include: colour of the under-wing coverts (dark centers with buff-coloured margins indicate male), weight and length (unusually large birds are

always male, small birds are always first-year females), and persistence of white-tipped feathers (females commonly more white-tipped than males) (Kessel, 1951).

A B C

Figure 1. Adult (A), juvenile (B), and adult male (C left; note steely blue rami and primarily dark iris) and adult female (C right; note creamy rami and 2-tone iris) European starling (*Sturnus vulgaris*) emphasizing distinguishing colour patterns (source: A: http://wdfw.wa.gov/wlm/living/graphics/t_starlings1.jpg; B: http://files.myopera.com/RobinL/blog/2009-07-27%20008%20juv%20starling.jpg; C: http://farm3.static.flickr.com/2059/3539584765_b4ef3b2291_o.jpg).

The entire plumage of juvenile birds is mouse-brown except for some whitish feathers below the chin (Figure 1B). Following their post-juvenile moult in fall (finished by early October), juvenile birds resemble adults birds with a spotty appearance. Kessel (1953) provided a number of different physical features than can be used to distinguish post-juvenile molts from adult birds.

Distribution: There were many attempts to introduce starlings to North America. The earliest documented attempts date back to 1850 in West Chester Pennsylvania, and again in Cincinnati, Ohio in winter 1872 - 1873 (Cooke, 1928). An introduction of 20 pairs to Portland Oregon failed in 1889; although, some individuals persisted until 1901. None of these previous attempts were successful. Their foothold into North America was established following the introduction of 80 pairs to Central Park, New York in 1890, and another 80 pairs in March 1891 (Figure 2). Starlings first appeared in Canada near Esquimaux Point, Labrador in 1917 and Brockville, Ontario in July 1919 (Mousley, 1924; Cooke, 1928). By 1927, their distribution included much of southern Quebec and Ontario.

Since their initial establishment in eastern North America, starlings have moved westward and arrived on the west coast in the early 1940s: California in 1942 (Jewett, 1942); and, Oregon (Jewett, 1946) and Washington in 1943 (Wing, 1943). Although their numbers were small initially, by the 1950s, their winter flocks ranked in the 10,000s in western Oregon alone (Elliott, 1964). By the mid 1960s, estimated abundance at Oregon roost sites had been reported in the millions. They were first observed in B.C.

in 1945 (Jobin, 1952), and first confirmation with museum specimens and taxidermy mounts from Oliver and Bella Coola B.C. in winter of 1946-1947 (Myers, 1958), with individuals observed as far north as Williams Lake and Burns Lake in 1948 and 1949, respectively (Myers, 1958; Racey, 1950). Starlings dispersed to north-western B.C. from the Peace River area of B.C. and Alberta in the early 1950s (Munro and Cowan, 1947; Myers, 1958). Breeding in the Peace River region was fairly wide spread by the mid 1950s. Currently, breeding populations of starlings are well distributed across North America, with a majority of their range in British Columbia occurring from central B.C. south (Figure 3).

Within 10 years, they established themselves as a common breeding species in the interior of B.C., and only as a common winter resident in the Fraser Valley (Myers, 1958). The first record of starlings in the Lower Mainland was in Cloverdale in the summer of 1948 (Myers, 1958). However, by 1958 only one record (1952 in Victoria) of starlings breeding on the coast was made; thus, starlings at this time were primarily just a winter resident on the coast (Myers, 1958). The Christmas bird count failed to note any starlings in Vancouver in 1951-1953. In 1954, 2700 individuals were observed with this number rising dramatically to over 14,000 in 3 years. This rapid rise in the Christmas bird count likely reflected a significant increase in the breeding population in the interior of B.C. They became regular nesting species in south-western B.C. in the 1960s (Johnson, 1974).

The current distribution of starlings includes much of B.C. They currently occupy most of the southern part of B.C. from Vancouver Island to Alberta, and north to the Skeena River Valley (Figure 3). Their highest numbers in both summer and winter are in the Lower Mainland of B.C. Their abundance decreases as their distribution moves north, eventually resulting in a patchy distribution. The most northerly occurrence includes the Kelsall River valley and Kwokullie Lake in the east (Campbell et al., 2001).

Migration & Movement: Much of the information on movement patterns of starlings have been based on observations from eastern NA. In general, not all individuals from the same population migrate; many are permanent residents throughout their breeding range (Kessel, 1953). Those that appear to move great distances are young of the year, moving to southern areas for their first winter. However, individuals of all age classes have been observed migrating. Actual percentage of migrants, versus residents, appears to vary geographically. From early banding records in the eastern US, resident birds appeared to comprise 23 to 38% of wintering populations for individuals that roost in flocks. For individuals that roost solo, up to 57% of wintering individuals may be resident birds (Kessel, 1953).

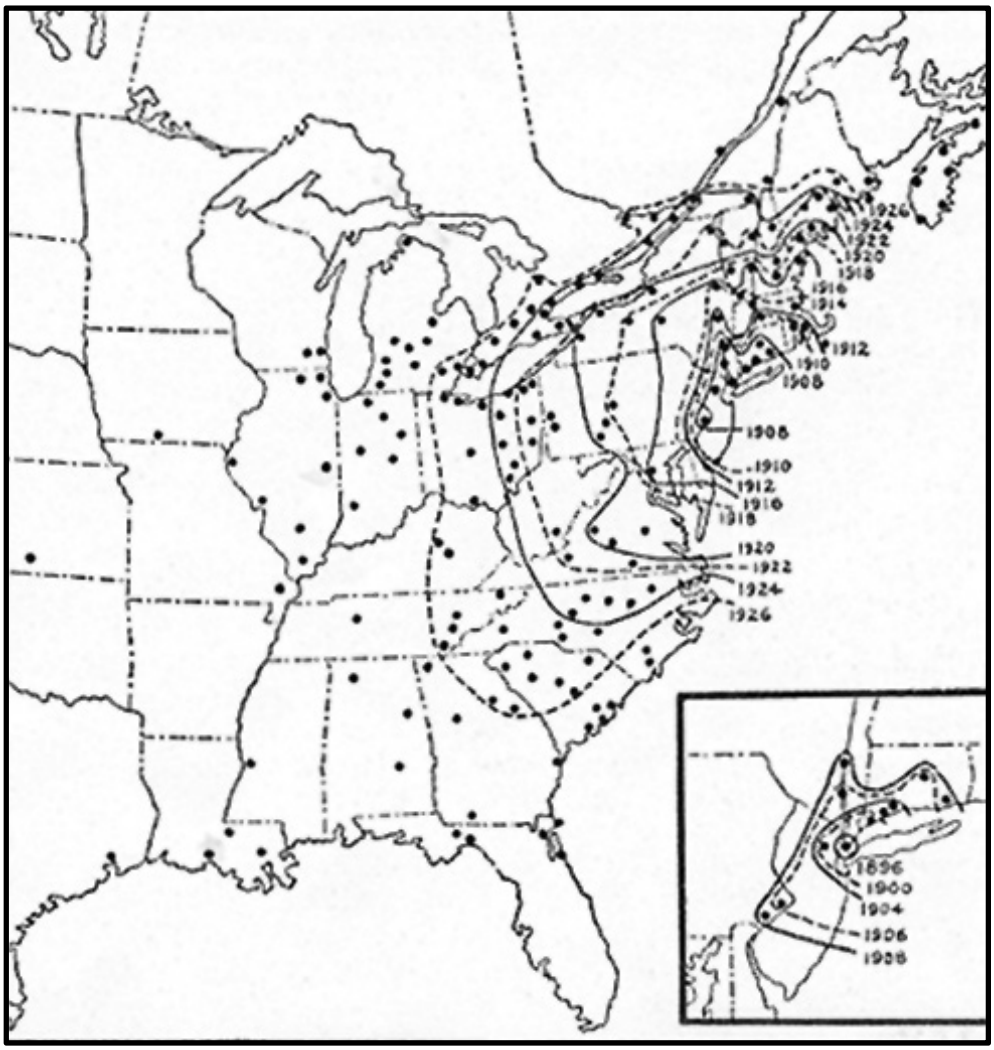

Figure 2. Initial radiation of starlings (*Sturnus vulgaris*) in eastern North America following introductions of 160 pairs into New York in 1890 & 1891 (Cooke, 1928).

Data from the Pacific Northwest indicated that 53% of band recoveries were from migrants (those than moved more than 30 minutes latitude (~ 55 km) or longitude (~ 43 km) from the banding location) (Johnson, 1974). Most (83-96%) of these returns from migrants were from north of their banding location for all seasons, indicating that many banded birds moved northward and stayed north rather than returning to their place of banding. Johnson (1974) suggested this represented expansion of their wintering range to the north. In general, both summer and winter populations of resident birds are augmented by migrating individuals (Kessel, 1953; Royall et al., 1972; Johnson, 1974). Less is known about the ratio of residents to migrants for breeding populations.

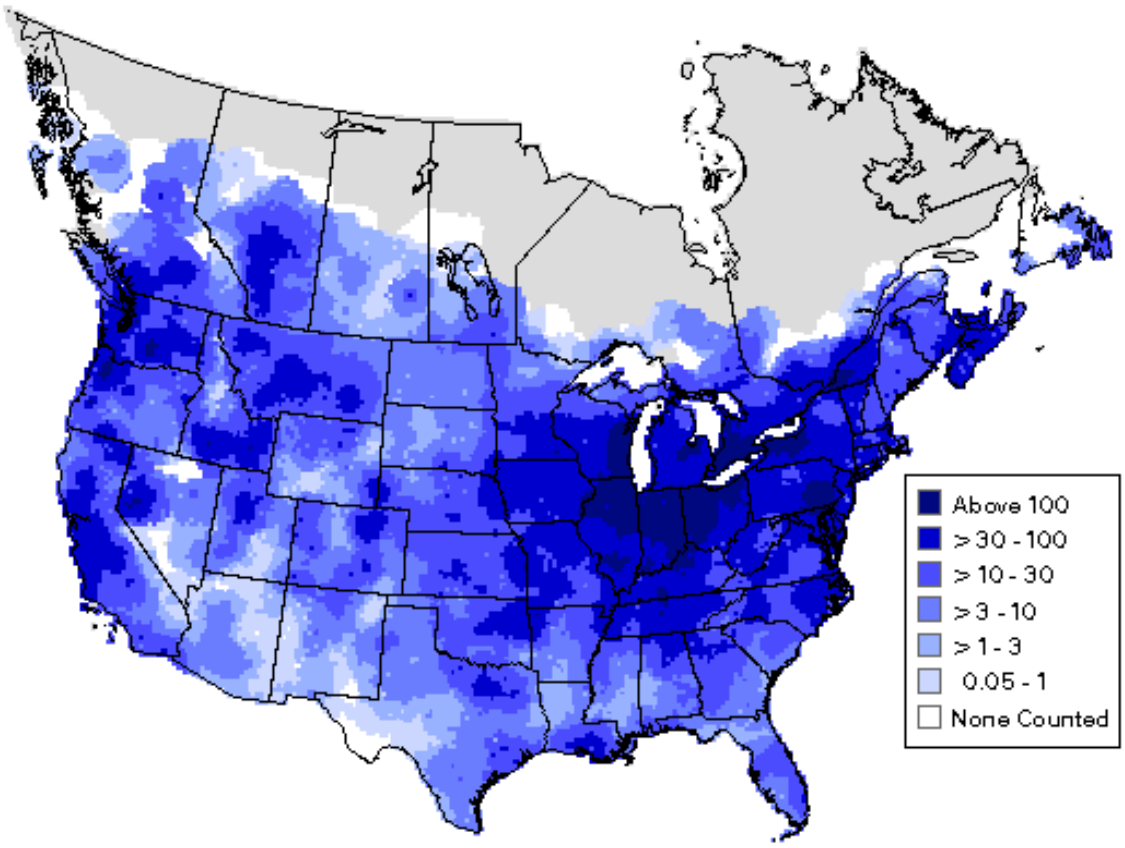

Figure 3. Average occurrence (1994 to 2003) of breeding European starlings (*Sturnus vulgaris*) in North America. Degree of shading indicates relative frequency of occurrence (source: Sauer et al., 2007).

Kessel (1953) suggested that at least 34% of the breeding birds in Ithaca New York were resident individuals. However, populations on the northern part of their range appeared to be more migratory than those in the center of their breeding range.

Historically, the timing of migration in NA appeared consistent with those in Europe. Peak spring and fall migration in North Bay Ontario was in early April and late August, respectively (Kessel, 1953). Individuals banded in winter in northern California progressed northward, appearing in southern Idaho and northern Oregon in early February, southern Washington in early March, and east-central Alberta and Saskatchewan at the end of March and early April (Royall et al., 1972). Some of these individuals were recovered in the Lower Mainland and Southern Interior of B.C. during the breeding season. Most individuals from this banded population bred in Alberta. However, Campbell et al. (2001) noted that birds banded in Washington, Oregon, and

California, and subsequently found in B.C., were found equally in the Lower Mainland and the Southern Interior of B.C. In B.C., spring migration is abrupt and takes place largely in late February and March (Campbell et al., 2001). In the Lower Mainland, there has been a 6-fold drop in number of starlings by the second week of April (and through to May) as flocks migrate to breeding areas throughout the valley and into the southern and central interior of B.C. (Figure 4). Their abundance increases dramatically throughout March in the Cariboo, Chilcotin, and sub-boreal interior (Campbell et al., 2001). Numbers naturally build through summer as young-of-the-year join the population. In fall, migrants start arriving in late August and continue to build until mid-October, then drop (up to 25% of September's numbers), possibly from migrants continuing their trip south (Campbell et al., 2001).

When starlings migrate they do so along topographic features such as river valleys, lake plains, and coastal plains flyways (Kessel, 1953). The general direction of their migration is north and south (pending season). For Midwestern states, they typically move north in a southwest to northeast direction (Kessel, 1953; Burtt and Giltz, 1977). Similarly, birds in California primarily migrate from a southwest to northeast direction to Alberta for breeding, although some travelled to southern B.C. to breed (Royall et al., 1972). Dolbeer (1982) noted that starlings, on average, moved 206 (± 299 Standard Deviation) km between nesting and wintering sites for eastern NA. For birds banded during breeding, average (± SD) distances moved to their winter roost sites for midwest states was 205 (± 292) km for adult birds and 455 (± 438) km for young of the year (Dolbeer, 1982). However, Royall et al. (1972) noted shorter distances (115 km) travelled between points of banding and winter recovery in California. Overwinter-roost sites can vary by 212 (± 324) km from one winter to the next (Dolbeer, 1982).

After leaving nests in late spring and early summer, young birds are highly variable in their movement patterns. Some birds wander and others migrate, eventually settling in any suitable place when they are ready to nest (Kessel, 1953). This variability is typical for juvenile, first-year, and second-year starlings that have not bred. Their final nest site may or may not be close to their original hatch site. Dolbeer (1982) found that 70% of banded starlings in the eastern states dispersed less than 50 km from their hatching site to their breeding site the following year; about 12% traveled greater than 200 km.

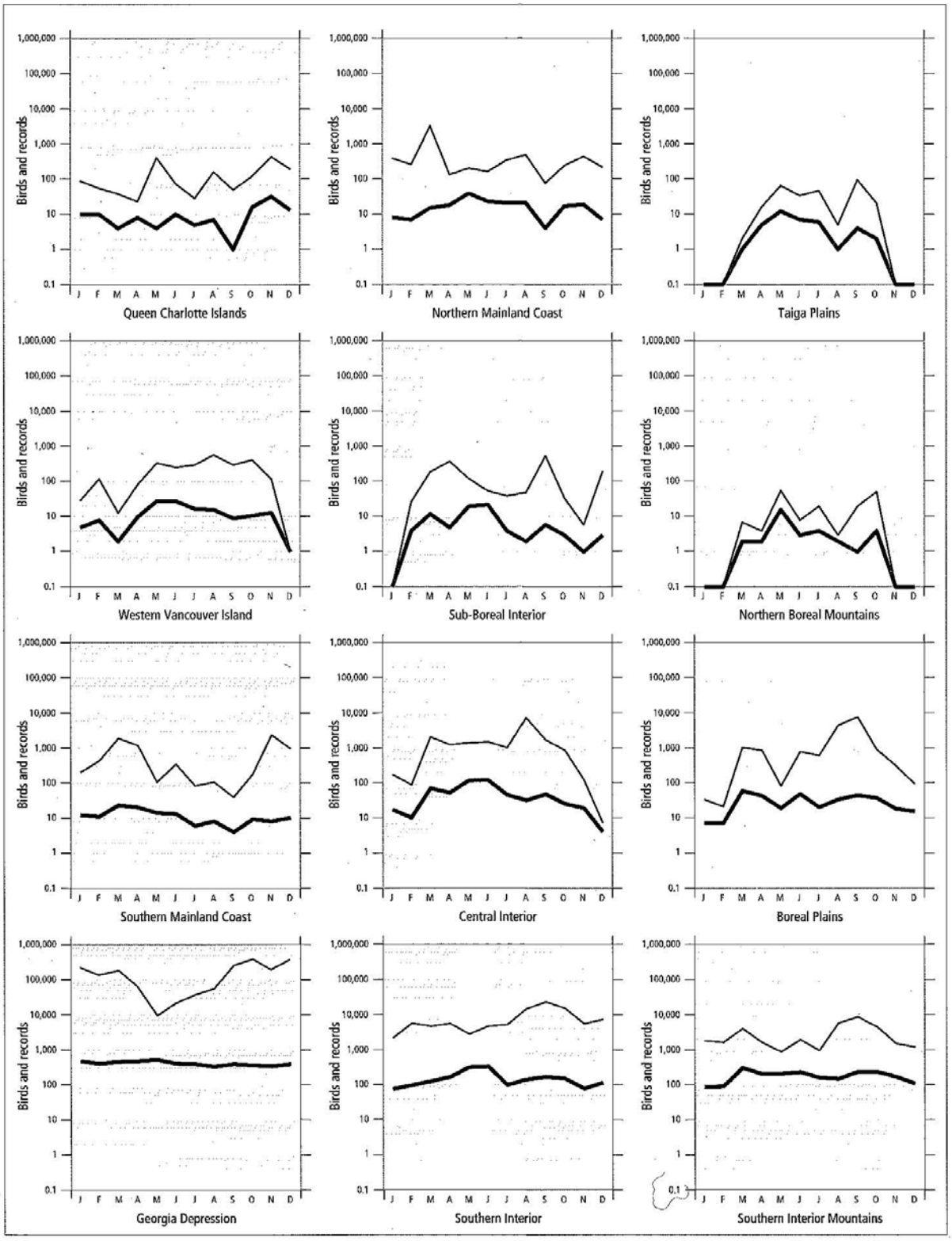

Figure 4. Monthly fluctuations in abundance of starlings for each ecoprovince in B.C. Thin lines represent total number of birds reported while thick lines represent total number of records (Source: Figure 567 from Campbell et al. (2001).

However, on average (± SD), young of the year nested 80 (± 197) km from their place of hatching, while older birds only moved 16 (± 390) km (Dolbeer, 1982). Conversely, Paton et al. (2005) noted that juvenile birds often returned to the same area to nest the following year. Adult birds appear to elicit greater site fidelity than young birds and nest in similar areas as previous years (Kessel, 1953; Paton et al., 2005). Potentially, it is this variability in movements of young birds that facilitated the rapid range extension of starlings across N.A. (Cabe, 1999).

Summer movements in California averaged 40 km between summer banding locations and recovery later the same summer (Royall et al., 1972). LeJeune et al. (2008) noted that most of their radio-collared starlings traveled within 20 km from their capture sites (dairy farms in Ohio) to night roost sites. However, Morrison and Caccamise (1985) recorded average daily distances between feeding and roost sites was 4 to 8 km in New Jersey. In Oregon, daily movements of radio-tagged starlings in winter were between roost sites and foraging areas and averaged 18 km (± 6.4 km) with a maximum distance moved of 19 km (± 6.6 km; Bray et al., 1975). However, different foraging areas were often used on successive days with an average distance between these activity areas of 4.8 km (Bray et al., 1975). Guarino (1968) reported (based on 200,000 banded and marked starlings and blackbirds) daily movements of up to 40 km for overwintering starlings between roost sites and feedlots in western states. These authors estimated the home range of starlings in winter in Oregon to be approximately 40 km^2 (± 17.6 km^2). However, daily movements and choice of activity centres varied significantly among some individuals; although, most starlings returned to the same general feeding area each day (Bray et al., 1975). Similarly, a foraging radius of 36 km was reported for wintering blackbirds and starlings (White et al., 1985; Glahn and Otis, 1986). In general, daily movements varied from 5 km to 40 km between foraging and roost sites. However, since starlings change their roost sites every few days, distance traveled within a day would under-estimate the general area starlings visit while foraging over multiple days. The data presented by Royall et al. (1972) may provide a better estimate of the distance starlings travel during summer, than distance traveled in one day.

Feeding & Roost-Site Selection: Starlings are most abundant around human habitation and avoid heavy timbered regions (Campbell et al., 2001). While feeding, starlings need suitable cavities for nest sites, and feeding areas adjacent to the nest site (Feare, 1984). Adults rarely feed more than 500 m from nests and often feed within 200 m of nest sites (Feare, 1984; Paton et al., 2005). Starlings are essentially grassland feeders, gleaning insects from ground surfaces and the upper few centimetres of soil (Feare, 1984). They prefer short-grass areas to facilitate visibility and predator avoidance. Thus, suitable breeding areas are provided by a nest cavity surrounded by 12 ha of grassland habitat (Feare, 1984). As starlings are colonial breeders, the best habitat supplies a number of nest cavities and grassland habitat in one area. In early

summer they almost exclusively feed on invertebrates (Feare, 1984). Survival of chicks appears dependant on adequate sources of invertebrates. Outside of the breeding season, they are less dependent on invertebrates as a primary food source. Starlings undergo seasonal modifications in their digestive tract to broaden their dietary options in the fall (Feare, 1984). Thus, food items consumed in late summer, fall, and winter can include fruits, seeds, and other plant foods, in addition to their strong reliance on invertebrates. In summer, starlings primarily forage in lawns and other substrates where soil invertebrates are common and feed at these locations all summer long (Caccamise, 1991). Thus, starlings have two major types of foraging areas: primary feeding areas used throughout the year with an abundant invertebrate food source, and supplemental feeding areas in fall and winter with abundant plant material (fruit, seeds, grains, etc.). It is these supplemental foraging areas (vineyards, berry fields, feedlots, etc.) that are the primary source of economic impact by starlings (Caccamise, 1990).

Initially, in spring, starlings are primarily independent and nest as individuals. As summer progresses, they begin to congregate in roosts in early summer near the end of the breeding season. Thus, given availability of spring foraging habitats, their night-time roosts are often close (< 2 km away: Morrison and Caccamise, 1990; Caccamise, 1990) and abundance of birds small (25-500 birds). At this time the number of roosts are numerous, but occupied by few individuals (Caccamise et al., 1983; Caccamise, 1990). As summer progresses, starlings start to include far greater proportions of plant materials (fruits, seeds) in to their diet, and travel greater distances (4 – 12 km away) to these sites, (Fischl and Caccamise, 1985, 1986; Morrison and Caccamise, 1990). Number of roosts decrease as small scattered roosts start to coalesce into large roosts (Caccamise et al., 1983: Caccamise, 1990). It appears they primarily change their roost locations in an attempt to intersect more supplemental foraging areas between their roost sites and their primary feeding areas (Caccamise, 1991). Thus, starlings are most faithful to their daily primary feeding area, and to some extent their supplemental feeding areas, and less faithful to roost sites (Bray, 1975; Feare, 1980; Caccamise, 1990; Paton et al., 2005). Paton et al. (2005) found that some individuals used 10 different roost sites during a three-month tracking period. Starlings primarily visit their supplemental feeding areas in mornings and evenings while traveling between their night roosts at their primary feeding areas (Fischl and Caccamise, 1987; Caccamise, 1990). This pattern of feeding explains the observations of Roberts (1992) of starling feeding behaviour in blueberry fields in the Pitt Meadow area of B.C. Roberts noted a bimodal activity pattern where starlings were most abundant in blueberry fields around 7 am to 11:30; then again between 4 pm and 7 pm. This feeding behaviour would indicate that blueberry fields are functioning as supplemental feeding sites. Starlings moved to their primary feeding sites between 12 pm and 4 pm. However, as noted by Roberts (1992) large flocks of starlings were observed feeding on insects in blueberry fields that have already been picked, and adjacent hayfields and cow pastures.

Potentially, not all feeding activity by starlings in blueberry fields were concentrated on blueberries; thus, blueberry fields may also supply primary feeding areas where insect populations are sufficiently abundant.

Although starlings show strong site fidelity to their primary feeding areas, they show considerable flexibility in their use of supplemental feeding areas (Glahn et al., 1987). These authors reported that the monthly turnover rate of starlings on their study farms in central Kentucky was between 67 and 70% from December to February. Similarly, White et al. (1985) reported that roosting birds, in general (red winged blackbirds, grackles, and starlings), changed roost sites every 3 to 4 days resulting in a population turnover at any one roost site of 23% each night. Paton et al. (2005) also noted that some individuals used 10 different roost sites during a three-month tracking period, and that they changed roosts every few nights. Therefore, starlings appear to select roost sites based on foraging areas, rather than the inverse. This behaviour would indicate that modifying roost sites may not reduce foraging activities if alternative roost sites are available and if availability of primary or supplemental food sources has not been changed. Searing et al. (1990) concluded that modification of roost sites would be ineffective in reducing abundance of starlings and the only method to reduce the population of resident starlings in Vancouver, B.C. is to reduce availability of nest sites. They reported a 60% reduction in starling abundance in two years in Kansas City following adoption of a policy of reducing nests sites within the city through mandatory building repair and modification to building design aimed at reducing nesting locations.

Roost sites chosen by starlings are either deciduous or coniferous trees with dense foliage. Roost sites are typically insular patches rather than continuous large forest tracts (Lyon and Caccamise, 1981; Campbell et al., 2001). Starlings are not physiologically well adapted for cold and require appropriate thermal cover to survive (Brenner, 1965). Flocking and roosting behaviour may be essential to their survival during cold temperatures (Brenner, 1965). This would explain why starlings tend to aggregate into fewer roosts during cold periods. Choices of roost sites primarily reflect the thermal requirements of starlings with protection from colds winds (Campbell et al., 2001). In the Mid-Atlantic region of the US, starlings preferred areas with high tree densities, low mean basal area, and compact enclosed canopies (Lyon and Caccamise, 1981). However, coniferous trees would provide superior protection from wind and rain and may provide preferred winter roost sites. Searing et al. (1990) noted that there were 10 major winter roosts in Vancouver, which were not in use 2 decades earlier. Arrival at roost sites in Vancouver was quite variable with most starlings arriving between 40 minutes and 2 hours before official sunset in late July and early August (Searing et al., 1990). Based on their feeding habits, low site tenacity of roost sites, and changing availability of supplemental food with changing agricultural practices, locations of roosts in the Lower Mainland will probably vary over time. In urban areas, starlings

have been a serious problem in late fall and winter when roosting by the thousands on buildings, bridges, and other structures (Campbell et al., 2001).

Starlings depart in the morning from their roosts in small groups at approximately 3-minute intervals, forming concentric expanding rings of birds from the roost sites (Eastwood et al., 1962). Upon returning, starlings often assemble at staging areas adjacent to roosts before entering roost sites (Feare, 1984).

Reproduction: During nesting, starlings have been observed up to 1450 m in elevation in the interior of B.C. Feare (1984) suggested that the primary driver of nest choice is protection from heat loss during incubation being the primary driver. The most common nest sites are holes in trees, but holes in cliffs, walls, and made-made structures are often used (Feare, 1984). Nests are primarily in trees (60%), with most of these in deciduous trees (35%) and snags (16%). Only 5% were found to be in conifers (Campbell et al., 2001). Males initiate nest building and females complete it (Ehrlich et al., 1988). They build nests inside the hole composed of dead grass, plant fibre, twigs, etc.; as well as live grasses that have fumigant properties against parasites (Ehrlich et al., 1988; Campbell et al., 2001).

Nesting season is synchronized into definite peaks of nest building, egg laying, hatching and fledging for starlings (Johnson and Cowan, 1974). Four to six eggs are typically laid from the end of March to late July with > 50% of the recorded laying occurring from May 2 to May 24 (Collins and De Vos, 1966; Campbell et al., 2001). In the Lower Mainland, egg laying can occur as early as February, with most laying occurring from early April to early May. A second clutch is then produced in coastal areas, and occasionally in the Okanagan, between late May and mid June (Bogatich, 1967; Campbell et al., 2001; Cannings et al., 1987), approximately 40 to 44 days after the first clutch (Collins and De Vos, 1966). On average 90% and 82% of the eggs in the first and second clutch, respectively, hatch (Kessel, 1957; Collins and De Vos,1966). Most nests (50%) contain young from May 16 to June 10, following a 10- to 12-day incubation period (Johnson and Cowan, 1974; Campbell et al., 2001). Young remain in nests for 18 to 21 days (Feare, 1984; Ehrlich et al., 1988). Juvenile starlings start appearing outside of nests and at feeding areas in early to mid June. Once juveniles leave the nests, they start to form small flocks composed mostly of juveniles. These flocks often range from 3 to 22 individuals in Maryland and are widely spaced apart (Williamson and Gray, 1975). Adults will usually stay close to the nest site since many would be raising second litters. As summer progresses, the flocks of juveniles begin to enlarge as more and more juveniles coalesce into fewer flocks. These flocks are composed almost entirely of juveniles (Elliott, 1964; Conover and Dolbeer, 2007). Starlings had produced 3 broods a summer in Idaho, with small juvenile flocks developing after the first brood leaves the nest in June (Elliott, 1964). It was flocks of juveniles primarily responsible for damage seen in Idaho and Washington (Elliott, 1964) and Australia (Paton et al., 2005).

Similarly, post-breeding flocks of juvenile starlings have been observed to congregate in late July and steadily increased in number throughout the summer in Colorado (Guarino, 1968) and Europe (Feare et al., 1992).

Survival & Mortality: As nestlings, survival is high for both broods and recorded as 82 – 87% (Kessel, 1957) and 89-94% (Collins and De Vos, 1966). The average egg-to-fledging ratio was 78.6% for three years in Guelph; thus, for all broods, 79% of the eggs laid will likely yield a juvenile starling (based on 1966 data: Collins and De Vos, 1966). Similarly, Mumby (1978) reported that 75 to 80% of nestlings survive to fledge. Average mortality rates of juvenile starlings was 65% (range: 56 to 73%; reviewed by Feare, 1984) across 8 studies in Europe and North America.

Stewart (1978) reported an annual survival rate of juveniles as 48.7% for southeastern US. Average mortality rate of adults (1+ year olds) was 55% (range: 33 to 68%; Feare, 1984: range 11 to 55%; Coulson, 1960; Frankhauser, 1971; Stewart, 1978). Thus, juvenile birds can expect to live 1.0 – 1.5 years, and adults an additional 1.0 – 1.5 years if they live to their first spring. In contrast, Kessel, (1957) reported that only 20% of fledglings survive to breed the following year in eastern North America. In eastern North America, most mortality occurred between January and May, possibly due to winter temperatures and cost of migration (Kessel, 1957). However, in areas of mild climates like the Fraser Valley, mortality may be greater in the breeding season (Mumby, 1979).

Current Trends in Abundance

Myers (1958) documented the arrival and spread of the European starling throughout B.C. He initially speculated that the abundance of starlings would continue to increase for another 10 years (20 years after arrival in B.C.). After this period of increase (to the late 1960s), he predicted a decline in abundance. This prediction by Myers (1958) was accurate. Analysis of the Christmas bird counts for British Columbia and the Lower Mainland from 1955 to 2009 (Figure 5A and 5B, respectively) showed the population reached a maximum abundance in 1966, roughly 20 years after its arrival in B.C. After this period, their abundance dropped significantly throughout B.C. and the Lower Mainland. Although the data presented do not reflect actual abundance, it does indicate the general trend in abundance, where current winter numbers are 10% of those recorded in the mid 1960s. The cause of this decline is unknown.

Breeding populations of starlings in Canada appears to have consistently declined (to 1/3 of 1968 levels) since the initiation of the Breeding Bird Surveys (BBS) in 1968 (Figure 6A). However, for both British Columbia and the Lower Mainland populations, relative indices of breeding starlings were relatively constant from 1968 through to the mid 1980s (Figure 6B, & 6C). After this period, relative abundance of breeding

individuals decreased to 2003, and then appeared to remain relative stable until 2008. A similar trend has been noted for the Pacific Northwest in general (Sauer et al., 2008).

Even though relative abundance among years has been well documented through the Christmas bird count (Figure 5) and breeding bird surveys (Figure 6), and relative abundance among months within a year has been well documented through personal observations and reports (Figure 4), there is no reliable estimate of abundance of starling in B.C. or any of its regions. In fact, throughout the review of the literature, only trends in relative abundance have been documented with no studies aimed at estimating absolute abundance of starlings. This reflects the difficulties associated with surveying a sufficiently large enough area to document majority of birds or to capture and mark a sufficient number to provide accurate estimates of absolute abundance.

The best indication of abundance is provided by Campbell et al. (2001). Based on records complied by Wayne Campbell and others, he provides an approximate number of adult starlings in early May of 10,000 individuals in the Georgia Depression[2]. This number increases 5 fold by mid August as juveniles join the population (approx. 50,000). Abundance of starlings increase dramatically from mid August to end of October as migrants join the Lower Mainland population. Abundance over this period can exceed 350,000 (Campbell et al., 2001, Figure 4 above).

As noted in Campbell et al. (2001) abundance of starlings then dropped a little, presumably as some bird continue on their southward migration. Subsequently, their abundance then drop significantly (to spring breeding numbers; ~ 10,000) from the beginning of March through to May as individuals both arrive from southern wintering grounds and stay to breed, or join majority of the birds and migrate east and north to their summer breeding grounds. Since there has been little change in the relative abundance of birds noted during the Christmas bird counts (Figure 5) for the past 15 years, the data presented by Campbell et al. (2001) would likely be similar today. The relative abundance of breeding starlings in B.C. and the Lower Mainland were decreasing steadily until 2002; thus, abundance of breeding starlings reported by Campbell et al. (2001) may be slightly higher than their current abundance.

[2] This Ecoprovince lies between the Vancouver Island Mountains and the southern Coast Mountains and encompasses the southeastern Vancouver Island Mountains and the Nanaimo Lowlands in the west, the Strait of Georgia and Gulf Islands in the middle, and the Georgia Lowlands and the Fraser Lowlands in the east.

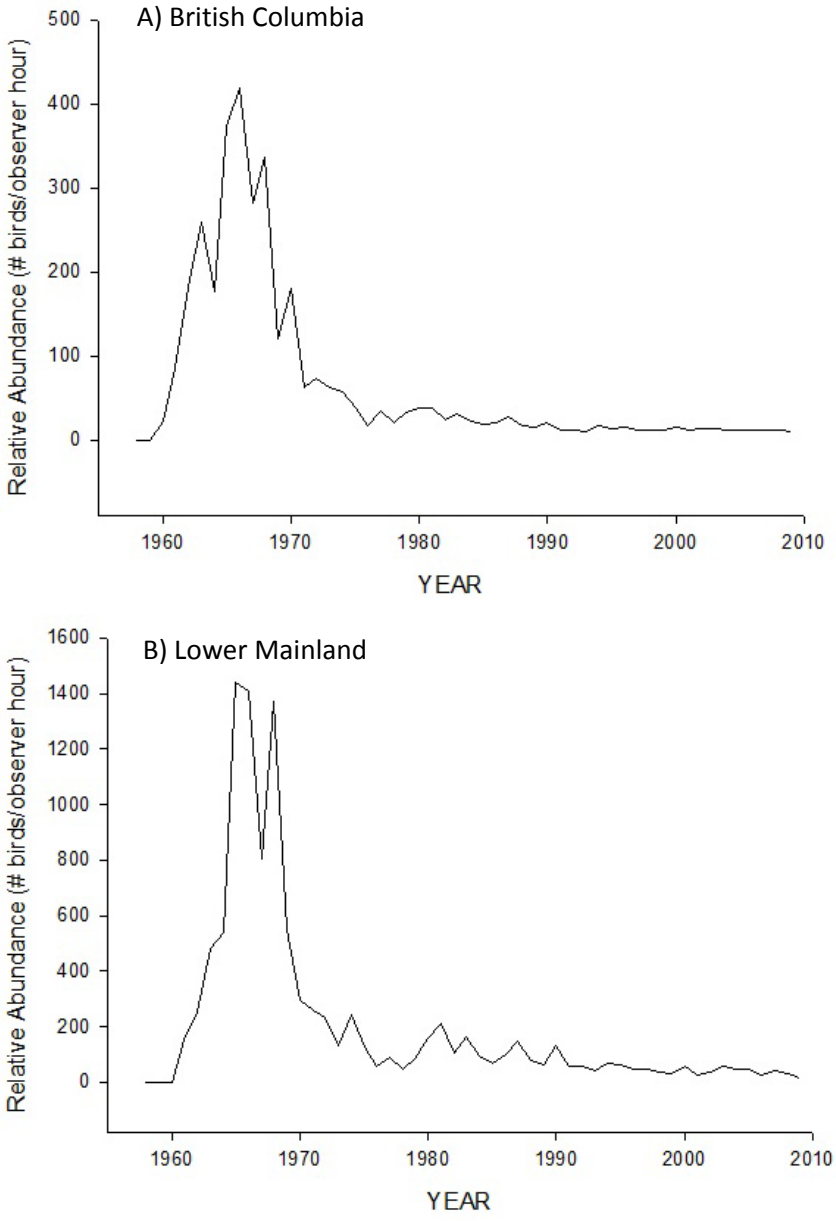

Figure 5. Relative abundance indices[3] (# birds/observer hour) of starlings recorded during the Christmas Bird Count for A) all of British Columbia, and B) for the Lower Mainland from 1955 to 2009 (Source: graphs are based on data provided by the Audubon Christmas Bird Count (http://audubon2.org/cbchist/graph.html)).

[3] The graphs above were generated using number of birds reported per observer hour; a measure of the amount of time spent searching for birds or amount of effort expended. This is one way to standardize Christmas Bird Count (CBC) data over time. Some years, there may have been a lot of people counting birds, while other years there may have been fewer participants in the field. As CBC participation fluctuates (and as number of CBC Count Circles increases), raw count numbers may also fluctuate (more counters can often lead to more birds reported). Standardizing the data helps correct for differences in effort over time.

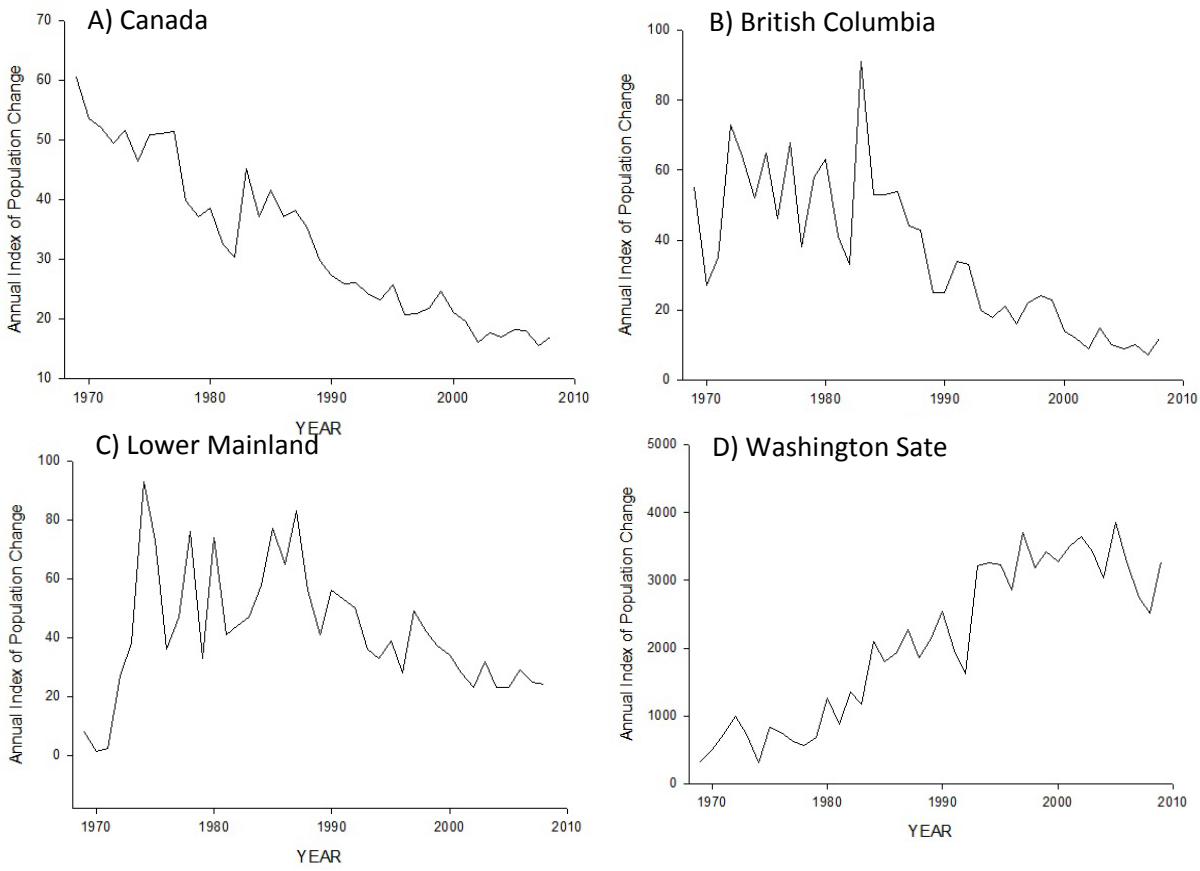

Figure 6. Relative abundance indices[4] (annual index of population change) of starlings recorded during the Breeding Bird Survey for A) all of Canada, B) British Columbia, C) for the Lower Mainland, and D) Washington from 1968 to 2008 (Source: graphs A-C are based on data provided by the Canadian Wildlife Service - Breeding Bird Survey; and D from Patuxent Wildlife Research Center Breeding Bird Count).

Starling Control

Winter Control: Most research to reduce starling numbers has been conducted on wintering populations at roost sites rather than summer residents. Roosting behaviour of starlings has gained significant attention due to their size (1000s to millions of birds per roost), location (adjacent to producers or urban areas), and problems (noise, excrement and source of disease). During winter, starlings congregate in large flocks and roost together in a few locations. For example, one roost site in Vancouver (10th and Guelph) was reported to have close to 20,000 birds in 43 flocks arriving each night on July 26, 1990 (Searing et al., 1990). Much of the research has been directed at dispersing these flocks or inducing high mortality during winter when roost sites are close to feed lots and grain storage. Most publications reviewed focused on reducing

[4] For an explanation of indices see: http://www.cws-scf.ec.gc.ca/nwrc-cnrf/default.asp?lang=en&n=F0768C53

populations of starlings and blackbirds around winter roosts using chemical control (starlicides and surfactants). Overall, much effort has been directed to discouraging starlings from roosts or population reduction at roosts (reviewed by Courtney et al., 1998) with mixed results.

For example, White et al. (1985) studied winter-roost populations at feedlots in Tennessee from November to mid March 1975 to 1978. The roost population often exceeded 10 million birds. Birds tagged at roost had an average duration at roost of 3.5 nights for tagged birds and 4.4 consecutive nights for radio-equipped birds. For blackbirds they found that the daily population turnover was 23%. Although majority of birds at this roost site were blackbirds, starlings also showed the same weak site fidelity to their roost sites. White et al. (1985) depopulated the roost site by 1.1 million birds (96%) using a surfactant when the abundance was 1.14 million birds. Abundance of birds returned to normal within 2 weeks. They found no significant difference along census routes between abundance of birds surveyed before and after removal (except for the week immediately after treatment) and a reduction at feedlots for only 9 to 15 weeks following treatment. The treatment temporarily reduced the population for a 40-km radius after which new birds moved into the area replacing ones killed. They concluded that roost population reduction wasn't effective.

Similarly, Knittle et al. (1980) removed 50,000 birds (blackbirds outnumbered starlings) at stations and feedlots baited with a starlicide in January 1977, 1978, & 1979. Abundance of birds prior to treatment ranged from 20 – 3600 at feedlots and 5000 at bait stations in Kentucky. Following treatment, abundance of birds ranged from 0-1400 with some densities up to 5600. In Tennessee, number of birds ranged from 4000-25000 during both pre-treatment and post-treatment periods. They concluded that there was no noticeable decline in blackbirds due to treatment.

Dolbeer et al. (1997) conducted a meta-analysis of 19 years of using a surfactant to control birds at 83 roost sites. They estimated that 32 million birds (30% starlings) were killed during this period with an average kill of 2 million per year. Since most of the application of surfactant occurred in Indiana, Michigan, and Ohio, they used the data from the nationwide breeding bird survey to examine changes in abundance of these birds following treatments. They concluded that there was no association between number of starling kills in winter and percent-annual change in relative abundance during the subsequent breeding season.

In contrast, Elliott (1964) removed 1.2 million starlings using thallium sulphate during the winter of 1962-1963 during 44 days of baiting at 8 feedlots in Idaho and Oregon. He acknowledges that the number of birds killed wasn't as important as the point that control was obtained at every feedlot where bait was used.

Many other studies reported significant reductions in abundance of starlings using surfactants or starlicides: 78-88% reduction at 53 feedlots across 6 states in winter of

1965-1966 (Ford, 1967); 94% reduction in starlings in 7 weeks in Colorado during starlicide application from November 1964 to March 1965 (West, 1968); a 75% reduction of starlings using a starlicide in January 1963 in Nevada (Besser et al., 1967); a 69% reduction in birds using a surfactant at 8 roost in 1983 to 1985 (Stickley et al., 1986); a reduction from 42,000 (25,000 starlings) to < 1000 over three years at a feedlot in California with an integrated control approach (Palmer, 1976). Knittle et al. (1980) reported that 3500 starlings were reduced to zero after three days of treatment. Unfortunately, these studies only reported number of birds killed and not the rate of recovery at feeding location or other roost sites following treatment. Therefore, it is unknown whether these reductions resulted in temporary or long-term changes in abundance.

Although significant short-term reduction in abundance of birds can be obtained during winter, it appears that long-term reduction in either damage or abundance of starlings in winter is not well supported. These observations in North America support the conclusion of Feare et al. (1992). They concluded that since starlings can range over many kilometres in wintering areas with considerable plasticity of behaviour and that winter accumulations are of birds from many different areas, population reduction would need to target birds from breeding colonies over a wide geographical area. Thus, reducing winter populations at roost sites and feeding sites would unlikely be successful. Although reductions at winter roosts with toxicants remove a significant abundance of birds, the annual mortality rate on a large scale is still below their annual natural mortality rate of 33% to 49% (Feare et al., 1992). They concluded that lethal control of winter roost sites in Europe would not produce a sustained population reduction. Their conclusion was supported by the studies above that documented little change in abundance of birds following winter treatments; too many birds were waiting to replace removed birds (Weatherhead, 1980). Since starlings routinely change roost sites (every 3 or 4 days) and supplemental feeding sites (50% turnover every two weeks; Guarino, 1968), the potential for influx from outside control areas to completely compensate for lost birds is high.

In the short term, Feare et al. (1992) acknowledge that winter densities of birds around roosts could be temporarily reduced and control programs had value in terms of immediate crop protection. Elliott (1964) reported ‘control’ was obtained at every feedlot they baited with thallium sulphate. I have interpreted ‘control’ to mean that damage was reduced to acceptable levels. Unlike many other studies, they continued to bait the 8 feedlots through the winter (44 days of baiting) which probably removed new recruits to the feedlots, following removal of their conspecifics. However, in absence of continued control during winter, starlings can re-establish large flocks at good feeding sites and roost sites, after heavy winter mortality. Therefore, a program targeting local population reduction in winter would only provide temporary relief from damage.

Summer Control: Paton et al. (2005) modelled the benefit of culling breeding adults at different times of the year. Their model suggested that within a year, removal of 50% of the *breeding pairs* early in the nesting season should significantly reduce size of the starling population that subsequently damaged grapes (mostly juveniles). Culling breeding pairs would be more effective than a comparable cull during the damage period. Their three-year extrapolation suggested that a 50% cull during the breeding season would require ¼ the effort required to attain the same benefit if a 50% cull was conducted during the damage period. Consequently, spring cull of breeding adults would be more effective than targeting fall juveniles. Their analysis only factored in resident breeding birds and their offspring (there was no mention of migration).

However, resident birds compose a small proportion of the late fall and winter population in the Lower Mainland. Thus, a winter cull during and after arrival of migrants would have significantly less impact on the resident population in the Fraser Valley, than that predicted by Paton et al. (2005). Potentially, many of the birds removed in fall and winter would be composed of juveniles that would otherwise return to their breeding grounds in spring (93% of juveniles returned to within 1 km of their nest site; Kessel, 1953), or resident juveniles that already have a very low survival rate (< 50%) and would not be needed to supplement the spring breeding population.

For the Lower Mainland, most damage to summer crops occurs in summer by breeding adults and their young of the year. Consequently, a control program aimed at reducing starling abundance in late fall and winter would provide a poor return, if the goal of the control program is to reduce damage to summer crops. Control of resident populations early in the damage season could help reduce the consistent nature of starling damage throughout the summer damage season (Glahn et al., 1987; Paton et al., 2005). This is supported by the observation that it was large flocks of resident juvenile birds that often cause a majority of the damage (Elliott, 1964), especially in blueberry fields (Conover and Dolbeer, 2007).

Trapping: Trapping has been used to both reduce abundance of starlings and to reduce damage to a variety of agricultural products. Trapping was successfully used in Sonoma County, California to reduce abundance of starlings (McCracken, 1972). It was found that young starlings were very easily trapped and by keeping resident birds under control (through shooting and trapping), a noticeable decrease in nesting adults was evident by the 4th and 5th year of the control program. For the year previous to publication, they had not received a single call of damage to grapes.

Within the Pacific Northwest, during spring and summer of 1963, entire flocks of juvenile starlings were removed from cherry operations in the Yakima Valley, Washington. Most flocks were removed within a few days of trapping with more than 15,000 individuals removed by June with 100 traps operating (110,000 were removed by December; Elliott,

1964). It was reported that the Yakima Valley trapping practically eliminated starling damage to their cherry crop (Elliott, 1964).

Nelson (1970) reported that by caging blueberries, they documented a 35% loss to starlings to blueberry bushes not caged when compared to those protected by cages. They initiated a trapping program based on recommendations by the U.S. Fish and Wildlife people based upon reports that trapping was successful in starling control in Washington. They reported up to 35,000 birds (starlings and grackles) were trapped by one blueberry producer. However, it was noted that constant attention must be applied to traps for effective removal, and that trapping didn't work for robins and orioles.

Bogatich (1967) noted that juvenile starlings caused considerable damage to cherry crops in Washington in the 1960s. Traps in prime nesting areas only captured a few (700) adult starlings in April and May, and > 7000 in June. Juveniles were easily caught. He concluded that the modified crow trap rapidly reduced local flock build up and contributed greatly to crop protection.

Conover and Dolbeer (2007) reported that large flocks of juvenile starlings were a serious problem for berry growers (strawberries, grapes, blueberries, and other fruit). They examined if numbers of juvenile starlings foraging in blueberry orchards could be reduced by catching them in decoy traps and relocating them in the late 1980 in Connecticut. For two years prior to trapping, number of juvenile starlings in blueberry fields started to increase the last week of July and reached 600 and 750 birds in 1987 and 1988, respectively. During two years of removals in July and August, number of starlings foraging in the same field decreased to 100 birds for both control years (1989 and 1990). A proportion of trapped starlings were marked and all starlings were relocated between 50 and 100 km away; none of the marked birds returned to the farm. They only captured juvenile starlings in traps, and few non-target species.

Gorenzel et al. (2000) conducted a nation-wide survey and literature review on the status of trapping to control bird damage. Although 75% of the total respondents rated trapping as moderate to excellent for starlings, 80% of those respondent in agriculture rated benefits of trapping as 'slight'. It wasn't clear whether respondents were referencing trapping programs aimed at protecting winter crops or summer crops. However, a majority of California Agriculture Commissioners rated trapping as important for control of starlings.

Many general claims have stated that trapping starlings has been an effective means to control birds (Vaudry, 1979; Johnson and Glahn, 1994; Tracey, 2007; VPCH, 2010). However, no data or observations were presented to directly support their claims.

In contrast to above information, many general claims have stated that trapping may not be an effective method to control starlings. For example, Zajanc (1962) stated that trapping cannot be considered a practical means of reducing blackbird populations around rice and corn fields. His report did not provide details about time of year,

location, or observations to support the claim. However, he stated that preliminary tests indicated that trapping might be useful for trapping young starlings during summer months in orchards and vineyards. Dolbeer (2005) stated that decoy traps are of questionable value in trying to reduce large roosting populations and the damage to surrounding fields. He suggested that decoy traps can be used to temporarily reduce local populations of blackbirds in special situations. Similarly, Weatherhead et al. (1980) found that traps were only effective against younger birds, and during 24 trap-weeks only < 1% of the population in a nearby roost were removed. They conclude that trapping was ineffective to control roost populations, but may reduce problems in agricultural settings. Johnson and Glahn (1998) stated that wide-spread range movements of starlings, timing necessary to maintain traps, and number of starlings that can be captured compared to overall abundance often make trapping an impractical control method. However, they stated that trapping can be successful at locations where a static population is causing damage (i.e., orchards). Bomford (1992) stated that removal of young birds from a population is unlikely to have any sustained effects on density because removals only replace a high natural mortality rate. It is the doomed surplus of young inexperienced birds that are mainly caught by trappers. She concluded that it is not effective to trap enough birds to reduce the population sufficiently in the long run to reduce damage. Finally, Feare (1984) argued along the same lines as Bomford (1992) stating that given the high mortality rate of starlings, and that mortality factors tend to substitute one for another, that high levels of removal seldom result in a significant change in abundance of adults. However, Feare (1984) acknowledged that local heavy mortality can confer crop protection over the short term provided that immigration of new individuals is limited.

Summary: Overall, there were few studies that provided a rigorous evaluation on effectiveness of chemicals or trapping to reduce either abundance of starlings or damage caused by starlings in an agricultural setting (Hone, 1994; Gorenzel et al., 2000; this review). With the exception of White et al (1985), none of the studies reviewed provided an experimental design or statistical analyses to adequately test benefits of chemical control or trapping on abundance of starlings or their damage. Many of the studies supporting reduction of starlings through use of chemicals and trapping were unreplicated studies and lacked control sites. To adequately evaluate whether changes in abundance of starlings or their damage was the result of the treatment applied (chemical or trapping) rather than natural processes, control sites are a requirement. A general review of Figures 4 - 6 and 10, 11, & 13 clearly show that abundance of starlings fluctuates dramatically from year to year. In fact, a number of reports on chemical control of starlings reported strong influence of weather on success of their program (Ford, 1967, Stickley Jr., 1979; Strickley Jr. et al., 1986). In addition, a majority of these studies measured number of birds removed without recording data supporting the claim that the reduction either reduced overall abundance or damage caused by starlings. Consequently, it is not possible to evaluate effectiveness of control

programs to reduce abundance of starlings or their damage to agricultural crops based on well-conducted studies. However, the following generalizations were possible:

Winter control

- Many reports documented high removal rates of starlings in winter with rates ranging from 25,000 to 2 million/year for 19 years; and 69% to 96% reduction in local (roosts or feedlots) winter numbers. Those reports that recorded post-removal numbers indicated that these removals had little long-term reductions in winter abundance of starlings (Knittle et al., 1980; Dolbeer et al., 1997; White et al., 1985). One exception was Elliott (1964) who continually removed starlings during one winter and reported full control of starlings at 8 feedlots.
- Given the biology of starlings, in the long term starlings can re-establish large flocks in winter at good feeding sites and roost sites after heavy winter mortality, in absence of continued control. Local population reduction in winter would only provide temporary relief from damage caused by starlings in winter.
- Since adult and juvenile starlings nest close to their natal nests, all migrants removed during winter trapping would have minimal influence on spring abundance of resident individuals and the damage they cause.
- The greatest damage experienced to blueberries in the Lower Mainland is likely due to resident juveniles and adults prior to arrival of migrants.
- A strong winter cull would probably have minimal impact on abundance of resident starlings and the damage they cause in summer and fall.

Summer Control and Trapping

- Damage to summer crops in the Lower Mainland primarily results from flocks of resident juveniles and, to a lesser extent, flocks of resident adults.
- Population reduction aimed at reducing flock size of resident birds (adults and juveniles) would be more effective at reducing damage than reducing flocks of fall and winter migrants (Glahn et al., 1987; Paton et al., 2005).
- Those reports that stated that trapping was ineffective at reducing abundance of starlings primarily referenced reducing winter/roost populations (Dolbeer, 2005; Weatherhead et al., 1980) or they primarily provided general statements based on biology to support their claim (Feare 1984; Bomford, 1992).
- Some reports suggested that significant removal of juveniles through trapping would have minimal effect on density of adults. However, since juveniles cause a significant proportion of the damage to summer crops, reducing their abundance should reduce the damage observed in summer, independent of changes seen in the breeding population. These same authors acknowledge that trapping can be successful at reducing static populations (Johnson and Glahn, 1998) or confer crop protection to summer crops (Feare, 1984).

- In support of the above claim, those reports that examined summer reduction in starlings (often significant reduction in flocks of juveniles) report high success in reducing damage to summer crops (cherries & blueberries) or significant reduction in birds observed in summer crops (Elliott, 1964; Bogatich, 1967; Conover and Dolbeer, 2007). These observations correspond to those of local producers (C. Bielert, R. Hol, H. Bierlink, pers. comm.).
- As a general trend among the papers reviewed, there was stronger support that summer trapping would be effective at reducing damage to summer crops than that which indicated a summer control program would be ineffective at reducing damage. However, this generalization is only based on a few field-based reports that directly examined summer control programs.
- An intense summer trapping program focused on removing juveniles in spring through to fall would be more effective and efficient at reducing damage to summer crops than trapping outside this time period.

Analysis of Trends Using Breeding Bird Surveys

In the Pacific Northwest, two control programs are currently being conducted in Whatcom County Washington (since 1997) and the Okanagan region of British Columbia (since 2003). Between these two programs, close to 1 million birds have been removed. Both programs have removed close to 40,000 birds a year.

Breeding bird data was used to assess whether the currently-conducted control programs were resulting in a reduction in number of resident starlings breeding in areas adjacent to control areas. Each spring over 2500 highly competent, and carefully selected, observers and professional biologists volunteer to participate in the North American breeding bird survey (BBS). This survey is a long-term, large-scale, international avian monitoring program initiated in 1966 to track status and trends of North American bird populations. Each year during the height of the avian breeding season (June for most of the U.S. and Canada) participants skilled in avian identification collect bird population data along roadside survey routes (Figures 7 & 8)(Link and Sauer 1998). Each survey route is 39.5 km long with stops at 800-m intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen or heard within a 400-m radius is recorded. Surveys start one-half hour before local sunrise and take about 5 hours to complete. Over 4100 survey routes are located across the continental U.S. and Canada with 3000 routes surveyed annually in June (Link et al., 2008). Once analyzed, BBS data provide an index of population abundance that can be used to estimate population trends and relative abundances at various geographic scales. The BBS is the primary source, and often the only source, of data to assess population change and relative abundance for many North American bird species (Sauer et al., 2003). These researchers showed that 72% of the species surveyed had survey-wide

trend estimates that were precise enough to detect a 3% change per year in relative abundance over the interval 1966 – 2000. Thus, the BBS currently does a reasonable job of estimating long-term trends within the survey area (Sauer et al., 2005). Consequently, in absence of direct monitoring, the BBS may be the only source of data to evaluate the effectiveness of control programs aimed at reducing abundance of resident starlings over the long term.

Throughout Washington and British Columbia there are 108 and 136 active survey routes, respectively. Many of these routes have had birds monitored for the past 20 years, with many going back to the early 1970s. For the purpose of this report, survey routes were chosen adjacent to the active starling control programs in Whatcom County Washington and the Southern Interior of British Columbia. Data on relative abundance of starlings was retrieved from the Patuxent Wildlife Research Center; a joint database managed by the US Geological Survey and the Canadian Wildlife Service. This index of population abundance was compared among survey routes adjacent to areas with an active trapping program, to areas outside of the control program. Evidence of effectiveness of the trapping programs may be assessed by comparing indices of abundance of starlings between pre- and post-trapping on breeding bird routes within the effective trapping area of the control programs. A reduction in these indices may reflect a reduced abundance of resident starlings following the initiation of the trapping program. Essentially, the pre-trapping period functions as a 'control' against which to compare the post-trapping period, for evidence of reduced abundance of resident starlings. In addition, it is important to examine breeding bird routes outside the influence of trapping programs to ensure similar changes in indices did not occur under natural conditions. If a 'non-natural' decease in indices of abundance of starlings occurred following initiation of the trapping programs, this may indicate that trapping programs have induced a population reduction in starlings. To enhance this comparison, the average (± 95% confidence intervals) index of starling abundance was calculated for 10 years prior to and following initiation of the tapping programs. The average indices of starling abundance was also calculated for the final 5 years of trapping programs, assuming cumulative benefits of the programs would be most pronounced during the latter half of the programs and may provide a better comparison than including the early years of the trapping programs. Significant differences were identified by visual assessment of non-overlapping confidence intervals where the difference between the closest intervals is greater than 10% of the shortest interval (Browne, 1979; Julious, 2004).

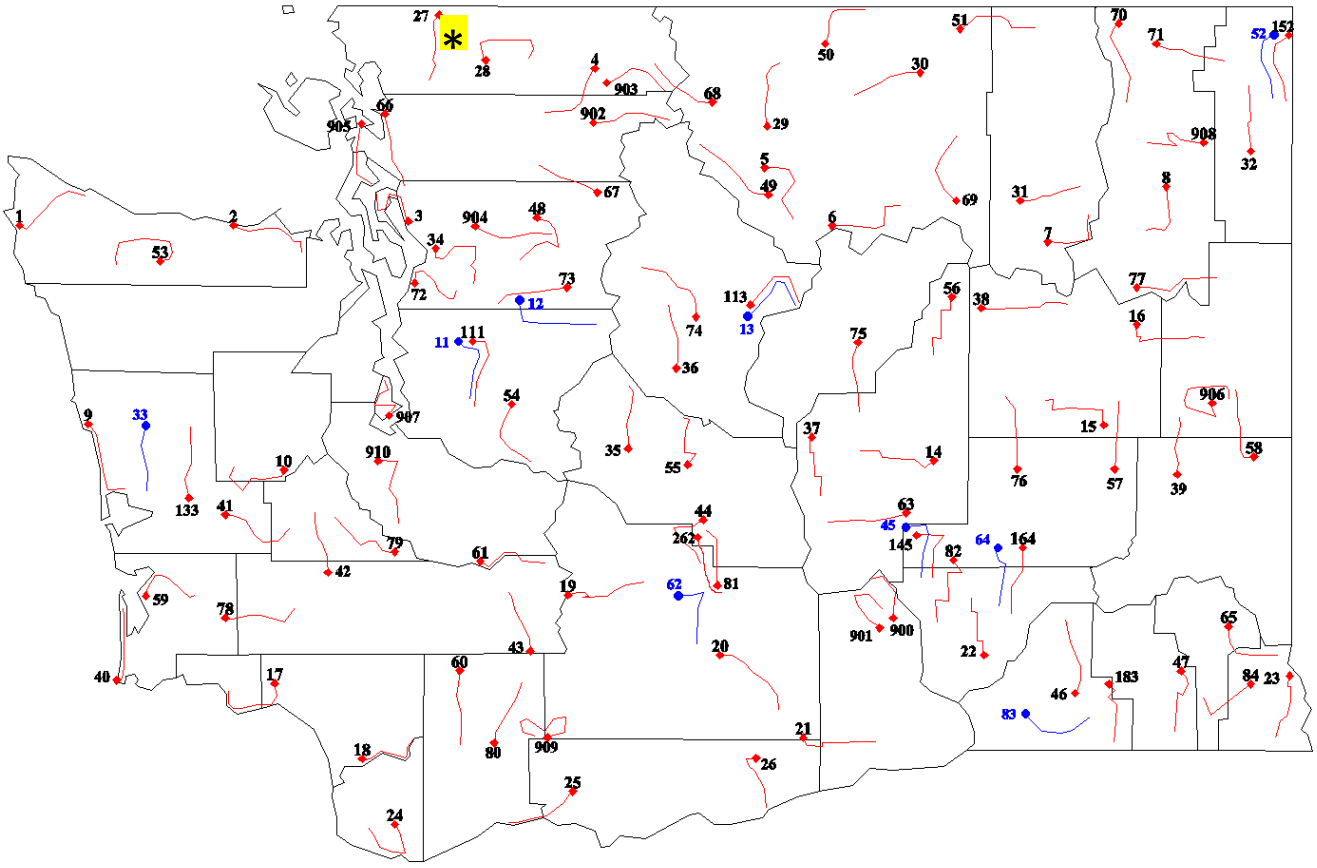

Figure 7. Survey routes used in the breeding bird survey throughout Washington (BBS routes 89000s). Blue routes represented dormant/discontinued routes, while red routes were active routes. Routes are not to scale and indicate approximate location within the state. Route numbers correspond to the graphs in Figure 10 to 12. The highlighted star indicates location of the Whatcom Country control program (Source: Patuxent Wildlife Research Center).

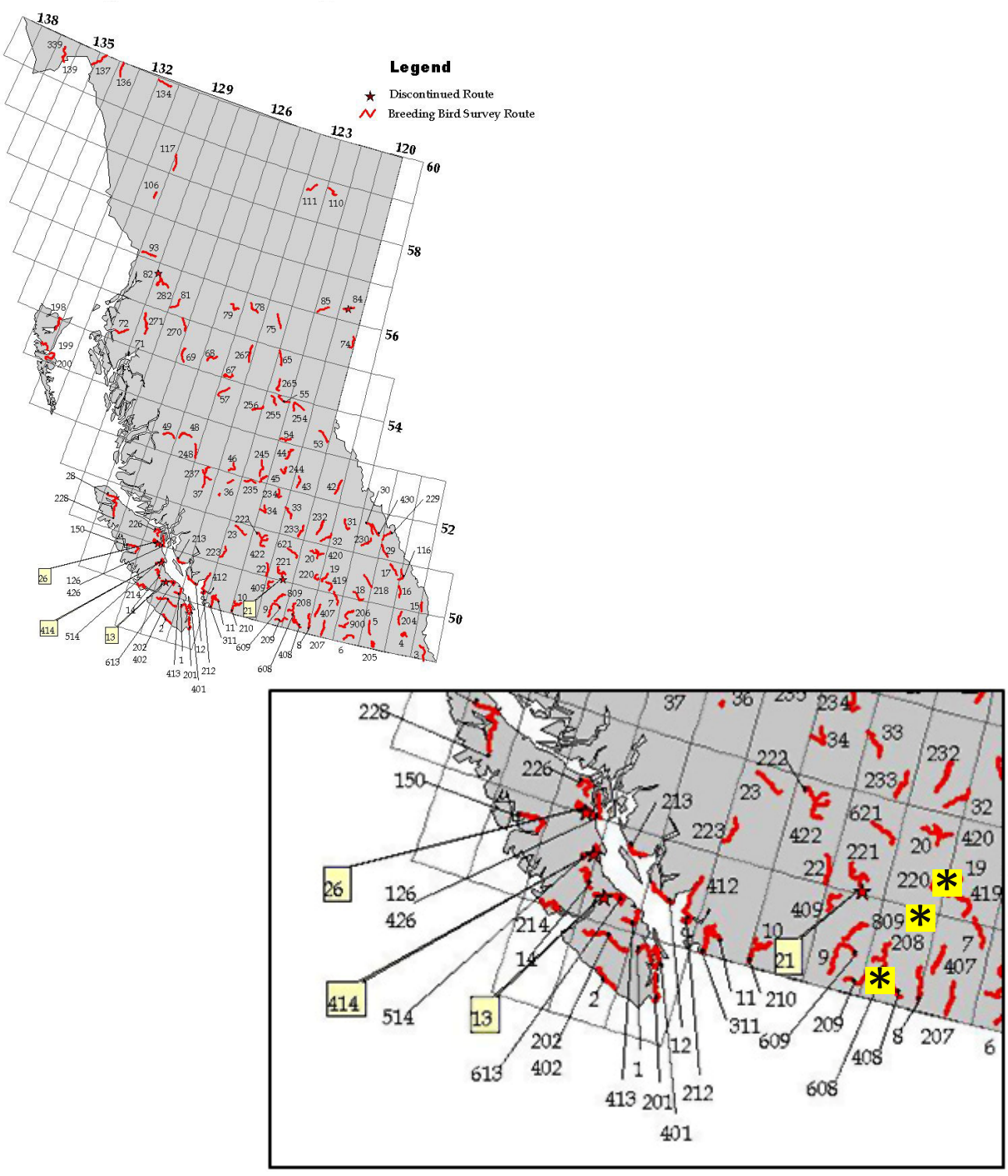

Figure 8. Survey routes used in the BBS throughout British Columbia (BBS routes 11000s). Routes are not to scale and indicate approximate location within the province. Route numbers correspond to the graphs in Figure 13 & 14 (Source: Patuxent Wildlife Research Center). Highlighted stars indicate approximate locations of trapping.

The BBS was chosen, rather than the similarly-conducted Christmas bird count, since the BBS tracks resident individuals. The BBS has a stronger standardized protocol than the Christmas bird count, to minimize variation in calculated indices due to unrelated factors (sampling error; Link et al., 2008; Strassburg et al., 2010). Given the timing of damage in the Fraser Valley, it appears to be the resident individuals that ar juveniles and adults e responsible for much of the damage to summer crops. In addition, if control programs are effective, it would be more apparent in reducing the smaller resident population than the very large winter population composed of residents and migrants.

Whatcom County Trapping Program: The control program in Whatcom County was initiated in 1997 and has removed 30 to 50,000 birds annually since 1997. Their control program is centered around Lynden Washington with most of their effort close to the B.C. border (Figure 9). Using banding data from Royall et al. (1972), starlings banded in summer were later recovered, on average, 40 km away later that same summer. Although smaller distances have been recorded as *daily* movement patterns, these would reflect distances travelled within a day. Starlings often change roost sites and supplemental feeding areas from one day to the next; thus, distances moved in one day would under-estimate the opportunity for starlings to encounter trapping locations operating all summer long. Using the distances recorded by Royall et al. (1972) would more accurately reflect effective trapping area associated with trapping programs than using daily movements. Based on this rational, 4 breeding bird routes fell within 40 km of the Whatcom County control program (Table 1).

No breeding bird routes occurred within the actual trapping area in Whatcom County. Route 89027 (Kendall) was the closest route to the trapping area and was approximately 12 km east of the area trapped (Figure 7; Table 1). In addition, two breeding bird routes in the Fraser Valley were within 40 km of the Whatcom County trapping area: 11210-Chilliwack (21 km) and 11011-Albion (23 km; Figure 8). Visual assessment of the change in indices in abundance of breeding starlings indicated:

- No significant difference between pre and post trapping for Kendall, the route closest to the Whatcom County trapping area (Figure 10a & 12). However, this route was primarily dominated by coniferous and deciduous forests (75%) with only 15% of the route potential foraging habitat for starlings. Other routes in Washington had a significantly higher proportion of foraging habitat (ranging from 38 to 55%) than Kendall's 15%; thus, 89027 Kendall may not be an adequate route to evaluate the effectiveness of the trapping program.
- A significant decrease in relative abundance of starlings between the pre-trapping and last five-year post-trapping period along the Chilliwack, and Albion routes (Figures 10A & 12), and a visual decrease on the Bay View route (Figure

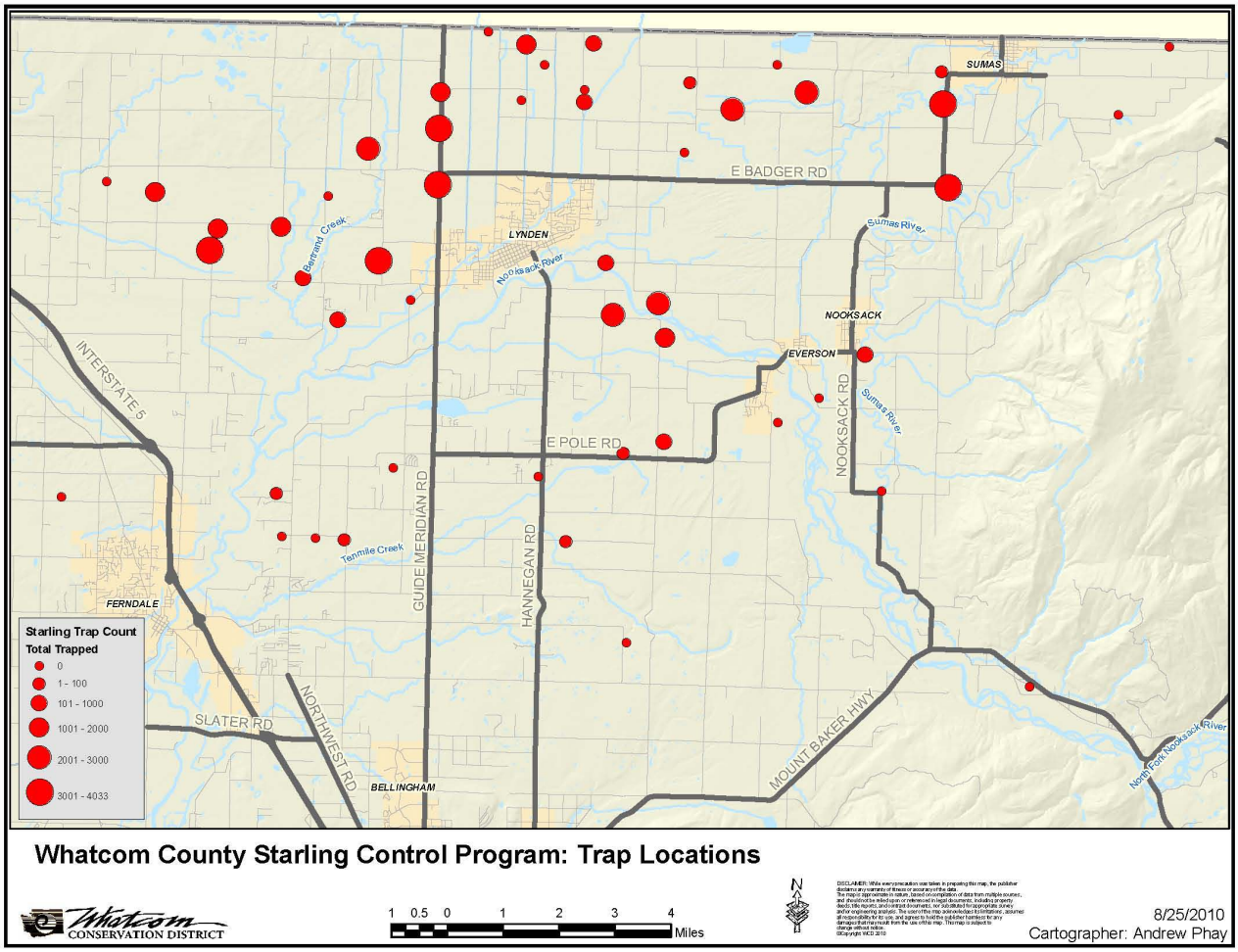

Figure 9. Trap locations and trapping success from 1998 to 2010 of starling control in Whatcom County, Washington (Source - H. Bierlink, Program Coordinator).

10A) following initiation of the trapping program (Figure 10A & 12) – all three routes were within the effective trapping area of the Whatcom County trapping program.

- There was a similar decrease in most survey routes ranging from 53 km to 161 km outside the trapping area of the control program in Whatcom County (Figures 10 & 12).
    - However, none of these routes showed significant differences between pre- and post-trapping periods except Warm Beach (68 km outside trapping area; Figure 12).
- In southern Washington, most survey routes, which ranged from 260 to 375 km away from the Whatcom County trapping area, showed no significant differences between pre- and post trapping in Whatcom County (Figure 11). Most of these routes showed relatively low indices of abundance of starlings (Figure 11 & 12).
- Overall, two of the three routes associated with this trapping period showed a significant decrease in relative abundance of starlings between pre- and post-trapping periods. While most routes outside the effective trapping area showed a decrease in relative abundance of starlings, this difference was not significant. Potentially, the *significant* decrease in relative abundance of starlings noted in areas adjacent to the trapping program, as compared with non-significant *slight* decrease outside the effective trapping area, may indicate that the trapping program intensified the decrease of starlings within the effective trapping area.

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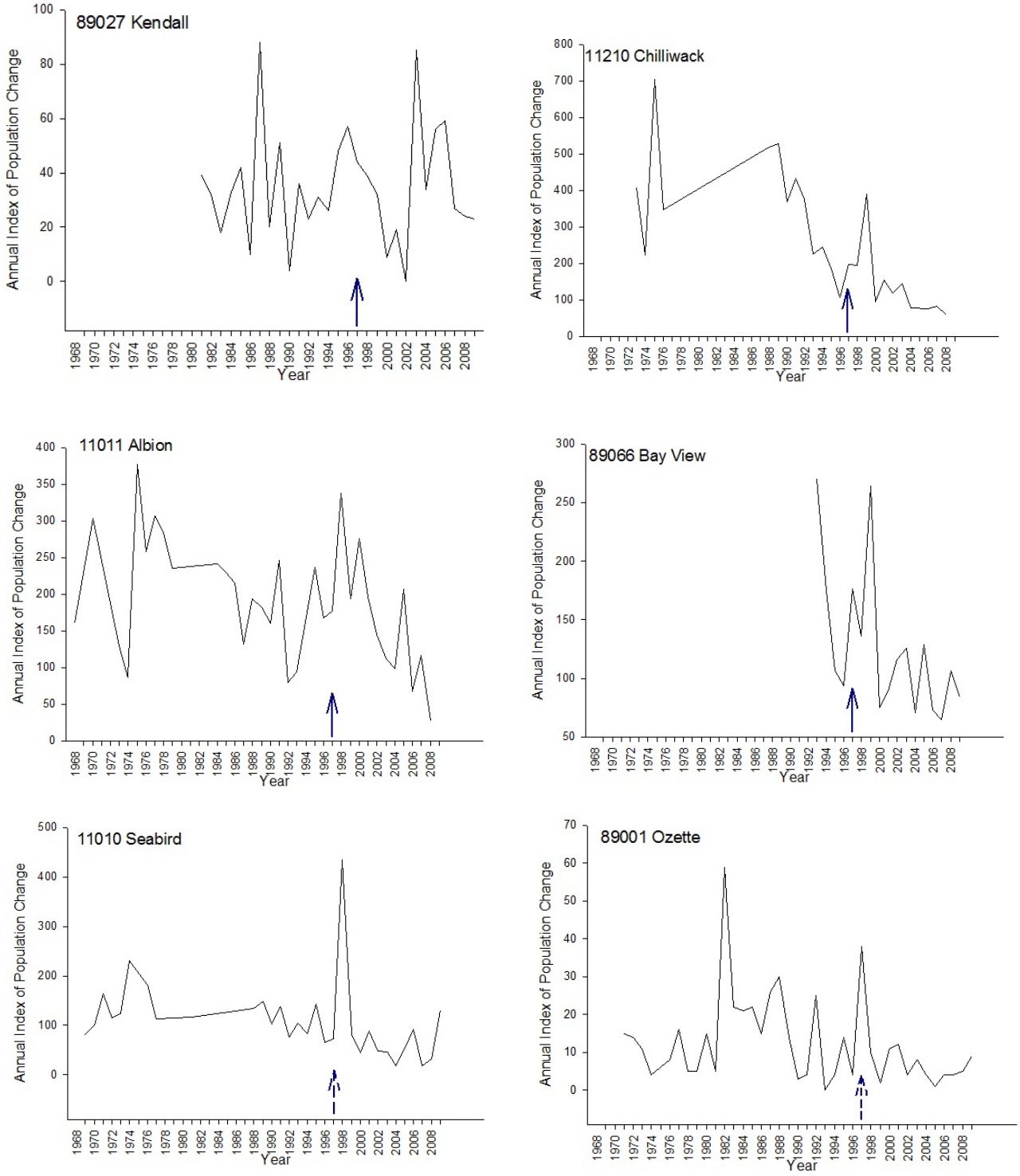

Figure 10a. Index of abundance of starlings from BBS routes adjacent to and surrounding the control program in Whatcom County (initiated in 1997)[5]. The solid arrow indicates the initiation of the control program. The dashed arrow is a reference to the same time period for breeding bird survey routes outside the control program area.

[5] Data points for 1981 (1109) and 1983 (3726) were removed for route 11011 Albion

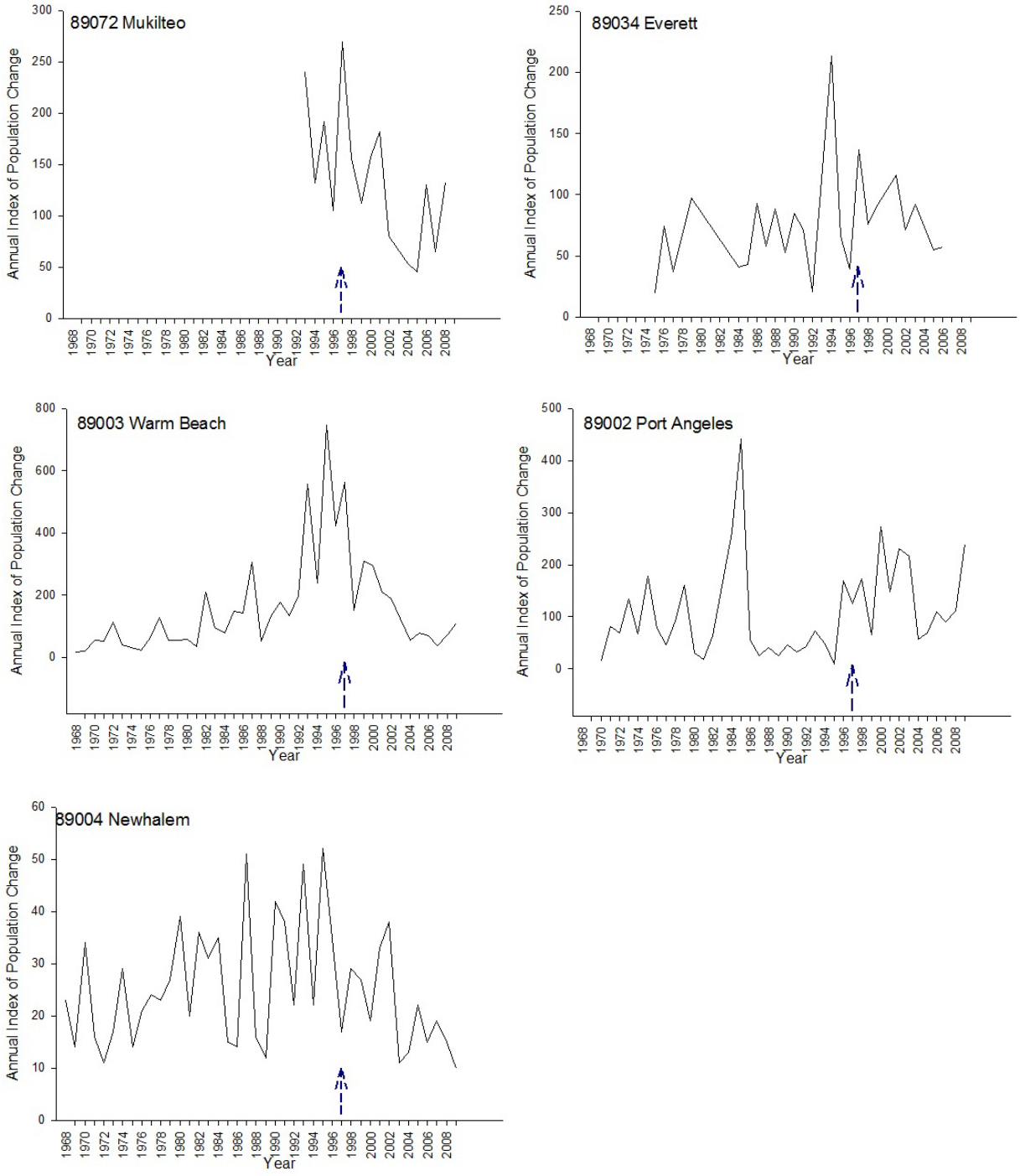

Figure 10b. Index of abundance of starlings from BBS routes adjacent to and surrounding the control program in Whatcom County (initiated in 1997). The solid arrow indicates the initiation of the control program. The dashed arrow is a reference to the same time period for breeding bird survey routes outside the control program area.

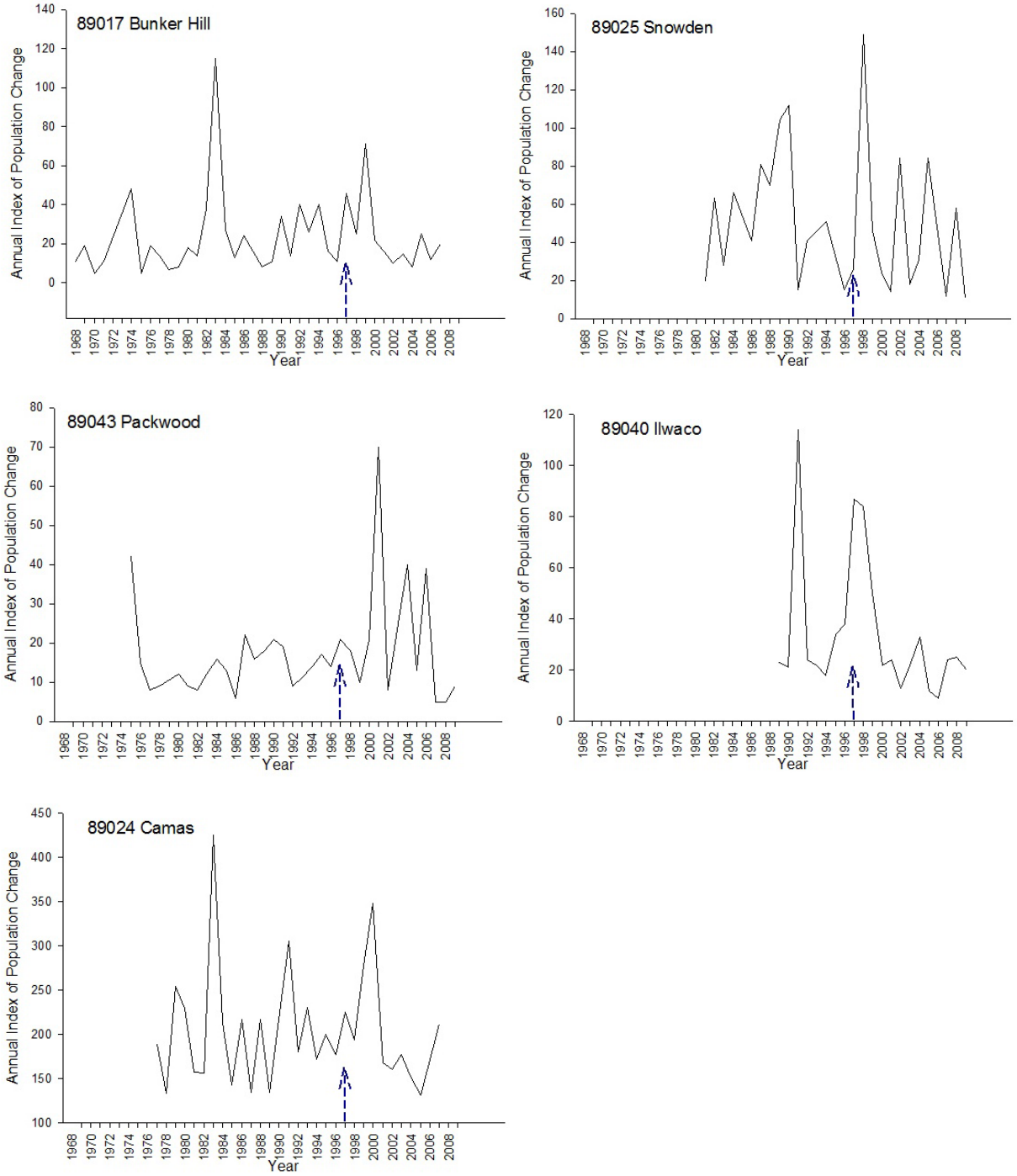

Figure 11. Index of abundance of starlings from breeding bird survey routes in south-western Washington. The dashed arrow is a reference to initiation of the starling control program in Whatcom County.

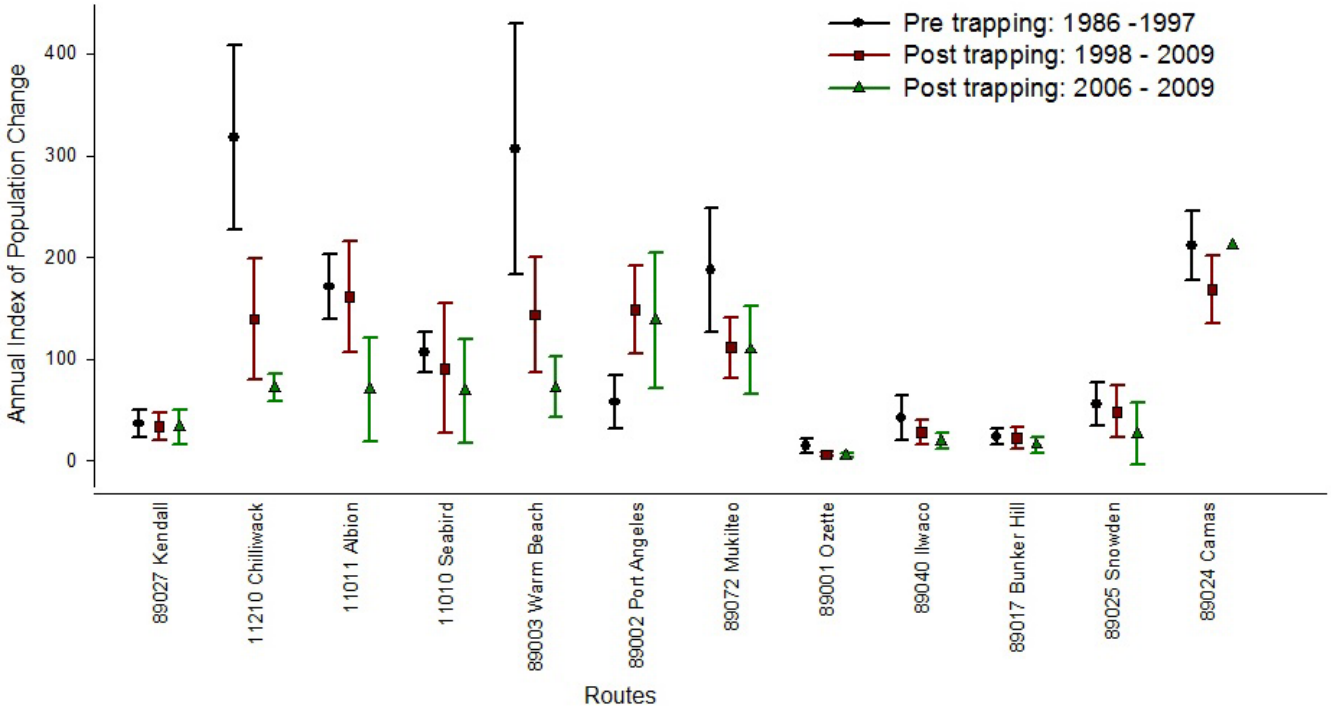

Figure 12. Comparison of three mean indices (± 95% confidence intervals) of abundance for starlings on all routes examined in western Washington: for 10 years prior to the 1997 initiation of the Whatcom County trapping program, for all years following initiation of the trapping program, and the last 5 years of the Whatcom County trapping program. Distance routes were from the trapping area increases from left to right. The first three routes were within the effective trapping area. Non-overlapping confidence intervals indicate significant differences between means.

Southern Interior Trapping Program: the Okanagan Similkameen trapping program was initiated in 2003 and has removed approximately 300,600 birds from 2003 – July 2010. The trapping program was conducted in three general regions (Figure 8):

- North Okanagan Region (18 trapping sites) including the Vernon landfill, north to Enderby, then east to Coldstream and Lumby; initiated 2007 and 2008.
- Central Okanagan with one major site at a local feed lot; with additional seasonal trapping conducted in the Kelowna area.
- South Okanagan around Oliver and Similkamen area, initiated early in the tapping program, with trapping all year.

Based on the general locations of the trapping programs, five breeding bird transects appear to be within the effective trapping area (within 40 km) of the control programs: 11208 Summerland, 11408 Oliver, 11019 Mable Lake, 11419 Creighton V., and 11220 Lavington (Figure 8). A visual assessment of the change in indices in abundance of breeding starlings indicated:

- Relative abundance of starlings increased initially on 11208 Summerland and 11408 Oliver, followed by a decrease (Figure 13A); however, overall there was no significant difference between pre- and post-trapping periods (Figure 14).
- Relative abundance of starlings increased significantly on the 11408 Oliver route for most years following initiation of the trapping program in the southern Okanagan region (Figure 13A; 14).
- For 11019 Mable Lake, 11220 Lavington, and 11419 Creighton (all within the effective trapping area of the north Okanagan region) there was a slight increase in the relative abundance of starlings following the initiation of the north Okanagan trapping program (Figure 13A). Based on non-overlapping confidence intervals, there were no significant differences between pre- and post-trapping periods. However, McCracken (1972) noted that there was a time lag following initiating a trapping program as trappers learn key flight paths, feeding areas, and roost locations to place traps. Since the program in the north Okanagan is relatively recent, it lacks the benefit seen through the compounding effects of multiple years of trapping, coupled with the initial time in learning, a lag time may exist before results are visible.
- Although route 11008 Beaverdell is close to the edge of the effective trapping area, it is separated from the Okanagan valley by extensive forests and hills. As starlings avoid heavily forested regions and areas that lack sufficient foraging areas in grassland habitats, this route was classified as being outside of the effective trapping area. Trends in relative abundance for this route, and most other routes outside of the effective trapping area (Figure 13B), showed an increasing relative abundance of starlings following initiation of the trapping

programs in the Okanagan area. However, when examining the mean indices of abundance between pre- and post-trapping, most areas showed no significant difference between periods (Figure 14).

- Overall, most areas within and outside of the trapping program in the Okanagan showed no significant difference between pre- and post-trapping periods, with the exception of route 11408 Oliver, in the southern Okanagan trapping area. It showed a significant increase in relative abundance of starlings following initiation of the trapping program.

Limitations of this Comparison: Objectives of the NA Breeding Bird Survey is to provide scientifically credible measures of the status and trends of North American bird populations at continental and regional scales to inform biologically sound conservation and management actions (Kempthorne and Myers, 2007). Although more than 270 scientific publications have relied heavily, if not entirely, on BBS data; there are limitations to its application (Link et al., 2008). The above comparison primarily provides a superficial approach to examine whether the trapping programs have had an effect on resident starling populations. There are substantial variation among BBS observers; thus, different observers may favour, miss-classify, or consistently underestimate or overestimate counts of a species. Changing observers may produce an increase or decrease independent of true changes in relative abundance of birds. Median year of service is approximately 4 or 5 years (Link et al., 2008). Variation can occur within new recruits as well. However, given the unique appearance of starlings, their abundance (among the most abundant bird species in North America) and their affinity for urban areas, these limitations may be minimal for this species. A key limitation of the analysis presented above is that correlation does not imply causation. Other factors may have produced similar trends in the relative abundance of starlings that may superficially indicate that the trapping programs were/were not effective. A reliable test/evaluation of the effectiveness of trapping to reduce abundance of resident starlings would require replicated and controlled trapping programs, coupled with a significantly stronger monitoring program than that provided by the BBS.

The effective trapping area was based on estimates of distances travelled by starlings in summer in California. This distance may vary in Washington and Okanagan areas; unfortunately, there was no data to adjust this movement pattern within these areas. However, in acknowledgment of this missing data, the route-specific graphs and estimated distances to the effective trapping area is provided such that reassessment can be made should this information become available. The distances estimated between effective trapping and breeding bird routes are approximate distances based on the data presented in Figures 7 - 9, and personal communication with trapping program coordinators. The actual distances may vary slightly from those used here. This data is provided should adjustments be needed.

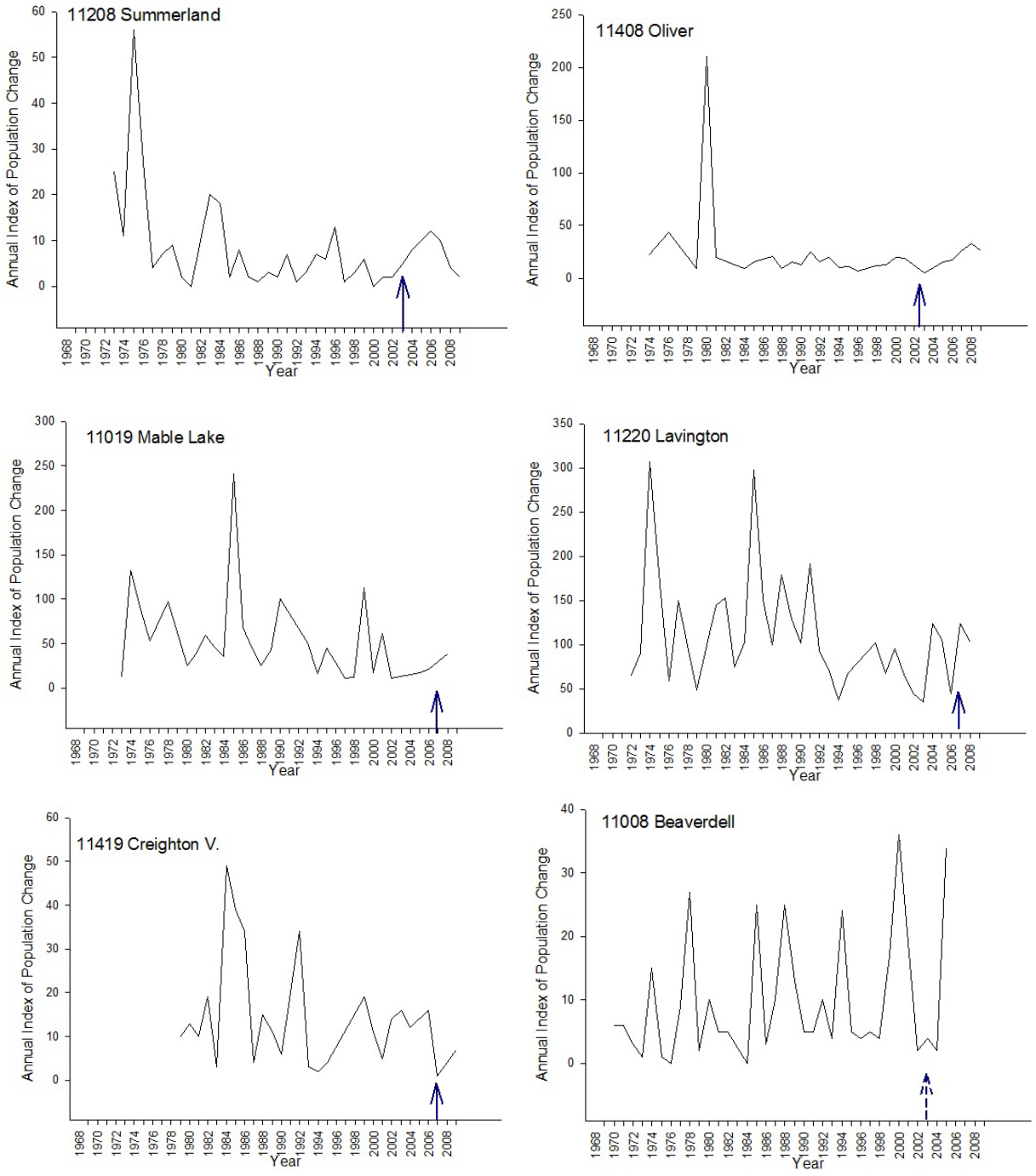

Figure 13a. Index of population abundance for BBS routes adjacent to and surrounding the control program in Southern Interior of British Columbia (initiated in 2003). The solid arrow indicates initiation of the control program. The dashed arrow is a reference to the same time period for breeding bird survey routes outside the control program area.

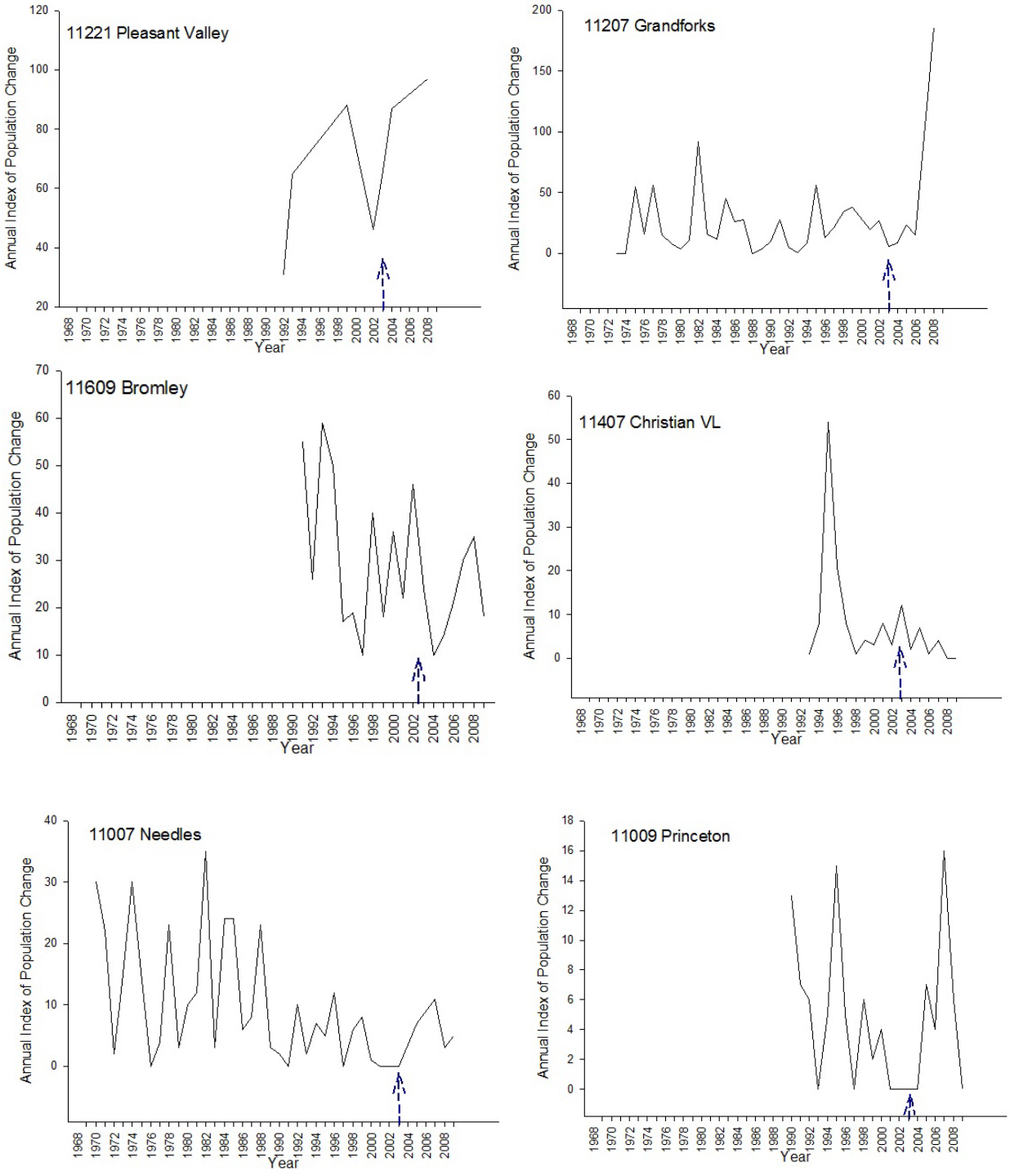

Figure 13b. Index of population abundance for BBS routes adjacent to and surrounding the control program in Southern Interior of British Columbia (initiated in 2003). The solid arrow indicates initiation of the control program. The dashed arrow is a reference to the same time period for breeding bird survey routes outside the control program area.

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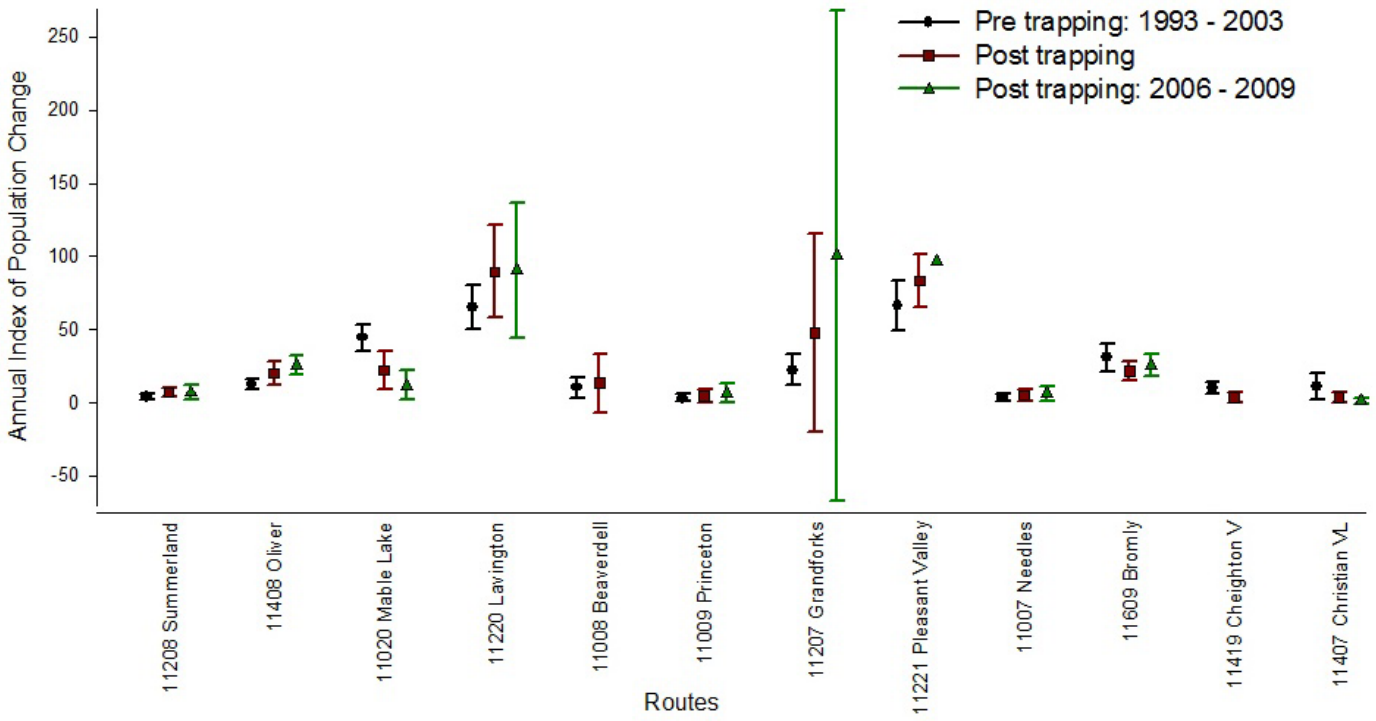

Figure 14. Comparison of three mean indices (± 95% confidence intervals) of abundance for starlings on all routes examined in the Okanagan area: for 10 years prior to the 2003 initiation of the South Okanagan trapping program, or 2007 initiation of the north Okanagan program; for all years following initiation of the trapping programs, and the last 5 years of the trapping programs. The first four routes were within the effective trapping area. Non-overlapping confidence intervals indicate significant differences between means.

Table 1. Distances from starling control areas to survey routes for breeding birds in Washington, USA and British Columbia, Canada. Route numbers correspond to those in Figures 7-8 &10-14.

Route ID	Distance (km)	Route ID	Distance (km)
Washington			
89027 Kendal	12	11210 Chilliwack (B.C.)	21
89066 Bay View	35	11011 Albion (B.C.)	23
89003 Warm Beach	68	11010 Seabird (B.C.)	53
89002 Port Angeles	105	89004 Newhalen	80
89001 Ozette	161	89034 Everett	112
89017 Bunker Hill	315	89072 Mukilteo	120
89043 Packwood	260	89025 Snowden	370
89024 Camas	375	89040 Ilwaco	287
British Columbia			
11208 Summerland	Trapping Area	11407 Christian	48
11009 Princeton	74	11408 Oliver	Trapping Area
11008 Beaverdell	42	112007 Grandforks	75
11419 Creighton	30	11020 Mable Lake	Trapping Area
11221 Pleasant Valley	91	11220 Lavington	Trapping Area
11609 Bromley	50	11007 Needles	100

Conclusion

If the primary objective of a trapping program is the long-term reduction in abundance of starlings in the Lower Mainland, then it is unlikely a trapping program would achieve this objective. Many studies that have examined trapping and its impacts on starlings have shown strongly that few adult starlings enter traps. Consequently, the vast majority of starlings removed by trapping are not from the breeding population. For example:

> Assuming adult starlings have an annual mortality rate of 55% (see Survival and Mortality), then approximately 1 bird from each breeding pair fail to survive to the following breeding season. Thus, only 1 juvenile from each breeding pair is required to survive to breed the subsequent spring to replace the over-winter adult mortality. Given that starlings typically have two broods each summer with an average clutch of 5 eggs each (see reproduction), each pair of starlings produces 10 young. The average egg-to-juvenile survival was 79%, so 8 eggs may survive to become juveniles. Although there was variability in survival rates of juveniles, approximately 50% of juveniles survive to spring. Therefore, for the breeding population to remain the same from year to year, only one juvenile is needed to survive to breeding age;

however, 4 juveniles could survive. Potentially, there are four-fold more juveniles individuals present each spring than needed to replace lost adults.

A key uncertainty is whether trapping induces additional mortality beyond that occurring naturally (mortality is additive) or whether trapping just replaces natural mortality (compensatory mortality). If the primary source of mortality to juvenile starlings is starvation during winter, mortality would be primarily compensatory, and trapping would primarily remove the 'doomed surplus' – i.e. the 50% that would die anyway. Similarly, if starlings primarily die from lack of access to good winter roost sites that provide good thermal cover, mortality is compensatory and trapping would remove the doomed surplus. However, if the primary source of overwinter mortality is independent of current starling densities (density independent events like weather), any additional removal would add to the natural mortality. In all likelihood, primary mortality agents are likely density dependant (Dr. Michael Conover, Utah State University, pers. comm.); thus, trapping would primarily remove a portion of the doomed surplus. However, if trapping can remove majority of the juvenile production each summer, insufficient juveniles would be available to adequately replace the losses represented by over-winter mortality of adults. A continued removal of this level could result in a long-term reduction of the resident population. Actual proportion of juveniles needed to be removed depends on accurate estimates of local survival rates, mortality factors, and proportion of outsiders dispersing to the area. Conversely, potentially any reduction in starling density could induce birds from outside areas to move in (migrants stay rather than head north), or resident birds to experience significant increases in survival rates associated with less competition (more food or good thermal roost sites) thereby offsetting any reductions achieved.

Overall, it would be a difficult and challenging task to induce a long-term reduction in abundance of resident starlings in the Lower Mainland. Potentially, an intense trapping effort to reduce abundance of juveniles, coupled with application of a starlicide at key accumulation areas of adult birds (where access to grain is available) may induce a long-term reduction of resident birds (Dr. Ron Johnson, Clemson University, pers. comm.). This integrated approach targets juveniles through trapping and both juveniles and adults using a starlicide.

It would be significantly more difficult to reduce over-winter populations, than resident populations, when one considers the huge influx of migrants into wintering areas. This influx pattern may explain the failure of chemical control and trapping programs to reduce long-term abundance of starlings at winter roosts and winter feeding areas (feedlots, dairy farms, etc.), despite millions of birds being removed. This may also explain the justification behind the general statements indicating that controlling starlings (with an emphasis on winter populations) is not feasible. In addition, given the abundance of migrants coming into the lower mainland (based on Figure 4), during fall

and winter, controlling starlings in winter would probably have minimal impact on summer populations.

A review of the data presented by the BBS provided ambiguous results. Two of the three BBS routes that showed a significant decline in relative abundance of breeding adults were deemed to be within the effective trapping area of the Whatcom County control program. Eight other routes deemed outside of the effective trapping area failed to show a significant decrease in relative abundance of breeding adults during the same time the trapping program was running. Initially, this may have been interpreted as an indication that the trapping program in Whatcom County effectively reduced the relative abundance of starlings in the control area. However, the BBS route number 89003 Warm Beach was outside of the effective trapping area and showed a similar, significant decrease in relative abundance of breeding starlings for the same periods. Therefore, the same causal mechanism that induced a decrease at Warm Beach, may have caused the decrease on the Chilliwack and Albion routes, independent of the trapping program. Similarly, BBS routes within the effective trapping area of the Okanagan trapping program failed to show a significant decrease in relative abundance of starlings on most routes. The Summerland and Oliver route were within the longest running trapping program in the southern region (since 2003). Both routes failed to show a significant decrease in relative abundance of starlings. In fact Oliver showed a significant increase (Figure 14). Most routes outside of the effective trapping area showed no change in relative abundance of starlings.

Given the discussion above and the ambiguous results of the review of the data provided through the BBS, the objective to induce a long-term reduction in abundance of starlings in the Lower Mainland is unlikely obtainable through a trapping program.

If the primary goal of the trapping program is to reduce damage to summer crops (independent of the size of the breeding population), an intense trapping program from May/June – August, may yield significant reduction in damage to summer crops. A number of reports indicated that it was large flocks of juvenile birds that caused considerable damage to summer crops (Elliott, 1964; Bogatich, 1967; Conover and Dolbeer, 2007). This is supported by the observation that juveniles should outnumber adults by four to one by late summer and early fall, potentially accounting for 80% of the damage during summer months (assuming adults and juveniles have similar feeding habits). Juvenile starlings are easily trapped in live traps and significant numbers of juveniles were removed during summer trapping programs (Elliott, 1964; Bogatich 1967; McCracken, 1972; Conover and Dolbeer, 2007). Potentially, an intensive summer trapping program aimed at reducing juveniles could directly result in reduced damage during the summer months, if reductions occur early enough. This speculation is supported by reports documenting the impact of removing summer juveniles on crop damage (Elliott, 1964; Bogatich 1967; McCracken, 1972; Conover and Dolbeer, 2007).

These reports consistently indicated that effective control of damage to summer crops (e.g., cherries & blueberries) was obtained by trapping summer juveniles. Discussion with Dr. Michael Conover supports this conclusion. Dr. Conover is a specialist in wildlife damage at Utah State University and wrote the book titled: Resolving Human-Wildlife Conflicts, the Science of Wildlife Damage Management (2000). He agreed that a control program aimed at summer juveniles could be 'very successful' at reducing damage to blueberries, if the control program was large enough and maintained over time. He also agreed that reduction in damage to blueberries can be attained without attempting to reduce the spring breeding population. The goal of the trapping program in early summer and fall would be to induce compensatory mortality earlier than natural mortality. Successfully doing so may reduce abundance of juveniles before they can cause significant damage to berry crops. Thus, this program would be a long-term program providing protection of blueberries as long as the program runs. Potentially, as soon as the program stopped, damage could return to levels observed prior to program initiation. In addition, it may take a few years for a positive benefit of a trapping program to be seen as there is a time lag of a few years before trappers identify key locations to focus trapping efforts and to identify key primary and supplemental feeding areas for effective removal (McCracken, 1972).

Summary: None of the reports examined (with the exception of White et al., 1985) that evaluated the effectiveness of starling control programs had an experimental design, statistical analyses or adequate controls. Thus, most reports were not scientifically-based studies, but rather reports documenting observations without rigorous evaluation of the program they documented. However, these general observations provided an indication as to whether a trapping program might be effective in the Lower Mainland.

A trapping program aimed at the long-term reduction in abundance of starlings in the Lower Mainland is unlikely to be successful, especially if the emphasis is during winter. Previous winter control programs appeared to provide little long-term reduction in abundance of starlings. In additional, little evidence was available to support the idea that a summer trapping program could result in a long-term reduction in the resident population in the Lower Mainland. However, a number of reports have found that a summer trapping program was very effective at reducing damage to summer crops. Implementing an intensive trapping program from May/June to August, targeting juvenile starlings, may reduce a significant number of juvenile starlings and the damage they cause in summer crops. Given the lack within previous reports to monitor the effectiveness of their control programs to reduce damage, it is strongly recommended to monitor the change in damage levels during a trapping program, if implemented. Using a strong and reliable monitoring protocol would indicate if the program is being successful, and if the level of trapping is sufficient. It also permits modification of the

program as an adaptive-management approach, enhancing effectiveness and efficiencies.

Literature Cited

Avery, M., J. Nelson, and M. Cone. 1992. Survey of bird damage to blueberries in North America. Proc. East. Wildl. Damage Control Conf. 5:105-110.

(BBS) Breeding Bird Survey. 2010: Accessed January 2010: http://www.cws-scf.ec.gc.ca/mgbc/trends/index.cfm?lang=e&go=info.bird&speciesid=4930&provid=3&sort=e

Besser, J.F., W.C. Royal Jr., and J.W. Degrazio. 1967. Baiting starlings with DRC-1339 at a cattle feedlot. Journal of Wildlife Management 31:48-51.

Bielert, C. And R. Hol. 2008. A starling control program for the Okanagan and Similkameen. British Columbia Grapegrowers Association. Accessed January 2010: http://www.grapegrowers.bc.ca/starling.shtml.

Bogatich, V. 1967. The use of live traps to remove starlings and protect agricultural products in the state of Washington. Proceedings of the 3rd Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Bomford, M. 1992. Review of research on control of bird pests in Australia. Proceedings of the 15th Vertebrate Pest Conference (J.E. Borrecco and R.E. March, editors). University of California, Davis California.

Bray, O.E., K.H. Larsen, D.F. Mott. 1975. Winter movements and activities of radio-equipped starlings. Journal of Wildlife Management 39:795-801.

Brenner, F.E. 1965. Metabolism and survival time of grouped starlings at various temperatures. Wilson Bulletin 77:388-395.

Browne, R.H. 1979. On the visual assessment of the significance of a mean difference. Biometrics 35:657-665.

Burtt, H.E., and M.L. Giltz. 1977. Seasonal directional patterns of movement and migration of starlings and blackbirds in North America. Bird Banding 48:259-271.

Cabe, P.R. 1999. Dispersal and population structure in the European starling. The Condor 101:451-454.

Caccamise, D.F. 1990. Communal starling roosts: implications for control. Proc. 14th Vertebrate Conference (Davis, L.R., and R.E. Marsh, eds.). University of California, Davis California.

Caccamise, D.F. 1991. European starling fidelity to diurnal activity centers: role of foraging substrate quality. The Wilson Bulletin 103:13-24.

Caccamise, D.F., L.A. Lyon, and J. Fischl. 1983. Seasonal patterns in roosting associations composed of starlings and common grackles. Condor 84:474-481.

Campbell, W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser, A. Stewart, M.C.E. McNall. 2001. Birds of British Columbia, Vol. 3:486-497. UBC Press, Vancouver, British Columbia.

Cannings, R.A., R.J. Cannings, and S.G. Cannings. 1987. Birds of the Okanagan Valley, British Columbia. Royal British Columbia Museum, Victoria.

Collins, V.B. and A. De Vos. 1966. A nesting study of the starling near Guelph, Ontario. The Auk 83:623-636.

Cooke, M.T. 1928. The spread of the European starling in North America (to 1928). Early classics in biogeography, distribution, and diversity studies: to 1950. Accessed June, 2010 from http://people.wku.edu/charles.smith/biogeog/COOK1928.htm

Conover, M.R., and R.A. Dolbeer. 2007. Use of decoy traps to protect blueberries from juvenile European starlings. Human-Wildlife Conflicts1:265-270.

Coulson, J.C. 1960. A study of the mortality of the starling based on ringing recoveries. Journal of Animal Ecology 29:251-271.

Courtney, S.P., N.I. Litchi, and Z.A. Bassett. 1998. A literature review on starling (*Sturnus vulgaris*) biology and control methods. Sustainable Ecosystem Institute, Portland Orgeon.

Dickinson, T., and N. Flood. 2008. Determining the Population Structure of European Starlings (*Sturnus vulgaris*) in Southern British Columbia. Accessed January 2010: http://www.grapegrowers.bc.ca/pdf/Starling_Proposal-T_Dickinson-May_08.pdf.

Dolbeer, R.A. 1982. Migration patterns for age and sex classes of blackbirds and starlings. Journal of Field Ornithology 53:28-46.

Dolbeer, R.A. 2005. Blackbirds and their control. Internet Center for Wildlife Damage. Accessed: August, 2010. http://icwdm.org/handbook/birds/Blackbirds.asp.

Dolbeer, R.A., D.F. Mott, and J.L. Belant. 1997. Blackbirds and starlings killed at winter roosts from PA-14 application, 1974-1992: implications for regional population management. Proceedings from the Eastern Wildlife Damage Management Conference 7:77-86.

Eastwood, E., G.A. Isted, and G.C. Rider. 1962. Radar ring angels and the roosting behaviour of starlings. Proceedings of the Royal Society of London; Series B Biological Sciences Vol. 156, No. 963:242-267.

Elliott, H.N. 1964. Starlings in the Pacific Northwest. Proceedings of the 2nd Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The birder's handbook. Simon and Schuster, New York.

Feare, C. 1984. The Starling. Oxford University Press, Oxford New York.

Feare, C.J., P.D. De Franssu, and S.J. Peris. 1992. The starling in Europe: multiple approaches to a problem species. Proceedings of the 15th Vertebrate Pest Conference (J.E. Borrecco and R.E. March, editors). University of California, Davis California.

Fischl, J., and D.F. Caccamise. 1985. Influence of habitat and season on foraging flock composition in the European starling (*Sturnus vulgaris*). Oecologia 67:532-539.

Fischl, J., and D.F. Caccamise. 1986. Relationship of diet and roosting in the European starling. American Midland Naturalists 117:395-404.

Fischl, J., and D.F. Caccamise. 1987. Relationships of diet and roosting behaviour in the European starling. American Midland Naturalist 117:395-404.

Fitzwater, W. 1992. Getting physical with birds. In Bird control in flood plains (Baur, F. And W. Jackson, editors). The American Association of Cereal Chemists, St. Paul, Minnesota.

Ford, H.S. 1967. Winter starling control in Idaho, Nevada, and Oregon. Proceedings of the 3rd Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Frankhauser, D.P. 1971. Annual adult survival rates of blackbirds and starlings. Bird Banding 42(1): 36-42.

Glahn, J.F., and D.L. Otis. 1986. Factors influencing blackbird and European starling damage at livestock feeding operations. Journal of Wildlife Management 50:15-19.

Glahn, J.F., S.K. Timbrook, and D.J. Twedt. 1987. Temporal use patterns of wintering starlings at a southeastern livestock farm: implications for damage control. The 3rd Eastern Wildlife Damage Control Conference, University of Nebraska.

Gorenzel, W.P., T.P. Salmon, and A.C. Crabb. 2000. A national review of the status of trapping for bird control. Proceedings of the 19th Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Guarino, J.L. 1968. Bird movements in relation to control. Wildlife Damage Management, Internet Center for Bid Control Seminars Proceedings. University of Nebraska, Lincoln, Nebraska, USA.

Hone, J. 1994. Analysis of vertebrate pest control. Cambridge University Press., Cambridge, Great Britian.

Jewett, S.G. 1942. The European starling in California. Condor 44:79.

Jewett, S.G. 1946. The starling in Oregon. Condor 48:245.

Jobin, L. 1952. The European starling in central British Columbia. Condor 54:318.

Johnson, S.R. 1974. Analysis of starling and myna movements in the Pacific Northwest. The Journal of Ornithological Investigations 45:197-292.

Johnson, R.J., and J.F. Glahn. 1994. European Starling. Prevention and Control of Wildlife Damage (Hygnstron, S.C., R.M. Timm, and G.E. Larson, eds.). USDA APHIS, University of Nebraska, Lincoln, Nebraska.

Johnson, R.J., and J.F. Glahn. 1998. Starling management in agriculture. NCR 451, North Central Regional Publications. University of Nebraska, Lincoln, Nebraska.

Johnson, S.R., and I. McTaggart Cowan. 1974. Thermal adaptation as a factor affecting colonization success of introduced Sturnidae (Aves) in North America. Canadian Journal of Zoology 52:1559-1576.

Julious, S.A. 2004. Using confidence intervals around individual means to assess statistical significance between two means. Pharmaceutical Statistics 3:217-222.

Kempthorne, D., and M.D. Myers. 2007. Strategic plan for the North American breeding bird survey: 2006-2010. U.S. Geological Survey Circular 1307.

Kessel, B. 1951. Criteria for sexing and aging European starlings (*Sturnus vulgaris*). Bird-Banding 22:16-23.

Kessel, B. 1953. Distribution and migration of the European starling in North America. Condor 55:49-67.

Kessel, B. 1957. A study of the breeding biology of the European starling (Sturnus vulgaris) in North America. American Midland Naturalist 58:257-331.

Knittle, C.E., J.L. Guarino, P.C. Nelson, R.W. Dehaven, and D.J. Twedt. 1980. Baiting blackbirds and starling congregating areas in Kentucky and Tennessee. Proceedings of the 9th Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

LeJeune, J. J. Homan, G. Linz, and D.L. Pearl. 2008. Role of the European starling in the transmission of E. Coli 0157 on dairy farms. Proceedings from the 23rd Vertebrate Pest Conference, University of California, Davis, California. Pp. 31-34.

Link, R. 2004. Living with Wildlife: Starlings. Washington Department of Fish and Game, Olympia Washington. Accessed January, 2010: http://wdfw.wa.gov/wlm/living/starlings.pdf.

Link, W.A. and J.R. Sauer. 1998. Estimating population change from count data: application to the North American Breeding Bird Survey. Ecological Applications 8:258-268.

Link, W.A., J.R. Sauer, D.K. Niven. 2008. Combining breeding bird survey and Christmas bird count data to evaluate seasonal components of population change in northern bobwhite. Journal of Wildlife Management 72:44-51.

Linz, G., J. Homan, S. Gaukler, L. Penry, and W. Bleier. 2007. European starlings: a review of an invasive species with far-reaching impacts. Managing Vertebrate Invasive Species: Proceedings of an International Symposium (G. W. Witmer, W. C. Pitt, K. A. Fagerstone, eds.). USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, CO. 2007.

Lowe, S., M. Brown, S. Boudjelas, and M. Depoorter. 2000. 100 of the world's worst invasive alien species. World Conservation Union, Gland, Switzerland.

Lyon, L.A., and D.F. Caccamise. 1981. Habitat selection by roosting blackbirds and starlings: management implications. Journal of Wildlife Management 45:435-443.

McCracken, H. 1972. Starling control in Sonoma County. Proceedings of the 15th Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Morrison, D.W., and D.F. Caccamise. 1985. Ephemeral roosts and stable patches? A radiotelemetry study of communally roosting starlings. The Auk 102:793-804.

Morrison, D.W., and D.F. Caccamise. 1990. Comparison of roost used by three species of communal roostmates. The Condor 92:405-412.

Mousley, H. 1924. Further notes on the starling (*Sturnus vulgaris*) in Canada. Auk 41:158-159.

Mumby, P. 1979. The starling (*Sturnus vulgaris*) in North America: a review of its biology, economic status, and control. M.Sc. Thesis, Simon Fraser University, Burnaby, British Columbia.

Munro, J.A., and I. McT. Cowan. 1947. A review of the bird fauna of British Columbia. Special Publication 2 of the B.C. Provincial Museum.

Myers, M.T. 1958. The European starling in British Columbia: 1947-1957. Occasional Papers of the British Columbia Provincial Museum No. 11.

Nelson, J.W. 1970. Bird control in cultivated blueberries. Wildlife Damage Management, Internet Center for Bid Control Seminars Proceedings. University of Nebraska, Lincoln, Nebraska, USA.

Palmer, T.K. 1976. Pest bird damage control in cattle feedlots: the integrated systems approach. Proceedings of the 7th Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.

Paton, D.C., R.G. Sinclair, and C.M. Bentz. 2005. Ecology and management of the common starling (*Sturnus vulgaris*) in the McLaren Vale Region. A Final Report

to Grape and Wine Research & Development Corporation. University of Adelaide, Australia.

Prairie Farm and Ranch. 2010. Accessed June 10, 2010: http://www.prairiefarmandranch.com/cms/grain/european-starlings-decimating-b.c.-crops/.

Pyle, P. 2001. Identification Guide to North American Birds. Slate Creek Press, Bolinas, CA.

Racey, K. Status of the European starlings in British Columbia. Murrelet 31:30.

Roberts, W.M. 1992. Controlling bird damage to blueberry crops in Pitt Meadows: a study of bird behaviour and crop protection devices. A report for the Corporation of the District of Pitt Meadows, B.C. Provincial Ministry of Agriculture, Fisheries, and Food, and the B.C. Blueberry Development Council.

Royall, Jr., W.C., J.L. Guarino, A. Zajanc, C.C. Siebe. 1972. Bird-banding 43:26-37.

Sauer, J.R., J.E. Fallon, and R. Johnson. 2003. Use of North American breeding bird survey data to estimate population change for bird conservation regions. Journal of Wildlife Management 67:372-389.

Sauer, J., W.A. Link, J.D. Nichols, and J.A. Royle. 2005. Using the North American breeding bird survey as a tool for conservation: a critique of Bart et al. (2004). Journal of Wildlife Management 69:1321-1326.

Sauer, J.R., J.E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Searing, G.F., K.H. Morgan, C. Engelstoft. 1990. Starling control and dispersal in Vancouver: 1990 implementation. City of Vancouver Archives, Vancouver, B.C.

Stewart, P.A. 1978. Survival tables for starlings, red-winged blackbirds, and common grackles. North American Bird Bander: Vol. 3, No. 3, July-September.

Stickley Jr., A.R. 1979. Extended use of Starlicide in reducing bird damage in southeastern feedlots. Wildlife Damage Management, Internet Center for Bird Control Seminars Proceedings. University of Nebraska, Lincoln Nebraska.

Stickley Jr., A.R., D.J Twedt, J.F. Heisterberg, D.F. Mott, and J.F. Glahn. 1986. Surfactant spray system for controlling blackbirds and starlings in urban roosts. Wildlife Society Bulletin 14:412-418.

Strassburd, M. G. Linz, and W. Bleier. 2010. Evaluation of Christmas bird counts and landscape factors as indicators of local blackbird and European starling winter roots. USDA, National Wildlife Research Center, University of Nebraska, Lincoln, Nebraska.

The British Columbia Fruit Growers Association. 1998. 1998 bird damage survey to fruit trees. Kelowna, British Columbia.

Tracey, J., M Bomford, Q. Hart, G. Saunders, R. Sinclair. 2007. Managing bird damage to fruit and other horticultural crops. Bureau of Rural Science, Canberra, Australia.

Vaudry, A.L. 1979. Bird control for agricultural lands in British Columbia. British Columbia Ministry of Agriculture, Victoria, B.C. 71-21.

VPCH (Vertebrate Pest Control Handbook). 2010. Accessed Sept. 2010. http://www.vpcrac.org/images/starlingpart2peter.pdf

Weatherhead, P.J., H. Greenwood, S.H. Tinker, and J.R. Bider. 1980. Decoy traps and the control of blackbird populations. Phytoprotection 60:65-71.

Weber, W. 1983. Bird damage to blueberries in the lower Fraser Valley, British Columbia. Presented to the Western Committee on Vertebrate Pests, Penticton, B.C. October 18, 1983. Ministry of Agriculture and Lands, Abbotsford, B.C.

West, R.R. 1968. Reduction of a winter starling population by baiting it preroosting area. Journal of Wildlife Management 32:637-640.

Wing, L. 1943. The starling in eastern Washington. The Condor 45:159.

Whatcom Farm Friends. 2008. Farm Flash. Lynden, Washington. Accessed Jan. 2010: http://www.wcfarmfriends.com/posted/1579/February_2008_Newsletter.192854.pdf

White, S.B., R.A. Dolbeer, and T.A. Bookbourt. 1985. Ecology, bioenergetics, and agricultural impacts of a winter-roosting population of blackbirds and starlings. Wildlife Monographs 93:3-42.

Williamson, P., and L. Gray. 1975. Foraging behaviour of the starling (*Sturnus vulgaris*) in Maryland. The Condor 77:84-89.

Zajanc, A. 1962. Methods of controlling starlings and blackbirds. Proceedings of the 1st Vertebrate Pest Conference, University of Nebraska, Lincoln, Nebraska, USA.