Using Trace Elements to Chemically Fingerprint European Starlings (*Sturnus vulgaris*) in the Okanagan Valley of British Columbia

by

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Abstract

European starlings (*Sturnus vulgaris*) are an introduced pest that cause significant economic and ecologic damages and losses in areas where they thrive. In the Okanagan Valley of British Columbia, Canada, a trapping program has been established in an attempt to minimize the damage to agricultural crops caused by the starling. Although over 260 000 have been trapped and euthanized the population remains stable and is thought to be increasing. As the starling is a highly mobile species it is not known where the population originates. In order to determine origin(s) of the 2010 starling population in Kelowna, a portion of the Okanagan Valley, trace element analysis was performed on six different tissue types of starlings (brain, bone, muscle, heart, liver and feathers) to determine which, if any, would be the most appropriate for origin determination. Starlings from the same location were sampled over two time periods to evaluate the degree of temporal separation provided from the various tissues. The most appropriate tissue for origin analysis will have a slow turnover time that would retain the chemical signature of where it was synthesized. As bone turns over very slowly in humans it was hypothesized that it would be the most appropriate for origin determination. Using cluster analysis bone was deemed to be the best temporal separator and the most appropriate tissue to trace origins of starlings. Bone was further examined for its ability to separate populations spatially. Bones from starlings obtained from four regions in British Columbia, and one in the United States, were analysed to create a database of source populations that the fall population of Okanagan birds could be compared to. Using principal component analysis bone proved to separate areas with high spatial resolution. All of the 2010 fall population was from immigrant sources with the majority from unknown locations. Three source populations were identified using principle component analysis by comparing immigrant birds to 95 % confidence intervals calculated around the means of each source population, proving that this technique can be applied to address small-scale movements in mobile organisms. More potential source locations are needed to characterize the Kelowna population. Trace elements proved to provide high spatial resolution, separating populations within several hundred kilometers of each other.

Preface

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Dedication

For Dustin…..

Chapter 1 Subject Introduction

1.1 European Starling – History of Introduction

The European starling (*Sturnus vulgaris*) (hereafter referred to as starling) is native to Europe, south west Asia and North Africa (Linz et al. 2007). Several attempts were made to introduce the starling to North America, however it wasn't until 1890 that a successful introduction took place. The American Acclimatization Society, with the mandate of introducing all avian species mentioned in Shakespeare's plays, released 60 individuals in Central Park, New York City, in 1890 and then an additional 40 in 1891 (Cabe 1993). The population began to spread west and north, reaching the Canadian border by 1940, the west coast of the United States by 1942 and into Alaska by 1970 (Cabe 1993; Linz et al. 2007). Presently, starlings have colonized the North American continent from the temperate zone in the south to the boreal forest in the north, with populations concentrated around urban development (Alsop 2004).

1.2 Starlings as Invasive Pests

European starlings are one of three birds listed on the "100 World's Worst Invaders" list (Lowe et al. 2004). In North America they are an introduced species, where they have become an agricultural pest. There are several aspects of their life history that enable them to be a successful pest. Firstly, they have multiple clutches per year laying between 4-6 eggs per clutch (Cabe 1993) with a rate of nest success between 48-79% (Linz et al. 2007). Secondly, they practice interspecific nest parasitism further increasing the number of chicks fledged at a reduced energy cost. Thirdly, they are a dietary generalist species, which enables them to thrive in a diversity of habitat types (Cabe 1993). Fourthly, as they are an introduced species, natural predators, parasites and diseases are not strong controlling factors in limiting the population. Finally, the starling is a migratory species that forms large roosts ranging from several birds to over 100 000 individuals (Cabe 1993) making it an efficient disperser. Distance migrated depends on region, food availability, and individual bird. If food is available year round, and temperatures are mild, individuals may remain in a region year

round. Taken together these factors have facilitated the growth of the starling population to reach a stable population of over 200 million individuals in North America (Cabe 1993). As pests, starlings cause ecological, economic and social problems. Firstly, they compete with native species for both food and nesting sites. Most commonly starlings displace woodpeckers (Picidae family), flycatchers (Tyrannidae family) and bluebirds (*Sialia sp.*) from nest cavities. Secondly, starlings consume high value agricultural crops including cherries, peaches, blueberries, strawberries, apples and wine grapes (Linz et al. 2007). They also consume and contaminate cattle feed, as well as serve as disease vectors spreading disease to both livestock and humans (Linz et al. 2007). Starlings are a flocking species and form large roosts. Aircraft have been damaged by large flocks leading to the loss of human life (Linz et al. 2007). Total economic costs are difficult to quantify, however, it was estimated in 2000 that the starling caused > $800 million USD in crop damage/loss and between $200-$250 million in dairy losses due to disease transmission (Pimentel et al. 2000). Finally, as they form large roosts, often in urban structures, they cause noise, odour and health and safety issues (Linz et al. 2007). Indirectly, starlings cause conflict between neighbors, especially in areas of rural/urban interface where noisy and/or unsightly bird deterrents are used.

1.2.1 Mitigation of Loss and Damage Caused by Starlings

Affected parties can mitigate loss and damage caused by starlings by either deterrence/avoidance methods or implementing control/eradication measures. However, neither of these techniques is wholly effective (Linz et al. 2007). In areas where starlings cause major economic damage, namely regions of high value food crops, they are a seasonal problem, as harvest time of many crops coincides with late summer- early fall migration (Linz et al. 2007; Cabe 1993). Large flocks of starlings congregate in regions of food production; it is not known where these individuals originate, or if they remain in the area and reproduce the following spring, further contributing to the local population (Cabe 1993).

1.2.1.1 Deterrence/Avoidance

Deterrence measures include: visual deterrents, such as scarecrows, reflective tape, flashing lights and mirrors (Seamans et al. 2001), chemical deterrents such as applying sticky materials to discourage roosting and applying taste aversive compounds to crops (Linz et al. 2007). Finally, auditory deterrents such as propane cannons and recorded avian distress calls and netting of crops.

1.2.1.2 Eradication

Typical eradication techniques include: using falconry over susceptible crops, blocking active and potential nest sites, trapping starlings, both individually and in larger flocks, and designing buildings that do not provide nesting and roosting sites. Success varies for all of these methods, and the best results are often achieved through a combination of techniques (Seamans 2001; BCGA 2008). None of these techniques addresses the problem at the source. The source of pest starling populations is very poorly understood. If the source(s) of starlings was better understood control efforts could be concentrated in key areas, and better, more informed management decisions could be made before large destructive flocks invade and cause damage.

1.3 Innovations in Source Population Identification

In general there are two main methods that can be used to track migratory species. Within each type there are two specific techniques. The broad categories are extrinsic tracking and intrinsic tracking. In each case there are both advantages and disadvantages in their application.

1.3.1 Extrinsic Tracking

Extrinsic tracking is a direct approach of tracking animals' movements on an individual basis. It involves using external markers to follow an organism in the form of marking the individual through a device such as a tag or transmitter (Rubenstein and Hobson 2004).

1.3.1.1 Mark-Recapture

Mark-recapture entails attaching a marker to an individual at a point in time and space and then recapturing the same individual at a later time and space. This can include attaching a leg band or neck collar with a unique number, patagial tags or plumage marking with a dye (Hobson 1999). This technique is ideal for larger, and/or game species that are easy to spot and capture. It has been used successfully on waterfowl and shorebirds (Webster et al. 2002). If the organism is a game species the marker is often recovered after the animal is harvested. It is advantageous in that it is non-destructive, inexpensive as it does not require highly technical equipment, and requires minimal time compared to more active tracking techniques such as remote sensing. The biggest limitation to this approach is that an individual has to be caught twice; the recovery rate decreases with decreasing body size. For passerine sized birds, such as the starling, the rate of recovery is around 1 % (Berthold 1993; Wassenaar and Hobson 2001).

1.3.1.2 Remote Sensing

This technique traditionally involved attaching a radio transmitter to an individual and tracking it by triangulation. Advances in satellite technology have enabled satellite transmitters to be attached to individuals allowing tracking of individuals globally (Webster et al. 2002). The individual's movements can then be tracked without having to recapture or spot the individual again. This has the potential to provide useful information on daily movements and migratory pathways as well as habitat selection. This technique is only appropriate for species physically able to carry the transmitter and works well for larger species (Hobson 1999; Rubenstein and Hobson 2004; Webster et al. 2002). It is also non-destructive, however in the case of radio telemetry, it is a much more active tracking technique than mark-recapture, therefore it requires more time. Radio telemetry is also limited to species that do not travel long distances, as they need to remain within range of the sensing capability of the telemetry equipment. Satellite tracking is limited by cost; transmitters can cost between $4000-$6000 USD, including tracking time. However they eliminate the need to follow the organism, significantly reducing the time investment (Webster et al. 2002). Satellite tracking is limited by species size and often only feasible for

small samples size due to the cost. While radio telemetry is a less costly alternative to satellite tracking, it is time intensive and limited to species that do not disperse long distances.

Factors common to both of these techniques include they are non-destructive and they focus on individuals rather than the population.

1.3.2 Intrinsic Tracking

Intrinsic tracking is an indirect approach of tracking an organisms' movements based on inferring origins from internal markers such as tissues, which contain chemical or genetic information (Rubenstein and Hobson 2004).

1.3.2.1 Biological/Genetic Marking

Biological and genetic marking involves using morphology, behaviour and genetic variation to gain an understanding of the population as a whole. This technique is less reliant on the individual organism and focuses on finding individuals of the same population or members from similar areas (Rubenstein and Hobson 2004). Populations often have unique genetic markers (Webster et al. 2002). This technique has been successful when applied to tracking shorebird migration (Clegg et al. 2003). In contrast it has not been very successful in tracking songbirds, as they tend to disperse vast distances resulting in few differences in genetic structure (Clegg et al. 2003; Rubenstein and Hobson 2004). Where applicable, the spatial resolution for this application is quite coarse; the resolution of genetic marking is determined by species dispersal and range size. Studies of songbirds have revealed low variation in intraspecific genetic structure, making this form of tracking movements limited for passerines (Clegg et al. 2003). Although this technique can be non-destructive, depending on the tissue chosen for analysis, it is not appropriate for measuring localized, smaller scale movements (Webster et al. 2002).

1.3.2.2 Trace Element/Stable Isotope Analysis

Trace element and stable isotope profiling is a technique that has emerged with advances in technology (Hobson 1999; Rubenstein and Hobson 2004). It has been applied to a wide variety of problems ranging from determining provenance of food crops, such as tea (Pilgrim et al. 2010) and wine (Greenough et al. 2005), to assigning humans to their geographic origin using hair samples (Mutzel et al. 2009) to tracking a wide variety of animal movements (Hobson 1999; Hobson 2005; Webster et al. 2002; Rubenstein and Hobson 2004). It involves using chemical markers that are present in organism's tissues to infer their previous location(s). This technique is often referred to as 'chemical fingerprinting' and is based on the fact that elements vary spatially. Areas produce regionally distinct chemical fingerprints based on differences in environment and environmental processes including geology, climate, vegetation and food webs (Hobson 1999; Rubenstein and Hobson 2004). Geochemical fingerprints are acquired in organisms as they forage in their environment they incorporate elements into their tissues, and the regional fingerprint is retained for a period of time. When they move between areas that are geochemically distinct the fingerprint can be retained and previous location(s) inferred. The length of time a signature from a previous area is retained varies by species and tissue type (Hobson and Clark 1992; Hobson and Bairlein 2003).

Tissues that grow incrementally (e.g. feathers, hair, claws) can be sampled non-destructively and can be used to provide a timeline of organisms' movements over space, providing the tissue growth rate is known (Mazerolle and Hobson 2005). In contrast, tissues which do not grow incrementally (e.g. blood, organs, muscle, bone), which require destructive sampling, can give insight into previous locations ranging from a few days to years (Hobson 2005a; Mazerolle and Hobson 2005; Hobson and Clark 1992; Martin et al. 2007; MacAvoy et al. 2006). Stable isotopes and trace elements are powerful tools that eliminate many of the inefficiencies of other techniques of tracking movement patterns. In some cases the spatial resolution of geochemical fingerprinting can be as small as three kilometers (Norris et al. 2007). Unlike extrinsic tracking, which is time intensive and provides no information on movements prior to the marker being attached, intrinsic tracking, namely stable isotope and

trace element tracking, can provide information for an individual over its lifespan up to the point of sampling.

Depending on the study species, and what information is of interest, any of the above techniques may be appropriate. For example, if seasonal diet of an individual or population or a timeline of movements is desired, stable isotopes and/or trace elements should be used. The geochemical distinctness of the habitat will dictate whether stable isotopes or trace elements are most appropriate. If habitat use or daily movements are of interest radio/satellite tracking is most appropriate, providing the species is large enough to carry the transmitter. If population movements as a whole need to be understood biological markers are the most suitable technique. However, a limitation of this approach is that there must be clear genetic distinction between populations (Rubenstein and Hobson 2004; Webster et al. 2002). For example over small spatial scales it is unlikely that there would be genetic distinction between populations, however, in areas of diverse geology, populations will/can be distinct geochemically over the same spatial scale. No one technique for tacking organism movements is necessarily better than another. The combination of circumstances and spatial resolution desired will dictate which technique is most appropriate.

Taken together, elemental tracers are the most appropriate technique for inferring source populations of highly mobile flocks of pest starlings because they are a small species, they can be destructively sampled and they potentially disperse long distances, increasing the likelihood that origin habitats would be geochemically distinct.

Chapter 2 – Chemical Fingerprinting European Starlings in the Okanagan Valley

2.1 Introduction

The European starling is a major North American pest that causes significant crop loss and damage in areas where it thrives (Chapter 1). Starlings are migratory, making it extremely difficult for managers to effectively protect against them. In order for managers to be effective in developing avian pest management plans they must be informed as to movement patterns, population dynamics and source populations.

Animal movements can be tracked using stable isotope (e.g. C, H, N, O, S) and trace element (e.g. Sr, Cu, Zn, Se, Cd, Ba, Pb, Co, Sc, Sn) profiles because they vary across space (Hobson 1999; Rubenstein and Hobson 2004; Norris et al. 2007; Chapter 1). Chemical signatures or "fingerprints" are laid down in tissues of organisms at a period in time, as they cross into areas that are isotopically or geochemically distinct, their tissues can be sampled and previous location inferred (Rubenstein and Hobson 2004; Norris et al. 2007; Inger and Bearhop 2008). Isotope and trace element profiles in an organism's tissues can be expressed in equation 1.

$$\text{Equation 1: } X_t = X_d + \triangle_{dt,}$$

where X is isotope of interest, *t* is the tissue of interest, *d* is the diet, and $\triangle$ is the isotopic fractionation factor between diet and tissue where X is expressed in mg/kg (Hobson 2005). Elements are deposited in tissues, leaving a long-term record of the site where they were synthesized (Szep et al. 2003; Szep et al. 2009). As organisms cross isotopically and/or geochemically distinct regions they carry the information of previous food web locations, bedrock type, and precipitation patterns with them in their tissues (Hobson 1999; Webster et al. 2002; Chapter 1). Due to the difference in turnover rate, tissues carry information on a temporal scale and, in the case of migratory organisms, spatial scale (Bearhop et al. 2002).

Organisms continuously incorporate elements into their tissues (Bauchinger and McWilliams 2009). The length of time a particular element will remain in the tissue depends on tissue type and metabolic rate of the particular tissue (Bauchinger and McWilliams 2009; MacAvoy et al. 2006). Different tissues carry information from different time periods in an organisms history and provide insight ranging from days, in the case of blood plasma (Hobson and Clark 1992; Mazerolle and Hobson 2005; Bearhop et al. 2002), to weeks, in the case of organs (Tieszen et al. 1983; Bauchinger and McWilliams 2009), to years, in the case of bones (Libby et al. 1964; Martin et al. 2007). Understanding turnover time in tissues is important when deciding which compartment to analyse to provide insight into a particular time period in an organism's life.

In order for elemental fingerprinting of organisms to work, there must be movement between areas that are geochemically distinct; otherwise there will not be a measurable difference in the elemental signature in organisms' tissues. Because organisms integrate variability in their tissues over space, the space they are foraging in must not be too large relative to the variability in the geochemistry, otherwise the elemental signature will be too uniform to distinguish between foraging regions. For example, trace element fingerprinting would not be appropriate for the Prairies as the geology and soils are homogenous across thousands of kilometers (Figure 1) (NRC 2012). However, in areas that are geochemically diverse, such as British Columbia, there are many opportunities for elemental fingerprinting.

Figure 1. Major rock categories of Canada

(http://atlas.nrcan.gc.ca/site/english/maps/geology.html) Accessed June 2012

Elemental fingerprinting can be done at any spatial scale, providing there is migration between areas that are chemically distinct. As different tissues carry different spatial and temporal information due to turnover time (Hobson 1999; Inger and Bearhop 2008),

location of organisms over various timelines can be inferred. For example, feathers can be used to identify wintering vs. breeding grounds in birds as there is a difference in the elemental fingerprint of feathers within the same individual grown in two different locations (Szep et al. 2003). Isotopes are more appropriate for large-scale movements as they vary over large scales, similar to migration patterns (Chamberlain et al. 1997; Miller et al. 2011; Hobson and Wassenaar 1997). For example, stable hydrogen isotope ratios (deuterium) patterns in precipitation have been mapped across the North American continent on a latitudinal scale. The range is approximately 30 ‰ over thousands of kilometers (Hobson and Wassenaar 1997).

In contrast, trace elements can vary over several kilometers, providing the underlying geology is heterogeneous (Norris et al. 2007). In certain areas, where the geology is homogenous, trace elements will not be useful for tracking movements, however, neither will stable isotopes, unless the area of concern is vast. Furthermore, as stable isotopes vary over a latitudinal scale and do not provide good resolution longitudinally, the application of them is limited to a coarse latitudinal scale. The geochemical variability of an area will dictate whether it is appropriate to use stable isotopes (coarse scale) or trace elements (fine scale).

In order to determine if migration could be tracked over small scales using trace elements, I tested a variety of tissue types from a population of pest starlings from Kelowna, British Columbia, Canada, where starlings cause > 4 million dollars in crop damage annually (BCGA 2008). In Kelowna, and the surrounding Okanagan Valley, the large starling population has led to the development of a Starling Control Program. Since 2008 over 263 000 starlings have been trapped and euthanized (BCGA 2012 pers. comm.). Despite the removal of a large number of individuals, grower observations in the region, combined with Christmas Bird Count data of the surrounding areas, indicate an increase in the winter cohort of starlings (National Audubon Society 2011; BCGA 2012 pers. comm). To try and gain an understanding of source population(s) and migration into this region, euthanized birds were geochemically fingerprinted to determine whether trace element profiling could potentially identify source populations. Stable isotope

fingerprinting was not well suited to this question because stable isotope variance is only meaningful at very large scales (> 100 -1000 km) (Hobson et al. 1999; Chamberlain et al. 1997; Hobson and Wassenaar 1997). Indeed, isotope ratios in birds can be homogeneous for thousands of kilometers (Inger and Bearhop 2008). In contrast, the province of British Columbia (BC) is geochemically diverse across small spatial scales (Figure 2) (Yorath 1990) making trace elements potentially much more sensitive for tracking regional starling movements.

As starlings are a pest, and were able to be destructively sampled, a range of tissues were chosen based on turnover rates from literature. Resolution in time and space can be achieved through elemental fingerprinting of different tissues because organisms acquire a chemical fingerprint in space over time (Inger and Bearhop 2008; Hobson 1999; Rubenstein and Hobson 2004). Tissues that have a rapid turnover will be appropriate for providing temporal resolution as they give insight into movements in the short term. They are best applied to study daily (plasma) or seasonal movements (liver) as they incorporate elements quickly from diet and turnover quickly reflecting the current conditions/environment (Bauchinger and McWilliams 2009). Tissues that have a slow turnover, such as bone, will be appropriate for spatial resolution as they integrate diets and habitat use over the long term; therefore they can be used to show where organisms have been over large spatial scales, as long as movements are not too rapid leading to a homogenization of the elemental signature. In the case of the mineral phase of bone, it can take years or the lifetime of an individual for the elements to turnover (Martin et al. 2007). This makes it extremely useful for origin analysis, as the chemistry from the area where it was synthesized will be retained. The length of time that a tissue retains chemical information is critical to the ability to chemically fingerprint. If a tissue has too rapid of a turnover it will not be possible to use it for spatial analysis as it will only reflect recent diet and environmental conditions. Conversely, if a tissue has a long turnover time it is able to reflect differences in elemental signatures over space.

Starling populations were fingerprinted using trace elements to evaluate temporal separation across tissue types. Different tissues from birds caught in the same region at

different times of year (summer and fall) were analysed to evaluate the ability of each tissue to demonstrate temporal separation. It was assumed that at least a portion of the fall birds would be remaining in the area from the summer population. Multivariate statistics were used to identify if a portion of the fall birds in each tissue category overlapped with the summer birds. The best tissue for determining origin/source would have a slow turnover, so that the chemical signature from previous location(s) is retained (Hobson 1999). The criteria for choosing an appropriate tissue to identify source populations included the ability to accurately separate between distinct populations in time and have a turnover rate that would reflect origin.

Once the tissue that provided the most appropriate separation was determined, I tested to see what portion of the Kelowna starling population was locally derived, and what portion was formed from immigrants. This was evaluated by using the selected tissue that was most appropriate for evaluating temporal separation to fingerprint populations from across South and Central BC and Northern Washington. Kelowna immigrant birds (birds caught in the fall) were then compared to these potential source populations to see if sources could be identified.

2.2 Site Description

The province of BC is geologically diverse in rock type (NRC 2012) (Figure 2). Elemental fingerprinting is dependent on heterogeneous underlying geology in order for differences in elemental signatures to be measurable. Because BC is geologically heterogeneous, birds were collected from different areas in the province and were used as potential source populations to compare birds caught in Kelowna to. These sites included Central BC (Quesnel), Southern BC (Grand Forks) and Northern Washington state (Lynden) (Figure 3).

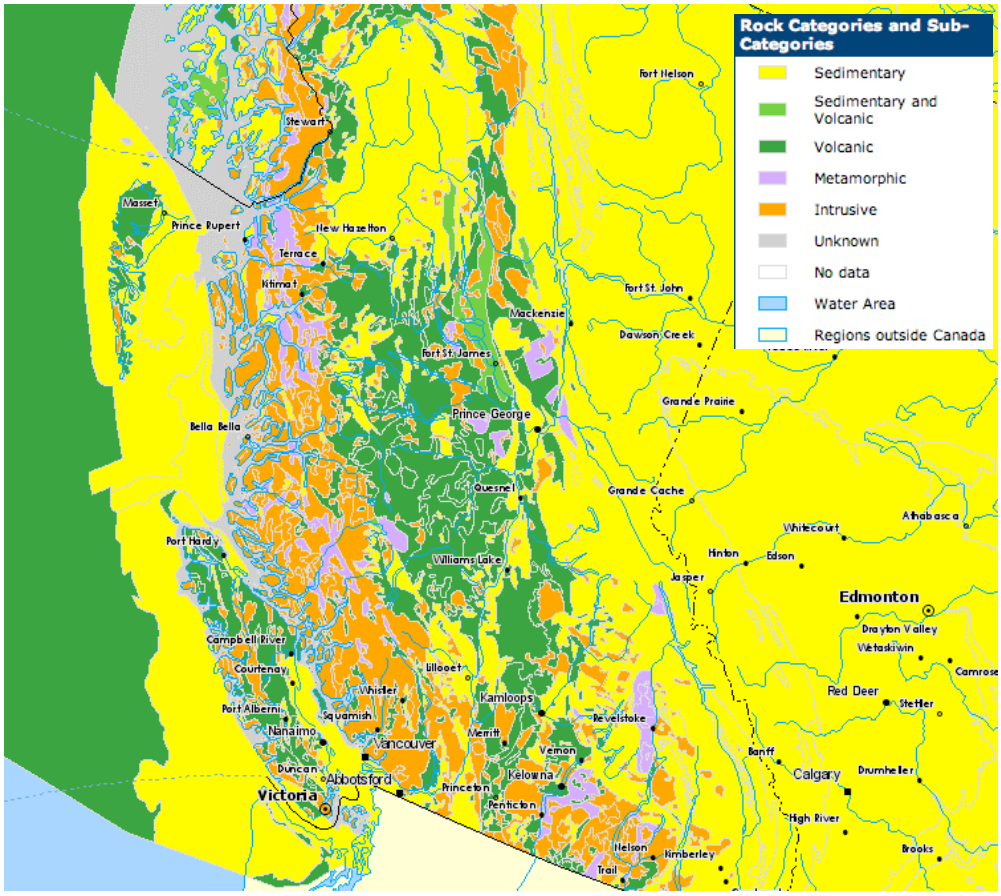

Figure 2. Major rock categories of British Columbia, Canada

(http://atlas.nrcan.gc.ca/site/english/maps/geology.html) Accessed June 2012

2.2.1 Study Site – Okanagan Valley

The Okanagan Valley is located in the southern interior of BC, approximately 300 km east of the Pacific Ocean and 160 km north of the United States border (Figure 3). It is in the interior Douglas fir and ponderosa pine biogeoclimatic zones (Gov of BC 2012) and is located between two north-south running mountain ranges; the Coast Mountains to the west and the Rocky Mountains to the east. The geology is comprised of volcanic, sedimentary, metamorphic and intrusive rocks (NRC 2012). The Okanagan Valley is characterized by relatively mild, short winters and long, hot summers, with the average temperature in July and August reaching 22 $^{\circ}$C and -0.3 $^{\circ}$C in December and January (City of Kelowna 2012). It has a range of growing degree-days from 950 in the north to1630 in the south (Bowen et al. 2005). Several large lakes in the Valley regulate temperature extremes. These factors make it ideal for a variety of agriculture including cattle operations (dairy and feedlot), soft fruit, and wine and table grape production. The Okanagan Valley contains 95 % of the Province's vineyards and 90 % of its orchards (Shepherd et al. 2006). Taken together the mild winters, high growing degree-days, rural/urban interface and year round food sources make Kelowna and the Okanagan Valley a hotspot for starlings.

Three sites within the Okanagan Valley were sampled: North Okanagan (Vernon/Armstrong), Central Okanagan (Kelowna) and South Okanagan (Keremeos/Oliver). Samples were collected from various locations within a ~30 km radius in the North Okanagan, from a single feedlot in the Central Okanagan, and from a ~60 km radius in the south Okanagan.

Figure 3. Sample collection sites

2.2.2 Site Description of Source Sites

Quesnel is located in the interior plateau of central BC. The geology is comprised of sedimentary and volcanic rocks (NRC 2012). Each rock category contains different mineral and chemical composition depending on how it was formed (NRC 2012). Volcanic rocks are composed of materials from the earth's crust. While sedimentary rocks are formed from sediments consolidating over time (NRC 2012). From a

mineralogical perspective each rock category is geochemically distinct. Therefore, areas that have different geologic composition will have distinct local geochemistry.

Grand Forks is located in the southern interior of BC near the United States border. It is comprised of intrusive, metamorphic and volcanic geology (NRC 2012). Metamorphic rocks are formed from existing rocks by physical actions including temperature, pressure and/or chemical processes. Minerals in metamorphic rocks are reorganized from the original composition that made them up (NRC 2012). Intrusive rocks are formed at depth and are similar in composition to volcanic rocks.

Lynden, Washington is located ~10 km south of the Canadian border and west of the Cascade Mountains. It is characterized by Mesozoic crystalline and metamorphic rocks (Dept. of Natural Resources, WA 2012). Like BC, Washington is geologically diverse (Figure 4). There are rocks units from every geologic period in the state (Dept. of Natural Resources, WA 2012).

Figure 4. Rock categories of Washington, USA

(www.dnr.wa.gov/geology/) Accessed January 2013

Key to Geologic Units

Unconsolidated Sediments

- Qd Holocene dune sand
- Qa Quaternary alluvium
- Qls Quaternary mass-wasting deposits
- Ql Quaternary loess
- Qf Pleistocene outburst-flood deposits
- Qgd Pleistocene continental glacial drift
- Qad Pleistocene alpine glacial drift

Sedimentary Rocks and Deposits

- QTc Quaternary–Tertiary continental sedimentary rocks and deposits
- Tc Tertiary continental sedimentary rocks
- Mzc Mesozoic continental sedimentary rocks
- Tn Tertiary nearshore sedimentary rocks
- Mzn Mesozoic nearshore sedimentary rocks
- Tm Tertiary marine sedimentary rocks
- Mzm Mesozoic marine sedimentary rocks

Volcanic Rocks and Deposits

- Qv Quaternary volcanic rocks
- QTv Quaternary–Tertiary volcanic rocks
- Tvcr Tertiary volcanic rocks, Columbia River Basalt Group
- Tv Tertiary volcanic rocks
- Tvc Tertiary volcanic rocks, Crescent Formation
- Mzv Mesozoic volcanic rocks
- Qvt Quaternary fragmental volcanic rocks and deposits (includes lahars)
- Tvt Tertiary fragmental volcanic rocks

Intrusive Rocks

- Qi Quaternary intrusive rocks
- QTi Quaternary–Tertiary intrusive rocks
- Ti Tertiary intrusive rocks
- TKi Tertiary–Cretaceous intrusive rocks
- Mzi Mesozoic intrusive rocks
- Pzi Paleozoic intrusive rocks
- pCi Precambrian intrusive rocks
- MzPzu Mesozoic–Paleozoic ultramafic rocks

Metasedimentary and Metavolcanic Rocks

- Mzms Mesozoic metasedimentary rocks
- Pzms Paleozoic metasedimentary rocks
- PzpCms Paleozoic–Precambrian metasedimentary rocks
- pCms Precambrian metasedimentary rocks
- Mzmt Mesozoic metasedimentary and metavolcanic rocks
- MzPzmt Mesozoic–Paleozoic metasedimentary and metavolcanic rocks
- Pzmt Paleozoic metasedimentary and metavolcanic rocks
- Mzmv Mesozoic metavolcanic rocks
- Pzmv Paleozoic metavolcanic rocks
- pCmv Precambrian metavolcanic rocks

Metamorphic Rocks (Amphibolite Facies and Higher)

- Mzhm Mesozoic heterogeneous metamorphic rocks
- MzPzhm Mesozoic–Paleozoic heterogeneous metamorphic rocks
- pChm Precambrian heterogeneous metamorphic rocks
- Mzam Mesozoic amphibolite
- MzPzam Mesozoic–Paleozoic amphibolite
- TKgn Tertiary–Cretaceous gneiss
- Mzgn Mesozoic gneiss
- Pzgn Paleozoic gneiss
- TKog Tertiary–Cretaceous orthogneiss
- Mzog Mesozoic orthogneiss
- Mzmi Mesozoic migmatite and mixed metamorphic and igneous rocks

2.3 Methods

Starlings were collected and analysed to reflect both temporal and spatial scales. All samples were from 2010 in order to minimize variability between years. Juvenile birds were collected because they had not migrated yet; therefore their tissues reflected the chemical fingerprint of where they were collected. Starlings from the Okanagan Valley were obtained from the Starling Control Program between July and August (*n*=20). An additional set of birds was obtained from the Program in November from the same location (*n*=20). Birds had been euthanized by CO_2 gas and then frozen to await analysis. Six different tissues including: brain, liver, heart, muscle, tail feathers and bone were analysed to see which, if any, could demonstrate temporal separation.

Using multivariate statistics (cluster analysis) tissues were evaluated to determine the degree of temporal separation they provided. Tissues were ranked in order of most rapid turnover (having no overlap between fall and summer birds from the same location) to slowest (demonstrating some level of overlap between birds caught at same location over different time periods). Other mechanisms responsible for there being no overlap could be variability in the population resulting from different food sources. The tissue that demonstrated the most appropriate temporal separation was then evaluated for its ability to separate populations spatially also using cluster analysis. Juvenile birds from five locations across Southern and Central BC, and one from Northern Washington, were collected. Birds were obtained through a combination of the Starling Control Program and putting a request out to various agricultural producers to trap and collect juvenile starlings on their property. These samples were also collected in 2010 from May through August. Locations included: Kelowna BC, Canada (*n*=20), North Okanagan BC, Canada (*n*=15), South Okanagan BC, Canada (*n*=15), Quesnel BC, Canada (*n*=10), Grand Forks BC, Canada (*n*=10) and Lynden Washington, USA (*n*=15) (Figure 3).

Finally, using the tissue that provided the most meaningful temporal and spatial separation the Kelowna population was characterized. Principal component analysis (PCA) was used to compare birds caught at a single space and time to birds caught from different locations over the same time period to determine how much of the population

was locally derived, how much was made up of immigrant birds and determine if any sources could be identified.

2.3.1 Sample Preparation

The internal tissues (liver, muscle, brain and heart) were prepared by dissection, freeze-drying to remove excess water, and then pulverizing with mortar and pestle to homogenize. All tools were acid washed with 1% nitric acid (HNO_3) between individual samples to avoid cross contamination. Feathers were prepared by washing with a 2:1 chloroform:methanol solution to remove external contaminants and then air-dried. The third rectrice feather was used to minimize variability between feather types. The left tarsometatarsus bone was extracted, split open and all marrow removed because it contains blood cells. Blood and plasma turnover rapidly, if they were not removed the chemical signature in bone could be distorted by recent foraging locations. The marrow was scraped out and then the bone pieces were wiped clean with a disposable wipe. Samples were then prepared by wet acid digestion.

For internal tissues the digestion process involved taking a sample between 20 and 30 mg, which were weighed out in screw-top Savillex fluoropolymer (PFA) vials. In the case of feather and bone samples the whole sample was added which ranged from 15 mg to 25 mg and 30 mg to 80 mg respectively. 2 ml of trace metal grade concentrated HNO_3 was added to samples and allowed to sit for 2 hrs before placing in a pressure cooker and heated for 3 hrs. After samples cooled, 1 ml of trace metal grade hydrogen peroxide was added to further digest dissolved organic compounds. Samples were then placed on a hot plate until all liquid had evaporated. Another 2 ml of 1 % HNO_3 with 10 ppb indium solution, which was used as an internal standard to track for instrument drift, was added to each vial and allowed to sit for 2 hrs to dissolve residue before being transferred to acid washed polyethylene centrifuge tubes. Each vial was rinsed 3 times with the HNO_3 indium solution and emptied into the centrifuge tube for a final volume of 10 ml (method adapted from Norris et al. 2007). Samples were then further diluted using 1 % HNO_3 with 10 ppb indium to fall within the detection limits of the instruments. The dilution factors ranged between 5×10^3 and 8×10^3. Method blanks were prepared in the same way and

run for every set of digestions to track contamination. For each tissue type, with the exception of liver, a tissue from an individual bird was weighed into three separate vials and run to assess instrument and method reliability. Percent relative standard deviation (%RSD) was calculated on the triplicates. See Appendix A.

2.3.2 Trace Element Analysis

Twelve elements (Al, Ba, Ca, Cd, Co, Cu, Pb, Sc, Se, Sn, Sr, Zn) were measured in all tissue types using a Thermo-Fisher Element XR sector field inductively-coupled plasma mass spectrometer (ICP-MS). These elements were chosen because they were used in previous studies for fingerprinting regions in Canada by soil type (Taylor et al. 2003; Greenough et al. 1997; Greenough et al. 2005) and in fingerprinting various species of birds (Poesel et al. 2008; Szep et al. 2003; Kaimal et al. 2009; Norris et al. 2007; Torres-Dowdall et al. 2010). In addition they were able to be reliably measured and have considerable variability in abundance across spatial scales. Elements were analysed in either low resolution or medium resolution to resolve poly-atomic interferences. A combination of counting and analog modes were used to detect element intensities. In addition, four elements (Ca, Na, Mg, K) were measured in digests of bone using a inductively-coupled plasma optical emission spectrometer (ICP-OES) as their concentration was too high to be reliable measured by ICP-MS without much greater dilution. Yttrium was used as internal standard for ICP-OES. Both Instruments were calibrated with external multi-element standards (Table 1). Three different concentrations of the multi-element standard were run to produce a calibration curve and samples were diluted to fall within the range of the curve.

Table 1. Multi-element standard concentrations for ICP-MS and ICP-OES calibration

Element	Concentration ICP-MS (PPB)	Concentration ICP-OES (PPM)
Aluminum	1000	-
Calcium	2000	50
Copper	100	-
Zinc	600	-
Selenium	10	-
Strontium	10	-
Cadmium	1	-
Barium	20	-
Lead	10	-
Cobalt	50	-
Scandium	50	-
Tin	50	-
Magnesium	-	50
Potassium	-	50
Sodium	-	50

2.3.3 Statistical Analysis

The dilution factor and sample weight were used to calculate the actual elemental concentration in the original tissue. Z-scoring was then used to standardize the data in order to prevent individual elements from having an disproportionate influence on the groupings (Appendix B). A Z-score (equation 2) is calculated by subtracting the overall population mean from the raw score to be standardized, and dividing by the standard deviation of the population (Fowler et al. 1998).

$$\text{Equation 2: } Z = \frac{X - \mu}{\sigma}.$$

2.3.3.1 Cluster Analysis

To evaluate temporal separation, cluster analysis was used to evaluate the ability of each tissue to separate the Kelowna summer and fall populations. Briefly, cluster analysis assigns samples into groups (clusters) based on how alike they are. Individuals in a cluster are more similar to each other than samples in other clusters (Yu and Chan 2012); it is a form of similarity index. In this study the similarity referred to elemental composition in different tissue types. Two criteria were used to choose an appropriate tissue to use in spatial analysis. First, the tissue must have the ability to separate between populations temporally, because organisms acquire a chemical fingerprint in space over time (Inger and Bearhop 2008; Hobson 1999; Rubenstein and Hobson 2004; Chapter 2). Secondly, the tissue must have a long enough turnover time to reflect origin. The cluster analysis output provided R^2 values that were used to show the tightness of the clusters or groups. Groups were defined as such if three or more individuals clustered together. An R^2 value of 0.90 was set to define the number of clusters because it provided a high degree of confidence that the individuals in each group were related. The centroid method of clustering was used because it is robust to outliers.

The centroid method forms clusters based on the distance between centroids (means) of groups (Fowler et al. 1998). Other methods of clustering include, but are not limited to, Manhattan, Euclidean, Pearson, nearest/furthest neighbour and average linkage. Problems can arise with Manhattan and Euclidean methods if the range of values between measurements is greater for one measurement than for others. In this case the measurement with the greatest variance dominates the distance measurement (Fowler et al. 1998). The Pearson method corrects for this by standardizing the data prior to clustering, however, if data points are correlated in multiple ways this is not accounted for. Nearest and furthest neighbour form clusters based on the distance between the closest and furthest sampling units in the two clusters. Average linkage focuses on the mean of the distances between clusters. Indeed, different clustering methods can produce different outcomes. As cluster analysis is a descriptive technique that, if used appropriately, can help identify patterns in the data the most appropriate choice of which

type to use is the type that makes the most sense (Fowler et al. 1998). The average linkage method was also calculated on this data set. However, as fall immigrant birds from unknown, and likely multiple locations, were being analyzed, the centroid method was used for final analysis as it was anticipated there would be outliers (ie. individual birds that were from a variety of areas). Cluster analysis was run using SAS software, Version 9.2 (Copyright (c) 2002-2008 SAS Institute Inc. SAS and all other SAS Institue Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA).

In cluster analysis there is no way to precisely measure spatial separation (where fall caught birds originate), unless individuals cluster with the potential source populations. Therefore cluster was only used in evaluating temporal separation, rather than spatial.

2.3.3.2. Principal Component Analysis

In order to evaluate spatial separation, a principal component analysis (PCA) was run on the tissue that was determined by cluster analysis to provide the most meaningful temporal separation. PCA was run on Z-scored data to reduce the number of variables (elements). Briefly, PCA reduces the dimensionality of data where there are interrelated variables while retaining variation in the data (Jolliffe 2002). The reduced variables are converted into a set of principal components, which are linear combinations of the original variables (Fowler et al. 1998). PCA reveals the most important gradients in the data in a way that best explains the variance (Fowler et al. 1998). The first few principal components retain the most variation that was present in all of the original variables (Jolliffe 2002).

The first two principal components were computed on the tissue which provided the best temporal separation; these two components were used to evaluate separation between potential source populations. Only the first two principal components were evaluated because they explained a large portion of the variability in the data and using only two components enabled a simple scatter gram to be plotted in two-dimensional space,

allowing for confidence intervals to be easily calculated around the mean of each population.

Principal component space was defined for each of the six sample populations by calculating the mean and 95% confidence limit of the two principal components. Individual birds caught in Kelowna in the fall were then plotted against the principal component space of the sample populations to determine what portion were from local sources, what portion was immigrant and if sources could be identified. If there was overlap of individual birds within the 95 % confidence limits of a sample population, that individual was considered to have originated from that region. PCA was carried out using SYSTAT software, Version 13 (Copyright 2008. Systat Software, a subsidiary of Cranes Software International Ltd).

2.4 Results

2.4.1 Temporal Separation

Three of the six tissues were useful in providing temporal separation by cluster analysis. Liver, feathers and bone demonstrated that birds caught in the same space (Kelowna) over different times (summer and fall) could be distinguished by the trace elements present in the select tissue. Liver appeared to give the best separation between summer and fall populations, followed by feathers and bone.

There are two mechanisms responsible for providing temporal separation. Firstly, rapid turnover and replacement compartments, like liver and feathers, when moulted and re-grown, will show that populations are different over time because they reflect differences in seasonal diets. Although they may not actually be separate populations, they will appear to be different due to the rapid turnover of the tissue. This is due to a change in diet at different seasons, causing a change in trace element composition. Secondly, long turnover compartments, like bone, will reflect temporal differences based on differences in origins, which is ultimately representative of space. Because the mineral phase of bone is synthesized early, and turns over very slowly (~ 1% per year in humans (Martin et al.

2007)) it contains the trace element composition of the area where it was laid down, and is not reflective of recent changes in diets or locations.

The other half of the tissues (muscle, brain and heart) did a poor job of separating populations temporally. The best temporal separator was bone because it provided a high degree of separation, and has a slow turnover time relative to the other tissues which was the most appropriate to this study.

2.4.1.1 Temporal Analysis of Liver

Three clusters formed using the R^2 value of 0.90 in liver tissue to evaluate the separation between populations in time (Figure 5). In one cluster a small portion (15 %) of summer birds grouped with 25 % of the fall caught birds, in another cluster 25 % of fall birds clustered independently of summer birds, and in the final cluster 70 % of summer caught birds clustered with 25 % of fall birds. The remaining 15 % of summer and 25 % of fall birds did not form clusters. This data is consistent with the rapid turnover of liver; the majority of fall birds (50 %) were distinct from summer. This is further demonstrated when comparing the cluster analysis for a rapid turnover tissue (liver) to the cluster analysis for a long-term turnover tissue (bone). According to the liver, 70 % of summer caught birds group with 25 % of fall caught birds (Figure 5). According to the bone chemistry all but two (85 %) of those same individual summer birds group together without any fall birds (Figure 7), indicating that the bone from the summer juveniles reflects the local summer signature. The fact that individuals from the same location in the summer have similar bone chemistry but different liver chemistry is reflective of the rapid turnover of liver. The liver is likely reflecting the local diet and chemistry, rather than the natal origins as bone does. Because liver turns over quickly, it likely changed over between sampling times.

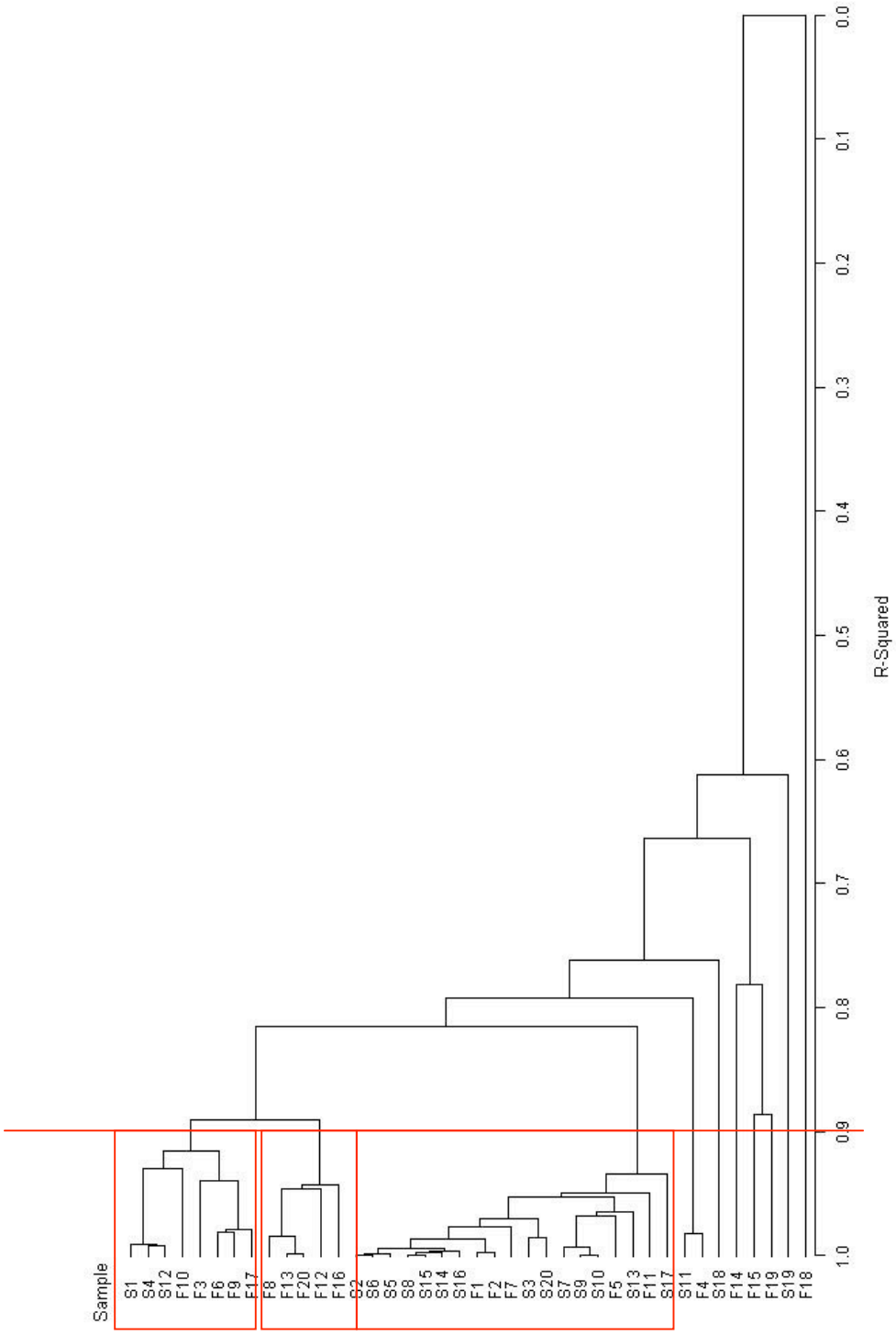

Figure 5. Cluster analysis of liver in Kelowna summer juveniles and fall caught Kelowna birds. Where S = Summer, F = Fall. Groups based on R^2 value of 0.90.

2.4.1.2 Temporal Analysis of Feathers

Two clusters were formed at $R^2 = 0.90$ for feathers (Figure 6). The majority of fall birds (85 %) clustered together, mixed with 40 % of summer birds, while 20 % of summer birds clustered independently. The remaining 40 % of summer caught birds and 15 % of fall birds did not form clusters. The high degree of overlap between fall and summer birds could be due to feathers being moulted after birds had migrated to Kelowna and reflecting local chemistry. Unlike the other tissues examined, feathers do not turnover; they incorporate information quickly and, after synthesis, they are no longer connected to the circulatory system. Therefore, they do not change chemically. However, all information of previous location is lost immediately during moult. Thus, without information on whether individuals have moulted, it is difficult to evaluate these results for temporal separation. While there appears to be a portion of both the summer and fall population that overlap, it is difficult to determine whether this is due to them having similar origins or if they simply moulted and re-grew feathers that reflect local chemistry.

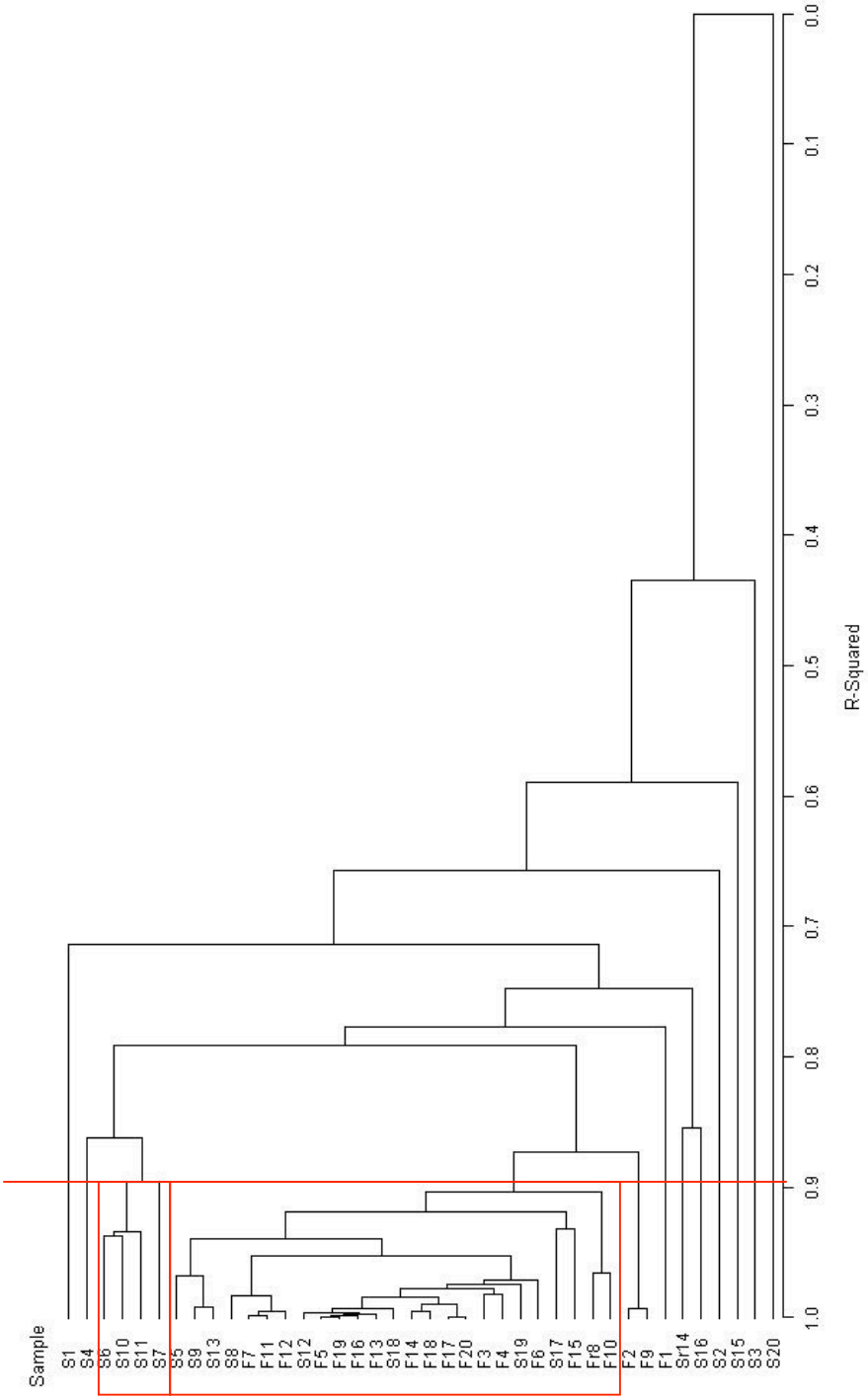

Figure 6. Cluster analysis of feathers in Kelowna summer juveniles and fall caught birds. Where S = Summer, F = Fall. Groups based on R^2 value of 0.90.

2.4.1.3 Temporal Analysis of Bone

Three clusters formed at $R^2 = 0.90$ for bone (Figure 7). The majority (55 %) of fall birds clustered together with 10 % of summer birds mixed in, while 40 % of summer birds formed two separate clusters independent of fall birds. The remaining 45 % of fall birds and 50 % of summer birds did not form clusters. Bone is a slow turnover compartment; the results demonstrate this by showing minimal overlap between the fall and summer populations. Although there is a slight overlap temporally (10 % of summer birds clustered with the majority of fall birds), this can be interpreted as variability in the data. Bone had the highest percentage (40 %) of summer birds that clustered independently of fall birds, which could be a reflection of the local elemental signature.

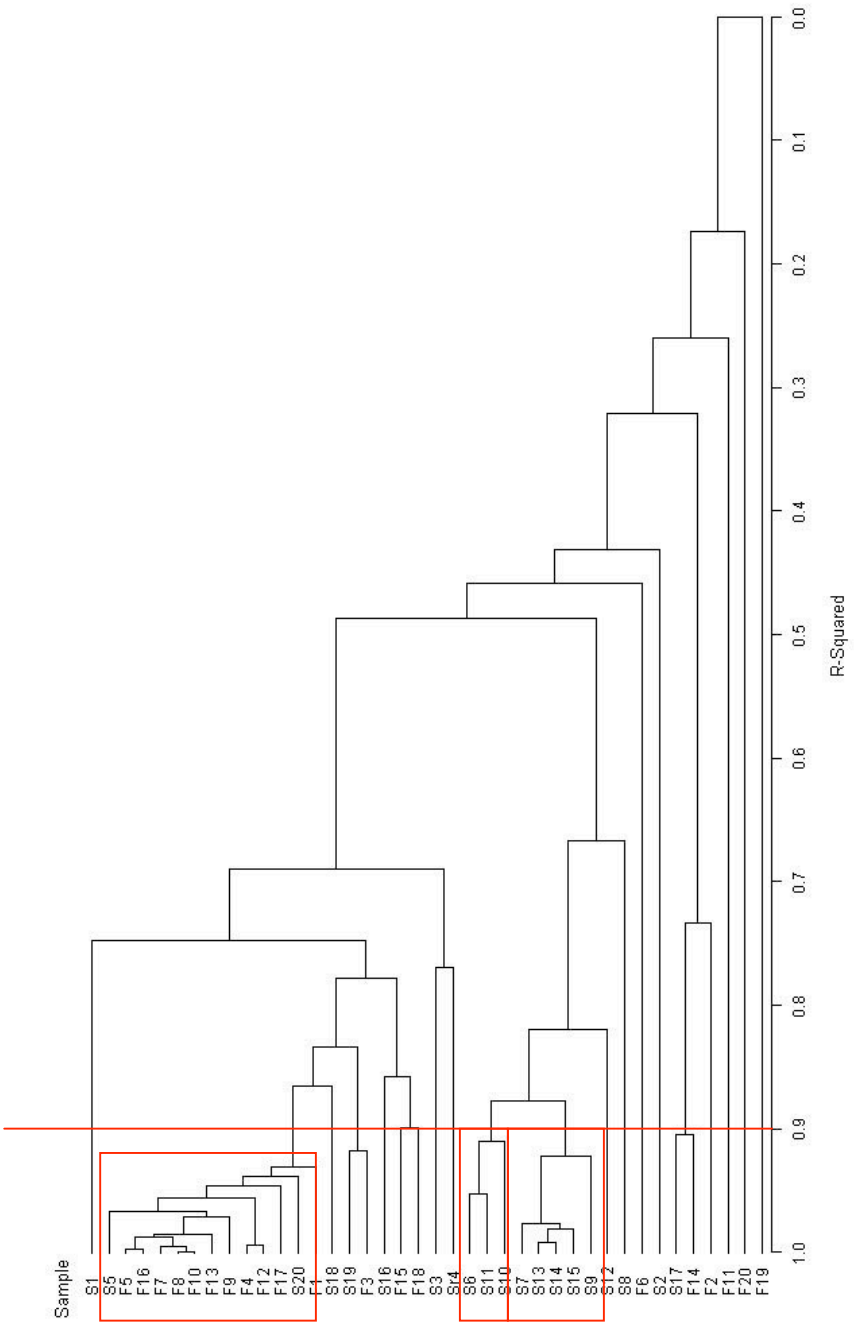

Figure 7. Cluster analysis of bone in Kelowna summer juveniles and fall caught Kelowna birds. Where S = Summer, F = Fall. Groups based on R^2 value of 0.90.

2.4.2 Spatial Separation

As bone provided the best and most appropriate temporal separation, and is not complicated by moult, it was further evaluated to determine its ability to separate populations in space. A cluster analysis was run to see if reference locations clustered

together (Figure 8). The cluster analysis demonstrated the strength of trace element fingerprinting. 93 % of the birds collected from Washington, which is separated from the Okanagan Valley by a mountain range, plotted together as did 50 % of the Kelowna summer population, 100 % of the Quesnel birds plotted together in two separate groups and 50 % of the Grand Forks birds grouped together (Figure 8). While the reminder of the populations were mixed with clusters of birds caught in different regions, likely due to variability within populations, and/or in the local geology.

A total of seven principal components were computed, however only the first two were evaluated. The first principle component accounted for 26.5 % of the variability in the data, the second for 12.75 %, together the first two principal components explained 39.25 % of the variability in the data. The PCA demonstrated that bone does separate populations in space. The means of each population plot distinctly, and half of the 95 % confidence intervals do not overlap, with the exception of the North Okanagan, South Okanagan and Grand Forks populations (Figure 9). Taken together the cluster and principal component analysis demonstrate that bone works well for separating populations in space and time.

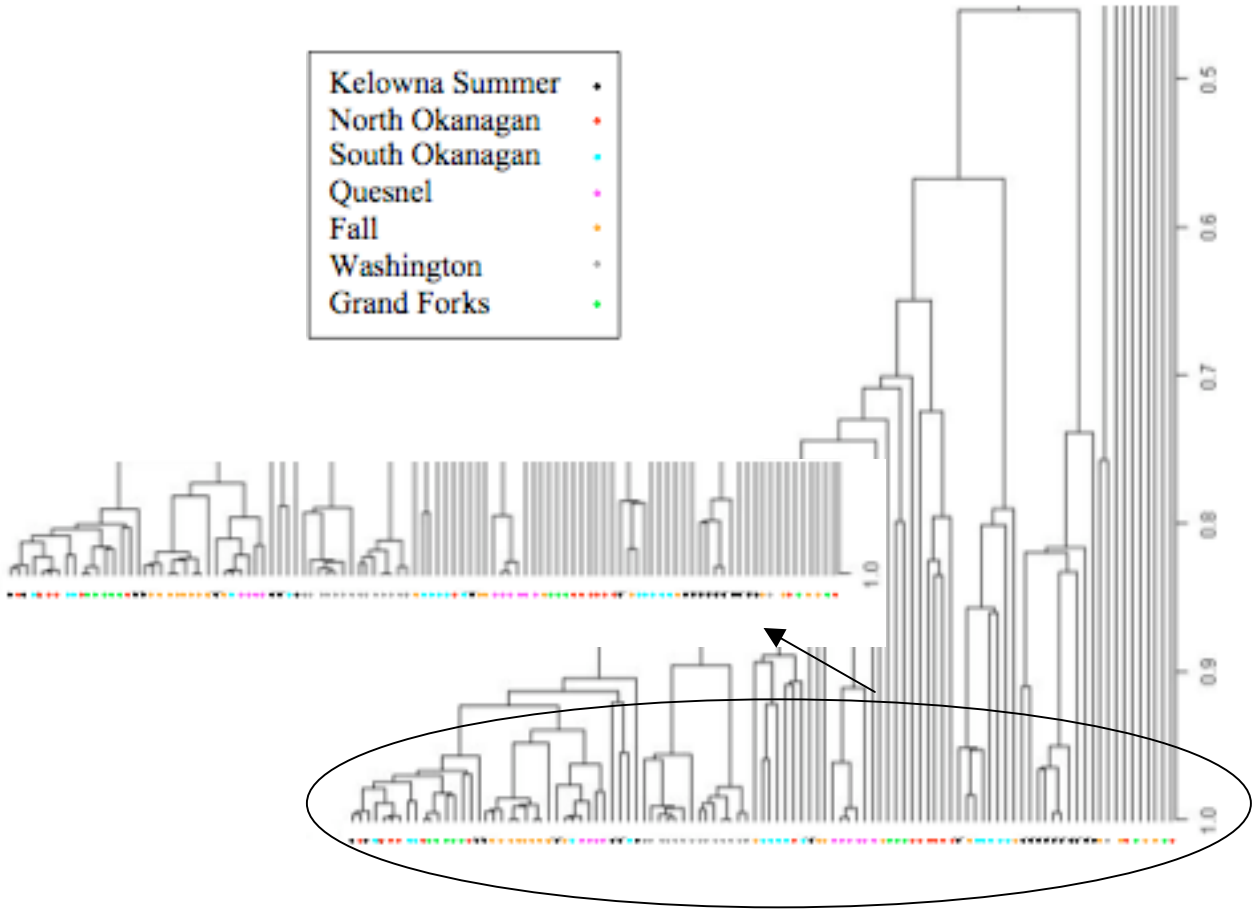

Figure 8. Cluster analysis of bone for all reference locations

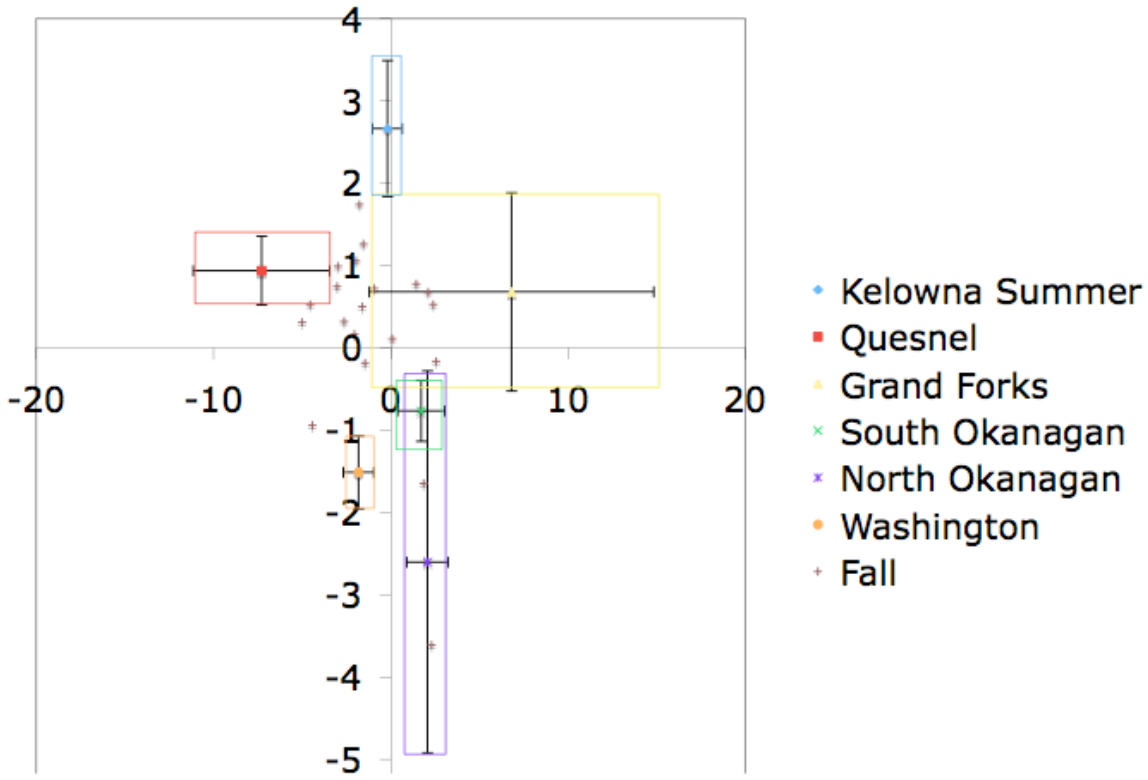

Figure 9. Principle component analysis of all potential source locations. Individual fall birds plotted against 95% confidence intervals surrounding each population

2.4.3 Space/Time Interaction

The bone data from the potential source populations (spatial information), and bone data from Kelowna fall birds (temporal information) was combined to determine what portion of the Kelowna starling population was local, what portion was immigrant and see if source(s) could be identified. PCA was used to evaluate the separation of populations across space. The means of each population were plotted and then all fall caught birds were plotted against the 95% confidence intervals around the means to determine membership.

In contrast to the cluster analysis, the PCA showed that there was no overlap between fall caught birds and the Kelowna summer population. Although none of the fall birds appeared to be from Kelowna, some sources were implicated. A small portion (10 %)

appeared to be from the North Okanagan, 5 % appeared to be from Quesnel and 30 % appeared to be from Grand Forks (Figure 9). The majority (55 %) of the fall birds did not overlap with any reference populations, indicating they were immigrant birds from areas not sampled in this study. This result was also found in the cluster analysis of bone (Figure 7) where 55 % of fall (immigrant) birds clustered together.

The apparent discrepancy between the results of the cluster and principal component analysis can be explained by the differences in the way they treat data. Cluster analysis is focused on grouping individual samples that are similar. While PCA is focused on reducing the number of variables in a data set and compressing the variables into a reduced number of principal components. The confidence interval around the principal component means define what space a population resides in, enabling individuals from outside a population (in this study fall caught birds) to be tested for population membership. This is not possible in cluster analysis.

2.5 Discussion

Of the six tissues examined, bone was the best for tracing origins of migrant starlings because spatial fractionation of elements is captured, while the turnover is the slowest of all examined compartments. The elemental signature of the area where it was synthesized is laid down and retained. The bone is extremely useful for origin analysis as the mineral phase in the bone matrix grows rapidly when an individual is a juvenile and then turns over very slowly. Depending on the phase of bone (outer hard bone or inner spongy bone), the turnover rate in humans is approximately 1 % per year and 8 % per year respectively (Martin et al. 2007).

Using trace elements in bone to trace origins of migrant species has never been done before. However, other tissue types have been used successfully with feathers being the most conventional. A study of trace elements in western sandpiper (*Calidris mauri*) feathers achieved a spatial resolution of 3 km in one study (Norris et al. 2007). Feathers were collected on the sandpiper's wintering grounds where they had moulted and re-

grown flight feathers. The focus of the study was demonstrating the utility of using trace elements in feathers rather than identifying origins of birds. Similar to my study area, the wintering grounds of western sandpipers proved to be geochemically distinct (Norris et al. 2007). This is essential in order for trace elements to be applied to track migratory species over fine spatial scales. However, my study differed in that I did not have a sense of where feathers had moulted or where individual fall birds originated, therefore I used a tissue that was reflective of past locations, not present. My study demonstrated that unknown origins can be inferred from an alternative tissue.

Stable isotope analysis is the more common approach to tracing organisms' migrations/movements. Stable isotopes have been applied to track a wide variety of products and organisms over space including tracking monarch butterfly (*Danaus plexippus*) migration to Mexico (Miller et al. 2011), assigning humans to their geographic origins using hair (Mutzel et al. 2009), determining food provenance (Pilgrim et al. 2010; Greenough et al. 2005) and tracking illegal drugs back to their origins (Shibuya et al. 2007). Common to this wide variety of problems is spatial scale. In all of these examples the scale of interest is coarse; large distances between sampling sites are being examined, which enables small differences in isotopic composition to be measured. My study differed from these studies in two ways. Firstly, I used the less common approach of trace elements rather than stable isotopes and secondly the spatial scale was fine. Trace elements were chosen because the underlying geochemical variability of the study areas was exceptional and stable isotopes do not vary widely over space as demonstrated by deuterium patterns in precipitation (Chamberlain et al. 1997; Miller at al. 2011; Hobson and Wassenaar 1997; Chapter 2).

Deuterium contours were used to classify five species of migrant songbirds, sampled on their wintering grounds in South America, to their breeding ranges in North America. This study demonstrated the spatial scale of stable isotopes in feathers. In contrast, trace elements can vary over a few kilometers as demonstrated by the western sandpiper study and this work. I was able to distinguish between South Okanagan and North Okanagan populations using cluster analysis (Figure 8), a distance of ~155 km. Additionally,

another source population ~340 km away in Washington State was distinguishable geochemically from the Okanagan. This is consistent with the fact that trace elements vary across the landscape and geochemically diverse terrain is reflected in tissues of organisms. Trace element profiling to identify origins may have limited application/success in areas characterized by relatively uniform geochemistry.

The five other compartments, with the exception of feathers, were not useful for origin analysis but may have a variety of useful applications ranging from tracing origins to tracking short-term movement patterns. Additionally, for the organs/tissues (four of the six tissues in this study) the sample preparation was time intensive. Although feathers are less time consuming to prepare, they are complicated in that they moult. If moult patterns are well understood feathers can be extremely useful for tracing seasonal movements as they can be sampled non-destructively and do not turnover after synthesis (Poesel et al. 2008; Szep at al. 2003; Hobson 1999). However, if moult patterns are poorly understood feathers are of limited value for origin analysis because the location they were grown in cannot be identified. They could have grown in the location they were sampled and therefore, would not be reflective of the origin of the individual, rather the location of sampling.

In a study of white-crowned sparrows (*Zonotrichia leucophrys*) feathers from museum specimens with known capture dates were examined to determine if a moult was in progress. Wild caught birds were then compared to the museum specimens to determine stage of moult. Once feathers were verified as moulted or grown prior to migration, individuals were successfully assigned to their origins with a spatial resolution of < 400 km (Poesel et al. 2008). Similarly, a comprehensive study of passerines in Europe and Africa revealed that feathers are indeed indicative of the local area where they were grown. This multi year study involved sampling feathers from an individual when it arrived to a wintering area, forcing it to re-grow feathers and then re-capturing the same individual once it's feathers had been replaced. Results showed that there is a difference in the elemental fingerprint of feathers within the same individual grown in two different locations (Szep et al. 2003). Although moulting complications can be overcome, and

feathers are easier to prepare for analysis than bone, feathers only carry information from a single year therefore they are not the best tissue if natal origins are of interest.

The fall 2010 Okanagan starling population does not appear to be locally derived. There was no overlap of fall birds within the 95 % confidence intervals in the PCA with the Kelowna summer population. A portion (45 %) of the fall population was characterized into source populations. While the majority (55 %) of the fall population was from unidentified sources that were not matched with sources. The technique of trace element fingerprinting is limited by poor representation of potential source populations. Trace element profiling is the most appropriate/effective for species where a large portion of the population can be sampled (Norris et al. 2007; Donovan et al. 2006). If the objective is to identify natal origins, there must be appropriate representation of source populations. For broad ranging generalist species, like the starling, origin determination may not be possible due to too many potential sources and/or too much geochemical diversity due to their broad range. Species that are rare or restricted to only a few source areas would be more feasible to trace by chemical fingerprinting (Donovan et al. 2006). For example the western sandpiper study collected feathers from only five wintering sites, however they represented 45 % of the over-wintering range of the birds (Norris et al. 2007). Trace element profiling is more difficult for wide-ranging, continuously distributed species as the number of potential source areas is vast. In order to apply the technique to these types of species there must be an adequate representation of reference sites.

My study demonstrates the robustness of using trace elements in bone to track small scale movements with a high degree of spatial precision. Populations within the Okanagan Valley were separated by < 200 km. Although the number of source populations sampled limited the ability to determine origin(s) of the fall Kelowna population, it demonstrated that bone is a useful tissue to trace natal dispersal. These findings suggest trace element analysis of bone could be applied to address and trace the larger North American starling population. Additionally, source populations of other pest species of interest could also be identified using this technique targeting control measures in key areas, providing

regions have distinct geochemistry and that individuals are moving between areas that are geochemically distinct.

In spite of the promising results of using bone to trace origins, there are two limitations to the application of it. Firstly, it requires destructive sampling. This may not be possible for rare or protected species. Secondly, the chemical signature may be distorted due to lifetime averaging of the tissue. As the bone turns over very slowly (Hobson 2005; Martin et al. 2007), its elemental signature is based on dietary averages. Many months to years of information are incorporated; therefore caution must be used as individuals increase in age the signature may become diluted across many different locations (Hobson 2005). Using juvenile birds to create an elemental signature for a particular location limits the homogenization of the elemental signature overtime and ensures the area is being accurately represented. Knowing the age of the individual when comparing it back to the potential source area may be important for understanding if the elemental fingerprint is diluted. In this study the fall caught birds appeared to all be hatch year individuals, therefore their bones should be representative of their origins, rather than an average of locations over time.

2.6 Conclusion

This study set out to characterize a fall population of pest starlings from a region of high geochemical diversity using trace element analysis. In order to determine origin, an appropriate tissue had to be determined as different compartments carry different information. Multiple compartments were analyzed to determine which would be the most useful for origin analysis. Both temporal and spatial separation were evaluated. A variety of tissue types were analysed initially to evaluate temporal separation. Bone had the most statistical and mechanistic rationale for separation between populations, demonstrating the least amount of overlap between the Kelowna summer and fall population and the highest portion of summer birds that clustered independently of fall. It also has a slow turnover, which is ideal for origin analysis. Therefore, bone was used to evaluate spatial separation. Bone was also an excellent spatial separator, correctly clustering the majority of birds caught in the same region together, as well as plotting the

majority of the means of each reference population distinctly. Feathers were the next best for tracking long-term history, while the four other tissues proved to be time intensive and inappropriate for origin analysis.

Principal component analysis demonstrated that all of the 2010 fall Kelowna population was from immigrant sources with the majority from unknown locations. More potential source sites are needed to characterize the Kelowna population. Trace elements proved to provide high spatial resolution, separating populations within several hundred kilometers of each other. In areas of diverse geochemistry trace elements can be extremely useful for tracking migration and/or movement patterns of organisms.

Chapter 3 Applications, Management Options and Future Directions

The intention of this study was to see if trace elements could be used to characterize a mobile population of pest organisms in a region where the spatial scale was small and geologic diversity was high. Several key factors had to be in place in order for this technique to work including finding a tissue that retained the chemical signature long enough to reflect origin, high regional geologic diversity, migration of birds between regions and partitioning of trace elements into the tissue of choice. Bone was determined to be the most appropriate tissue to trace origins of starlings as it turns over very slowly, thereby preserving the chemical signature of the area it was synthesized. Bone proved to separate areas with high spatial resolution, therefore satisfying the assumption that elements partition into the mineral phase of bone in a meaningful manner. As the spatial resolution of stable isotopes is coarser than the distribution of source populations examined in this study, they could not be utilized in this regional study. However, to examine future source populations, which are more broadly distributed, stable isotopes may prove useful. The province of BC is geologically diverse, which enabled trace elements to be used with a high degree of spatial precision.

Using bone enabled three potential source populations in the study region to be identified, proving that this technique can be applied to address small-scale movements in mobile organisms. Although the majority of the study population was determined to be immigrant, a knowledge gap exists in where most of the birds originated. Fingerprinting of more source populations is required. However, because the starling is a broad ranging generalist species, it is not known if it will be possible to sample enough regions to identify all sources. Other knowledge gaps include understanding what the variability of the Okanagan population is; as birds were only collected from a single location in Kelowna, it is not understood if the elemental signature is different in birds collected from other sites within the region. Also, it is not known if the chemical signature changes between years in the local Kelowna population and in source populations. Finally, as this study only looked at birds from a single year, it is not known if the same source populations would remain consistent between years.

3.1 Applications

This research demonstrated the robustness of using trace elements to separate starlings in space and time. These findings can be extended to answer a variety of questions involving other organisms over spatial and temporal scales. These include, but are not limited to, assessing movement patterns over various timelines, understanding dietary information and identifying certain cohorts or individuals within a population. As different tissues contain different information, the number of options and applications for using trace elements to track organisms is diverse.

If elemental fingerprinting of space is of interest, the following four factors need to be addressed: First, what is the size of the study area? The size of the region will determine whether stable isotopes or trace elements should be used. Stable isotopes are appropriate for large, continental scales while trace elements are ideal for smaller, regional scales. Second, is the area geologically diverse? If trace elements are being used the study area must be geologically diverse. Using trace elements is dependent on heterogeneity in foodwebs (Inger and Bearhop 2008; Hobson 1999), which is an extension of having diverse underlying geology. Third, do organisms move within or between regions, and if so, when? Organisms must move between regions of distinct geochemistry otherwise differences in chemical signatures will not be measurable. Knowing when movements take place will determine the appropriate sampling time. Fourth, can organisms be destructively sampled? Whether the organism can be destructively sampled will dictate the choice of tissue that can be used. The ideal tissue to show spatial separation of organisms will have moderate turnover time that will reflect the current seasons movements.

Knowing how organisms use their environment over time can be extremely useful information for managers of many different groups of organisms including pest species, ecologically and economically important species and endangered species. The key factor in tracing organisms over time is choosing a tissue that will reflect the timeline of interest. If very recent dietary history is required, stomach contents could be analysed. If a timeline of previous locations or movements is desired keratinous tissues, such as hair

and claws, are ideal as they grow incrementally. Providing the growth rate is known, exact locations in space and time can be determined (Mazerolle and Hobson 2005). Liver is ideal for studying movements in time intervals less than a few months, for example, seasonal movements. As food sources change between seasons it is reflected in the liver due to the rapid turnover. Other tissues, not analysed in this study, can also be useful to providing insight over time including plasma and blood, which reflect very recent history (Hobson and Clark 1992; Mazerolle and Hobson 2005; Bearhop et al. 2002).

Finally, in addition to tracing organisms in space and time another application of using trace elements could be identifying a specific cohort within a population. In the case of a pest species it would be invaluable to know if there was a certain age group that was causing the majority of the damage, this could be achieved by analyzing a relatively rapid turnover compartment that would be reflective of recent dietary information. In a predator and prey relationship it may be beneficial to know if certain individuals were responsible for consuming a vulnerable or critical portion of the prey base. As organisms 'are what they eat' trace elements can be used to analyse diets of organisms giving insight into feeding patterns of individuals.

Generally, trace elements can be used to track virtually any organisms that migrate or move across regions of distinct geochemistry. The list of potential applications is vast, however, examples include determining origins of species of interest, predator/prey relationships and migration and movement patterns.

3.2 Implications for Management

This study showed that mobile organisms can be traced back to their origins using a slow turnover tissue. In the case of a pest species this will allow managers to make informed decisions about how and where to concentrate control efforts. For organisms that are economically or ecologically important knowing origins could aid in protecting natal grounds. As stable isotopes do not vary across small spatial scales, some organisms will be difficult or impossible to track if they do not undertake large-scale migration. Trace elements can be used when the scope of isotopic ratios is limited if geochemistry is

heterogeneous across the study area. In certain situations trace elements and stable isotopes can be used in conjunction; if organisms undertake large-scale movements and forage in areas of diverse geochemistry. Because geochemistry is not uniform across the landscape, stable isotopes could be used to supplement trace element analysis if movement patterns are large enough to cross isotopically distinct areas.

In addition to determining origins of individuals and/or populations knowing how organisms use the environment over space and time will allow managers to make informed decisions. Essentially, any portion of the lifecycle of an organism can be accounted for which presents almost endless possibilities for managers.

3.3 Direction for Future Okanagan Studies

This study focused on finding the optimal tissue type to determine starling origins, as well as method development including determining the ideal dilution factors, which elements to use and determining if trace elements could be used to track a generalist species over small spatial scales. In addition, only birds from a single year were looked at. The next focus should be on expanding both the temporal and spatial scale as they apply to management.

Expanding the temporal scale across years for the same location would enable evaluating the consistency of chemical profiles in bone within and between populations. There has been some evidence that suggests the chemical profile of feathers vary in the same individual (Torres-Dowell et al. 2010). I did not measure variability within starlings. It is not understood if this is the case in bone. However, there have been suggestions that bone is made up of a lifetime average of diets and locations. In the case of fingerprinting source populations, as long as juveniles are used to create the regional chemical fingerprint this will not be an issue. However, when comparing immigrant birds to potential source populations the age of the individual could have an influence on the chemical signature. This is not anticipated to be a problem as starlings have a short lifespan; it is unlikely a large enough portion of the mineral phase in bone will turnover to lose the natal signature. However, knowing the actual length of time it takes to

turnover the mineral phase of bone in starlings would be beneficial to understanding how and when bone can be applied to track dispersal. Finally, another area to investigate would be determining the inter-annual variability; it is not understood if individuals from the same population group between years.

Expanding the spatial scale should include determining the variability in both the Kelowna and Okanagan population. The Kelowna samples were all collected from the same feedlot; it is not known if there is a 'feedlot effect' or if the Kelowna population is more variable. In order for areas to be distinguished from one another the annual variation must be less within than among sites (Torres-Dowell et al. 2010). The spatial targets to focus on should include within the Okanagan Valley and among BC, which would capture both the local variability and large-scale variability.

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APPENDICES

APPENDIX A

Replicate Data for Five Different Tissue Types Using ICP-MS

Appendix A: Replicates of Five Different Tissue Types by ICP-MS

		Isotope															
		^{82}Se(LR)	^{88}Sr(LR)	^{111}Cd(LR)	^{112}Cd(LR)	^{118}Sn(LR)	^{137}Ba(LR)	^{206}Pb(LR)	^{208}Pb(LR)	^{27}Al(MR)	^{45}Sc(MR)	^{59}Co(MR)	^{63}Cu(MR)	^{65}Cu(MR)	^{66}Zn(MR)	^{68}Zn(MR)	^{118}Sn(MR)
Sample ID																	
								BONE									
4G	PPM	0.522	159.250	0.016	0.041	3.332	70.216	8.585	8.968	30.953	0.000	1.159	1.866	1.823	173.913	237.433	3.550
	Concentration AVG	0.228	69.539	0.007	0.018	1.455	30.661	3.749	3.916	13.516	-0.004	0.506	0.815	0.796	75.942	103.679	1.550
4G1	PPM	0.464	157.048	0.032	0.072	4.264	71.576	11.136	11.416	46.872	0.104	1.472	1.440	1.400	171.568	212.504	4.472
	Concentration AVG	0.058	19.631	0.004	0.009	0.533	8.947	1.392	1.427	5.859	0.013	0.184	0.180	0.175	21.446	26.563	0.559
4G2	PPM	0.264	198.800	0.024	0.024	2.248	89.712	14.104	14.472	23.808	0.072	0.720	0.896	0.864	187.560	226.824	2.872
	Concentration AVG	0.033	24.850	0.003	0.003	0.281	11.214	1.763	1.809	2.976	0.009	0.090	0.112	0.108	23.445	28.353	0.359
AVG		0.417	171.699	0.024	0.046	3.281	77.168	11.275	11.619	33.878	n.c.	1.117	1.401	1.362	177.680	225.587	3.631
SD		0.135	23.496	0.008	0.024	1.009	10.885	2.762	2.758	11.807	n.c.	0.378	0.486	0.481	8.636	12.510	0.803
%RSD		**32.495**	**13.684**	**33.256**	**53.163**	**30.748**	**14.105**	**24.495**	**23.734**	**34.852**	**n.c.**	**33.820**	**34.722**	**35.276**	**4.860**	**5.546**	**22.117**
								BRAIN									
8F	PPM	0.791	0.255	20.612	19.770	0.000	0.000	0.689	0.689	0.000	0.000	11.046	15.102	15.332	2616.607	2578.316	0.000
	Concentration AVG	0.031	0.010	0.808	0.775	-1.168	-0.011	0.027	0.027	-1.085	-0.015	0.433	0.592	0.601	102.571	101.070	-1.210
8F1	PPM	0.668	0.184	0.392	0.115	0.000	0.000	1.267	1.175	43.779	0.000	0.599	12.442	12.327	145.945	180.346	0.000
	Concentration AVG	0.029	0.008	0.017	0.005	-1.209	-0.006	0.055	0.051	1.900	-0.016	0.026	0.540	0.535	6.334	7.827	-1.264
8F2	PPM	0.876	0.128	0.321	0.064	0.000	0.000	0.427	0.449	0.000	0.000	1.303	12.222	12.778	98.162	98.120	0.000
	Concentration AVG	0.041	0.006	0.015	0.003	-1.174	-0.013	0.020	0.021	-1.098	-0.020	0.061	0.572	0.598	4.594	4.592	-1.231
AVG		0.778	0.189	7.108	6.650	0.000	0.000	0.794	0.771	n.c.	0.000	4.316	13.256	13.479	953.571	952.261	0.000
SD		0.104	0.064	11.695	11.363	0.000	0.000	0.430	0.370	n.c.	0.000	5.839	1.603	1.620	1440.429	1408.806	0.000
%RSD		**13.424**	**33.607**	**164.529**	**170.870**	**n.c.**	**n.c.**	**54.102**	**48.010**	**n.c.**	**n.c.**	**135.278**	**12.092**	**12.021**	**151.056**	**147.943**	**n.c.**
9F	PPM	0.521	0.000	0.379	0.071	0.000	0.000	0.569	0.569	0.000	0.000	1.256	11.564	10.948	100.284	103.578	0.000
	Concentration AVG	0.022	-0.002	0.016	0.003	-1.196	-0.016	0.024	0.024	-1.245	-0.021	0.053	0.488	0.462	4.232	4.371	-1.259
9F1	PPM	0.962	0.084	0.105	0.000	0.000	0.000	0.732	0.690	0.000	0.000	0.607	13.222	13.264	79.226	75.356	0.000
	Concentration AVG	0.046	0.004	0.005	-0.007	-1.197	-0.013	0.035	0.033	-0.229	-0.025	0.029	0.632	0.634	3.787	3.602	-1.243
9F2	PPM	0.962	0.000	0.017	0.000	0.000	0.000	0.378	0.378	0.000	0.000	1.134	11.271	11.031	47.938	47.904	0.000
	Concentration AVG	0.056	-0.004	0.001	-0.011	-1.213	-0.019	0.022	0.022	-1.823	-0.025	0.066	0.656	0.642	2.790	2.788	-1.264
AVG		0.815	n.c.	0.167	n.c.	0.000	0.000	0.560	0.546	n.c.	0.000	0.999	12.019	11.747	75.816	75.613	n.c.
SD		0.255	n.c.	0.189	n.c.	0.000	0.000	0.177	0.157	n.c.	0.000	0.345	1.052	1.314	26.339	27.838	n.c.
%RSD		**31.226**	**n.c.**	**113.112**	**n.c.**	**n.c.**	**n.c.**	**31.677**	**28.853**	**n.c.**	**n.c.**	**34.546**	**8.751**	**11.183**	**34.741**	**36.817**	**n.c.**
25F	PPM	0.071	0.000	0.000	0.000	0.000	0.000	0.381	0.405	0.000	0.000	32.476	12.881	13.357	55.357	44.167	0.000
	Concentration AVG	0.003	-0.008	0.000	-0.010	-1.151	-0.023	0.016	0.017	-1.855	-0.013	1.364	0.541	0.561	2.325	1.855	-1.169
25F1	PPM	0.089	0.000	0.000	0.000	0.000	0.000	0.284	0.284	0.000	0.000	24.184	12.145	12.163	75.390	63.209	0.000
	Concentration AVG	0.005	-0.001	0.000	-0.010	-1.153	-0.021	0.016	0.016	-1.488	-0.013	1.364	0.685	0.686	4.252	3.565	-1.185
25F2	PPM	0.331	0.000	0.000	0.000	0.000	0.000	2.003	1.969	0.000	0.000	22.927	20.557	21.045	85.314	75.592	0.000
	Concentration AVG	0.019	-0.003	0.000	-0.010	-1.154	-0.020	0.115	0.113	-1.595	-0.011	1.316	1.180	1.208	4.897	4.339	-1.182
AVG		0.164	n.c.	n.c.	n.c.	n.c.	n.c.	0.889	0.886	n.c.	n.c.	26.529	15.195	15.522	72.020	60.989	n.c.
SD		0.145	n.c.	n.c.	n.c.	n.c.	n.c.	0.966	0.940	n.c.	n.c.	5.189	4.659	4.821	15.260	15.830	n.c.
%RSD		**88.672**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**108.624**	**106.110**	**n.c.**	**n.c.**	**19.558**	**30.662**	**31.057**	**21.188**	**25.955**	**n.c.**
								HEART									
8E	PPM	1.609	0.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.236	0.814	17.277	16.895	48.236	56.168	0.000
	Concentration AVG	0.354	0.045	-0.002	-0.011	-1.117	-0.069	-0.044	-0.012	-3.581	0.052	0.179	3.801	3.717	10.612	12.357	-0.986
8E1	PPM	1.446	0.228	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233	0.000	19.594	19.851	43.609	48.891	0.000
	Concentration AVG	0.292	0.046	-0.002	-0.013	-1.322	-0.073	-0.047	-0.014	-4.547	0.047	-0.006	3.958	4.010	8.809	9.876	-1.195
8E2	PPM	1.531	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.159	0.310	15.816	16.105	31.523	43.305	0.000
	Concentration AVG	0.366	0.029	-0.002	-0.013	-1.400	-0.046	-0.048	-0.016	-3.559	0.038	0.074	3.780	3.849	7.534	10.350	-1.250
AVG		1.529	0.185	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.209	n.c.	17.562	17.617	41.123	49.455	n.c.
SD		0.082	0.056	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.044	n.c.	1.905	1.975	8.630	6.450	n.c.
%RSD		**5.351**	**30.316**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**20.847**	**n.c.**	**10.848**	**11.210**	**20.985**	**13.042**	**n.c.**
8E3	PPM	1.413	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.184	0.214	15.254	15.672	30.701	44.731	0.000
	Concentration AVG	0.284	0.018	0.000	-0.010	-1.440	-0.067	-0.041	-0.009	-3.298	0.037	0.043	3.066	3.150	6.171	8.991	-1.273
8E4	PPM	1.603	0.297	0.000	0.000	0.000	0.177	0.000	0.000	12.022	0.155	0.000	15.513	15.815	30.039	41.496	0.000
	Concentration AVG	0.372	0.069	0.000	-0.011	-1.426	0.041	-0.036	-0.005	2.789	0.036	-0.007	3.599	3.669	6.969	9.627	-1.253

		Isotope															
		^{82}Se(LR)	**^{88}Sr(LR)**	**^{111}Cd(LR)**	**^{112}Cd(LR)**	**^{118}Sn(LR)**	**^{137}Ba(LR)**	**^{206}Pb(LR)**	**^{208}Pb(LR)**	**^{27}Al(MR)**	**^{45}Sc(MR)**	**^{59}Co(MR)**	**^{63}Cu(MR)**	**^{65}Cu(MR)**	**^{66}Zn(MR)**	**^{68}Zn(MR)**	**^{118}Sn(MR)**
8E5	PPM	1.411	0.193	0.000	0.000	0.000	0.000	0.733	0.782	10.723	0.158	0.119	50.564	51.505	33.965	46.158	0.000
	Concentration AVG	0.285	0.039	0.000	-0.012	-1.435	-0.068	0.148	0.158	2.166	0.032	0.024	10.214	10.404	6.861	9.324	-1.255
AVG		1.476	0.193	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.166	n.c.	27.110	27.664	31.569	44.128	n.c.
SD		0.111	0.104	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.016	n.c.	20.312	20.647	2.102	2.389	n.c.
%RSD		**7.494**	**53.754**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**9.546**	**n.c.**	**74.924**	**74.636**	**6.658**	**5.414**	**n.c.**

		Isotope															
		^{82}Se(LR)	^{88}Sr(LR)	^{111}Cd(LR)	^{112}Cd(LR)	^{118}Sn(LR)	^{137}Ba(LR)	^{206}Pb(LR)	^{208}Pb(LR)	^{27}Al(MR)	^{45}Sc(MR)	^{59}Co(MR)	^{63}Cu(MR)	^{65}Cu(MR)	^{66}Zn(MR)	^{68}Zn(MR)	^{118}Sn(MR)
Feathers																	
14C	PPM	0.000	3.130	0.000	0.000	28.902	2.033	0.630	0.650	333.760	0.142	1.992	11.016	10.020	202.439	207.358	29.045
	Concentration AVG	-0.024	0.154	0.000	-0.005	1.422	0.100	0.031	0.032	16.421	0.007	0.098	0.542	0.493	9.960	10.202	1.429
14C1	PPM	0.000	3.151	18.203	16.771	19.974	1.693	0.677	0.651	170.495	0.182	11.276	4.479	3.698	2463.568	2573.906	20.104
	Concentration AVG	-0.018	0.121	0.699	0.644	0.767	0.065	0.026	0.025	6.547	0.007	0.433	0.172	0.142	94.601	98.838	0.772
14C2	PPM	1.168	1.193	22.741	21.269	29.365	0.051	0.736	0.711	37.132	0.000	12.868	2.716	1.447	2374.569	3063.832	30.254
	Concentration AVG	0.046	0.047	0.896	0.838	1.157	0.002	0.029	0.028	1.463	-0.007	0.507	0.107	0.057	93.558	120.715	1.192
AVG		n.c.	2.491	n.c.	n.c.	26.081	1.259	0.681	0.671	180.462	n.c.	8.712	6.070	5.055	1680.192	1948.365	26.468
SD		n.c.	1.125	n.c.	n.c.	5.294	1.060	0.053	0.035	148.565	n.c.	5.874	4.373	4.445	1280.545	1527.527	5.544
%RSD		**n.c.**	**45.138**	**n.c.**	**n.c.**	**20.297**	**84.199**	**7.795**	**5.160**	**82.325**	**n.c.**	**67.424**	**72.039**	**87.933**	**76.214**	**78.400**	**20.946**
Muscle																	
13B	PPM	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.625	19.663	17.284	40.240	39.327	0.000
	Concentration AVG	0.001	-0.030	-0.002	-0.011	-0.442	-0.026	-0.003	-0.004	-2.236	-0.002	0.026	0.818	0.719	1.674	1.636	-0.446
13B1	PPM	0.065	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.000	0.000	1.126	20.714	19.091	30.476	31.580	0.000
	Concentration AVG	0.003	-0.025	-0.002	-0.011	-0.435	-0.023	0.001	0.000	-1.770	-0.001	0.052	0.957	0.882	1.408	1.459	-0.427
13B2	PPM	0.000	0.000	0.221	0.000	0.000	0.000	0.980	0.907	10.564	0.000	1.054	15.515	14.706	42.108	39.363	0.000
	Concentration AVG	-0.015	-0.021	0.009	-0.002	-0.456	-0.021	0.040	0.037	0.431	-0.003	0.043	0.633	0.600	1.718	1.606	-0.448
AVG		n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.935	18.631	17.027	37.608	36.757	n.c.
SD		n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.271	2.749	2.204	6.247	4.483	n.c.
%RSD		**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**28.957**	**14.757**	**12.943**	**16.610**	**12.196**	**n.c.**
43B	PPM	0.453	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.478	12.428	10.725	20.543	19.221	0.000
	Concentration AVG	0.025	-0.009	-0.002	-0.012	-0.327	-0.016	-0.001	-0.003	-2.010	-0.004	0.192	0.686	0.592	1.134	1.061	-0.319
43B1	PPM	1.152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.951	14.216	13.676	35.123	37.157	0.000
	Concentration AVG	0.047	-0.010	-0.002	-0.010	-0.325	-0.021	-0.001	-0.002	-1.839	0.000	0.202	0.580	0.558	1.433	1.516	-0.329
43B2	PPM	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	6.037	12.981	12.426	32.500	33.130	0.000
	Concentration AVG	0.027	-0.004	-0.002	-0.010	-0.333	-0.018	0.000	-0.001	-1.928	0.002	0.326	0.701	0.671	1.755	1.789	-0.329
AVG		0.702	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	4.822	13.208	12.276	29.389	29.836	n.c.
SD		0.391	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	1.284	0.915	1.482	7.772	9.411	n.c.
%RSD		**55.688**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**26.633**	**6.930**	**12.070**	**26.444**	**31.541**	**n.c.**
50B	PPM	0.377	0.377	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.354	11.321	10.094	110.778	109.009	0.000
	Concentration AVG	0.016	0.016	-0.002	-0.012	-0.301	-0.028	-0.016	-0.016	-2.621	-0.001	0.015	0.480	0.428	4.697	4.622	-0.295
50B1	PPM	0.000	0.376	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.282	10.141	9.038	91.620	91.150	0.000
	Concentration AVG	-0.028	0.016	-0.002	-0.011	-0.333	-0.029	-0.013	-0.013	-3.526	-0.002	0.012	0.432	0.385	3.903	3.883	-0.330
50B2	PPM	0.037	0.599	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.311	9.738	8.689	71.573	71.105	0.000
	Concentration AVG	0.002	0.032	-0.002	-0.011	-0.361	-0.026	-0.021	-0.022	-3.518	-0.004	0.070	0.520	0.464	3.822	3.797	-0.343
AVG		n.c.	0.342	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.649	10.400	9.274	91.324	90.422	n.c.
SD		n.c.	0.129	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	0.575	0.823	0.732	19.604	18.963	n.c.
%RSD		**n.c.**	**37.604**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**n.c.**	**88.554**	**7.910**	**7.891**	**21.467**	**20.972**	**n.c.**

Notes
AVG - Average
SD - standard deviation
%RSD - percent relative standard deviation
n.c. - not calculated
PPM - parts per million
LR - low resolution
MR - medium resolution

APPENDIX B

Z-Scored Data for all Tissue Types From Starlings Caught in Kelowna in The Summer and Fall 2010

Appendix B: Z-Scored Data of Liver Tissue from Kelowna Caught Birds in the Summer and Fall 2010 (mg/kg)																	
	^{82}Se	^{88}Sr	^{111}Cd	^{112}Cd	^{137}Ba	^{206}Pb	^{208}Pb	^{118}Sn	^{27}Al	^{44}Ca	^{45}Sc	^{59}Co	^{63}Cu	^{65}Cu	^{66}Zn	^{68}Zn	^{118}SnMR
Sample ID																	
Kelowna Fall																	
F1	0.17171	-0.57045	-0.22372	-0.22448	-0.25306	-0.11889	-0.11482	0	-0.29214	-0.33643	-0.50161	-0.25980	-0.14864	-0.14760	-0.14793	-0.15730	0
F10	2.21836	-0.63360	0.63292	0.57053	-0.69054	-0.17518	-0.17685	0	-0.43975	-0.31492	0	0.26990	-0.14664	-0.14846	-0.14509	-0.13843	0
F11	-0.09542	-0.11774	-0.54699	-0.58181	-0.72347	-0.15190	-0.15241	0	0.30186	0.20428	0	-0.40045	-0.14970	-0.15207	-0.16967	-0.16017	0
F12	1.72684	-0.35700	0.16493	0.15856	-0.37766	-0.15910	-0.16001	-0.32791	0.09175	-0.05761	1.48450	-0.99437	-0.14759	-0.14941	-0.15681	-0.14380	-0.20242
F13	0.71501	-0.67744	-0.17464	-0.19798	-0.78590	-0.15250	-0.15288	0	-0.35840	-0.33010	1.17454	-0.73612	-0.15025	-0.15235	-0.16109	-0.14828	0
F14	0.84198	-0.65911	3.99615	3.92437	-0.74211	-0.12186	-0.12000	0	-0.35690	-0.41577	1.22638	-1.49583	-0.14978	-0.15171	-0.16871	-0.15037	0
F15	1.16265	-0.79285	1.60442	1.58389	-0.87792	-0.11660	-0.11776	0	-0.48167	-0.56025	1.03889	-1.80666	-0.15108	-0.15267	-0.14940	-0.14281	0
F16	1.67404	-0.73847	-0.55391	-0.57123	-0.99217	-0.16503	-0.16675	0	-0.40955	-0.48304	0.88209	-1.64950	-0.14884	-0.15113	-0.17073	-0.15449	0
F17	0.81015	-0.70984	1.47351	1.45283	-0.70784	-0.14188	-0.14332	0	-0.22114	-0.36796	0.85956	0.67049	-0.14907	-0.15121	-0.17825	-0.15975	0
F18	-0.01043	0.32798	0.29220	0.46331	1.36980	6.92467	6.92406	2.84556	1.83480	1.45146	1.09386	3.01860	6.92750	6.92738	6.92481	6.92680	4.00465
F19	0.64841	-0.16897	2.23701	2.19003	-0.10060	-0.12706	-0.12678	0	0.31349	0.49523	1.59165	-1.01374	-0.14938	-0.15100	-0.16566	-0.14826	-0.27416
F2	0.42812	-0.63730	-0.55869	-0.57897	-0.25363	0.03215	0.04239	-0.32311	-0.36360	-0.45608	-0.44730	-0.41622	-0.14704	-0.14566	-0.15731	-0.16255	-0.20491
F20	0.47904	-0.58967	0.15917	0.12403	-0.46388	-0.15365	-0.15543	0	-0.32435	-0.17184	0.89291	-0.80880	-0.14988	-0.15262	-0.17246	-0.15673	0
F3	-0.11925	-0.65021	1.15373	1.17582	-0.76107	-0.04534	-0.03835	0	-0.30292	-0.36628	-0.68059	-0.38246	-0.14885	-0.14702	-0.14863	-0.15693	0
F4	-0.38818	-0.50285	1.29271	1.30601	-0.13090	-0.10763	-0.10512	0	-0.33135	-0.57413	-0.52648	1.95844	-0.14684	-0.14572	-0.15693	-0.16115	0
F5	-0.82681	-0.42170	-0.44933	-0.48626	-0.42182	-0.15489	-0.15680	-0.32595	-0.21564	-0.35999	0.66753	0.58876	-0.15095	-0.15495	-0.16524	-0.14828	-0.23109
F6	1.28025	-0.61305	1.22564	1.15790	-1.04111	-0.15458	-0.15541	0	-0.34813	-0.35012	0.04590	-0.19136	-0.15076	-0.15432	-0.16968	-0.15391	0
F7	0.12364	-0.39662	-0.07459	-0.09493	-1.03971	-0.17184	-0.17311	0	-0.40348	0.18293	-1.52844	-0.26882	-0.14658	-0.14956	-0.13967	-0.12845	0
F8	1.00593	-0.65316	0.29432	0.26586	-0.43924	-0.16848	-0.16951	0	-0.43003	-0.43693	0	-0.88048	-0.14897	-0.15012	-0.14807	-0.14290	0
F9	0.83813	-0.50704	1.78081	1.72787	-0.21490	-0.15620	-0.15671	0	-0.03805	-0.40734	0	-0.12706	-0.14812	-0.14991	-0.16081	-0.15396	-0.27493
Kelowna Summer																	
S1	1.49005	-0.42597	-0.07690	-0.08319	-0.12603	-0.15676	-0.15810	0	-0.31560	-0.46675	-1.36875	-0.14254	-0.14585	-0.14735	-0.15714	-0.14927781	0
S10	-1.37964	-0.39774	-0.65488	-0.67292	0.02897	-0.14889	-0.14901	0	-0.38901	-0.46984	-0.39404	0.19526	-0.14256	-0.13896	-0.12171	-0.14366267	0
S11	-1.13320	-0.57825	0.35952	0.91962	-0.32139	-0.15935	-0.16074	0	-0.32243	-0.47746	-0.37445	1.78969	-0.14298	-0.13990	-0.11101	-0.13598998	0
S12	0.68980	-0.55949	0.26581	0.28580	-0.54198	-0.16290	-0.16381	0	-0.41273	-0.43561	-0.75221	0.09345	-0.14935	-0.14750	-0.12466	-0.14747638	0
S13	-0.72066	-0.36405	-0.65198	-0.66646	-0.52633	-0.08760	-0.08709	0	0.02933	-0.12273	-0.64831	1.31781	-0.13732	-0.13379	-0.08792	-0.12086531	-0.25863313
S14	-0.61811	-0.55620	-0.45214	-0.45860	-0.24322	-0.12441	-0.12346	0	-0.51197	-0.49964	-0.75986	0.36363	-0.14524	-0.14275	-0.10729	-0.13322441	-0.26053027
S15	-0.97673	-0.63575	-0.55074	-0.57645	-0.85587	-0.12454	-0.12131	0	-0.51794	-0.52054	-0.72328	0.15570	-0.13770	-0.13335	-0.11936	-0.14071724	0
S16	-0.19189	-0.49709	-0.41854	-0.43468	-0.62738	-0.15318	-0.15371	-0.30940	-0.48078	-0.50632	-0.70433	-0.01070	-0.14902	-0.14723	-0.13255	-0.14967741	-0.20198751
S17	-0.33567	-0.07502	0.53301	0.49928	0.10625	-0.07282	-0.06928	0	-0.12705	0.09033	-0.39041	0.51431	-0.14140	-0.13890	-0.10690	-0.12944675	-0.27394935
S18	0.84813	0.29067	-0.66848	-0.41502	1.03540	-0.14285	-0.14407	0	-0.17979	0.00345	-0.43461	2.83520	-0.10281	-0.09436	0.02571	-0.0380349	0
S19	0.19510	1.17665	-0.17425	-0.08687	4.61475	-0.11343	-0.11238	0	-0.12391	-0.16882	-0.52145	0.95387	-0.13023	-0.12557	-0.13031	-0.1451945	0
S2	-0.12383	-0.39833	-0.52272	-0.56885	-0.22120	-0.11426	-0.11259	0	-0.32045	-0.37280	-1.36408	-0.21920	-0.14566	-0.14650	-0.15858	-0.15785682	0
S20	0.76324	-0.17507	-0.58082	-0.59985	0.57661	-0.15561	-0.15708	0	-0.17892	-0.32752	-0.59123	0.50849	-0.13803	-0.13548	-0.10360	-0.12817086	0
S3	0.25383	-0.19080	-0.28515	-0.34123	0.12855	-0.11701	-0.11596	0	-0.32554	-0.34565	-1.37115	0.67775	-0.13022	-0.12758	-0.10831	-0.12420577	0
S4	1.12472	-0.54939	0.33410	0.30306	-0.23463	-0.12081	-0.11835	0	-0.32283	-0.44366	-1.37075	0.74804	-0.11993	-0.11490	-0.10937	-0.12864687	0
S5	-0.47958	-0.56610	-0.33567	-0.37398	-0.44963	-0.14530	-0.14545	0	-0.38527	-0.52546	-1.38372	0.21848	-0.14078	-0.13821	-0.14702	-0.15594986	-0.27398166
S6	-0.20766	-0.17915	-0.45619	-0.50386	-0.36281	-0.14269	-0.14190	0	-0.42872	-0.34177	-1.47916	0.12766	-0.15114	-0.14985	-0.13807	-0.15126494	0
S7	-1.69893	0.09799	-0.81110	-0.83324	0.09347	-0.13914	-0.13787	0	-0.07183	-0.07948	-0.48162	-0.11712	-0.14793	-0.14678	-0.16327	-0.16825763	0
S8	-0.78217	-0.51129	-0.73051	-0.74794	-0.66941	-0.14800	-0.14751	0	-0.48695	-0.46409	-0.70376	0.09305	-0.14628	-0.14378	-0.14159	-0.1550762	0
S9	-1.09019	-0.46366	-0.56169	-0.56253	0.00172	-0.14880	-0.14876	0	-0.22592	-0.29096	-0.38353	0.63957	-0.14300	-0.14093	-0.12576	-0.14536318	0

Notes:
MR- medium resolution mode

Appendix B: Z-Scored Data of Feathers from Kelowna Caught Birds in Summer and Fall 2010 (mg/kg)																
	^{82}Se	^{88}Sr	^{111}Cd	^{112}Cd	^{118}Sn	^{137}Ba	^{206}Pb	^{208}Pb	^{27}Al	^{45}Sc	^{59}Co	^{63}Cu	^{65}Cu	^{66}Zn	^{68}Zn	^{118}SnMR
Sample ID																
Kelowna Fall																
F1	0.15315	1.28829	0.43901	-0.02348	-0.75235	0.35214	0.85529	0.90447	-0.09964	-0.26461	-0.807272	0.53135	0.39739	0.38338	0.67793	0.50753
F2	-0.29995	2.68864	-0.19308	-0.39650	0.43183	-0.32647	0.09735	0.12054	-0.77347	-0.01457	0	-0.31084	-0.16747	-0.18503	-0.15180	-0.15644
F3	-0.37503	0.56010	-0.19016	-0.39465	0.51579	-0.35417	0.03016	0.05104	-0.74671	-0.23275	0	-0.27844	-0.27187	-0.27632	-0.15142	-0.14804
F4	-0.36128	-0.31435	-0.19091	-0.39506	0.88626	-0.38714	-0.36099	-0.37636	-0.58912	-0.19377	0	-0.20206	-0.02166	-0.06668	-0.16441	-0.16179
F5	0	-0.17210	-0.14253	-0.36731	0	-0.71852	-0.26271	-0.25188	-0.76321	-0.37971	0	-0.12261	-0.43350	-0.42369	-0.08957	-0.10410
F6	0.25867	0.34445	-0.24221	0	0	-0.07607	-0.51301	-0.47349	-0.58228	-0.29717	0	-0.34654	0.43821	0.45802	-0.20792	-0.20319
F7	-0.62528	0.39238	-0.24163	0	0	0.44836	-0.02524	-0.03186	-0.27717	0.20521	0	0.15248	-0.22041	-0.24160	-0.21255	-0.20370
F8	0	2.37376	-0.24294	0	0	-0.39027	-0.26081	-0.28978	-0.66208	0.19509	0	-0.38958	-0.01439	-0.00317	-0.22368	-0.21177
F9	1.75592	-0.19267	-0.24288	0	0	0.52679	-0.36128	-0.35382	-0.12652	-0.19656	0	-0.35474	-0.32397	-0.29940	-0.23007	-0.21105
F10	-0.60983	0.24427	-0.24278	0	0	0.76966	-0.25967	-0.24873	-0.17002	0.00299	0	-0.29788	-0.26915	-0.24419	-0.21988	-0.20335
F11	-0.21701	0.79363	-0.24209	0	0	0.70238	-0.39000	-0.40363	-0.30214	-0.05468	0	-0.28789	-0.05658	-0.07792	-0.19181	-0.18351
F12	0.50499	-0.46633	0	0	0	-0.83549	-0.53128	-0.55187	-0.62171	-0.71396	0	-0.40143	-0.29612	-0.28169	-0.21740	-0.20313
F13	-0.87318	-0.43941	0	0	0	-0.94604	0.01072	-0.00578	-0.85937	-0.81104	0	-0.40285	-0.21400	-0.19425	-0.23589	-0.21580
F14	0	1.24646	-0.24143	0	0	-0.05379	0.88354	0.84982	-0.25090	0.33924	0	-0.32134	-0.33966	-0.33817	-0.20016	-0.17760
F15	0	-0.02844	-0.242857	0	0	-0.36978	-0.72787	-0.73299	-0.77159	-0.47388	0	-0.40186	-0.39548	-0.40160	-0.23419	-0.21825
F16	-0.81394	0.03027	0	0	0	-0.56937	-0.62737	-0.62904	-0.96300	-0.11425	0	-0.40836	-0.30117	-0.31835	-0.23460	-0.21710
F17	-1.07850	-0.40894	-0.242844	0	0	-0.17769	-0.01093	-0.03609	-0.73407	-0.54058	0	-0.34504	-0.02976	-0.08048	-0.22809	-0.21253
F18	0	-0.27659	0	0	0	-0.68007	-0.33028	-0.37243	-0.84585	-0.39519	0	-0.24355	-0.36129	-0.37199	-0.23422	-0.21229
F19	-1.08826	0.22976	-0.242565	0	0	-0.66925	-0.38977	-0.38329	-0.67438	-0.15476	0	-0.12780	-0.33326	-0.35290	-0.19550	-0.18234
Kelowna Summer																
S1	3.31763	-0.68210	-0.23135	-0.41557	-0.85795	-0.05638	0.44690	0.37001	0.22537	0.67470	1.42600	0.37492	0.46424	0.51128	-0.17143	-0.17131
S2	1.43645	0.37843	-0.23433	-0.41717	-0.82050	3.07514	0.98804	0.99366	3.04894	1.21907	2.01134	0.16946	0.80230	0.83194	-0.18032	-0.17779
S3	0.56120	-1.04661	-0.24253	-0.42261	-0.95147	-0.42729	0.52054	0.51150	0.27090	-0.02218	1.03854	-0.08583	6.41380	6.39225	-0.17952	-0.17281
S4	0.69669	0.06754	-0.23872	-0.41999	-0.73939	1.74979	0.75770	0.76341	0.79357	0.36505	1.41509	-0.10773	0.24977	0.30336	-0.18919	-0.17859
S5	-0.95884	-0.97086	0	0	0	-0.67612	0.02709	0.07008	0.47091	-0.03710	-0.98596	-0.19433	-0.23973	-0.23651	-0.20716	-0.20023
S6	-0.09974	1.31227	-0.241054	0	0	1.66783	0.28996	0.25489	1.04693	1.06824	-0.18159	0.04077	-0.00426	-0.02275	-0.20478	-0.20265
S7	0	0.34777	0	0	0	2.06327	-0.13044	-0.08307	2.81775	0.99393	0.19269	-0.00745	-0.25210	-0.30020	-0.17590	-0.17660
S8	-0.87239	0.29465	0	0	0	0.41268	-0.18639	-0.17293	0.56924	0.05806	-0.47748	-0.10365	0.14297	0.17244	-0.20645	-0.20940
S9	0	-0.87793	0	0	0	-0.51908	-0.59746	-0.57925	0.53650	-0.84066	-0.40493	-0.26448	0.14295	0.18082	-0.20952	-0.21194
S10	-0.99035	0.71054	-0.242221	0	-1.16421	1.20531	0.09513	0.11824	1.09394	1.29821	-0.42776	-0.09246	0.17016	0.15912	-0.20300	-0.20253
S11	0	0.56341	-0.240728	0	-0.21190	0.83584	-0.38768	-0.38113	1.03098	1.02547	-0.87682	-0.20537	-0.25313	-0.23509	-0.21064	-0.20977
S12	0	-0.44836	-0.239233	0	0	-0.72349	-0.64546	-0.62073	-0.08465	-0.33056	0	-0.31300	-0.40225	-0.40861	-0.20513	-0.20452
S13	0	-0.99753	0	0	0	-0.35921	-0.40080	-0.37013	0.76757	-0.74870	-0.893631	-0.27039	-0.42533	-0.41626	-0.21875	-0.21351
S14	-0.04719	-0.61508	-0.241736	0	1.46474	-0.86729	0.20373	0.20625	2.21432	5.27376	0	0.82541	0.22424	0.30143	-0.06465	-0.09812
S15	-0.73926	0.56284	-0.24255	0	1.93810	0.86774	0.41198	0.47526	1.82986	0.13915	0	-0.20317	0.02736	0.06296	-0.21075	-0.20891
S16	-0.57401	-0.14484	-0.241287	0	0.32749	0.17227	1.00386	1.05814	-0.06737	-0.31521	0	-0.22229	-0.23020	-0.25206	-0.21422	-0.20943
S17	-0.66119	-0.72461	0	0	0	-0.85817	-0.59304	-0.56332	-0.81886	-0.75835	0	-0.33075	-0.32839	-0.32729	-0.22995	-0.21935
S18	0	-0.46096	-0.24114	0	0	-0.61820	0.48821	0.49341	-0.53650	-0.19313	0	-0.15938	-0.45249	-0.43859	-0.22461	-0.21001
S19	0.86124	-0.90835	5.60189	3.11078	-0.92993	-0.19629	5.89802	5.86997	-0.02750	-0.44385	0.70635	6.32566	-0.44361	-0.45951	6.59272	6.64319

Notes:
MR- medium resolution mode

Appendix B: Z-Scored Data of Brain Tissue from Kelowna Caught Birds in the Summer and Fall 2010 in mg/kg																
Sample ID	**^{82}Se**	**^{88}Sr**	**^{111}Cd**	**^{112}Cd**	**^{118}Sn**	**^{137}Ba**	**^{206}Pb**	**^{208}Pb**	**^{27}Al**	**^{45}Sc**	**^{59}Co**	**^{63}Cu**	**^{65}Cu**	**^{66}Zn**	**^{68}Zn**	**^{118}SnMR**
Kelowna Fall																
F1	-0.14139	0	1.00100	0.77926	0	0	-0.15398	-0.15715	0	-0.50014	0	-0.08000	-0.14583	-0.12828	1.29616	1.25341
F2	-0.62638	-0.53777	-0.44434	0	0	0	-0.14065	-0.13965	0	-0.40488	0	2.40097	-0.09878	-0.09075	-0.22681	-0.23443
F3	-0.39400	0	-0.45399	0	0	0	-0.14817	-0.14733	0	0	0	2.68848	-0.12108	-0.09480	-0.26439	-0.27990
F4	-0.94915	0	0.00000	0	0	-0.37922	-0.16383	-0.16332	0	0	0	2.56824	-0.16980	-0.15353	-0.29024	-0.30343
F5	-0.52573	0	0.00000	0	0	0	-0.17253	-0.17219	0	-0.48048	0	-0.13036	-0.14305	-0.15104	-0.30619	-0.30431
F6	-0.64207	-0.54426	-0.43757	0	0	0	-0.17196	-0.17161	0	0.04337	0	-0.53270	-0.17956	-0.17242	-0.17476	-0.18500
F7	-0.06762	0	0	0	0	0	-0.16796	-0.16753	0	0	0	-0.48543	-0.20034	-0.21735	-0.29759	-0.29100
F8	0.50708	0	0	0	0	0	-0.17916	-0.17897	0	-0.51372	0	-0.50866	-0.15945	-0.15465	-0.28254	-0.28682
F9	-0.96463	0	0	0	0	0	-0.17533	-0.17505	0	0	0	-0.52162	-0.19721	-0.20663	-0.29237	-0.29887
F10	-0.92089	0	0	0	0	0	-0.16914	-0.16873	0	0	0	-0.50410	-0.19238	-0.18312	-0.28440	-0.29413
F11	-0.89663	-0.38293	0.00000	0	0	0	-0.15011	-0.15185	0	-0.12233	0	-0.41730	-0.15840	-0.16318	-0.19170	-0.17926
F12	-0.58300	0.0	-0.43907	0	0	0	-0.14645	-0.14557	0	-0.45607	0	-0.47667	-0.22688	-0.24734	-0.27571	-0.26574
F13	-0.39355	0.0	0	0	0	0	-0.16329	-0.16276	0	-0.52904	0	-0.51497	-0.23449	-0.25547	-0.28785	-0.27340
F14	-0.40352	0.0	0	0	0	0	-0.16357	-0.16553	0	0	0	0.81191	-0.20599	-0.22482	-0.30279	-0.29502
F15	0.01842	-0.15689	0	0	0	0	-0.16165	-0.16109	0	-0.15783	0	-0.52689	-0.20299	-0.21980	-0.29255	-0.27818
F16	-0.69350	0	0	0	0	0	-0.15305	-0.14954	0	0	0	-0.54027	-0.25159	-0.26504	-0.31667	-0.31299
F17	0.70522	-0.48504	0	0	0	0	-0.16720	-0.16675	0	0	0	-0.52319	-0.17435	-0.18717	-0.30777	-0.30754
F18	-0.43116	0	0	0	0	0	-0.16357	-0.16305	0	0	0	-0.53249	-0.18761	-0.20513	-0.30836	-0.30192
Kelowna Summer																
S1	2.94284	-0.15243	0	-0.51280	-0.21359	-0.19273	-0.11573	-0.12042	-0.28551	-0.02114	-0.39184	-0.37228	0.03929	0.05050	-0.24093	-0.23260
S2	1.66636	-0.23967	0	-0.51289	1.08954	-0.37629	0.30343	0.30440	-0.39822	-0.11656	-0.40699	-0.39711	1.15050	1.26992	-0.06149	-0.05162
S3	1.44046	-0.30522	0	-0.51276	-0.87595	-0.32977	-0.12144	-0.12517	-0.33230	-0.16351	-0.38883	-0.49295	0.04627	0.06681	-0.25081	-0.24266
S4	1.82428	-0.30896	0	0	0	-0.35304	-0.12097	-0.12567	-0.39075	-0.18924	-0.39604	-0.43624	-0.01729	-0.01208	-0.25805	-0.25063
S5	-0.55914	0.00000	0	0	0	0	-0.15381	-0.15090	-0.59191	-0.50958	0	-0.54307	-0.12493	-0.10348	-0.26626	-0.27853
S6	0.17296	-0.44181	0	0	0	0	-0.16164	-0.16108	0	-0.26333	0	-0.52679	-0.18576	-0.16642	-0.27412	-0.28383
S7	0.04936	0.66437	0	0	0	-0.48020	-0.15595	-0.15527	0	2.41631	0	-0.52999	-0.13694	-0.13145	-0.15885	-0.17530
S8	-0.13530	-0.52739	-0.44965	0	0	0	-0.15848	-0.15559	0	-0.35027	0	-0.50083	-0.11606	-0.09798	-0.25261	-0.26650
S9	-0.38969	0	0	0	0	0	-0.16858	-0.16817	0	0.0	0	-0.50031	-0.12966	-0.11509	-0.26792	-0.28288
S10	-0.09442	0	0	0	0	0	-0.16692	-0.16646	0	-0.52432	0	-0.53849	-0.17958	-0.17689	-0.28493	-0.29436
S11	-0.58550	0	-0.38445	-0.46787	0	0	-0.16727	-0.16442	0	-0.56503	0	-0.52209	-0.15980	-0.16742	-0.15290	-0.16947
S12	-0.36732	-0.52355	2.93535	2.50408	0	0	-0.13824	-0.13719	0	-0.21224	0	1.17166	-0.11615	-0.10473	5.56945	5.62222
S13	0.05088	-0.49390	-0.36592	-0.45827	0	0	-0.11690	-0.11804	0	-0.44190	0	0.76239	-0.13596	-0.12859	-0.11071	-0.13246
S14	-0.35581	-0.53370	-0.37992	-0.46513	0	0	-0.15735	-0.15669	0	-0.51243	0	-0.49032	-0.11425	-0.10415	-0.13736	-0.16228
S15	0.22699	0	-0.39687	-0.48214	0	0	-0.14372	-0.14279	0	-0.50250	0	-0.30532	-0.18843	-0.19803	-0.12535	-0.12886
S16	-0.16981	-0.49659	0	0	0	0	-0.16790	-0.16747	0	-0.23070	0	-0.52174	-0.14272	-0.14117	-0.24168	-0.25675
S17	-0.45005	0	0	0	0	0	-0.15310	-0.14985	0	-0.47416	0	-0.54182	-0.18058	-0.17015	-0.28050	-0.29063
S18	-0.11151	-0.54484	0	0	0	0	-0.15998	-0.16359	0	-0.46443	0	-0.48805	-0.15911	-0.15960	-0.28399	-0.28989

Notes:
MR- medium resolution mode

Appendix B: Z-Scored Data of Bone Tissue from Kelowna Caught Birds in the Summer and Fall 2010 (mg/kg)

Sample	^{82}Se	^{88}Sr	^{111}Cd	^{112}Cd	^{118}Sn	^{137}Ba	^{206}Pb	^{208}Pb	^{27}Al	^{45}Sc	^{59}Co	^{63}Cu	^{65}Cu	^{66}Zn	^{68}Zn	^{118}SnMR
Kelowna Fall																
F1	0.30566	0.21143	-0.20294	0	0.17069	-1.05013	0.18599	0.17600	0.17995	0.63806	-0.45128	0.58007	0.54973	-0.56937	-0.52431	0.24055
F10	-0.31863	-0.95065	-0.20294	0	-0.56373	-0.56058	-0.71326	-0.69943	-0.93330	-0.54025	-1.18322	-0.34171	-0.32531	-0.71090	-0.75203	-0.59713
F11	-1.86292	1.66271	-0.20294	4.70653	-0.59613	2.20325	-0.36769	-0.38539	-0.78734	0.46973	-0.85792	0.09256	0.09810	0.36128	0.34722	-0.63564
F12	-0.58149	0.37911	-0.07012	-0.43628	-0.68408	0.04349	-0.53322	-0.53268	-0.51422	-0.03526	-0.23441	-0.15325	-0.17208	0.42529	0.46844	-0.65971
F13	0.66709	-0.76139	-0.20294	0	-0.70877	-0.93071	-0.63969	-0.63088	-1.06195	-0.20359	-1.23744	-0.46051	-0.44225	0.04226	0.02499	-0.69823
F14	-0.02291	-0.74434	-0.13653	0	-0.65785	-0.03403	3.75008	3.83150	-0.53352	0.63806	0.19934	-0.34580	-0.32531	1.86594	1.84104	-0.57948
F15	-0.81149	1.00828	-0.20294	-0.43628	-0.63934	1.21182	0.88584	0.83929	0.13344	0.80639	0.19934	-0.25158	-0.26483	0.10170	0.13180	-0.62441
F16	0.43709	-0.53523	-0.07012	-0.12459	-0.45264	-0.66115	-0.69293	-0.67905	-0.42566	-0.03526	-0.45128	-0.30483	-0.30918	-0.36175	-0.26536	-0.45751
F17	-1.83007	-0.69189	-0.00371	-0.12459	-0.80906	-0.78196	-0.29993	-0.31313	-0.83831	-0.03526	-1.10190	-0.42774	-0.42209	-0.20650	-0.21730	-0.73514
F18	0.27280	1.85049	-0.20294	0	-0.66402	1.98373	1.35724	1.34324	-0.25991	1.64804	-0.47839	-0.32942	-0.33338	1.34263	1.22150	-0.61799
F19	-1.63292	1.05907	-0.07012	-0.12459	-0.63008	0.64011	0.49768	0.44558	0.59013	2.65803	-0.15308	6.48357	6.42504	2.58938	2.56529	-0.62762
F2	0.14137	2.09632	-0.13653	0	-0.44339	1.80030	2.92923	2.91160	0.49711	0.46973	-0.39706	-0.34171	-0.34548	0.38455	0.35563	-0.46233
F20	-1.00863	-0.50533	6.90270	-0.28044	-0.63471	0.01928	-0.40544	-0.40577	-0.56073	-0.03526	-0.36995	-0.25567	-0.26483	-0.55150	-0.48110	-0.65811
F3	0.27280	-0.92985	-0.20294	0	-0.59151	-0.48563	1.55568	1.48498	-0.17480	-0.20359	0.06379	-0.29254	-0.30918	-0.25534	-0.24772	-0.56343
F4	0.50280	0.42203	-0.20294	0	-0.32458	0.30956	-0.51966	-0.51693	-0.29800	0.46973	-0.07175	-0.39496	-0.38580	0.38850	0.50113	-0.32272
F5	0.60138	-0.45148	-0.13653	-0.43628	-0.42179	-0.10410	-0.30381	-0.30572	-0.39152	-0.20359	0.49754	-0.34171	-0.34951	-0.30688	-0.31214	-0.48479
F6	2.83567	1.45081	-0.00371	-0.28044	-0.53905	0.08818	-0.43932	-0.44282	-0.52709	0.30140	0.79573	0.21546	0.19891	1.56085	1.46734	-0.52812
F7	0.23994	-0.25225	0.0	0.0	-0.66711	-0.44443	-0.00954	-0.03151	-0.96497	-0.54025	-0.83081	-0.35809	-0.36161	-0.77844	-0.80107	-0.61478
F8	-0.02291	-1.18660	-0.20294	-0.43628	-0.59768	-0.98495	-0.69196	-0.67905	-0.74727	-0.54025	-0.61393	-0.05903	-0.06724	-0.89649	-0.86483	-0.60997
F9	-0.31863	0.00442	-0.20294	0	-0.35390	-0.15345	0.59060	0.56693	-0.63594	-0.03526	-0.69526	-0.30074	-0.30112	-0.24973	-0.20580	-0.28260
Kelowna Summer																
S1	-0.66226	-1.23580	-0.24340	-0.45008	-0.69195	-1.72756	-0.60343	-0.59191	-1.05775	-1.67473	-1.28432	-0.44517	-0.43488	-1.17820	-1.64709	-0.70846
S10	0.43709	0.15557	-0.07012	-0.28044	2.44186	0.37683	-0.44416	-0.44560	0.74945	0.30140	0.33488	-0.30483	-0.28499	-0.43927	-0.41491	2.52732
S11	1.84995	0.76018	-0.13653	0	2.02528	0.18432	-0.40544	-0.40299	2.16700	0.46973	1.85299	-0.23929	-0.26079	1.11132	1.28559	2.02825
S12	-0.54863	0.65510	-0.13653	-0.28044	2.04688	-0.29102	-0.15377	-0.16398	1.66677	0.63806	1.22948	-0.19012	-0.19224	0.57097	0.70052	2.05071
S13	-0.28577	0.35078	-0.00371	0.03125	2.02991	0.71227	-0.31349	-0.32054	2.18184	1.31138	0.90417	-0.13277	-0.14385	0.51569	0.49725	2.09886
S14	0.56852	0.07480	-0.07012	-0.43628	1.73058	-0.75775	-0.17894	-0.19085	1.20366	0.97472	1.03972	-0.16964	-0.14788	0.03166	-0.02470	1.65755
S15	0.30566	1.38891	-0.20294	0	-0.13480	-0.28823	0.50445	0.46596	0.01717	-0.20359	-0.31574	-0.30893	-0.28902	1.13771	1.09979	-0.10126
S16	-0.45006	-0.28783	0.26192	0.03125	-0.20578	-0.37203	2.78694	2.82730	0.71828	0.13307	0.36199	-0.31712	-0.32935	0.77090	0.87628	-0.09324
S17	1.58709	0.62695	-0.13653	-0.43628	0.02103	1.18133	-0.65228	-0.64107	-0.18371	-0.20359	-0.36995	-0.30074	-0.30515	-0.10363	-0.02794	-0.08521
S18	1.91567	-0.36406	-0.13653	0	0.00097	0.45528	1.48501	1.48776	-0.21637	-0.20359	-0.45128	-0.32122	-0.29709	0.65618	0.63934	-0.06114
S19	-0.61435	-0.73551	-0.13653	0	0.07503	-0.90813	-0.63776	-0.62532	0.38776	0.80639	-0.12597	-0.30074	-0.29709	0.36252	0.37101	0.09773
S2	0.26717	0.96269	-0.21293	-0.19495	-0.38197	-0.61080	-0.41408	-0.40613	-0.07473	-1.05124	-0.36355	2.25230	2.43792	0.99149	0.01992	-0.40687
S3	-0.41547	-0.61151	-0.15172	-0.00061	-0.14126	-0.79571	-0.24095	-0.23011	1.05721	-1.16485	3.33109	0.22042	0.20063	-0.72508	-0.66419	-0.07701
S4	-0.13549	-0.44742	-0.21757	-0.06563	-0.72858	-0.42286	0.33302	0.34030	-0.14239	-1.14988	0.51811	-0.34262	-0.35492	-0.56029	-0.47410	-0.71718
S5	-0.81149	0.05434	-0.20294	0.03125	3.10840	-0.48959	-0.20410	-0.20659	0.13592	0.46973	-0.20730	-0.28025	-0.28499	-0.16078	0.08568	3.10503
S6	-0.05577	0.63954	-0.20294	0	1.29085	-0.49005	-0.46255	-0.46135	1.95276	2.32137	0.49754	-0.13687	-0.14788	0.36917	0.49805	1.13761
S7	-1.40292	2.03924	-0.20294	0	1.35720	1.55983	-0.13441	-0.15101	-0.10405	-0.20359	-0.18019	0.12123	0.09003	-0.35656	-0.34127	1.39116
S8	0.40423	-0.27559	-0.07012	0	1.71361	-0.12924	-0.55742	-0.55584	3.41137	2.82636	1.01261	-0.03035	-0.01885	-0.02757	0.04376	1.66557
S9	-1.40292	-0.71776	-0.20294	0	1.47600	-0.87787	-0.48288	-0.47802	0.65198	0.30140	-0.34284	-0.28845	-0.29709	-0.49933	-0.37380	1.45054

Notes:
MR- medium resolution mode

Appendix B: Z-Scored Data of Heart Tissue from Kelowna Caught Birds in the Summer and Fall 2010 (mg/kg)															
	^{82}Se	^{88}Sr	^{111}Cd	^{112}Cd	^{137}Ba	^{206}Pb	^{208}Pb	^{27}Al	^{44}Ca	^{45}Sc	^{59}Co	^{63}Cu	^{65}Cu	^{66}Zn	^{68}Zn
Sample ID															
Kelowna Fall															
F1	0.12788	-0.73523	-0.83110	0	0	0	0	0	-0.74019	-0.53252	-0.09612	0.62806	0.58943	0.15006	-0.14223
F2	-0.66516	-0.81854	2.44716	0.89886	0	-0.36492	-0.01690	0	-0.99180	-0.51379	4.44494	-0.20236	-0.22479	-0.41977	-0.47230
F3	-0.78680	-0.76228	0.55224	-0.61609	0	0	0	0	-0.74838	-0.50877	-0.34800	-0.54576	-0.47956	-1.15222	-0.82843
F4	-1.49775	-0.59987	0	0	0	0	0	0	-0.41173	-0.51088	0.09912	-0.56118	-0.55842	-1.05264	-0.80593
F5	0.83425	0	2.41893	0.83005	0	0	0	0	-0.94431	-0.51586	-0.42779	-0.37615	-0.39056	-1.00575	-1.11961
F6	-0.07039	-0.54132	-0.53492	0	0	0	0	-0.68906	-0.36444	-0.48267	0.89555	0.39035	0.30393	-0.11605	-0.18538
F7	-0.21761	-0.57923	0.58405	-0.61391	0	0	0	0	-0.49845	-0.50762	3.76061	0.13557	0.06162	-0.58190	-0.83918
F8	0.54927	-0.74366	1.72345	0.35991	0	0	0	0	-0.84649	-0.50567	-0.18121	0.29171	0.22224	-0.75810	-0.83577
F9	2.70455	-0.78337	0.59716	2.64170	0	-0.50316	-0.23409	-0.91175	-0.54869	-0.29347	-0.29783	0.25625	0.24654	-0.18102	-0.41416
F10	-0.57904	-0.60670	0	0	0	0	0	0	-0.55576	-0.52381	-0.38792	-0.37518	-0.34633	-0.90396	-1.02240
F11	1.28440	-0.71174	0	0	0	0	0	0	-0.61333	-0.49877	-0.18808	-0.27458	-0.21034	-0.80226	-0.95742
F12	0.16713	-0.51059	0	0	0	0	0	0	-0.06110	-0.51773	-0.43544	0.14488	0.13842	0.14348	0.22882
F13	0.74205	-0.22552	-0.16924	0	0	0	-0.83221	0	0.82974	-0.51128	-0.33786	1.00521	1.06998	-0.26757	-0.44441
F14	1.79276	-0.78746	-0.79967	0	0	0	0	0	-0.65270	-0.49662	0.00000	-0.26134	-0.30158	-0.37714	-0.31305
F15	2.44138	-0.38298	0	0	0	0	0	0	-0.87944	-0.48566	0.63023	0.22153	-0.01454	-0.39119	-0.55391
F16	0.37382	-0.32797	0.72623	-0.60413	0	0	0	0	0.07412	-0.50675	-0.45135	-0.22923	-0.38564	-0.77110	-0.80196
F17	-0.34816	-0.68594	0	0	0	0	0	0	-0.33584	-0.51227	-0.36679	0.23681	0.32928	-0.04520	0.05727
F18	0.00557	-0.57798	0.80782	-0.47905	0	0	0	0	-0.09418	-0.48599	-0.43930	-0.09621	-0.26276	0.24673	0.29809
F19	-0.35410	-0.55367	-0.44335	0	1.51512	2.21762	2.46334	0	-0.17669	-0.49696	-0.32639	-0.18961	-0.20189	1.66800	2.04084
Kelowna Summer															
S1	3.50832	0.57414	-0.55668	-0.38424	-0.70953	-0.56123	-0.67372	-0.04013	0.15015	1.73092	-0.04718	0.70797	0.69230	1.61412	1.21724
S2	0.33009	0.40786	-0.62175	-0.44240	-0.71529	-0.42714	-0.49681	-0.54071	0.15673	1.29668	-0.23080	0.11569	0.11976	0.28972	-0.10069
S3	-0.41337	-0.55755	0	0	0	0	0	0	-0.88528	-0.06599	0.52778	-0.12064	-0.21059	-0.63442	-0.85100
S4	0.73481	0.50097	-0.48525	-0.32041	-0.55060	-0.70571	-0.79355	-0.48635	-0.56524	1.42660	-0.10628	0.50219	0.58500	0.94140	0.53260
S5	-0.10812	-0.01870	-0.57306	-0.39888	-1.55091	-0.62842	-0.71251	-0.10279	-0.39768	1.55416	-0.13903	0.45382	0.40744	0.71617	0.30623
S6	-0.23180	-0.24824	-0.60317	0	0	0	0	0	0.44432	-0.24318	-0.31081	-0.21020	-0.22868	0.33365	0.37132
S7	-1.63304	-0.37927	0	0	0	0	0	0	0.05692	-0.33005	-0.37049	-0.04530	0.01213	-0.01661	-0.24827
S8	-1.34656	-0.24448	-0.81417	0	0	0	0	0	0.80824	-0.45317	-0.39850	-0.29015	-0.21009	-0.77395	-0.44104
S9	-1.17278	-0.62663	-0.80030	0	0	0	-0.51617	0	-0.74029	-0.47070	-0.30720	-0.46223	-0.39919	-1.06534	-0.70183
S10	-1.76880	-0.72067	0	0	0	0	0	0	-1.00112	-0.46195	-0.44840	2.39954	2.49566	-1.03617	-0.84206
S11	1.28738	-0.65936	0.22471	-0.63199	0	0	0	0	-0.83272	-0.49123	-0.40885	-0.13975	-0.10800	-0.07456	-0.39486
S12	-0.66788	-0.07492	0	0	0	0	-0.76410	0	0.00293	-0.49962	-0.36275	-0.19319	-0.12012	0.29461	0.42531
S13	-0.67289	-0.51915	0	0	0	0	0	0	-0.06542	-0.47070	-0.44168	-0.00275	-0.08296	0.15021	0.19871
S14	-0.52879	-0.10514	0	0	0	0	0	0	0.08094	-0.50486	-0.34988	-0.38661	-0.33115	-0.69679	-0.48043
S15	-0.66485	-0.63215	0	0	0	0	0	-0.58538	-0.88452	-0.50824	-0.42929	-0.83233	-0.78567	-1.36793	-0.95986
S16	-0.83065	-0.26243	-0.73490	0	0	0	0	0	-0.49140	-0.50007	-0.27748	-0.32114	-0.23398	-0.54977	-0.29162
S17	0.95572	0.03927	0	0	0	0	0	0	0.49198	-0.49162	-0.28293	1.40706	1.28478	1.12972	1.18632
S18	0.05771	-0.54602	-0.54059	0	0	0	0	0	-0.50530	-0.50568	-0.24189	0.60573	0.62022	0.38351	0.20226
S19	-0.33302	-0.21735	0	0	0	0	0	0	-0.55963	-0.51949	-0.36202	-0.73906	-0.62368	-0.84176	-0.59232

Notes:
MR- medium resolution mode

Appendix B: Z-Scored Data of Muscle Tissue from Kelowna Caught Birds in the Summer and Fall 2010 (mg/kg)															
	^{82}Se	^{88}Sr	^{111}Cd	^{112}Cd	^{206}Pb	^{208}Pb	^{118}Sn	^{27}Al	^{44}Ca	^{45}Sc	^{59}Co	^{63}Cu	^{65}Cu	^{66}Zn	^{68}Zn
Sample															
Kelowna Fall															
F1	-0.12644	0	0	0	0	-0.61063	0	0	0	0	-0.21031	0.10187	0.03470	-0.53760	-0.62724
F2	-0.07511	0	0	0	0	-0.49177	-0.57767	0	0.26117	0	-0.44993	0.01360	0.12968	1.35496	1.41822
F3	-0.73372	0	0	0	0	-0.55226	-0.66786	0	0	0	-0.56007	0.93730	0.52278	-0.87342	-0.76136
F4	-0.86375	0	0	0	0	-0.51782	-0.60490	0	-0.56737	0	-0.48516	0.49157	0.31709	-0.22540	-0.27084
F5	-0.62709	0	0	0	-0.89143	-0.59378	0	0	-0.31079	0	-0.49222	-0.30798	-0.04644	0.65746	0.70695
F6	0.27196	0	-1.05341	0	0	-0.00883	-0.12045	-0.81697	-0.37800	0	-0.48658	-0.46583	-0.46440	-1.24118	-1.23961
F7	-0.26197	0	0.86730	0	0	0.43296	0.32478	-0.89820	0.90814	0.33987	-0.44095	0.43229	0.17299	0.73585	0.98184
F8	-0.41204	0	0	0	0	-0.33331	-0.44957	0	-0.54405	-0.54284	-0.55902	2.10245	2.08599	-0.25371	-0.17582
F9	0.45572	0	0	0	0	-0.45428	-0.53330	0	-0.53506	-0.60421	2.13567	0.51345	0.39603	-0.09563	-0.17846
F10	1.30344	0	0	0	0	-0.41598	-0.52771	0	-0.35961	-0.56482	-0.56492	-0.08353	-0.12605	1.30861	1.18441
F11	-0.74177	0	0	0	0	-0.58254	-0.66842	0	0.00000	-0.20598	0	0.07905	-0.08778	-0.82673	-0.79368
F12	0.47734	0	0.11734	0	0	0.84230	0.71398	0.23742	-0.21437	0.49485	0	1.00212	0.92548	-0.37502	-0.22264
F13	-0.31782	0	0	0	0	-0.52941	-0.61368	0	0	-0.11375	-0.13987	-0.36952	-0.32278	-0.93355	-0.96679
F14	0.03945	0	0	0	0	-0.52080	-0.63722	0	0	-0.42781	1.72839	0.19654	0.30979	-0.52697	-0.52054
F15	-0.11190	0	0	0	0	0.00000	0.00000	0	0	0	0	0.30144	0.16184	-0.93147	-0.88009
F16	-0.14941	0	0	0	0	-0.51721	-0.63541	0	0	-0.66894	0	-0.24117	-0.20961	-1.00223	-0.90320
F17	-0.94805	0	0	0	0	-0.58144	0.00000	0	-0.61875	0	-0.51843	0.22645	0.24337	0.72044	0.76526
F18	-0.57393	0	0.51051	0	0	5.30943	4.88952	0	0	-0.42419	0	-0.63182	-0.65739	-1.37883	-1.40682
F19	-0.83934	0	0	0	0	-0.40522	-0.48992	0	0	0	0	0.44091	0.27928	-0.71533	-0.79283
F20	-0.19457	0	0	0	0	-0.58333	-0.66882	0	0	0	0	-0.11654	0.06974	-0.27462	-0.26536
Kelowna Summer															
S1	4.51969	-0.23399	-1.08524	0.70711	0.24207	0.68804	0.58995	2.82379	0.16000	4.33483	2.55269	1.21513	1.37575	2.01820	2.04780
S2	2.05280	-0.25409	0	-0.707107	0.07706	0.11770	0.01844	0.51905	-0.13985	1.26916	-0.38158	1.16734	1.27912	-0.01936	0.05411
S3	1.49642	-0.33642	0	0	0.37528	0.44938	0.33413	0.86162	-0.31021	0.61330	-0.28164	0.76578	0.93266	0.56173	0.55974
S4	1.85719	-0.33242	0	0	0.02211	0.29996	0.19297	0.68490	-0.15425	0.07861	-0.35914	1.02012	1.12268	0.54546	0.52878
S5	1.01088	-0.52068	0	0	-0.81686	0.13923	0.13872	-0.07887	-0.35791	0.12425	0	1.49020	1.52393	-0.32146	-0.15170
S6	1.22970	-0.35798	0	0	-0.77548	0.00959	0.02022	-0.39327	-0.17055	-0.02099	-0.567032	1.10043	1.21000	-0.53737	-0.43377
S7	0.13360	-0.40561	0	0	-0.80476	0.75271	0.69822	-0.56491	0.01870	-0.25055	-0.525061	1.96417	2.12443	0.09266	0.10660
S8	1.29492	-0.29273	0	0	0.60699	-0.12112	-0.12951	-0.40940	0.35330	-0.00467	-0.342431	0.83429	0.98100	-0.34540	-0.25661
S9	0.14416	-0.46270	0	0	-0.78472	0.64718	0.60937	-0.62594	-0.15096	0.00797	0.1709874	1.26964	1.44437	0.94601	0.91015
S10	0.39190	-0.46361	0	0	-0.87567	-0.00214	-0.00253	-0.47142	-0.23327	-0.06503	-0.558736	1.26191	1.46991	-0.14069	0.02718
S11	0	0	0	0	0	-0.53599	-0.61867	0	0	0	-0.566074	-0.32256	-0.45725	-0.97144	-1.01283
S12	-0.101231	0	0	0	0	-0.57789	-0.66607	0	0	-0.540278	0	0.21473	0.09802	-0.93887	-1.05558
S13	0	0	0	0	0	-0.57942	-0.66684	0	0	0	-0.53350	0.06624	-0.11621	-0.72621	-0.88844
S14	-0.68292	0	0	0	0	0	0	0	-0.60753	-0.56482	0	-0.21351	-0.26847	-1.02486	-1.11594
S15	-1.01599	0	0	0	0	0	0	0	0	0	0	-0.44460	-0.37797	-0.98856	-1.09998
S16	-0.76132	0	0	0	0	-0.5894	0	0	0	0	-0.27163	0.63084	0.37021	-0.75236	-0.91938
S17	0.18860	0	0	0	0	-0.5527	-0.6680	0	-0.16087	0	-0.07533	2.09996	2.12619	1.07908	0.91221
S18	-0.36116	0	0	0	0	-0.5803	0	0	-0.407293	0	0.20444	-0.12099	-0.17700	-0.56346	-0.53656
S19	-0.38622	0	0	0	0	0.6888	0.55371	0	-0.031677	0	0.22903	-0.06266	-0.20038	0.15279	0.27153

Notes:
MR- medium resolution mode