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Sacred Heart: A Stable Isotope Analysis of Childhood, Diet, and Mobility at a Nineteenth Century Ontario Cemetery

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SACRED HEART: A STABLE ISOTOPE ANALYSIS OF CHILDHOOD, DIET AND
MOBILITY AT A NINETEENTH CENTURY ONTARIO CEMETERY

(Thesis format: Monograph)

by

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Graduate Program in Anthropology

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Abstract

This thesis uses stable isotopes of carbon and nitrogen derived from bone collagen and tooth dentin to study infant feeding behaviour, diet, and mobility at the 19th century Sacred Heart Cemetery in Ingersoll, Ontario, in use from 1848 to 1880. $\delta^{15}N$ and $\delta^{13}C$ bone values indicate a diet high in protein with a mix of C_3 and C_4 plants. The most significant source of dietary C_4 plants is through secondary consumption, via livestock raised on maize fodder. The dietary profile of the Sacred Heart population is similar to two contemporary Ontario populations. There was no significant difference in the $\delta^{15}N$ and $\delta^{13}C$ bone collagen or dentin composition between the sexes, but consumption does vary by age. Supplementary infant feeding began between 8 and 10 months, and weaning continued until approximately 18 to 20 months. Although most individuals were local, there is evidence that some members of the population were landed migrants.

Keywords

Acknowledgments

many sentences with the phrase "so I was working on my thesis…" ever since I met you. You deserve better.

To the Vince Guaraldi Trio and *A Charlie Brown Christmas*: I am indebted to you for providing the ultimate study jam and the soundtrack to this project.

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To Sean: You rock! I hope that my days of being amazed by everything you do are only coming to their middle. I also promise fewer years of neglect in the future (I don't actually promise that, but I do love you excessively). Thank you.

And to you, dear reader: thank you for reading at least this page of my thesis. Only 111 to go!

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Chapter 1

1   Introduction

Bioarchaeologists use stable isotope analysis of human and animal tissues to reconstruct ancient and historic ways of life. Isotopic anthropology invigorates assessments of life history and the lived experience of the dead by incorporating data that are specific and localized to the ongoing dialogues of diet, mobility, and childhood. Isotopic anthropology accesses interpretations of the past by using the biochemistry of an individual as the specific unit of reference. The stable isotopic composition of soft and hard tissues provides invaluable clues to ancient environments. This thesis uses stable isotopes of carbon and nitrogen derived from the organic fractions of bone and tooth samples to inform interpretations of breastfeeding practices, diet, and mobility within the population of a 19th century cemetery at Sacred Heart Parish in Ingersoll, Ontario.

Ingersoll is located in Oxford County in southwestern Ontario, along the Thames River. The site was accidentally discovered during construction in January of 2008. Subsequent excavation associated the skeletal remains with the erstwhile Sacred Heart cemetery, affiliated with the Roman Catholic Church (Figure 1-1), in use from 1848 to 1880. The skeletal remains recovered at the Sacred Heart cemetery are the subject of a previous study by Spence (2012), who assessed the age, sex, and paleopathology of the population. The research in this thesis is intended to provide details of individual, lived experiences of people interred at the Sacred Heart cemetery site and to contextualize those details within the larger narrative of European settler experience in Ontario during the mid to late 19th century. It will supplement the osteological work done by Dr. Mike Spence on the Sacred Heart population, as well as incorporate available and relatively recent historical, census, and personal documents. This research will:

1. Assess differences within this population by age and sex categories;
2. Contextualize the story of the Sacred Heart population within the established narratives of life in Ontario;
3. Identify individuals who participated in the cross-continental diaspora of the 19th century;

4. Assess the experience of children in the population through discussion of the particulars of breastfeeding and the weaning process,

5. Contrast individual data with the medical doctrines of the time.

Chapter 2 begins with a literature review of the principles of stable carbon and nitrogen isotope analysis relevant to an anthropological project, including the assumptions inherent within the axiom "you are what you eat," as well as a review of timelines for bone and tooth formation. Chapter 3 details the particulars of the Sacred Heart site, including its initial excavation in 2008, the growth of the Roman Catholic Parish in Ingersoll, and the demographic composition of the sample population used in this study. Chapter 4 is a description of Ingersoll in the 19th century, detailing the geography and settlement of the Sacred Heart site, standards of living and healthcare at the time, the rural-to-urban shift and subsequent fluctuations in population size and composition that transformed Ontario as the twentieth century approached. Chapter 5 identifies dietary staples of colonial diet in Ontario, and how that diet is reflected isotopically in the bones and teeth of consumers. Chapter 6 is a review of the methodology used in this study, detailing sample preparation, pretreatment, collagen extraction, method duplicates, and the preservation criteria that must be met to insure quality of data. Chapter 7 is a discussion of the results of the stable isotope analysis, and situates those results within the food web of Ontario, assessing inter- and intra-population variation at the Sacred Heart site, as well as trends in diet, mobility, and infant feeding in Ingersoll at this time. Chapter 8 concludes this thesis with a review of significant findings from this population and their impact on the current understanding of life in Ontario during the 19th century.

Figure 1-1 Sacred Heart Parish in Ingersoll, Ontario (personal photograph by Emily Wells)

Chapter 2

2   Stable Isotope Analysis

Isotopes of the same element share a given number of protons, but have a different number of neutrons. Nitrogen has two stable isotopes: ^{14}N and ^{15}N, and carbon has three naturally occurring isotopes: ^{12}C, ^{13}C, and ^{14}C. Of these, ^{12}C and ^{13}C are stable, while ^{14}C is radioactive and will decay over time. The stable isotopic composition of a tissue is indicative of the conditions and materials present in the body when that tissue formed.

Isotopic ratios measure the difference between the heavy and light isotopes of both the sample and a reference standard. As the number of neutrons in an isotope increases, so too does its atomic mass. Lighter isotopes of a given element are more abundant than the heavy isotopes of that element. Isotopes of different masses will also have different bond energies, resulting in differences in kinetic behaviour during reactions (Schoeller 1999). This process produces isotopic fractionation. Kinetic fractionation separates heavy and light isotopes from each other, while equilibrium fractionation describes an exchange between heavy and light isotopes (Young *et al.* 2002).

Isotopic ratios are reported in parts per thousand, or "per mil," (‰), and are expressed by the delta notation (δ), where δ = difference and R = the ratio of heavy to light isotopes in the element in question:

$$\delta = \left[\frac{R_{sample}}{R_{reference}} - 1 \right]$$

(Coplen 2011)

The standards used in this project accord with the internationally recognized laboratory samples for stable isotope analysis. The standard for carbon is Vienna PeeDee Belemnite (VPDB), originally a marine fossil from the Cretaceous period (Coplen 1994), while Ambient Inhalable Reservoir (AIR, or atmospheric N_2) is used for nitrogen (Mariotti 1983).

2.1 Carbon

The base of a food web is where "the most important" isotopic fractionation of dietary carbon occurs (van der Merwe 1982). Plants are at the base of the human food web. Isotopic composition varies across plant species according to geography and climate, and is mitigated by photosynthetic processes. These variations make it possible to reconstruct dietary inputs by analyzing $\delta^{13}C$ values in sample tissue (Smith & Epstein 1971).

Carbon fixation is the process wherein CO_2 is converted from gas to a solid compound, and is practiced by autotrophic plants as a means of independently producing food. Photosynthesis is a method of carbon fixation; CO_2 is fixed and converted into sugars. The different photosynthetic pathways result in three plant categories: C_3, C_4, and CAM. The differences between these plant types are due to their evolution in areas with varying access to water and sunlight (Smith & Epstein 1971; Lerman *et al.* 1974).

Plants that practice C_3 carbon fixation thrive with moderate sunlight intensity, moderate temperatures, and plentiful groundwater, and form a molecule with three carbon atoms during photosynthesis (Smith & Epstein 1971). A majority of plants in the biomass (trees, nuts, legumes, fruits, vegetables, rice, wheat, and certain grasses) are C_3 plants (Smith & Epstein 1971). C_4 carbon fixation is an elaboration on the C_3 photosynthetic pathway, and results in a molecule with four carbon atoms. C_4 plants are adapted to hot and arid conditions with limited nitrogen or CO_2 (Smith & Epstein 1971). Maize, millet, sorghum, and sugarcane are edible C_4 plants, and have relatively high $\delta^{13}C$ values.

It is possible to distinguish between C_3 and C_4 plants since the former are depleted in ^{13}C relative to the latter. This depletion occurs because plants with the C_3 pathway discriminate against the ^{13}C isotope more than C_4 plants (Bender 1971). C_3 plants range in $\delta^{13}C$ values from –35 to –20‰ while C_4 plants have a range of –16 to –9‰ (van der Merwe 1982).

CAM (Crassulacean Acid Metabolism) plants flourish in hot, dry areas, and include aloe, pineapple, ferns, and succulents (Lerman *et al.* 1974). They can use either the C_3 or C_4 pathways. There is considerable variation in their carbon isotope composition, and their

$\delta^{13}C$ values overlap the ranges of both C_3 and C_4 plants. However, since CAM plants are not indigenous to Southern Ontario or Europe, and many are considered inedible, it is not likely that CAM plants are relevant in this study.

After the onset of the industrial revolution in the late 19th century, there was an increase in coal and fossil fuel burning, which led to global decrease in the carbon-13 content of atmospheric CO_2 known as the Suess Effect (Suess 1955, Revelle & Suess 1957). Suess (1955) found that variations in $\delta^{13}C$ values within and between trees in the same forest over many years were due to fluctuations in the atmospheric CO_2. These fluctuations are not a factor influencing the $\delta^{13}C$ values of the Sacred Heart population, as the cemetery operated from 1848 to 1880, and 1880 is often identified as the zero point of the Suess Effect (Yakir 2011).

2.2   Nitrogen

The nitrogen isotope composition of organisms is influenced by several factors. The $\delta^{15}N$ values in collagen increase according to trophic level, with a stepwise enrichment for each position in the food chain. The $\delta^{15}N$ values in an animal are influenced by the source of nitrogen in the diet, and by its trophic distance from the source (Minagawa & Wada 1984).

In many plants, nitrogen is obtained from dissolved nitrate (NO_3) or ammonia (NH_3) in water. Some plants are able to fix nitrogen directly from atmospheric N_2, and will have lower $\delta^{15}N$ values than non-N_2 fixing plants, as the atmospheric N_2 has a value of 0‰ (Szpak *et al.* 2014). Non-N_2 fixing plants have a range of $\delta^{15}N$ values between 3 to 6‰ (Pate 1994), while nitrogen-fixers are similar to atmospheric N_2, with values around 0‰ (Virginia & Delwiche 1982).

Marine algae and plants have high $\delta^{15}N$ values relative to land plants (Virginia & Delwiche 1982). Similarly, aquatic organisms have higher $\delta^{15}N$ values than their terrestrial counterparts, due to the increased number of trophic levels in that environment

(Schoeninger *et al.* 1983). Animals incorporate ^{15}N preferentially over ^{14}N. In the food chain, a stepwise enrichment is visible in dietary δ^{15}N values:

Plant < Herbivore < Primary Consumer < Secondary Consumer

(Minagawa & Wada 1984).

Dietary nitrogen isotopic values are also directly influenced by the consumption of protein (O'Connell & Hedges 1999). For example, in a controlled diet study, the δ^{15}N values of omnivores and ovo-lacto-vegetarians were on average +2‰ higher than those of vegans (O'Connell & Hedges 1999).

The nitrogen balance in the body is very sensitive to physiological fluctuations. Changes that occur during pregnancy result in a negative shift in δ^{15}N values. Fuller *et al.* (2004) noted a shift in δ^{15}N values of hair pre- conception to time of delivery in pregnant women ranging from –0.3 to –1.1 ‰.

Fasting and nutritional stress in individuals can increase tissue δ^{15}N values (Hobson *et al.* 1993). A study in the highland savannah grasslands of East Africa found a +2‰ increase in δ^{15}N values between water-dependent and drought-tolerant herbivores (Ambrose & DeNiro 1986). The ^{15}N enrichment also resulted from higher rates of excretion of ^{15}N-depleted urea, leading to an overall enrichment in tissue δ^{15}N values.

The physiological stress of starvation, infection, and certain diseases can effect changes in human protein metabolism, and alter the δ^{15}N values of the human skeleton (Olsen *et al.* 2014). For instance, White & Armelagos (1997) found marked differences in the δ^{15}N values of bone collagen between "normal" individuals and those individuals noted to suffer from osteopenia, resulting in a difference of 2-2.5‰ (White & Armelagos 1997). For this reason, it is ideal to sample "visibly normal bone," sampling away from lesion sites and near-lesion sites to avoid alteration in the δ^{15}N collagen values due to metabolic practices and not necessarily differences in diet relative to the population (Olsen *et al.* 2014).

Nitrogen fixation increases with the application of fertilizer nitrogen, resulting in artificially high $\delta^{15}N$ values of plants (Hardarson *et al.* 1984). While fertilization with nitrogen-based fertilizers is not recommended for legume cultivation because they independently source N_2 in the soil, N-deficient soils and non N_2-fixing crops greatly benefit from their application. Agricultural manuring is a source of increased $\delta^{15}N$ plant values, as plants fertilized with animal manure tend to have higher $\delta^{15}N$ values relative to either plants that are chemically fertilized or plants that are unfertilized (Szpak *et al.* 2012).

2.3   Collagen in Bone

The principal component of the organic phase of bone is collagen. Collagen is a complex polypeptide, and is approximately 22% of fresh bone weight (van Klinken 1999). Although dietary protein is only a minor energy source in human metabolism, it is a significant factor in collagen growth, and is derived from both plants and animals lower in the food chain (Ambrose & Norr 1993). Plant-derived carbohydrates represent a large portion of human diet, with significant quantities of meat and other protein-rich foods also consumed.

Isotopic data obtained for bone provide a recent average of dietary consumption, because bone forms during foetal growth and ossifies around birth, with perpetual turnover. Hedges *et al.* (2007) proposed that human bone turnover rates between the ages of 20 and 80 ranged from 4-3% and 3-1.5% per year for females and males, respectively. Bone remodels continually throughout adult life in a 10 to 12 year cycle, although this re-modeling rate slows as age increases (Schaffler *et al.* 1995). Bone collagen analysis of adults opens a window into diet during the most recent 10 to 12 years of life. Conditions that hinder scheduled skeletal growth include illness, nutritional imbalance, and vitamin and mineral deficiencies.

2.3.1 Collagen in Teeth

Teeth have three distinct anatomical tissues. The pulp cavity is surrounded by dentin, sheathed in enamel, and rooted to the alveolar process by cementum. Dentin is the only

tissue in the tooth to provide sufficient collagen for isotopic analysis and is the dental tissue used in this paper. Dentin is approximately 75% inorganic material, and the 25% organic component is mainly fibrous collagen proteins (Wang & Cerling 1994). Tooth formation and eruption follow a normally precise genetic program that is invaluable as a means of age identification in juvenile samples (Maas & Bei 1997) and was used by Spence (2012) to complete a detailed age and sex assessment of the Sacred Heart population. Factors affecting the organogenesis of teeth include nutritional stress and imbalance, vitamin deficiency, and childhood illness. Table 2-1 describes the timeframe of tooth mineralization onset and crown completion for the teeth[1] present in the Sacred Heart sample (w iu = weeks in utero, y = years):

Tooth	Mineralization Onset	Crown Completion	*n*	Associated Samples
ui1	14 w iu	1.5 months	1	66a
li	18 w iu	3 months	2	21, 56
m1	12.5-15.5	6 months	11	25, 35, 51, 67, 96, 125, 130, 133, 140, 143, 300
m2	12.5 - 18 w iu	10 months	7	3, 21, 38, 39, 89a, 89b, 132a
c	17-20 w iu	9 months	1	69
C	4-5 months	4.5 years	2	5, 72
P1	1.75 y	5.4 years	3	36, 66b, 131a
P2	2.2-2.5 y	6.1 years	4	9, 26, 114, 139
M1	birth	2.6 years	2	63, 73
M2	2.5-3	6.5 years	12	12, 47, 55, 62, 64, 70, 75, 85, 115, 119a, 141, 145
M3	8.5 years	13 years	6	37, 49, 60, 88, 90, 131b
		Total	**51**	

Table 2-1 Time of tooth formation (Ten Cate 1989; Schwartz 2007) and associated Sacred Heart samples (after Spence 2012).

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[1] Tooth classification: lower case = deciduous dentition, uppercase = permanent. U = upper, L = lower, I = incisor, M = molar, C = canine, P = premolar

2.4   Isotopic Fractionation

The fundamental premise of stable isotope analysis in archaeology is that humans are what they eat and drink. The relationship between diet and tissue composition is predicated on the input of isotopically distinct dietary sources and their interaction with factors relating to fractionation, mitigated by the turnover rate of the tissue in question (Tieszen *et al.* 1983). Inter-species and inter-individual variations in the isotopic composition of collagen are associated with diet. Dietary plants influence the composition of herbivore tissue, while the tissues of a carnivorous animal reflect those of the animals it has consumed. Omnivore tissues, which include those of humans, are indicative of both plant and animal dietary sources.

The assumption that the isotopic composition of collagen represents average dietary intake relative to the time of tissue formation is modified to account for a fractionation effect during the metabolism of macronutrients in the diet and during the formation of the tissue itself (DeNiro and Epstein 1978). This study incorporates an offset of $-3.7‰$ for carbon isotope composition between diet and collagen (Ambrose & Norr 1993; Szpak *et al.* 2012), and an offset of $-3‰$ for nitrogen isotope composition (DeNiro and Epstein 1981).

2.5   Further Interpretation

Both inter- and intra-individual comparisons are useful in reconstructing weaning habits and change in diet or location over time, as well informing socio-economic factors that may govern access to resources. The data collected by the Canadian census over generations are available and invaluable. The data is also inherently flawed due to the complications involved in self-reported statistical data, and the sample bias inherent in a survey of a diverse, pocketed population such as 19th century Canada. The results of the isotopic analysis are contextualized within the available census data in a later chapter.

2.5.1 Mobility

Maize, a C_4 plant, is a staple in the Ontario food web where it is eaten raw, cooked, ground into meal, baked into desserts, and used as agricultural feed (Kenyon & Kenyon 1992). Its isotopic signature is inescapable. The absence of C_4 plant influence in both bone and tooth collagen in individuals from this population would be indicative of relatively recent emigration from a region where C_4 plants are not consumed. With documentary evidence, it is possible to narrow those origins to a specific region.

2.5.2 Breastfeeding and Weaning

Breastfeeding behaviour is essential to understanding birth spacing and infant mortality in a population, and has significant import in family dynamics and regional demography. Breastfeeding practices can be reconstructed using stable isotopes. The fingernails of nursing infants have higher $\delta^{15}N$ values compared to their mothers, from the age of three months until a time several months after additional food sources were introduced to the diet of the infant (Fogel *et al.* 1989). This shift is attributed to the nature of infant feeding. Because breastfeeding babies consume the tissues of the mother, they are one trophic level above this food source. A spacing of approximately +2.4‰ is expected between the $\delta^{15}N$ values of mothers and their breastfeeding infants (Fogel *et al.* 1989).

The $\delta^{13}C$ values of infants can also be a useful tracer of breastfeeding and weaning activity (Fuller *et al.* 2006). Exclusively breastfed infants may have higher $\delta^{13}C$ values than their mothers by approximately 1‰ (Fuller *et al.* 2006; Katzenberg *et al.* 1993). With the introduction of solid foods to the infant diet, $\delta^{13}C$ values returned to maternal levels "more quickly" than did the $\delta^{15}N$ values (Fuller *et al.* 2006), indicating that $\delta^{13}C$ values indicate the introduction of solid food to the diet, while $\delta^{15}N$ values are more useful in tracking the duration of breastfeeding.

2.5.3 Status

Bone and tooth collagen $\delta^{13}C$ and $\delta^{15}N$ values of the Ingersoll population plotted against known local food resources can enable identification of social differences in diet. Status

is assessed by parsing out differential access to food resources by vulnerable persons (e.g., individuals exhibiting dietary stress, pregnant mothers, or infants) from factors surrounding mobility. The socio-economic factors that effect change in status often have roots in local minutiae. If wealth determines access to medical resources, and that access is essential in the propagation of one family line over another, then the factors that influenced wealth during the 19th century in Ingersoll are important determiners of social status in the Sacred Heart population.

2.6   Osteological Paradox

Wood *et al.* (1992) argue that it is not possible to sample all individuals at risk of disease or death at a given age in a skeletal sample, as it is only possible to see those who did indeed die. There is normally no record of those who overcame the illness, just as there is often no evidence of whether an individual was affected by the disease if they succumbed to it too quickly to offer up the type of physiological resistance that would have been recorded in the skeleton. A skeleton that shows the ravages of many pathological conditions does not necessarily belong to an individual who is more frail than one that appears untouched by disease. Skeletal lesions associated with disease necessitate a period of bone growth during or after the illness. Individuals without such lesions can be interpreted as having died without putting up a resistance to disease that is reflected in ravages of the skeleton. The osteological paradox is a reminder that biases are "built into the very structure of the data" (Wood *et al.* 1992). It is necessary to be aware of these biases and make interpretations with an eye to their impact on the data.

Chapter 3

3   Site and Sample

The Sacred Heart Cemetery site is located at 119 John Street in Ingersoll, Ontario. Although there had been no surface indications of a cemetery or burial lot, human remains were discovered and several burials were disturbed during installation of an east-west sewer trench in January 2008. D.R. Poulton & Associates assessed the site and undertook a Stage 4 archaeological excavation. They associated the burials with the Sacred Heart Parish of the Roman Catholic Church, and specifically the former Sacred Heart Cemetery, in use from 1847-1879 (D.R. Poulton & Associates, 2008).
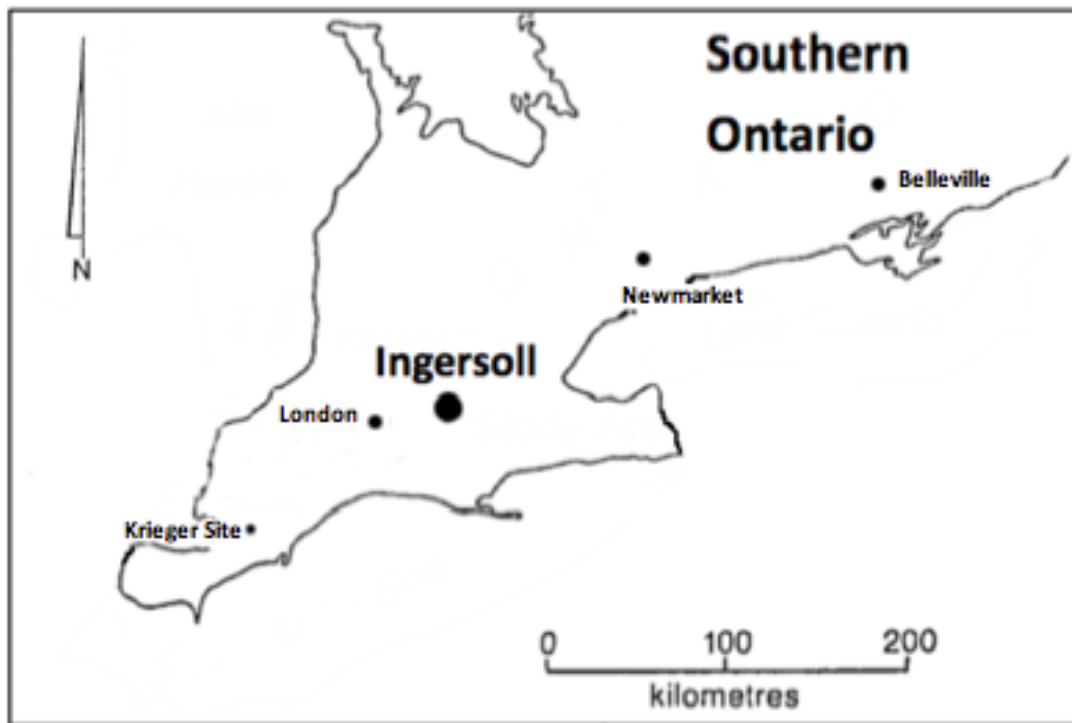
Figure 3-1 Map of Southern Ontario, showing sites mentioned in the text (after Emery & McQuillan 1988)

3.1 Sacred Heart Cemetery

The Sacred Heart congregation was established in 1838, with worship in Beachville, Ontario, 10 km southeast of Ingersoll (Sacred Heart Parish 2012) (see Figure 3-1). In 1848, a wooden church structure was erected for the congregation in Ingersoll proper. Sacred Heart was the first Catholic parish in Oxford County, fully established by 1856 (Sacred Heart Parish 2012).

There was much activity at the parish site, including the establishment of a Catholic cemetery, a school, a parish residence, and structural additions to the church itself (the building was extended and a steeple was added) (Sacred Heart Parish 2012). This church lasted until 1876. The current cathedral-style building at the corner of Thames Street North and Bell Street was completed in 1879, and dedicated August 22, 1880. The cemetery at John Street was eventually moved to a larger concession of land near Hampden Street, at the edge of Ingersoll. The expected upper and lower limit for burial activity at the John Street site begins in 1848 with the establishment of the parish, and ends in 1880[2] when that cemetery was closed.

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[2] It is unclear when exactly the cemetery was officially closed. It likely happened between 1870 and 1879, and occurred no later than 1880 (Spence, personal communication).
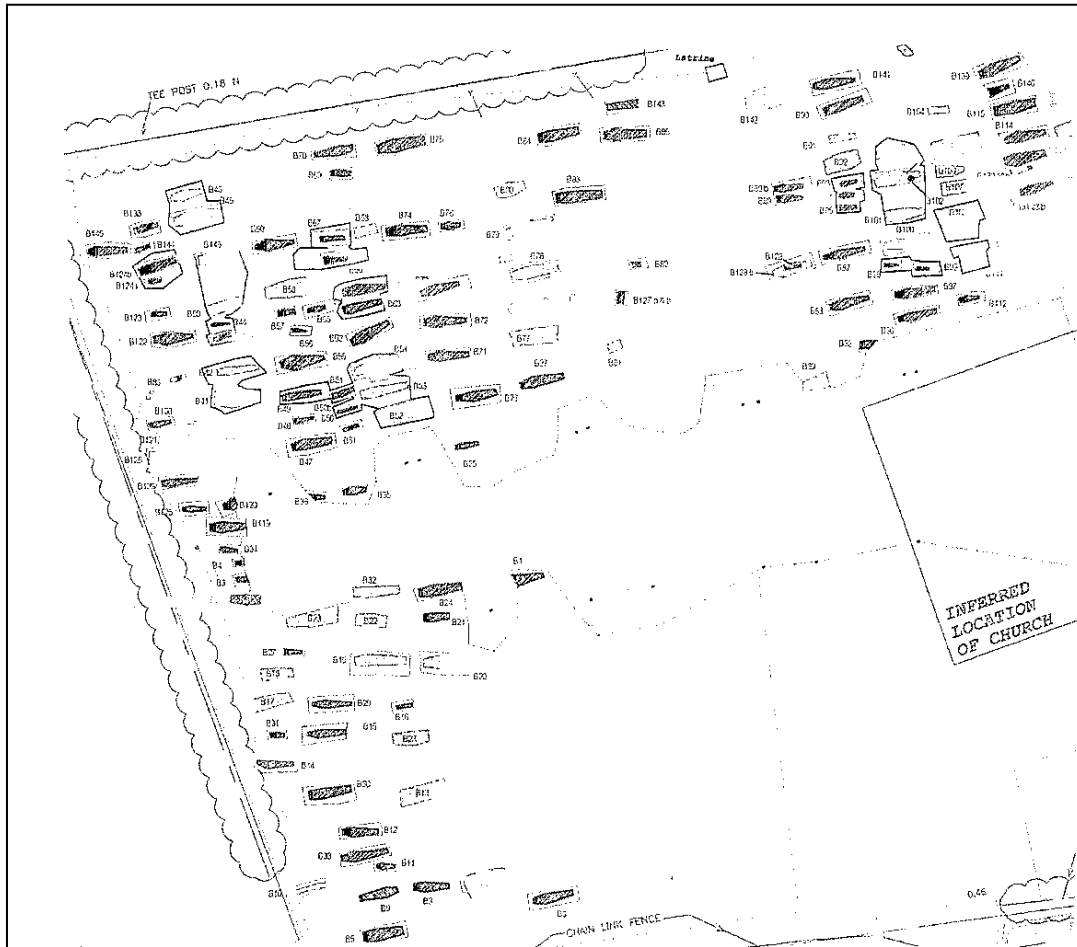
Figure 3-2 Map of Excavations at Former Sacred Heart Cemetery, 119 John Street, Ingersoll, Ontario (Spence 2010, Personal Communication)

The site has a surface area of approximately 0.28 ha, and the south and east limits were excavated (Spence 2012). There were 99 individuals recovered from 90 grave shafts, some of which were impacted by the excavation for the sewer trench, and an additional 13 burials were completely displaced by that trench (Spence 2012). The total number of individuals in the cemetery, including intact burials, exhumed burials, and individuals disturbed by the trench is at least 170, buried in 159 graves (Spence 2012). It is not known how many burials remain in the unexcavated area to the west and north, beyond the limits of the project, or how many were destroyed by construction in the intervening years (Figure 3-2).

In his age and sex assessment, Dr. Spence noted that adults who share traits and proximity do not follow a pattern of regularly alternating sex; there is no consistent burial pattern of husbands relative to wives, or of parents relative to children or extended family members. Burial is instead attributed to personal preference and "the unpredictability of death and the limitations of space" (Spence 2012:28). Most burials in the cemetery were arranged with a single body laid on its back, legs extended, with arms either laid at the side or laying on the hips or upper thighs, in the same east-west orientation common to most 19th century Christian cemeteries (Spence 2012)[3]. There were nine double burials (accommodating 18 individuals), six with coffins stacked vertically in a single plot, and three burials with individuals interred together, indicating contemporary death and burial (Spence 2012), some of which were located next to empty plots, indicating that lack of space was not a determining factor in these double burials.

3.2   Cemetery Population

The sample in this project is a subset of the sample originally taken. All identification numbers follow those used by Dr. Spence in the age and sex assessment (Appendix A; Table 3-1), with the exception of the individual referred to as "surface find," which was re-labeled "SH 300" and is identified as such in this text.

Age	Sex Unknown	Female	Male
0 foetal weeks -12 years	46	-	-
Teen	-	4	3
Adult	-	12	11

Table 3-1 Age and sex of sample, n = 76

---

[3] Most Sacred Heart burials are oriented east-west, with the head to the west and the feet to the east, according to Christian tradition, so that on Judgment Day when Christ returns, the deceased will be able to rise to their feet and face east, towards Paradise (Spence 2012; Jordan 1982, Daniell 1997; Smart 2011).

There is a fragmentary parish record of deaths associated with this cemetery population, with information regarding year of death, name and age of decedent and, in some cases, other notes or cause of death. Not all entries are complete. Furthermore, there are some burials with associated names and coffin plates that have no recorded entry in the parish registry (Spence 2012). Spence notes: the registry "is a record of burials, not deaths" (2012:70). It is also possible that the cemetery served non-parishioners, resulting in burials not included in the registry (Spence 2012). It is not known what the original extent of the cemetery was, how many other cemeteries (if any) were proximal, and whether or not there were designated areas within the cemetery for specific burial types (Spence 2012). The registry "reads like the Dublin telephone directory," and it is possible to confirm the Irish identity of many deceased members of the Sacred Heart congregation (Spence 2012). Appendix B is a photo-essay on 19th century grave markers from the Sacred Heart cemetery indicating various Irish birthplaces of members of the congregation. Ireland is the only country of origin recorded in the epitaphs.

After the completion of an age and sex assessment, permission was granted for the samples to be taken for stable isotope analysis. The skeletal material found at Sacred Heart was reinterred on October 16, 2009, at the current Sacred Heart Cemetery at the end of Hampden Street in Ingersoll, located a mere 1.5 km from its original resting place (**Figure 3-3**). The site of 119 John St. is now home to 12 townhouses as part of the Oxford County "Affordable Housing" project (Oxford County 2012).

3.3   Inter-Population Comparisons

Previous studies are useful in establishing a basis of comparison for the Sacred Heart population. The results of the stable isotope analysis of four other sites are referenced in this paper. All sites were active in the mid-19th century; two are located in Ontario (St. Thomas and Prospect Hill) and two in the United Kingdom (Lukin Street and Kilkenny Workhouse).

The St. Thomas sample comes from a 19th century Anglican cemetery population from Belleville, Ontario, active 1821-1874, located approximately 330 km northeast of Ingersoll on the north shore of Lake Ontario (Katzenberg *et al.* 2000). The Prospect Hill

population dates from 1824 to 1879, and is associated with a Methodist Cemetery in Newmarket, just south of Lake Simcoe and approximately 180 km northeast of Ingersoll (Katzenberg & Pfeiffer 1995). Prospect Hill, St. Thomas, and Sacred Heart are all located within Ontario, in regions with similar (but not identical) ecologies. Both St. Thomas and Prospect Hill are described as immigrant populations. Although there is no guarantee of cultural continuity between them, their relative proximity and location within the geo-political landscape of Upper Canada provide useful comparison. The Lukin Street cemetery in London, is associated with a Catholic Mission, and was active for a brief period in the mid-19th century (1843-1854) (Beaumont *et al*. 2013; Miles & Powers 2006) and the Kilkenny population was recovered during the excavation of the Union Workhouse in Kilkenny, Ireland, dating from 1847 to 1851 (Beaumont *et al.* 2013). Both Kilkenny and Lukin Street samples came from lower status, working class populations.

Figure 3-3 Monument to the re-interred, Sacred Heart Cemetery, Hampton Street, Ingersoll (Personal Photograph by Emily Wells)

Chapter 4

4 Ingersoll in the Nineteenth Century

Ingersoll is on the Thames River in Oxford County, approximately 30 km east of London in the southwestern peninsula of Ontario (Figure 3-1). The Thames River watershed feeds into the Great Lakes, and is located within the Carolinian Life Zone, a region with significant biological diversity and the warmest average annual temperatures in Canada (Thaler & Plowright 1973:1765). The relatively gentle climate, biodiversity, and plentiful, fertile farmland made this region a hospitable destination for migrant families seeking an agricultural lifestyle during the transcontinental diaspora of the 19th century.

4.1 History

Ingersoll owes its name to Thomas Ingersoll, an American Loyalist soldier who immigrated to Upper Canada[4] in 1793 to escape personal debts and increasing lawlessness in the United States after the Revolutionary War (Leavey 2012:29). The hamlet of Ingersoll was officially established during the 1820s, largely due to the industriousness of Ingersoll's son James, whose businesses included a sawmill, a gristmill, a store, a distillery, and an ashery (Emery 2012:35). James' sister, Laura Ingersoll Secord, achieved renown in her own right during the War of 1812 for her celebrated walk from Queenston to Beaver Dams to warn the British of an impending American attack (Morgan 1994:196). Ingersoll was incorporated as a village in 1852, and then as a town in 1865 (Emery 2012:35). The opening of the Great Western Railway in 1853 and the fertility of the soil contributed to the success of Ingersoll (Emery & McQuillan 1988:139).

In the early 19th century, Canada had an export-dependent economy, supplying British and American markets with products derived from abundant natural resources, including

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[4] Prior to 1841, Southern Ontario was known as Upper Canada, and was unofficially referred to as Upper Canada for many years afterwards.

timber, grain, and furs (Miller 1980). Ingersoll was notable as a producer of ground oats, and was the home of Robert Stuart's North Star Oatmeal Mill, the same mill that would eventually be bought by the Quaker Oats Company in 1901 (Stokes 2005:79). The establishment of a dairy factory in 1864 led to the mass-manufacture of cheese and other dairy products in Ingersoll (Bogue 1947:163). Ingersoll (and Canada) soon developed an international reputation for outstanding cheese production, and Ingersoll was the epicentre of the largest dairy-manufacturing district in western Ontario (Bogue 1947:163). The Canadian Dairymen's Association was established in Ingersoll in 1867 (Nadeau 1985:463). The oat and cheese industries kept Ingersoll gainfully employed, and provided the local population with ample food supply.

4.2   Ontario Demography in the 19th Century

Between 1851 and 1871, most Canadians lived in rural communities, with only a small percentage of the overall population living in various urban centers. In the last quarter of the century, urban centres increased in population and popularity. By the end of the century, however, the population of Canada underwent a dramatic regional shift. Approximately 43% of the country lived in urban centres by 1901, as compared to only 14% a mere 50 years previously in 1851 (Statistics Canada 2001). Just as the established port cities Toronto, Montreal, and Halifax experienced rapid growth, so too did the towns at the so-called frontier. This trend can help account for the rapid population growth that enabled Ingersoll to develop from a village to an incorporated town within the space of a decade.

The population of Ingersoll and its contiguous townships, North Oxford and West Oxford, numbered 4,462 individuals in 1852, and had nearly doubled to 8,205 people by 1901 (Emery & McQuillan 1988:137). According to the censuses of 1851[5]-1901, the population of Ingersoll nearly quadrupled between 1851-1871 before plummeting again

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[5] The Canadian census planned for 1851 was not completed until 1852. Data from this census is often attributed variously to the census of 1851 or 1852. This thesis refers to 1851.

in 1881 (Figure 4-1). By the onset of the twentieth century, the population was again growing rapidly.

There is no single cause for the steep drop in population between 1871-1881, but the prevalence of certain infectious diseases, coinciding with a decline in national fertility, and strict immigration quotas caused by frustration with poor migrants who had arrived previously, may have contributed to this decline in population.
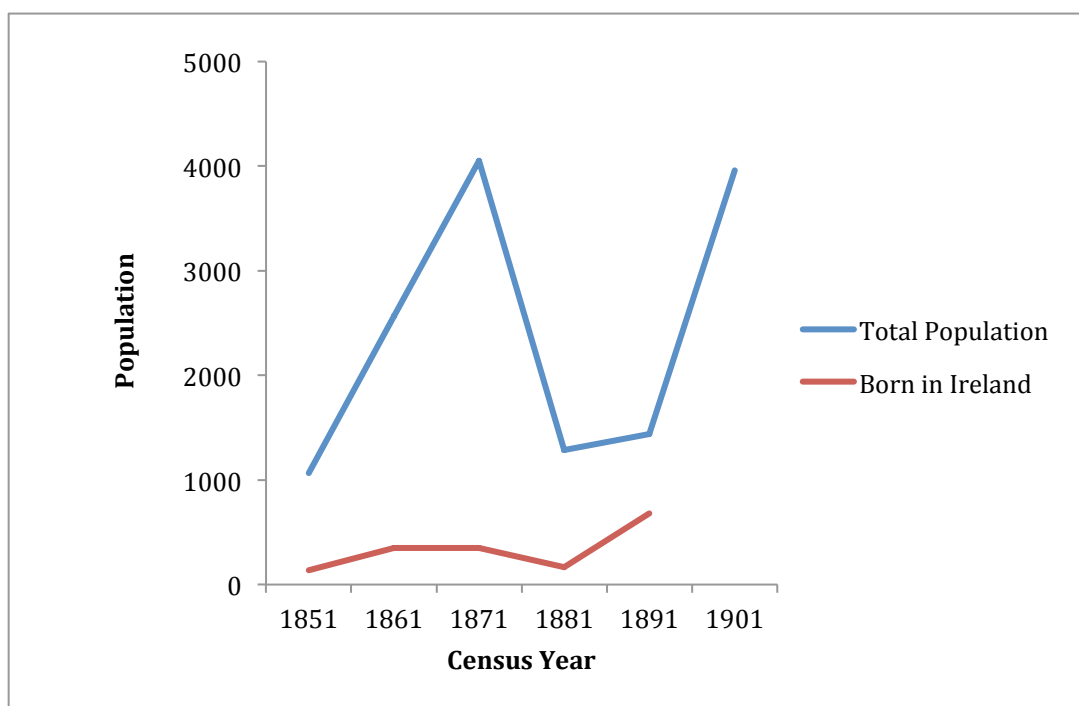
Figure 4-1 Population of Ingersoll 1851-1901 (Statistics Canada 2001)

4.2.1 Immigration

The history of Canada is that of a nation in motion. The 19th century saw an unprecedented diaspora of people across continents, and the Dominion of Canada is a microcosm of this global trend. The constant influx of immigrant settlers, the massive exports of furs, timber, and crops, and the changing borders of a nascent country all contribute to the omnipresent sense of fluidity inherent to this place and time. The allure of fertile farmland and industrial work were significant draws to Ingersoll, where the promise of land attracted several thousand immigrants. Although labour-intensive public

works were often hiring labourers, both skilled and unskilled, only the occupation of land could allow a family to escape the "transitory" lifestyle of canal or lumber camps (Houston & Smyth 1990:209).
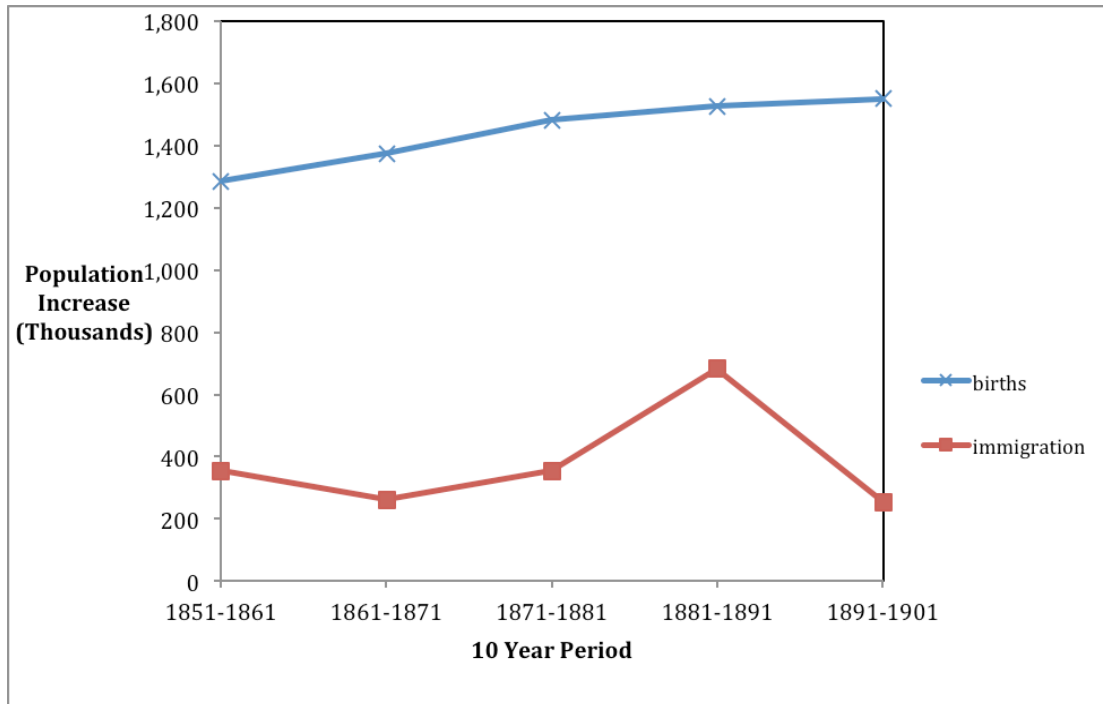
Figure 4-2 Relative Contributions of Immigration and births to Canada's Population Growth, 1851-1901 (data from Statistics Canada 2001).

Figure 4-2 is a comparison of the relative contributions of birth and immigration to overall growth in Canada's population between 1851 and 1901. Between 1851 and 1891, approximately 1,642,000 people immigrated to Canada (Statistics Canada 2001). The census is not an entirely accurate manifest of the population of Canada at that time due to the inherent limitations of accounting for sparsely populated frontier lands, and a dismissive attitude on the part of the census-takers towards certain cultural and indigenous groups with whom contact was perceived as either hostile or infrequent (Hubner 2007:198). The census does, however, provide a reliable baseline for demographic studies of urban centers of European heritage.

4.3   Irish Influence

Appendix B in this volume is a series of photographs taken at the current Sacred Heart Cemetery on Hampden Street in Ingersoll, showing headstones and grave markers dating to the last quarter of the 19th century. There are no grave markers from this period in the current Sacred Heart Cemetery that indicate origin from any country other than Ireland. No absolute association between these grave markers and the sample population of this study is possible, as it is not known how many grave markers were moved from the original John Street site, and how many of those moved survived until present day.

There is valuable demographic information in the epitaphs. The individuals to whom these grave markers are dedicated were contemporaries with many of the individuals from the John Street site, having out-lived that population by only a few years (the John Street site was in use until shortly before 1880). Furthermore, each of the grave markers in Appendix A indicates an individual or family origin in the country of Ireland. Counties of origin include: Tipperary, Dublin, Antrim, Wexford, Armagh, Waterford, Limerick, and Fermanagh (**Error! Reference source not found.)**[6]

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[6] The county of Kilkenny is not listed as a place of origin on any of the Sacred Heart epitaphs. Kilkenny is labelled here for reference in the Results and Discussion section.
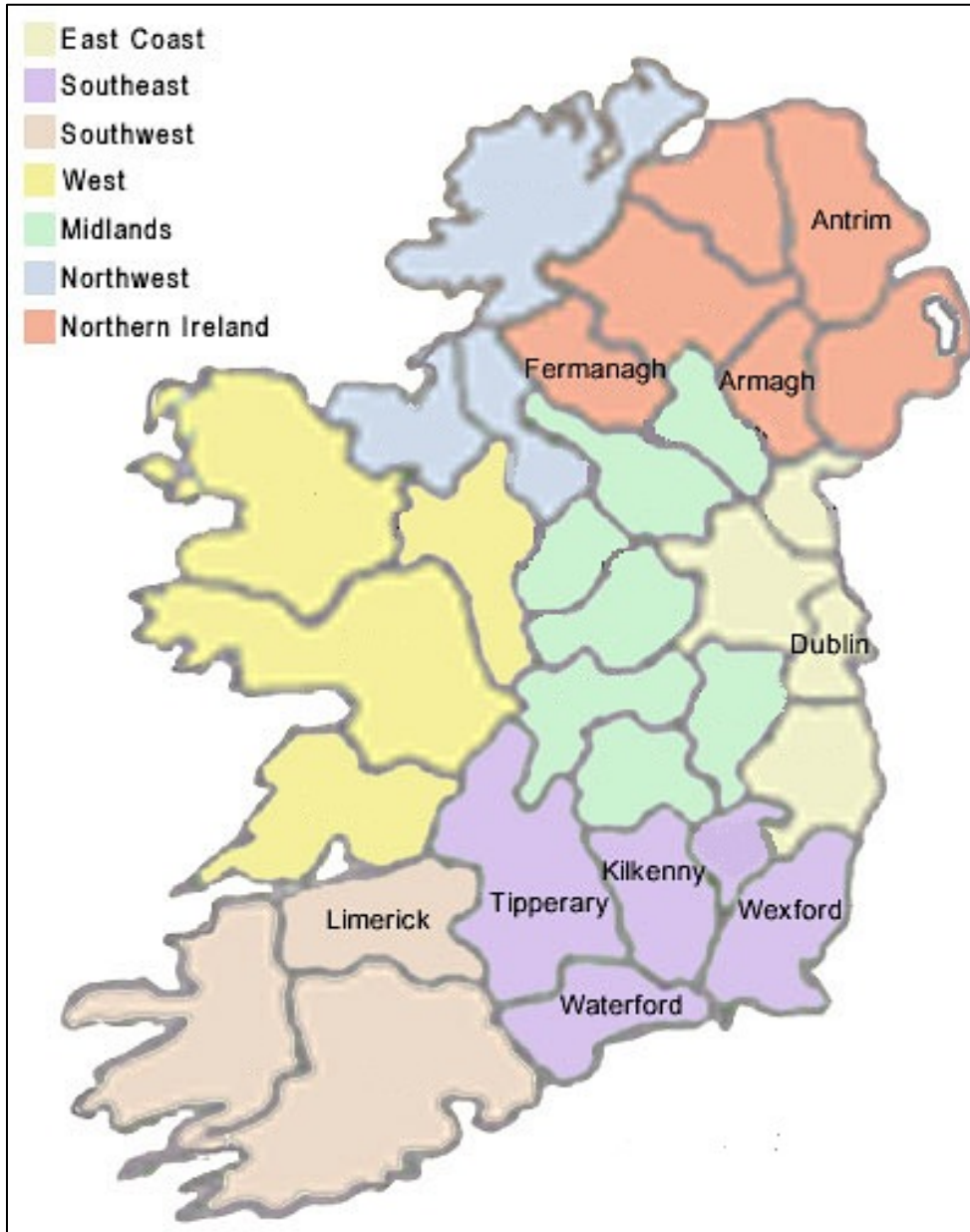
Figure 4-3 Map of Irish counties represented in epitaphs at the Sacred Heart Cemetery (after VisitIreland 2014)

Immigrants from countries in the United Kingdom represented approximately 83% of all new Canadians from 1851-1871, according to census reports (Brunger 1990:251). During this period in Ontario, 82% of the population claimed British heritage (Brunger 1990:251). The settlement and concentration of Irish Catholics specifically in Ontario as of 1871, is shown below in **Error! Reference source not found.**.
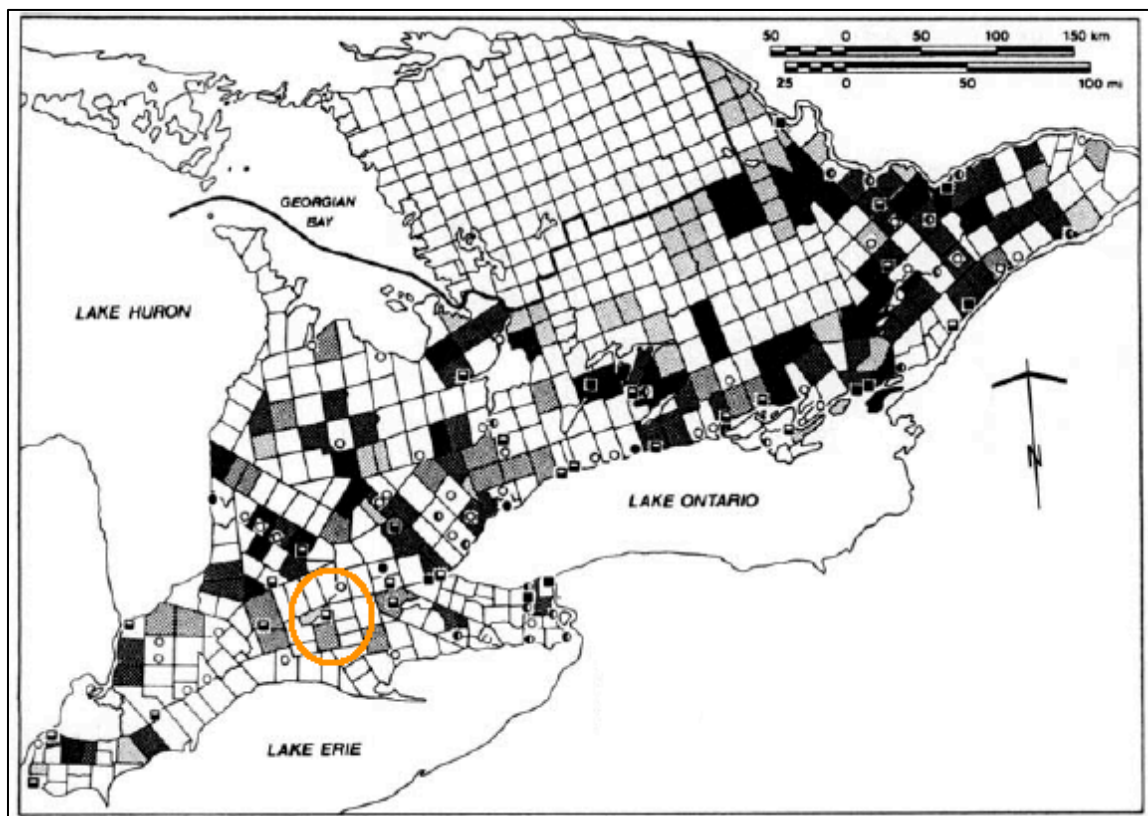
Figure 4-4 Irish Roman Catholic settlement of Ontario, 1871. (after Brunger 1990:256). Orange circle indicates Oxford County.

Although Roman Catholic Irish were more prominent in the eastern part of the province, areas in southwestern Ontario increasingly became a destination of choice. The map above indicates Irish ancestry by sub-district. Brunger (1990) notes that the heavy concentration of Irish Catholics in the areas surrounding Ottawa and Kingston, with less frequent settlement in the "frontier" southwestern part of the province and a total absence in the northerly region, reflects a later emigration from the British Isles.

4.3.1 The Great Famine

Many Irish immigrants to Canada in the mid-19th century were participants in the sweeping "mass exodus from a largely rural society", caused by the devastating potato famine of 1845-1852 (Houston & Smyth 1990:58). Potato blight, a crop disease, caused

countless fields to yield nothing but rotten roots (Fraser 2003)[7]. Many fled to Canada, a country that sought able bodies to till soil, labour on civic projects, and populate townships, and preferably bodies who were rich and Protestant. British North America was largely Protestant, and their historical antipathy towards Roman Catholics obliged the (mainly Catholic) famine-itinerant to either settle in eastern Canada, or to move west and occupy the "hinterland areas" in western Ontario (See 2000:430). In 1847, an estimated 90,000 Roman Catholic Irish immigrants arrived in Ontario (See 2000:429).

Table 4-1 documents the wealth and class of immigrants from Antrim County and is used as a likely approximation of the class composition of immigrants to Oxford County:

Amount Carried (£)	0	1-10	10-20	20-50	50-100	100+	Total
Number of Households	49	277	26	16	6	4	378

Table 4-1 Wealth carried by emigrants from Antrim County, 1835-1839 (Houston & Smyth 1990:58)[8].

Of the 378 families surveyed, 328 left Ireland with 10£ or less to their name after the purchase of trans-Atlantic passage (Houston & Smyth 1990:58). The price of transportation from Montreal to Kingston, from whence landed immigrants could travel by lake steamer to a permanent settlement, fluctuated slightly during the famine years, but was approximately 9 shillings[9] (Morehouse 1928). The Immigrant Tax of 5 shillings per person was suspended at the beginning of the 1840s (Morehouse 1928).

The abject poverty exhibited by many of these new arrivals to Canada discomfited the established class system in Ontario. Although many Canadians were initially sympathetic

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[7] Fraser (2003) provides a detailed account of the causes and consequences of the Great Famine.

[8] £1 in 1830 is approximately equal to $84 USD, currency conversion courtesy of The National Archives, the official government archive of the United Kingdom.

[9] Before 1971, there were 20 shillings in every pound (£). One shilling in 1830 is equal to $4.20 USD (2005).

to the droves of famine-stricken families, the unprecedented influx of "labouring paupers," as some immigration agents would call the famine poor, strained resources, the job market, and eventually the sympathies of the population (Bleasdale 1981). Contemporary historical documents show that the Protestant majority in Ontario feared the "Catholic ascendancy" supposedly looming after waves of famine migrants and the construction of Roman Catholic churches and monuments in areas settled by the famine migrants (See 2000:437). Discontent was also stirred by the apparent "dumping of dependents" (Morehouse 1928) by the British government on the Canadian settlements.

4.4 Health and Wellness

The Canadian tuberculosis epidemic was introduced by European immigrants during the 18th century, and persisted for decades afterwards (Grzybowski & Allen, 1999:1026). Tuberculosis had devastating effects on the population, indiscriminately affecting young and old. Despite the virulence of this infection, incidence of tuberculosis eventually decreased after an initial peak, even without medical intervention (Grzybowski & Allen, 1999:1027). Two individuals in the Sacred Heart population have non-diagnostic rib lesions (Spence 2012), possibly associated with tuberculosis, and it is possible that other members of the population contracted the disease but succumbed too quickly to show signs of illness and recovery on the skeleton.

According to data collected from the daybooks of Dr. James Miles Langstaff, who practiced in Richmond Hill, Ontario, from 1849-1889, stillbirths were the most frequent cause of death in every decade of his practice, accounting for 20-25% of mortalities (Duffin 1997:204). Among the Sacred Heart population, 16% of the sample is stillborn, skeletally aged below 0 years (n=12).

Malaria was also prevalent in Ontario during the early 19th century (McLintock & Iverson 1975:695). Cholera, a bacterial disease, spread through tainted water throughout the newly urbanized centres. Recognized cholera outbreaks occurred in Canada in 1832, 1834, 1849, and 1854, with minor outbreaks following, and had devastating effects on the population (Bilson 1977). Although it is not possible to say whether any individuals in

the Sacred Heart population suffered from malaria or cholera based on the available skeletal evidence, these conditions were quite likely present in the area.

Spence found cribra orbitalia, a skeletal reaction to anemia, in the population, with highest prevalence (31.3%) among young children and declining rates in the older youths and adults (Spence 2012). Mastoiditis was also a concern; the infection of the middle ear would often spread unchecked into the mastoid process in the time before antibiotic intervention. There are three individuals with skeletal lesions associated with mastoiditis in the Sacred Heart population.

4.5   Infant Feeding Policy

Breastfeeding infants are essentially carnivorous; their food source is enriched by one trophic level relative to their mothers, because their mothers are their food source (Katzenberg *et al.* 1996). Infants and young children whose bone collagen $\delta^{15}N$ values are up to +2.4‰ higher relative to the rest of the population are likely to have been breastfed (Fogel *et al.* 1989). There is also a growth effect associated with the $\delta^{15}N$ bone collagen values of children, but it is "very minor" when compared to the trophic level effect found in nursing infants (Waters-Rist & Katzenberg 2010:187). A similar positive trend is observed in the $\delta^{15}N$ values of tooth collagen relative to bone collagen from the same individual, as well as between deciduous and permanent teeth from the same individual, assuming that the individual lived beyond childhood, due to the different time periods when the tissues were forming.

Infants, more than any other cross-section of the population, are subject to mores, customs, and the ideology of nutrition and weaning behaviour (Dupras & Tocheri 2007). Because they are helpless, their agency in selection of food or lifestyle is muted. Therefore an analysis of data derived from infants and young children must be considered as not only individual consumption profiles but also as a reflection of the agency of adults and caregivers within the community. Dupras and Tocheri also note that, in a single population, there could be utterly distinct "consumer profiles" for the same age category and class: one representing healthy infants, who likely survived the weaning process, and one for the moribund infants who, since they did not survive, were likely to

have incurred debilitating childhood illnesses (2007:64). It is, therefore, important to keep in mind the tenets of the osteological paradox outlined above. The effect of an infant mortality bias on the results must be considered.

There are many tracts and medical edicts that dictate proper procedure for breastfeeding children and are contemporary with the Sacred Heart population. Dr. L. Emmett Holt, a prominent American paediatrician from the late 19th century, declared that the best infant food was mother's milk, provided four to five times daily (Holt 1894). For the nursing mother, Dr. Holt recommended a diet of eggs, cereals, vegetables, and soup, and avoidance of "sour fruits, salads, pastry, and most desserts" (Holt 1894). Holt also noted that the "nervous condition" of the mother affected the quality of the breast milk much more than the dietary intake; mothers were warned of being too worried, fatigued, or anxious, and were cautioned to avoid extremes of passion, grief, or fright (Holt 1894).

The period of weaning is dangerous for the infant because the child is no longer receiving passive immunity from their mother's breast milk, and the immune system of the infant faces new challenges from microbial attacks. Dr. Holt argued that the ideal age to begin weaning a child from breastmilk was in the eighth or ninth month of life, and the ideal food with which to start weaning is watered down cow's milk (1894). Dr. Job Lewis Smith, another prominent paediatrician, recommended that weaning begin a few months later, between the ages of ten months and one year, although it was agreed that mothers ought not to start weaning before eight months (Smith 1890; Holt 1894).

To counteract the acidity of cow's milk, Holt recommended the addition of lime-water or baking soda, with sugar dissolved into boiling water and mixed into the milk to make it as sweet as the breast milk. Interestingly, Holt warned against the use of cane sugar to sweeten the milk, as it could "ferment in the stomach and cause colic" (Holt 2005)[10]. It is not likely that these medical edicts would be available to members of all social classes, and higher rates of illiteracy would have prevented many families from reading such

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[10] Cane sugar is one of the few C_4 plants likely to be present in the 19th century North American food web, other than maize. Cane sugar contributed to the Atlantic trade network as a principal export of British colonies in the Caribbean.

advice. Nevertheless, Holt's warning against its use as a weaning food reinforces the notion that maize was the most important C_4 food in the contemporary diet, and likely the source behind any relative positivity in $\delta^{13}C$ values.

Dr. Holt prescribed a very strict dietary regime for young children. While he strongly cautions against giving children maize served as a raw vegetable, he recommended that cornstarch, corn flour, and corn bread all be incorporated into the diet of a developing child (Holt 2005). If parents were following these edicts, then it is likely that C_4 plants will play a significant role in the $\delta^{13}C$ values of young children.

The risks inherent in the cessation of breastfeeding and subsequent decline in the infant's immunity include severe indigestion and a severe risk of rickets and scurvy. Sudden weaning could cause diarrhoea that was often fatal (Smith 1890). The "romantic spirit" of the 19th century encouraged a belief that food from "Nature" was the best for encouraging healthy growth in young children (Levenstein 1983). By the end of the century, paediatricians were very sceptical of condensed milk as a replacement for mother's milk in infant diets, and (incorrectly) associated artificial feeding with rickets and scurvy infants (Levenstein 1983). "Artificially-fed" infants were noted to "do better" in the country, and developed fewer complications from the cessation of breast-feeding than their urban counterparts (Smith 1890).

In reality, the correlation between artificially-fed infants and the development of certain pathological conditions could be attributed to socio-economic status. Formula was an inexpensive alternative to fresh milk, came already sweetened, and did not require cold storage. In addition to the low price, formula would have been appealing for lower-income families because it freed the mother from being solely responsible for feeding the infant. Unfortunately, formula could easily be over-diluted, so that the inherent nutritional value would be compromised and could result in the "slow starvation" of the infant (Levenstein 1983). Furthermore, the relative shortage of servants and wet-nurses in North American as compared to Europe meant that only the wealthiest families could afford a nurse dedicated to providing fresh breast milk for the infant. Lower- and middle-class women who were expected to contribute financially to the homestead were more

likely to wean their infants onto artificial diets earlier to enable a prompt return to work without the pressures of caring for the infant (Levenstein 1983).

4.6   Birth Spacing

The latter half of the 19th century saw a decrease in the annual average number of children born in Ontario and Canada (Table 4-2). In 1851, the Canadian birth rate registered at 45 births per 1000 people (Gee 1979). By 1871, that number had increased to 189 births per 1000 people, but between 1871 and 1891, the birth rate in Canada decreased by 31%, possibly due to the limited number of married females in the population and lower marriage rates precipitating a trend in lower national fertility (Gee 1979)[11]. Within the English-Canadian community, there were immense societal pressures to have children, early and often, with the ultimate goal of out-numbering all other cultural groups in the country (McLaren 1978). The "revanche des berceaux" (revenge of the cradle), the phenomenon of consistently high birth rates in Quebec, and the fertility of the landed Irish immigrants contributed to an English-Canadian paranoia of being "outnumbered," and much of the propaganda and medical literature from the time reflects this attitude, wherein large family size is encouraged, and women were dissuaded from leaving the home for the workplace. The birth rate in Ontario nevertheless continued to decline in the latter half of the century (Table 4-2)

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[11] Note that census data and parish registers are fallible; extra-marital births are often overlooked in this context (Ward 1981).

Year	Ontario	Canada
1871	191	189
1881	149	160
1891	131	144
1901	108	145

Table 4-2 Mean annual number of births in Ontario and Canada (per 1000 women, aged 15-49)[12]

Women who marry but do not have children are criticized for engaging in "a life of legalized prostitution" in the popular book *What a Young Man Ought to Know* (Stall, 1897, quoted in McLaren 1978). This intense societal pressure to have children combined with the abundance of weaning foods and artificial substitutes for breast milk contributed to relatively short birth spacing in the population. On the subject of contraception, the Canadian Criminal Code of 1892 was quite clear:

> Everyone is guilty of an indictable offense and liable to two years' imprisonment who knowingly, without lawful excuse or justification, offers to sell, advertises, publishes an advertisement of, or has for sale or disposal any medicine, drug, or article intended or represented as a means of preventing conception or causing abortion. (McLaren 1978)

The revelations in historical sources of contemporary attitudes towards birth control, the "fertility of the Irish people," and a medically proscribed weaning age between eight months and one year of age, contribute to the likelihood that the Sacred Heart cemetery population reflects a community with short spaces between births and a high number of children per household.

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[12] In 1871, the number of births per 1000 people in Ontario exceeded the overall Canadian rate due to low birth rates in other provinces.

Immigration to 19th century Canada was sex-selective with a preference for men, and the national ratio of males to females consequently became skewed, resulting in a situation with favourable marriage opportunities for women (Gee 1979). This imbalance was addressed in the late 19th century with an "aggressive overseas recruitment campaign" from the Dominion government specifically targeting European women (Gee 1979.). Domestic workers were particularly desirable, and British women for "single male farmers" in the western provinces were the most highly sought after (Armacost 1995).

Chapter 5

5 Food web

The history of industry in Ingersoll is indicative of certain consumption habits in its population. It is likely that many in the area relied upon agricultural resources from the surrounding region for the food consumed at daily meals. It is known that Ingersoll was particularly involved in the mass production of cheese and oats, so it is important to consider these two foods as significant dietary contributors in the isotopic composition of the population.

5.1 Diet in Ontario

In Ontario[13] at this time, an average of three meals was served daily, and most meals were prepared by being boiled or fried (Katzenberg *et al.* 2000). Many homesteads on the frontier were limited in terms of kitchen supplies; a frying pan had to be versatile, and used indiscriminately to prepare any meal: "the frying pan… not only supplies successions of savoury pork, but also of bread or paste cakes, not less enticing from the oily drippings of the meat with which they are fried" (Radcliff 1953:15 in Kenyon & Kenyon 1992). Brown (1851) describes the table-setting at a boarding house:

> Say seven or eight in the morning for breakfast; twelve, one, or two for dinner; and six or seven for tea, or supper, as it is here called. Breakfast commonly consists, at even the most indifferent tables, of various meats, such as steaks, chops, ham and eggs, or bacon, with an abundance of wheaten bread, baked or roasted potatoes, and coffee or tea. Abundance of butcher-meat at dinner again, soup now and then, poultry on special occasions, and almost, if not always, every day a dessert of pie or pudding, closes the substantial meal. Many families serve up liberally preserved apples, and also tea or coffee to dinner. To those exercised in the open air, butcher-meat is served up again at the seven o'clock supper, with abundance of preserves of apples, plums, peaches, or cranberries, with coffee or tea.

(Brown 1851:369, in Kenyon & Kenyon 1992)

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[13] Katzenberg *et al.* (2000) did not refer to Ingersoll specifically in their study.

While not all tables "groaned beneath the weight of a profusion of sweetmeats and fine fruits," (Talbot 1824:II:9-11 in Kenyon & Kenyon 1992), there was no shortage of food in the settled areas of Ontario[14]. Not all households could afford such extravagant consumption, however the above description provides a good "upper-limit" description of foodstuffs likely to be consumed in Ontario during the latter 19th century. Ontario meals differed in two significant ways from the English: the consumption of meat at all three meals was common in Ontario, as was the serving of tea at breakfast, as opposed to only at tea-time (Kenyon & Kenyon 1992).

Sheep, pig, and cattle played an important role in Ontario agriculture, and so it would be expected to see these animals represented in the diet of a population depending on household domestic animals and farms local to Ingersoll. For landed farmers from the British Isles in Ontario, pork became a staple, while sheep, although ancestrally significant, required too much cleared acreage for grazing to be economically sustainable (Ferris & Kenyon 1983). Farm animals were provided with a diet of mainly C_3 plants, such as wheat and oats, although maize would be supplemented when other crops were unavailable, and pigs were often fed on kitchen waste from the farm (Karsten 1998). "Occasions of animal trespass" were encountered often in the agricultural community. Stray livestock searching for orchard fruit and grazing in a neighbour's crop of wheat or maize often embittered the relationships between neighbouring farms and provided ample employment for fence builders (Karsten 1998).

Potatoes, wheat flour, salted pork, and tea were all staples of the Ontario diet, and could be stored for a long time before spoiling (Kenyon & Kenyon 1992). In 1861, the average Ontario farmstead had at least one acre of land dedicated to potatoes (Kenyon & Kenyon 1992). Domestic diet could nevertheless be quite diverse, and animal by-products such as cheese, eggs, milk, and butter were often consumed (Kenyon & Kenyon 1992). Deer, turkey, and other products of the Canadian forest often supplemented diet (Kenyon & Kenyon 1992).

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[14] Good things grow-oh-oh in On-tar-i-o!

Chesshyre (1864) lists the recommended provisions consumed by two people during the course of a year's settlement in Canada, which served as a budget to help manage the expectations of an emigrating couple. They are presented in Figure 5-1 using weight conversions from Kenyon & Kenyon (1992):
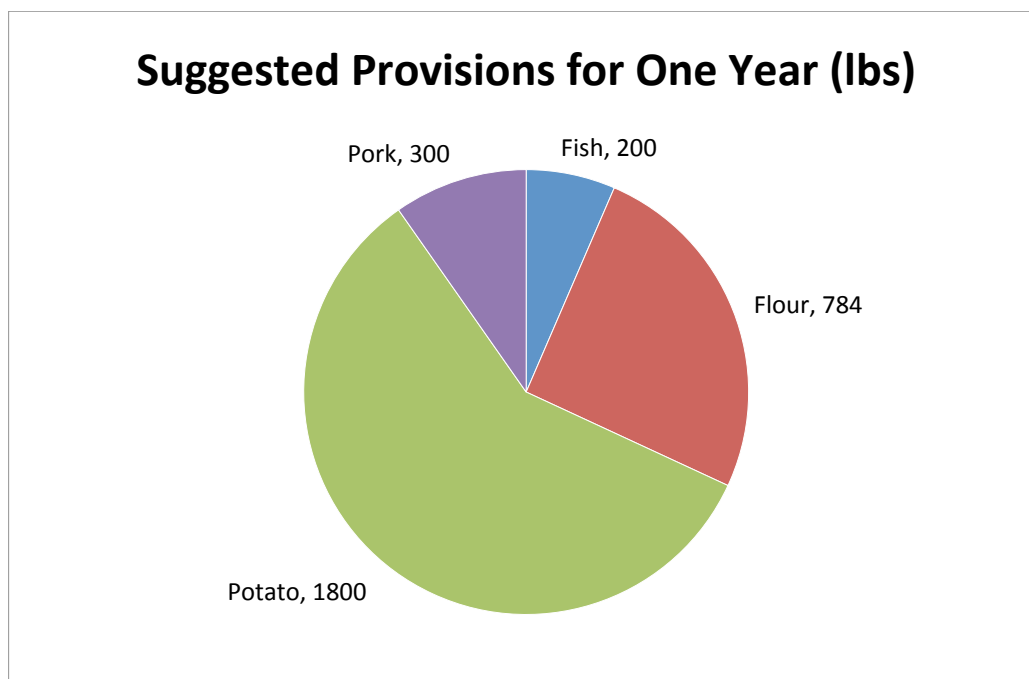
Figure 5-1 Suggested provisions for one couple for one year (Chesshyre 1864; Kenyon & Kenyon 1992).

5.1.1 δ^{13}C and δ^{15}N Values of Dietary Staples

Abonyi (1993) analyzed the isotopic composition of modern organically grown plants and ingredients from the Belleville area (where possible) to recreate a contemporary 19th century food web. Pumpkin cake, shortbread, cornbread, and whole wheat bread were all sampled in this study, as well as certain common beef stew ingredients. Abonyi also found that heating has a small effect on the δ^{13}C values of the stew ingredients, with changes in isotopic composition ranging from − 1.2 to + 1.0 ‰ relative to the raw food, and that the process of baking caused the original δ^{13}C values to decrease from +0.3 to +1.1 ‰ (Abonyi 1993; Katzenberg *et al.* 2000) (Table 5-1).

Baked Goods	Raw	Cooked	Δ (raw – cooked)
Pumpkin Cake	−17.4	−18.5	+1.1
Shortbread	−19.5	−19.8	+0.3
Cornbread	−13.6	−14.3	+0.7
Whole Wheat Bread	−23.0	−23.6	+0.6
Beef Stew Ingredients	Raw	Cooked	Δ (raw – cooked)
Carrot	−28.9	−27.7	−1.2
Barley	−25.6	−26.6	+1.0
Potato	−26.6	−27.6	+1.0
Turnip	−27.0	−26.9	−0.1
Onion	−27.1	−27.5	+0.4
Beef	−24.3	−24.4	+0.2

Table 5-1 The δ^{13}C values of modern ingredients used in popular 19th century recipes (Abonyi 1993; Katzenberg *et al.* 2000)

The use of baking powder (sodium bicarbonate) and activated yeast in recipes results in an isotopically lighter product, due to the release of CO_2 gas when wet and dry ingredients are combined (Katzenberg *et al.* 2000).

5.2 Regional Food Web
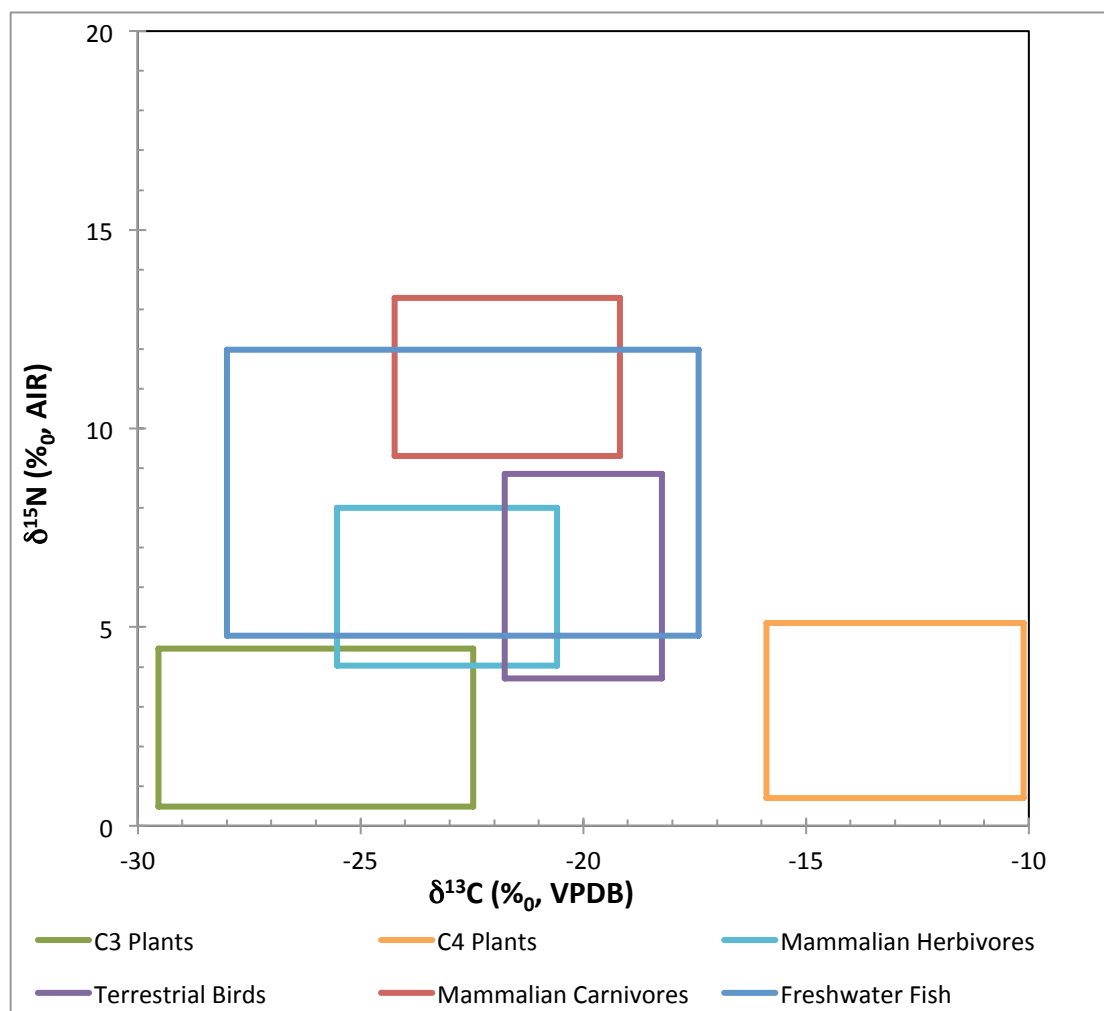
Figure 5-2 Regional food web (after Watts *et al.* 2011)

Ingersoll is located in the region archaeologically known as the home of the Western Basin peoples, an area that spans from southern Ontario to northern Ohio. Watts et al. (2011) created a nitrogen and carbon isotopic model, or food web, for the plants and animals indigenous to southern Ontario prior to the 15th century as part of their analysis of the Krieger site[15]. A version of this food web is reproduced above (Figure 5-2).

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[15] The Krieger site is noted on the map in Figure 3-1

The C$_4$ plant category indicates maize consumption (Tieszen *et al.* 1993; Jahren *et al.* 2006). C$_3$ plants have a range in δ^{15}N values between +2 and +6 ‰ (Watts *et al.* 2011). Modern and archaeological plants samples were used and referenced by Watts *et al.* (Lasa *et al.* 2011; Piasentier *et al.* 2003; Szpak *et al.* 2012; Tieszen & Fagre 1993). For the faunal sections, Watts *et al.* (2011) used data from a broad cross-section of Ontario fauna from previous studies including dog (Katzenberg 2006), bear, raccoon, deer (Katzenberg 1989; Katzenberg 2006; van der Merwe *et al.* 2003), goose, and grouse (Katzenberg 2006). Freshwater fish species sampled include eel, bass, salmon, catfish, sunfish, pike, trout, and pickerel, among others (Katzenberg 1989; van der Merwe *et al.* 2003; van der Zanden & Rasmussen 1996).

5.2.1 Maize

Corn flour from the maize plant is expected to be the most significant source of C$_4$ plants in the Sacred Heart diet. The production of maple sugar from the abundant maple trees in Ontario and Quebec, and the sugar beet industry in Quebec, mitigated Ontario's reliance on cane sugar derived from a Caribbean C$_4$ plant, unlike in New England and Europe where the cane sugar was more available through trade with the Caribbean (Galloway 1989:5). It is highly likely that the animals at the base of the Sacred Heart food chain were at least partially fed with maize, and would therefore have δ^{13}C collagen values that are positive relative to animals raised where maize agriculture is not common.

Kenyon & Kenyon's anthology of Ontario meals references "Indian Corn" several times, often in relation to hardship diets. One account tells of a man who, in a time of desperately low food stocks, was reduced to begging among neighbours for flour and could find only corn-meal, until at last he was able to secure "only enough for the mother of the babe" (Smith 1923 in Kenyon & Kenyon 1992). The following assessment of so-called "Indian corn" is an uncommonly positive one:

> It [maize] is of great use to eat, when green, either boiled or roasted; when ripe, the meal, mixed with half wheaten flour, makes very good bread. In all new settlements it is made into cakes, and is almost the only bread made use of. It fattens cattle, hogs, and poultry, and is also given to horses; when it has been prepared with lye, which takes off the rind, it is very good in soup.
> (Grece 1819, in Kenyon & Kenyon 1992)

Other accounts of maize are not so flattering, and indicate that it was used initially as a last resort in baking and food preparation. "Burnt Indian corn" was used to brew coffee by one settling family when provisions were low, and this same author noted with desperation that they "[had] literally used plain bran made into cakes, and used Indian corn boiled, when we could not procure flour" (Hall 1829:166-67 in Kenyon & Kenyon 1992).

Although maize would certainly not have been thought of as a staple, its role as a substitute during times of shortage, as well as its use as flour in cakes and its significant use in animal feed in Ontario will result in more positive dietary $\delta^{13}C$ values in the population relative to those individuals who originated in an area where the crop was not so ubiquitous in the base of the food chain.

5.3 Irish Diet

The carbon and nitrogen isotopic compositions of the Sacred Heart population are contrasted here with those of contemporaneous diets in Ireland. Potatoes were a staple of Irish diet, as the tuber is relatively high in calories, protein, and vitamin C (Beaumont *et al.* 2012; Clarkson & Crawford 2001). There is little variation in Irish diet before the Famine of 1845-1847: daily sustenance consisted of about 6 kg of potatoes per day, and could be supplemented by oatmeal, dairy, eggs and, in coastal populations, fish (O'Neill 1976; Litton 1994; and Clarkson and Crawford 2001, in Beaumont *et al.* 2012). However, dietary supplementation was not always possible because many people in Ireland were rural farmers, allotted small plots of land for growing their own potatoes while tending to the fields of wealthier landlords. This pattern of employment meant that farmers were rented land instead of given wages. When their crops failed there was no cash on hand to supplement the diet (Beaumont *et al.* 2012). This limited diet was interrupted by the Famine, when for a two-year period, maize was imported from the United States as a form of relief, distributed at the workhouses and at soup kitchens, or exchanged for labour in "cash-for-work schemes" (O'Gráda 1999; O'Neill 1976).

In an isotopic study that contrasts the Lukin Street Cemetery in London, England, known to have received many Famine migrants, with the cemetery at the Kilkenny Union

Workhouse in Ireland, both of which were active for a relatively short time frame coinciding with the Famine, Beaumont *et al.* (2012) hypothesized possible dietary regimes. These included an English diet of meat, fish and C_3 plants, a limited, a pre-Famine Irish diet ("which may resemble a vegetarian diet"), and a stressed diet where minimal calories were consumed. Their expectations can be transposed to the Sacred Heart population, with a few modifications:

1. A diet high in dairy, meat, fish, C_3 plants and maize, eaten by Ingersoll residents.

2. The restricted diet of rural Irish poor, high in C_3 plants but low in animal protein. No significant C_4 contribution is observable.

3. A more wealthy diet of C_3 plants mixed with fish and animal protein consumed by wealthier Ingersoll residents, still notable for a lack of C_4 influence.

5.4　Fertilizer

Prior to the discovery of ammonia synthesis by Fritz Haber and the introduction of synthetic fertilizers in the early twentieth century (Prasad 2005), most crops were organically grown with the use of animal-derived fertilizers (White 1970). The frontiers of the Saint Lawrence drainage basin provided Canada with ample material to produce a plant-based organic fertilizer called pot ash, or potash[16] (Miller 1980:187). Potash (K_2O) is an alkali salt, which occurs naturally in some geological salt deposits, or is derived from leaching wood ashes with water to precipitate potassium lye, a material useful in the production of glass, textiles, soap, and in the fertilization of crops (Miller 1980). Potash fertilizers are not a significant source of nitrogen. The trade in potash, the raw materials for which were abundant around European settlements due to widespread deforestation when clearing land for agriculture, was one of the earliest "frontier enterprises" in British North America (Miller 1980). Canadian potash was a lucrative and sought-after product in Europe for much of the 19th century; potash trade flourished until the 1870s, when

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[16] "Pot ash" is the label originally applied to the alkaline commodity derived from leaching wood ashes; "potash" is a generic term for the bulk, potassium-based raw material. The two terms were used interchangeably by the 1850s (Miller 1980).

Germany began to export potash salts mined on the continent, and declined further with the introduction of synthetic fertilizers (Miller 1980).

Fertilizer derived from animal waste and by-products (e.g., fish meal) may also have been used by farmers in Ontario to increase the yield of their crops. Companion planting is also an organic method of soil fertilization, and involves pairing a crop such as maize with a nitrogen-fixing plant, such as beans. Such polycropping was a well-established practice in North America before the Europeans arrived on the continent. The earliest evidence for the crop grouping known as the "three sisters" (maize, beans, and squash) dates to 667 ± 30 B.P (Hart 1999). Polycropping a cereal with a nitrogen-fixing legume results in "significantly higher" nitrogen uptake, and the legumes themselves also fix significantly higher amounts of nitrogen when intercropped (Patra *et al.* 1986:168). Treating agricultural soil with manure or fishmeal increases the $\delta^{15}N$ values of grain relative to crops treated with chemical fertilizer (Choi *et al.* 2006), fishmeal more so due to its higher $\delta^{15}N$ values resulting from the increased number of trophic levels in a marine ecosystem. Synthetic fertilizers, in contrast, have little effect on crop $\delta^{15}N$ values, (with a change close to 0‰) (Nardoto *et al.* 2006).

Chapter 6

6   Methodology

6.1   Sample Preparation

Bone collagen and tooth dentin were used in this analysis. Prior to preparation and treatment, all samples were weighed and measured in length and photographed for future reference. Cortical bone is the preferred tissue for isotopic analysis, as it is less prone to post-mortem or diagenetic alteration than the spongy trabecular bone. The bone samples were brushed clean, and then gently scraped to remove all trabecular material. For teeth, dentin was separated from the tooth and collected.

6.2   Collagen Extraction

After being cleaned, the samples were crushed with a mortar and pestle before being sieved through a 0.85 mm mesh. The crushed material was collected and weighed in amounts of approximately 500 mg for bone, and between 100 and 300 mg for dentin.

Lipids were extracted from the bone or tooth matrix using a series of three separate rinses in a solution of 2:1 chloroform:methanol, with each rinse lasting 15 minutes (after Bligh and Dyer 1959).

Collagen was then extracted in accordance with the standard protocols of the Laboratory for Stable Isotope Science at the University of Western Ontario, by means of a modified Longin method (Brown *et al.* 1988; Szpak 2011), which included demineralization over a longer period of time in a weak hydrochloric acid solution that dissolves the inorganic phase of the bone. The first acid rinse used 0.25 M hydrochloric acid. All subsequent rinses used 0.5 M hydrochloric acid. Between rinses, the samples were centrifuged. The rinses continued until the inorganic component of the sample had completely demineralised, which is indicated by the appearance of translucent collagen "ghosts," or psuedomorphs that offer no resistance when pressed with a glass pipette.

The samples were then treated with sodium hydroxide in order to remove fulvic and humic acids, before being given a final rinse of water, leaving the samples to sit in a weakly acidic solution (pH = 3). When heated to approximately 90°C, the samples gelatinize, becoming water-soluble. The collagen was then extracted by suctioning the liquid into a small vial that was heated until the water evaporated and only the collagen remained.

6.3   Preservation Criteria

Post-mortem alteration, or diagenetic processes, can compromise the chemical and/or structural integrity of archaeological tissues by addition, exchange, or loss of substance in the post-depositional environment. The quality of the dietary, mobility, and lifestyle reconstructions of the Sacred Heart material can only be assured if the isotopic composition of the samples themselves is well preserved. The degree to which the $\delta^{13}C$ and $\delta^{15}N$ values of the samples have been affected by diagenetic changes is assessed using three preservation criteria. These include collagen yield, the C/N ratio, and the minimum percentages of carbon and nitrogen. The data for these criteria for each sample are recorded in Appendix A.

6.3.1 Collagen Yield

Collagen yield is expressed as a weight percentage (mg/g), and is calculated using the following formula:

$$\% \text{ Yield} = \frac{(\text{Vial} + \text{Collagen Weight} - \text{Vial Weight})}{\text{Dry Weight}} \times 100$$

Fresh bone is approximately 22% collagen by weight but archaeological samples are expected to contain considerably less, as the amount of collagen drops steadily in the post-depositional environment (van Klinken 1999). As bone degrades, the absolute abundance of collagen decreases, and the remaining collagen becomes poorly chemically defined over time (Hedges *et al.* 1995). Samples with a collagen yield of 1.5% or less are generally considered unsuitable for analysis (Ambrose 1990). The Sacred Heart bone

collagen yields range from 3.8 to 23.1%, with a mean value of 17.0 ± 4.0%, and a median value of 18.0%. The dentin collagen yields ranged from 7.5 to 18.8%, with a mean value of 12.6 ± 2.6%, and a median value of 12.3%. These yields indicate that the Sacred Heart collagen samples were not systematically altered by diagenetic factors. There was no significant correlation between either the $\delta^{13}C$ values and collagen yield (Pearson's r = 0.09, df = 73), or the $\delta^{15}N$ values and the collagen yield (Pearson's r = 0.07, df = 73), suggesting preservation of the original collagen $\delta^{13}C$ values.

6.3.2 C/N Ratio

According to DeNiro (1985), all collagen samples with a C/N ratio outside the range of 2.9-3.6 must be discarded due to the potential influence of diagenetic processes in the post-depositional environment. The C/N ratios of the collagen samples in the Sacred Heart population are well within this range with an average value of 3.2 ± 0.03 (range = 3.2 to 3.3, median = 3.2 and therefore show no signs of post-mortem alteration detectable using this parameter.

6.3.3 Minimum C and N Percentage

The minimum concentrations of carbon and nitrogen in the prepared collagen samples also indicate collagen preservation by indicating the presence of inorganic substances in the extracted collagen (van Klinken 1999). Well preserved collagen should be above 13% for carbon, above 4.8% for nitrogen (Ambrose 1990). All Sacred Heart samples meet the minimum concentration requirements for carbon and nitrogen: the minimum carbon concentration ranged from 47.0 to 23.6%, with a mean value of 43.5%. The minimum nitrogen concentration ranged from 17.0 to 8.3%, with a mean value of 15.9%.

6.3.4 Analysis

Collagen was analyzed using a Costech Elemental Combustion System connected to a Thermo Finnigan Delta^{plus}XL mass spectrometer in continuous-flow (He) mode. The $\delta^{13}C$ values are calibrated to VPDB using IAEA-CH-6 (+10.45‰) and NBS-22 (–30.03‰). USGS-40 (accepted value –26.39 ‰; mean $\delta^{13}C$ = –26.39 ± 0.05‰, n = 13)

and USGS-41 (accepted value +37.63‰; mean $\delta^{13}C$ = +37.61 ± 0.09 ‰, n = 13) are analyzed to verify calibration curve. Sample $\delta^{15}N$ values are calibrated to AIR using IAEA-N2 (+20.3‰) and USGS-40 (–4.5‰). USGS-41 (accepted value = +47.6‰; mean $\delta^{15}N$ = +47.57 ± 0.42‰, n = 13) is analyzed to verify the calibration curve. A keratin standard (accepted values: $\delta^{13}C$ = –24.04, $\delta^{15}N$ = +6.36 ‰) is analyzed throughout this process (once approximately every 5-6 samples), with mean $\delta^{13}C$ = –24.10 ± 0.08 ‰ and mean $\delta^{15}N$ values of +6.34 ± 0.25 ‰, n = 22. Reproducibility of the data was tested using method duplicates (labelled "MDP"s) e.g., by repeating the collagen extraction procedure in its entirety on two separate batches from the same sample. The collagen protocol recommends running 10% of the sample as MDPs. There are eight MDPs of the 76 bone collagen samples (10.5%) and seven MDPs of the 51 dentin collagen samples (13.7%).

Chapter 7

7   Results and Discussion

Results of the stable isotope analysis of the bone and tooth collagen of the Sacred Heart Cemetery population are discussed below. A full catalogue of the isotopic results can be found in Appendix A.

7.1   Sacred Heart Results

The $\delta^{13}C_{bone}$ values range from –24.4 to –18.7‰, with a mean of –23.3 ± 0.9‰. The $\delta^{15}N_{bone}$ values range from +6.3 to +11.7‰, with a mean of +9.1 ± 1.1‰. The $\delta^{13}C_{dentin}$ values range from –25.1 to –17.6‰, with a mean of –23.4 ± 1.2‰. The $\delta^{15}N_{dentin}$ values range from +6.9 to +12.6‰, with a mean of +9.3 ± 1.4‰. The results can be seen in **Error! Reference source not found.**.

The two data points with substantially more positive $\delta^{13}C$ values relative to the others represent Sample 89a, a juvenile with a skeletal age between 3 and 4.5 years. As can be seen in Appendix B, collagen data from this individual come from a phalanx ($\delta^{13}C$ = –18.7‰), and a deciduous upper molar ($\delta^{13}C_{ulm2}$: –17.6‰). One of the assumptions of One-Way Analysis of Variance (ANOVA)[17] is that there are no significant outliers within the data sets. As a result, sample 89a is not included in the ANOVA results in this Chapter (but is still included in other analysis).

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[17] One-Way ANOVA (analysis of variance) tests determine if there is a statistically significant difference in the stable isotope values between age categories, sexes, and family groups, to reject the null hypothesis of no significant variation between categories. Levene's Test of Homogeneity of Variance challenges the assumption that the variances of the groups from one-way ANOVA are similar. Tukey's test compares the means of each treatment to the means of each other treatment in the sample to determine if any means are significantly different from each other.
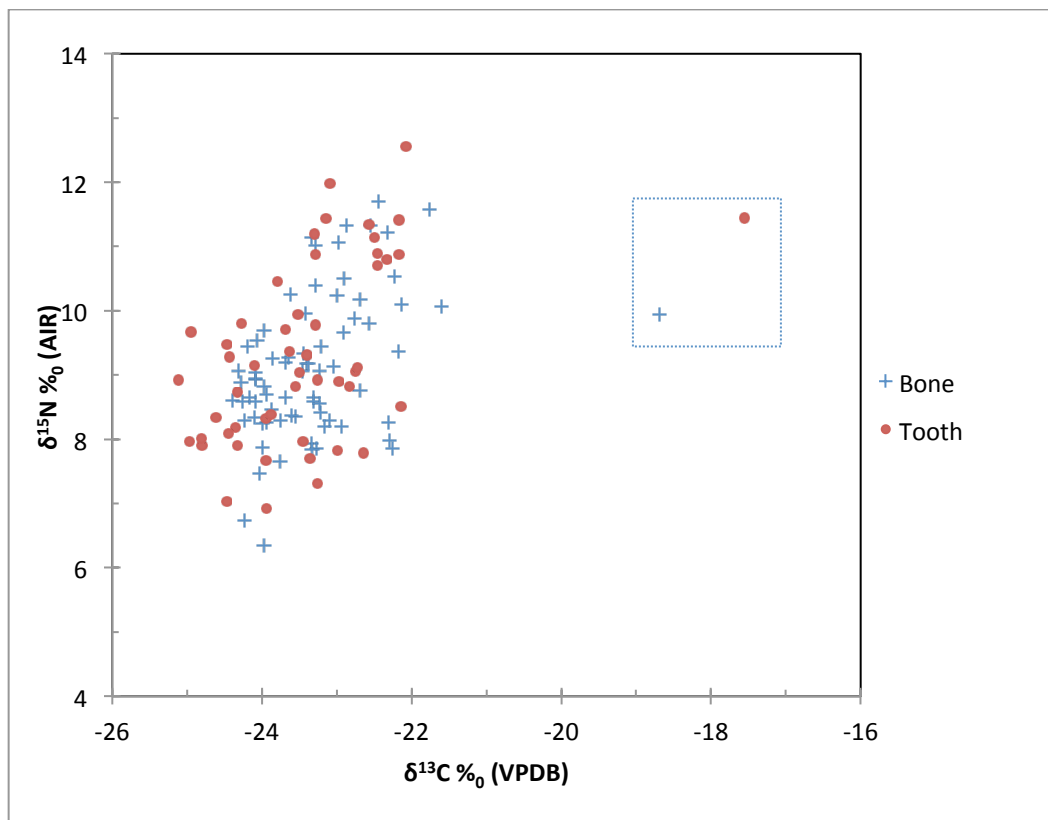
Figure 7-1 Sacred Heart bone (66) and tooth (51) collagen δ^{13}C and δ^{15}N values. Sample "89a" isolated by dotted line.

7.2 Intra-Population Variability in Diet: Sex and Age

Previous studies of diet in 19th century Ontario have concluded that while food was plentiful, there was little variation in the consumption patterns, with no significant distinction of food consumed by sex category or social class (Katzenberg *et al.* 2000). The δ^{13}C$_{bone}$ and δ^{15}N$_{bone}$ values of the Sacred Heart population reflect this homogeneity (Figure 7-2). The results of a T-test indicate no significant difference between the means of either δ^{13}C$_{bone}$ or δ^{15}N$_{bone}$ values of females (mean δ^{13}C: –23.7 ± 0.54‰, mean δ^{15}N: +8.6 ± 0.6‰) and males (mean δ^{13}C: –23.6 ± 0.6‰, mean δ^{15}N: +8.5 ± 0.6‰), (t=0.495 for δ^{13}C$_{bone}$; t=0.225 for δ^{15}N$_{bone}$: *p* > 0.05).

The isotopic composition of the whole population has a moderately positive correlation

between $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ values (df = 72, Pearson's r = 0.47, p <0.01) If the juveniles under the age of 15 are removed, this correlation disappears (df = 30, Pearson's $r = -0.01$, p <0.01), although the breastfeeding infants and children as a separate category retain the moderately positive correlation, (df = 44, Pearson's r= 0.39, p < 0.01). This is due to the trophic level effect between mothers and breastfed infants, and is indicative of the role maize played as a weaning food.
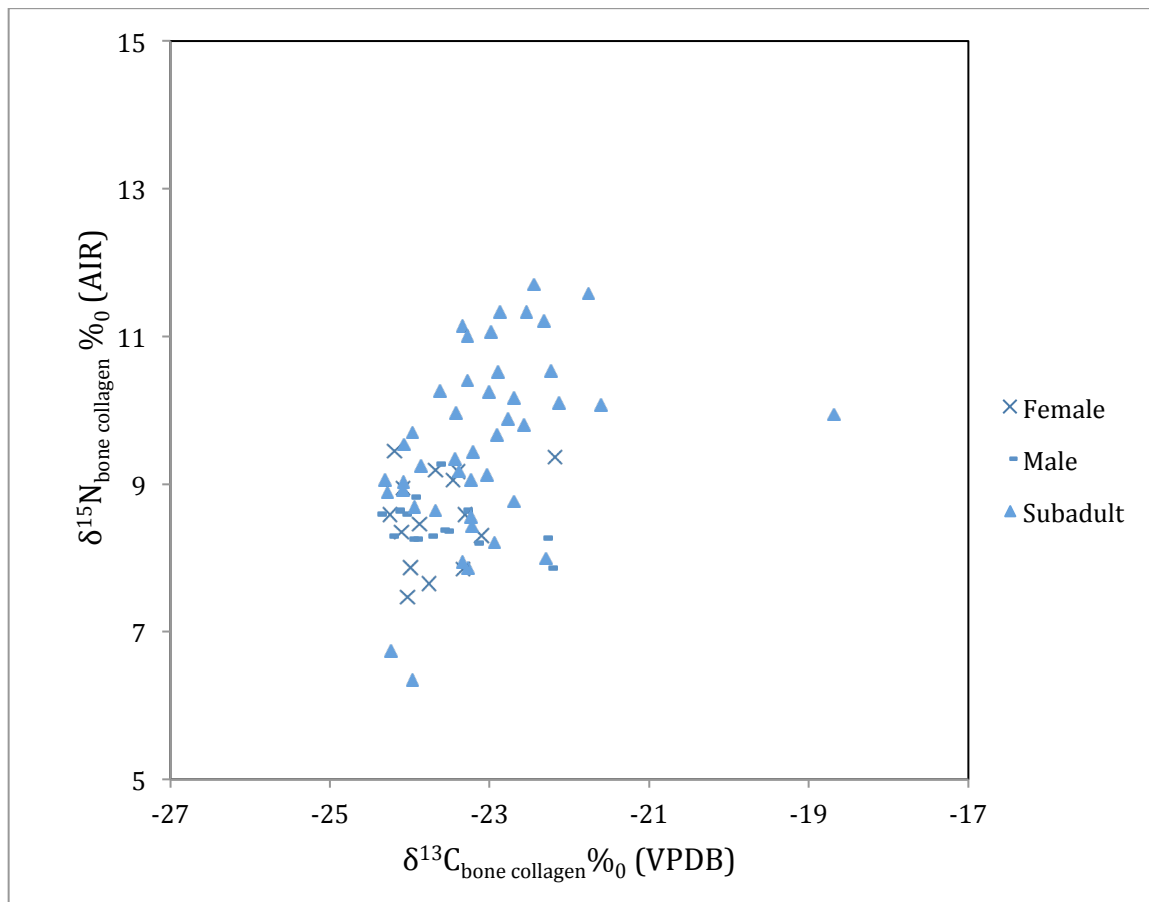
Figure 7-2 Comparison of female, male, and subadult $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$

While maize did not directly contribute much to the overall human diet, which accords with the relative distaste many had for the crop, it was likely consumed as flour in baking. Oat agriculture was one of the principal industries in Ingersoll so this C_3 plant was abundant locally (see Chapter 5), and could have contributed significantly to local diet.
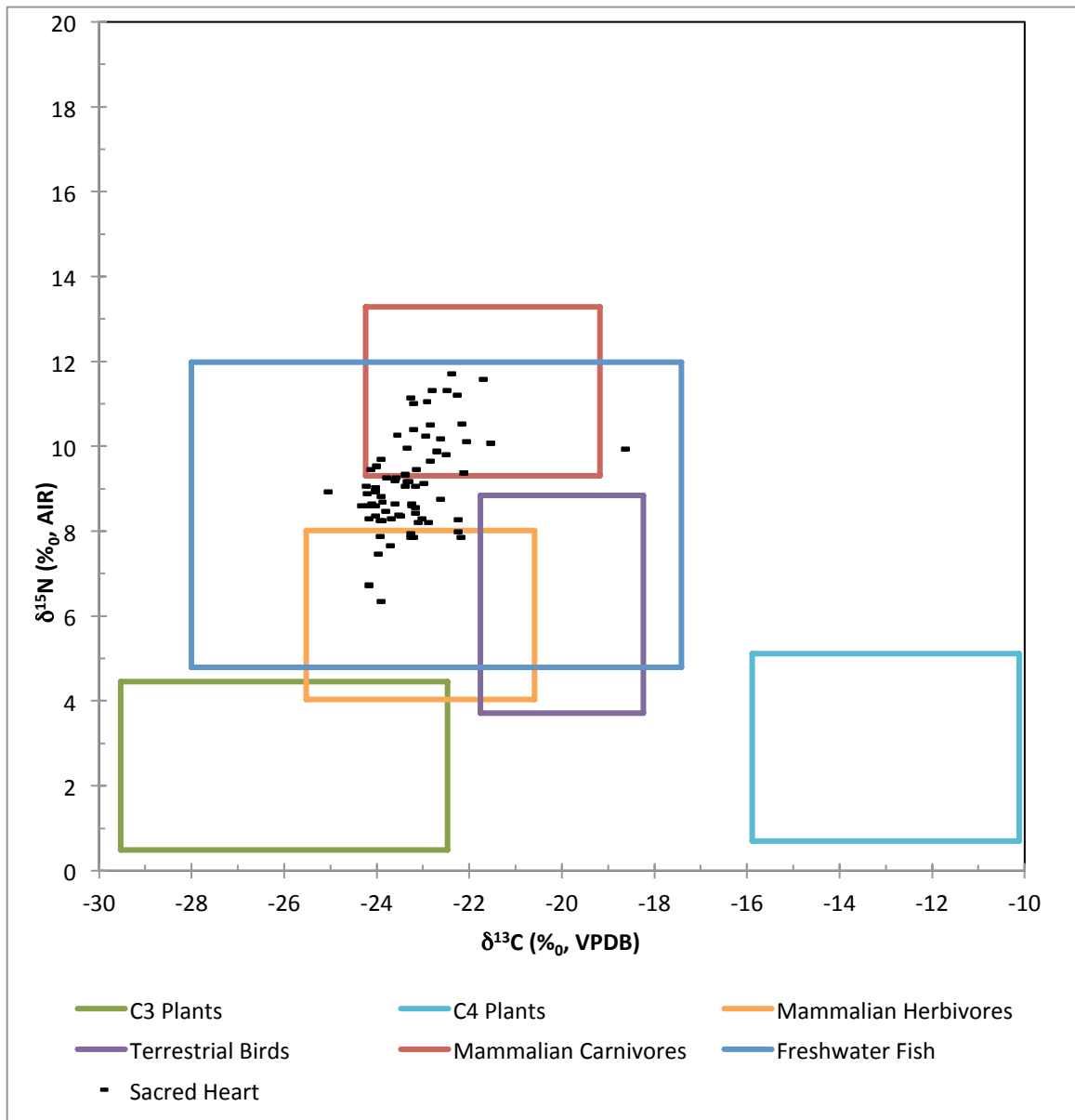
Figure 7-3 Sacred Heart bone collagen results overlaid on the regional food web (after Watts *et al.* 2011).
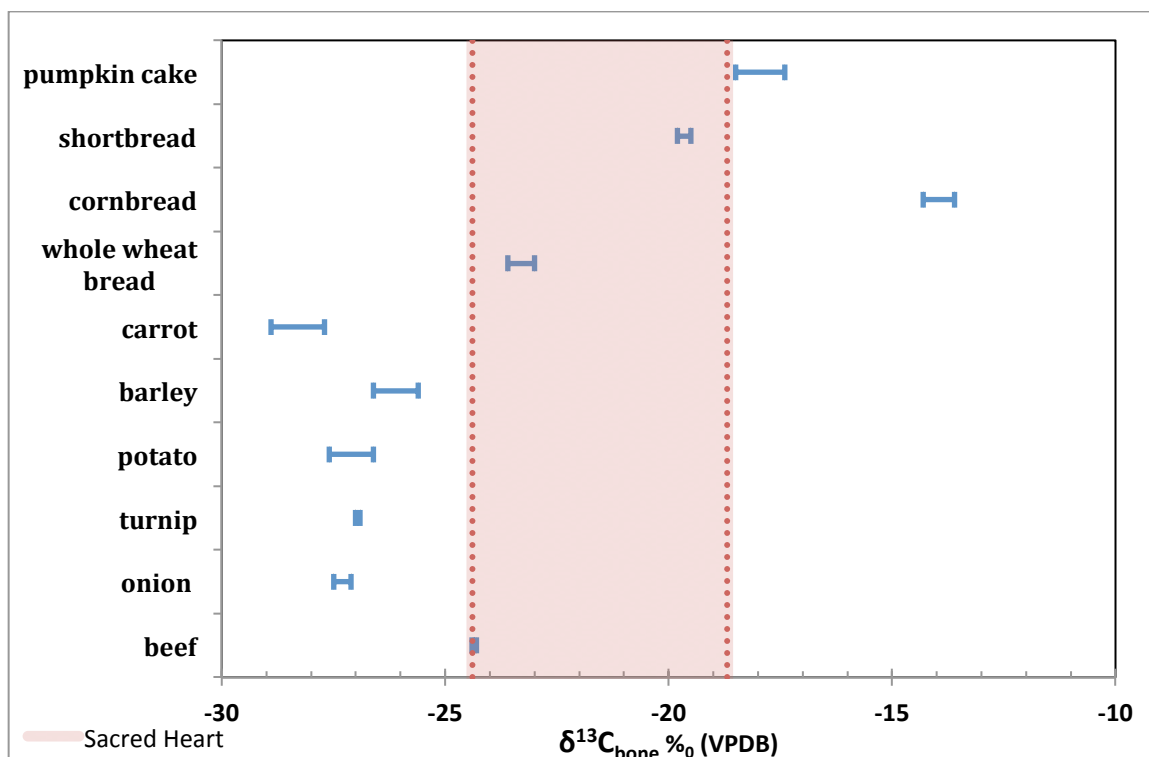
Figure 7-4 Sacred Heart $\delta^{13}C_{bone}$ values (Mean ± 1 SD, shaded red) compared with commonly consumed Ontario foods (Abonyi 1993; Katzenberg *et al.* 2000).

The Sacred Heart population has a relatively limited distribution in the available regional food web, which suggests limited intra-population dietary variation (Figure 7-3). The high $\delta^{15}N_{bone}$ values indicate a diet rich in animal protein. The $\delta^{15}N$ values could also be increased by the use of animal fertilizers in the soil, or Ingersoll's reliance on animal dairy products (Ingersoll was the hub of the largest dairy manufacturing district in Western Ontario, and was the seat of the Canadian Dairymen's Association by 1867 (Bogue 1947; Nadeau 1985). The $\delta^{13}C_{bone}$ values indicate consumption of baked goods made with maize flour (Figure 7-4).

The medical edicts of the day, which recommended to pregnant women a diet of eggs, cereals, vegetables, and eschewed pastries and desserts, were likely being followed. Both the mothers and juveniles have diets with mixed C_3 and C_4 sources.

The most noticeable variation in the $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ values of the Sacred Heart population is related to age (Figure 7-2). Differences in the carbon and nitrogen bone

collagen isotope composition among age categories inform infant feeding behaviour. Table 7-1 shows the results of the stable isotope analysis, organized by skeletal age categories. ANOVA and post-hoc tests found statistically significant variance in the $\delta^{15}N_{bone}$ between certain age categories at the $p<0.05$ level [$F_{(7,58)} =9.3$, $p<0.05$). No statistically significant variance between the age categories was found in the $\delta^{13}C_{bone}$ values [$F(7,58) = 1.3$, $p = 0.3$].

Age (n)	<0.25 y (13)	0.25-0.9 (9)	1-1.9 (8)	2-3.9 (10)	4-12.9 (4)	13-17.9 (4)	18-49.9 (9)	50+ (18)
$\delta^{15}N$ ‰	+9.7 ± 0.7	+10.4 ± 1.5	+10.3 ± 0.9	+8.9 ± 0.5	+7.6 ± 0.9	+8.8 ± 0.4	+8.7 ± 0.4	+8.4 ± 0.5
$\delta^{13}C$ ‰	−23.3 ± 0.8	−22.9 ± 0.7	−23.0 ± 0.5	−23.0 ± 0.1.6	−23.1 ± 0.7	−23.4 ± 0.2	−23.8 ± 0.8	−23.7 ± 0.6

Table 7-1 Mean $\delta^{15}N_{bone}$ and $\delta^{13}C_{bone}$ values by age category (in years), ± 1 SD.

Previous studies have shown that $\delta^{15}N_{nail}$ values of breastfeeding infants are approximately 2.4‰ higher, close to one trophic level, than those of their mothers (Fogel *et al.* 1989). A baseline of expected values for "mothers" in the population can be established by isolating data for women of childbearing age[18], e.g., 18 to 50 years. This group has a mean $\delta^{15}N$ value of +8.9 ± 0.3‰[19]. The age < 0.25 years category consists of peri-nates and neo-nates e.g., individuals who died too young for their bones to reflect feeding outside the uterine environment. A Student's t -test (t[15]=2.1, p=0.42) indicates that this age category is more representative of females of childbearing age (in this case,

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[18] For this study, the estimated age range for childbearing females is 18 – 50 years. Sample 119a, aged approximately 50 years at death, was buried with a juvenile (ID 119b, not sampled for stable isotope analysis) *in situ* in her abdomen.

[19] A T-test revealed no significant variation between these women and women over the age of 50 [t(12)=2.2, p > 0.05].

pregnant women) than breastfeeding activity. The juveniles in the 0.25–0.9 years age category had mean $\delta^{15}N_{bone}$ values that were on average 0.9‰ higher than the peri- and neo-nates, which indicates an abrupt increase in $\delta^{15}N_{bone}$ values after birth, consistent with the onset of breastfeeding. Such differentiation between stillborn babies or those who died shortly after birth, and breastfeeding juveniles, whose values are one trophic level above the adults in the population, is expected.
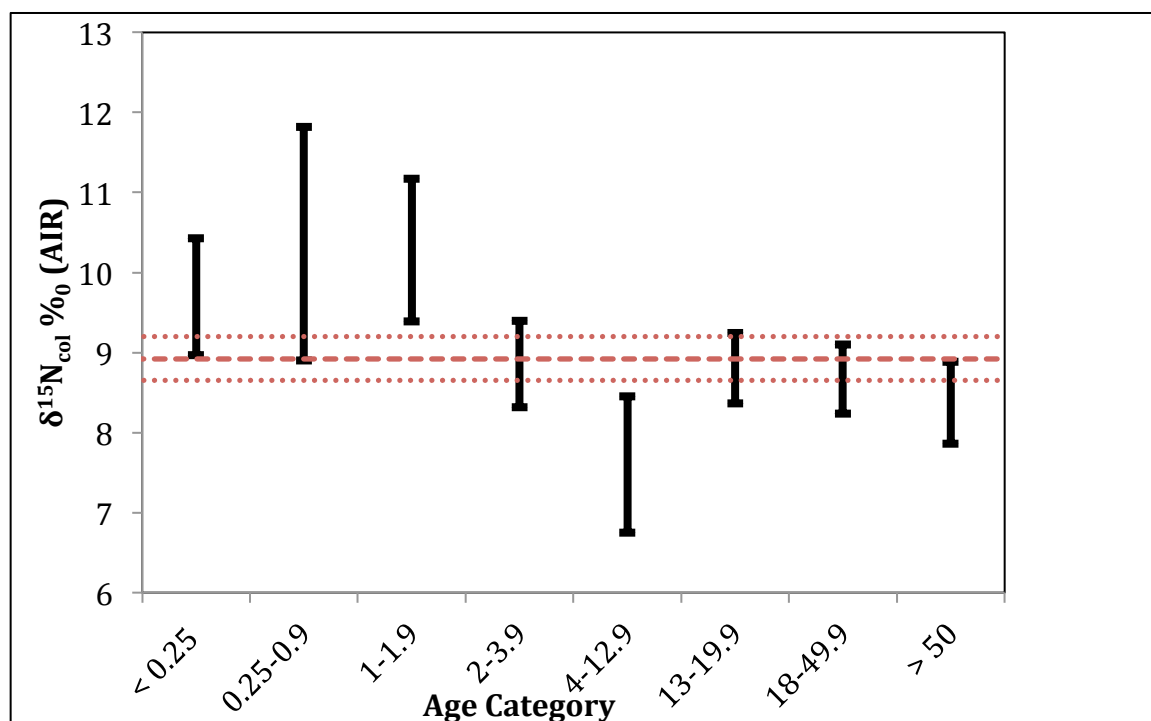
Figure 7-5 Range of $\delta^{15}N_{bone}$ values (± 1 SD) by age category, overlaid with mean values of females of childbearing age (red line), ± 1 SD (dashed lines).

The general duration of breastfeeding in the Sacred Heart population can also be inferred. In Figure 7-5, the $\delta^{15}N_{bone}$ values of each age category are overlaid with values of the "mothers". The mean $\delta^{15}N_{bone}$ values of the juveniles aged 0.25 to 1 year (10.4 ± 1.5‰) and 1-1.9 years (10.3 ± 0.9‰) are statistically different from almost every other older

cohort, and have mean $\delta^{15}N_{bone}$ values that are +1.4‰ higher than those of the "mothers."[20] The juvenile mean $\delta^{15}N_{bone}$ values start to approach the levels of the "mothers" at Sacred Heart in the 2-3.9 year category, indicating greater supplementation in a transition away from breast milk and towards the diet of the general population. From these data, it appears that the introduction of supplemental foods marking the onset of weaning did not occur before the child was at least eight months old, and the child was not totally weaned until shortly before their second birthday, between 18 and 20 months. This agrees with the medical edicts of the time.

The 4-12.9 year cohort has signficantly lower $\delta^{15}N_{bone}$ values than all other age categories, and does not overlap with the "mother" range. This indicates that high-protein foods were not a significant contributor to the weaning process, and that toddlers and young children were kept on a diet lower in dietary protein than older members of the population. Child labour was common on mills and farms, and many entered the work force in their early teenage years (Hurl 1988). Ontario farms functioned with a "heavy reliance on family labour" (Parr 1985). The dietary shift seen between the pre-adolescent children and the older teens and adults could be due to the teen's entry into the workforce, and the change to an adult-diet as adult-type labour is undertaken.

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[20] Results of post-Hoc Tukey HSD test: "+" = statistically significant variation

Cohort	1-1.9	2-3.9	4-12.9	13-17.9	18-49.9	50+
0.25-0.9	-	+	+	-	+	+
1-1.9	-	+	+	-	+	+
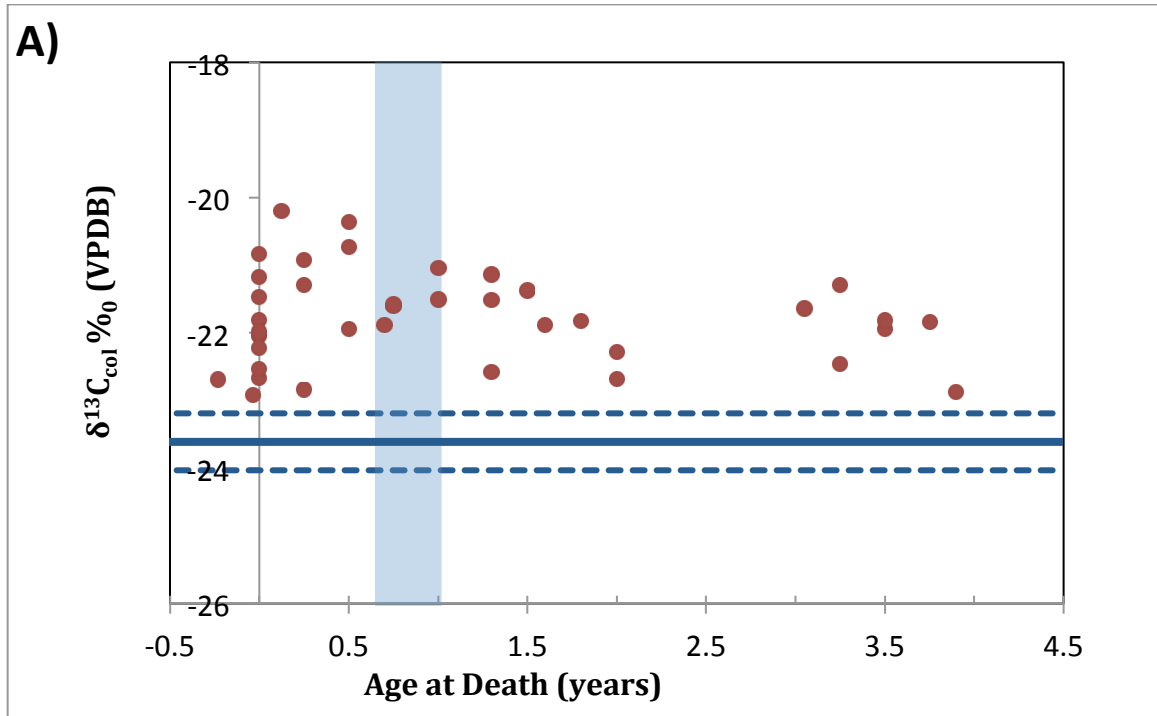
Figure 7-6 (A): $\delta^{13}C$ values of bone collagen *versus* age at death at Sacred Heart.
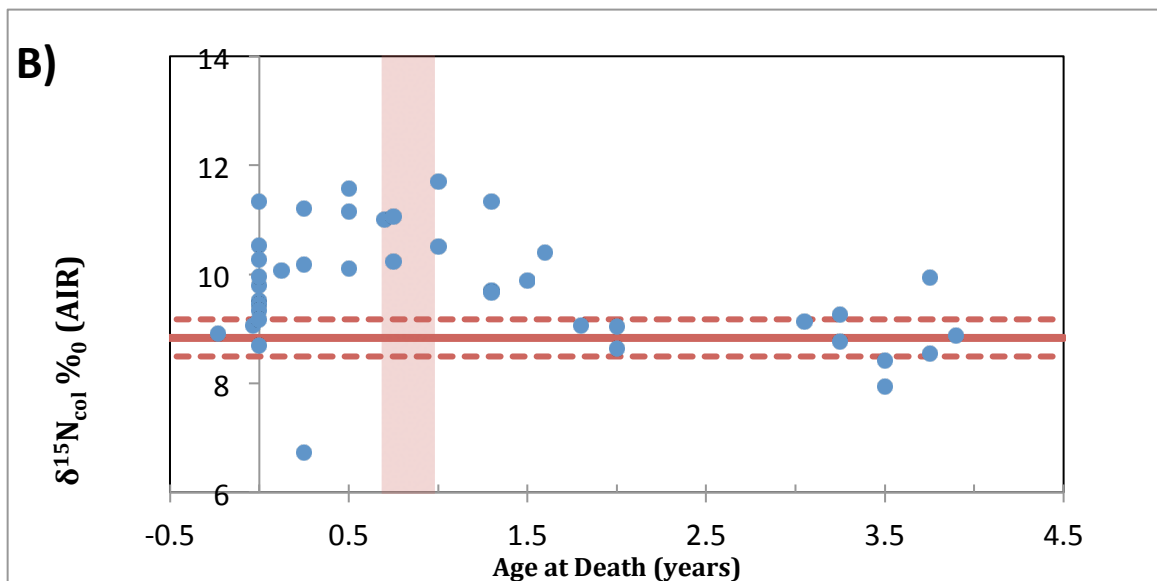
Figure 7-7 (B): $\delta^{15}N$ values of bone collagen *versus* age at death at Sacred Heart.

In both figures 7-6 and 7-7, horizontal lines show mean values of female adults of childbearing age, ± 1 SD (dashed line), shaded vertical box indicates physician recommended weaning time.

The vertical transparent bar represents the average timeframe recommended for cessation of breastfeeding and the commencement of weaning by contemporary physicians of 8 months to 1 year (Holt 1894; Smith 1890). Both isotopic and historic data indicate that there is significant differential access to resources among the infants and young children due to the dietary restrictions imposed upon them by cultural attitudes towards breastfeeding and weaning age.

Fuller *et al.* (2006) suggest that whereas infant $\delta^{15}N_{bone}$ values indicate the timeline of supplemental feeding and weaning, the $\delta^{13}C_{bone}$ values show the breadth of foods introduced during the weaning process. If a child was artificially-fed, then the isotopic composition of the formula can be inferred. There is normally a spacing of approximately +1‰ between the $\delta^{13}C$ values of breastfed juveniles and their mothers (Katzenberg *et al.* 1993; Fuller *et al.* 2006). In the Sacred Heart sample, the $\delta^{13}C_{bone}$ values of the juveniles are consistently higher than the mean (± 1 SD) "mother" values. This is due in part to the spacing of 1‰ between mother and breastfeeding child. The more positive $\delta^{13}C_{bone}$ values among the younger cohorts could also be indicative of the importance of maize as a weaning food. Once supplementary feeding has begun, there is a low, positive trend in $\delta^{13}C_{bone}$ values with increasing age at death (df=21, Pearson's $r = 0.12$, p < 0.01). Although parents were cautioned against feeding their child raw or whole maize, foods prepared with corn starch, corn bread, and corn flour were all recommended to feed a young child (Holt 1894). Furthermore, the most highly recommended weaning food was cow's milk, and the relatively high $\delta^{15}N_{bone}$ and $\delta^{13}C_{bone}$ values of children at Sacred Heart indicate that children were weaned from breast milk by substituting cow's milk from cows fed a diet high in C_4 plants.

The data in this study are consistent with previous isotopic studies of 19th century Ontario populations showing that infants were not totally weaned from breast milk until the second year of life (Herring *et al.* 1998). Although supplementary infant feeding begins

at approximately the same time, the $\delta^{15}N_{bone}$ values indicate that the weaning process at Sacred Heart is slower than at St. Thomas (Figure 7-8).
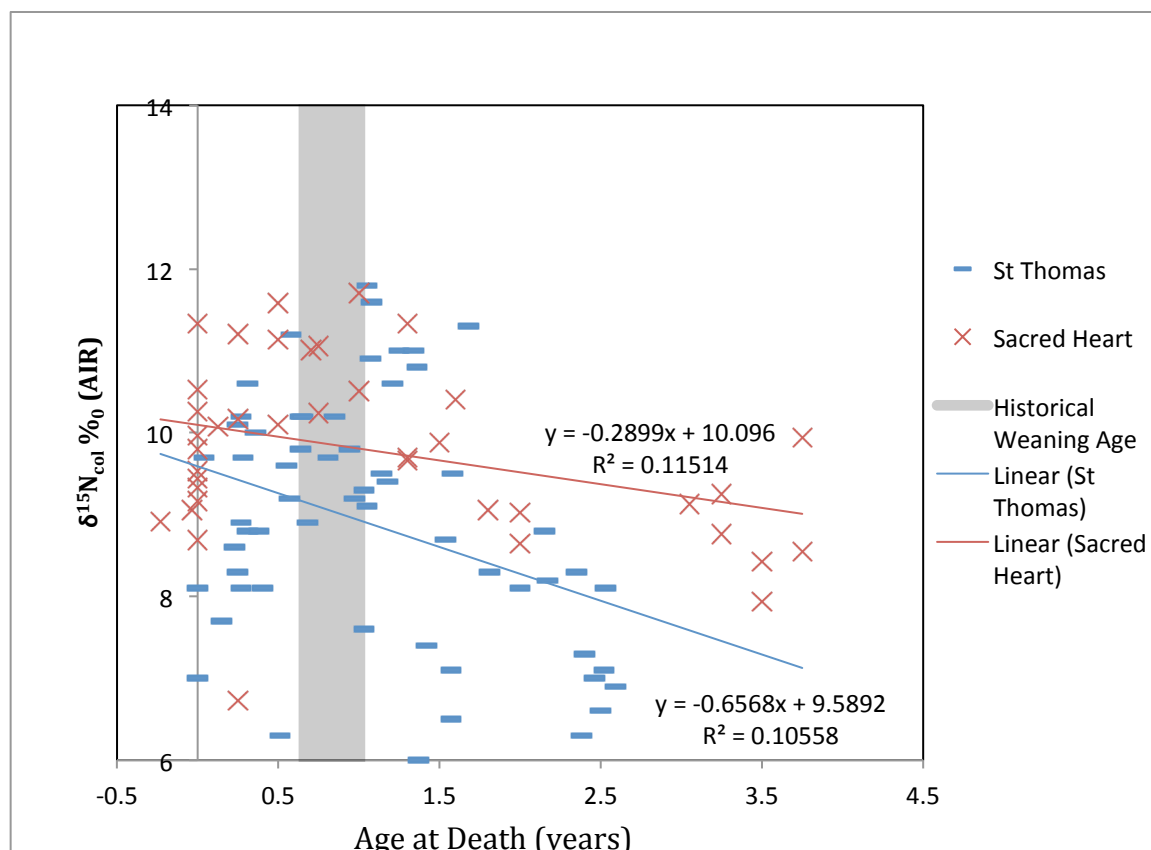
Figure 7-8 $\delta^{15}N_{bone}$ values *versus* age at death for Sacred Heart and St. Thomas (after Herring *et al.* 1988). The historically recommended weaning age is drawn from Holt (1894).

Spence concluded that juveniles among the Sacred Heart population experienced "episodes of poor health" between 2.2 and 3.2 years of age, and attributed this to the children acclimating to the diseases and illnesses of the wider population without the passive immunity inherited from their mother's breast milk (2012). The dental pathology (linear enamel hypoplasia) at Sacred Heart indicates that the process of weaning finished during the second year of life. Spence noted two different stress episodes (identified by clustering and spacing of linear enamel hypoplasia), the first occurring in the second half

of the second year of life, which likely marked cessation of breast feeding, and the next period of stress in the late-second to early-third year of life.

By using stable isotope analysis of collagen from both bone and dentin, it is possible to address the potential mortality bias when discussing infant feeding behaviour in a skeletal sample. Infant feeding behaviour is discussed above by means of cross-sectional study[21] of a skeletal sample. Assessment of the $\delta^{13}C$ and $\delta^{15}N$ values of consecutively forming teeth can also provide a "simulated longitudinal"[22] dimension to the available Sacred Heart data (Dupras & Tocheri 2007).

There is no statistically significant variation between the mean $\delta^{13}C_{dentin}$ values of specific teeth [$F(9,43)=2.72$, $p = 0.59$]. The means of $\delta^{15}N_{dentin}$ values varied significantly across age groups, [$F(9,43) = 4.08$, $p < 0.05$]. By grouping the teeth together into wider age categories, it may be possible to see different patterns emerge. The categories used are: birth – 10 months (exclusively breastfed individuals, represented by the deciduous dentition [ui1, li]), 10 months – 2 years (infants with supplementary feeding [C, M1]), 2 – 6.5 years (childhood, [P1, P2, M2]), and 6.5 years and over (late childhood [M3]). These categories still did not indicate any statistically significant variance in the $\delta^{13}C_{dentin}$ values [$F(3,43) = 2.44$, $p = 0.08$]. There was statistically significant variation in the $\delta^{15}N_{dentin}$ values in the broader age categories [$F(3,43) = 3.89$, $p = 0.01$], and a Tukey-Kramer test for difference between group means found significant variation between the two youngest cohorts. This indicates that a significant shift in dietary protein sources occurs between birth to 10 months and 10 months to 2 years, coinciding with the dietary change caused by the onset of weaning.

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[21] Cross-sectional study refers to a wide range of samples from a single time period (ie., a survey that met with respondents once). This is simulated in an archaeological population by the assumption that all individuals provide information from a comparable time period.

[22] In contrast with a cross-sectional study, a longitudinal analysis provides information over a long term, checking in with the same individual on multiple separate occasions. This is simulated in an archaeological population by taking samples from tissues with different formation periods.

Tooth	Age of Crown Formation	n	Mean δ^{13}C (‰)	Mean δ^{15}N (‰)
ui1	5 mos *in utero* to 1.5 mos	2	−23.4 ± 0.2	10.0 ±1.7
li	5 mos *in utero* to 3 mos	1	−22.2	11.4
m1	5mos *in utero* to 6 mos	12	−23.0 ± 0.9	9.9 ± 1.5
m2	5 mos *in utero* to 10 mos	7	−22.0 ± 2.0	10.8 ± 0.5
c	6 mos *in utero* to 9ms	1	−22.1	12.6
C	6 mos to 4.5 yrs	3	−24.9 ± 1.7	10.1 ± 2.3
M1	6 mos to 2.6 yrs	2	−24.5 ± 0.1	7.7 ± 0.9
P1	2 yrs to 5.4 yrs	3	−23.1 ± 1.1	8.5 ± 0.6
P2	3 yrs to 6.1 yrs	4	−24.5 ± 0.4	9.2 ± 0.2
M2	3 yrs to 6.5 yrs	13	−23.4 ± 1.7	8.6 ± 0.8
M3	9 yrs to 13 yrs	6	−23.5 ± 0.5	8.4 ± 1.0

Table 7-2 Age of crown formation, and average δ^{13}C$_{dentin}$ and δ^{15}N$_{dentin}$ values.
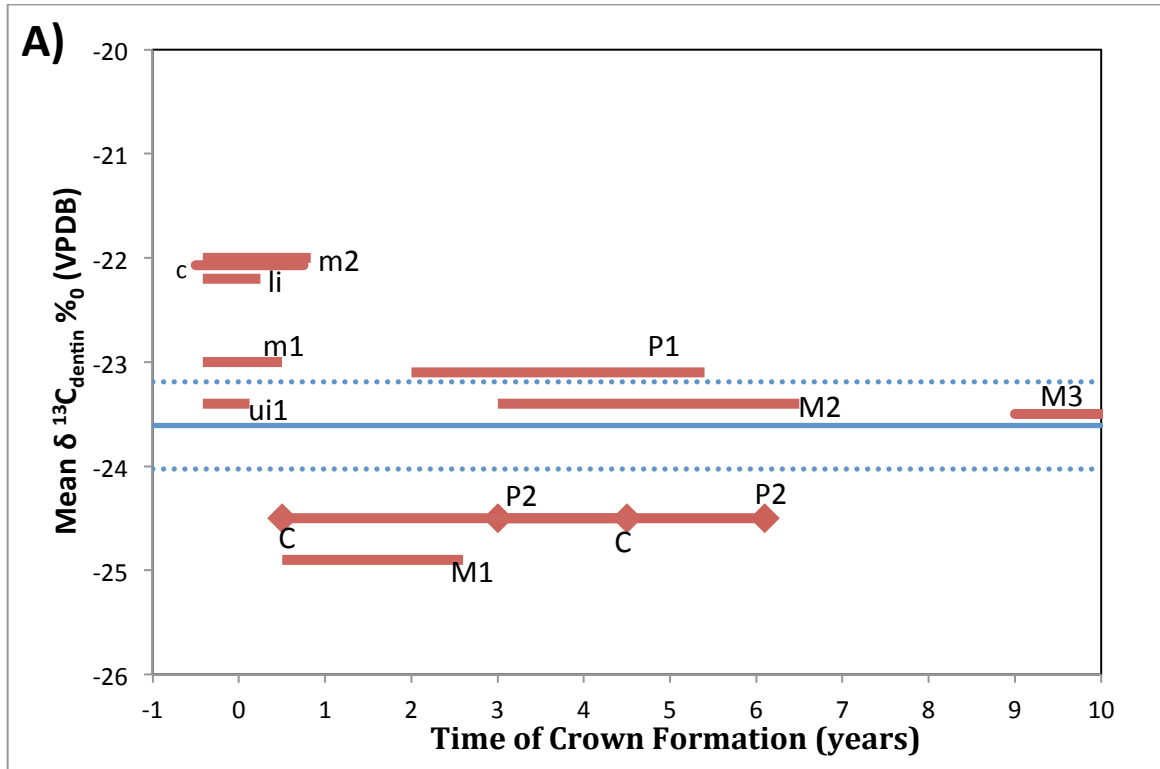
Figure 7-9 (A) $\delta^{13}C_{dentin}$ *versus* time of crown formation. Horizontal lines show mean values of female adults ± 1 SD.
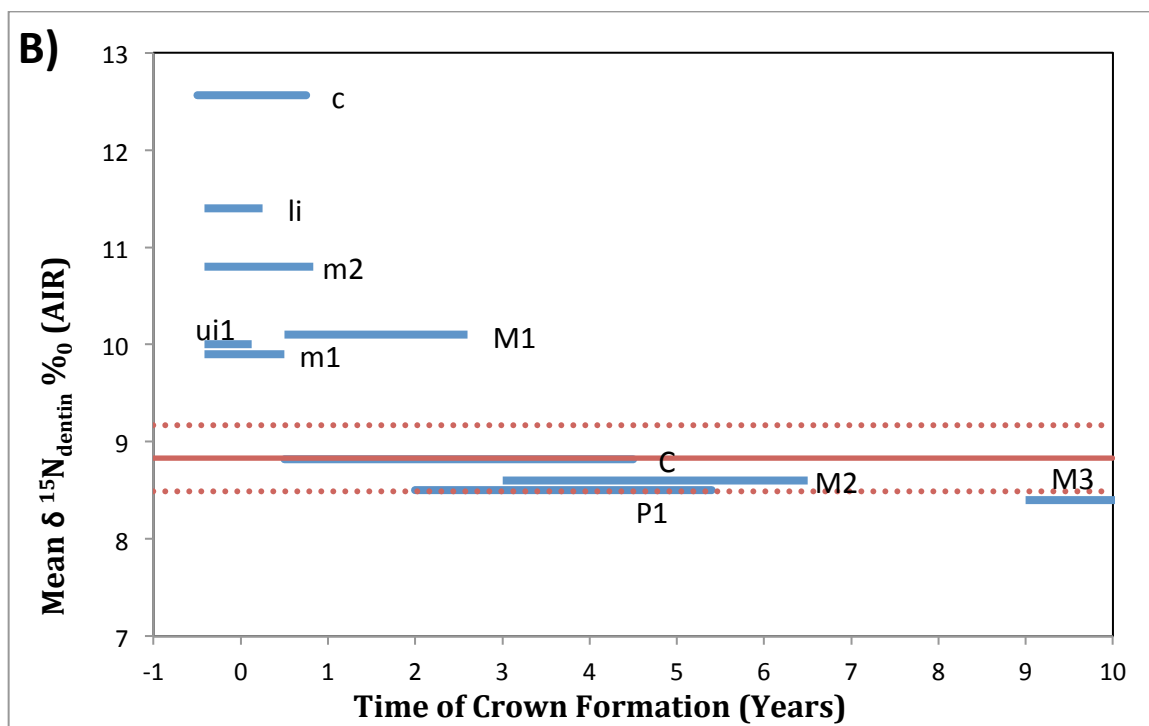
Figure 7-10 (B) $\delta^{15}N_{dentin}$ *versus* time of crown formation. Horizontal lines show mean values of female adults ± 1 SD.

In both figures 7-9 and 7-10, the horizontal lines show mean values of female adults of childbearing age, ± 1 SD (dashed line). The $\delta^{13}C_{dentin}$ values of the deciduous dentition are all higher than the baseline of mean values for females of childbearing age, likely due to the ~1‰ spacing between breastfed infants and their mothers. The $\delta^{15}N_{dentin}$ trophic level spacing between breastfeeding infants and their mothers is apparent in the earliest forming teeth, as the deciduous dentition values are consistently higher than those of the "mothers." The $\delta^{15}N_{dentin}$ values are at their lowest relative point in the P1 crown, formed between 6 months and 2.6 years. This finding is consistent with the $\delta^{15}N_{bone}$ values, which showed a similar relative decrease in the 2-3.9 years of age category. High protein foods were not a significant part of the weaning diet (meat is too difficult for an infant to chew and digest). By the time of formation of the first premolar, the $\delta^{15}N_{dentin}$ values approach equilibrium with the $\delta^{15}N_{bone}$ baseline of the females of childbearing age.

A post-hoc Tukey HSD test found that there were significant differences between the means of the $\delta^{15}N_{dentin}$ values of the deciduous second molar and those of each of the M1, M2, and M3. Using least square means to find a "best fit" in the data, the different teeth indicate two distinct but overlapping groups:

	M1	M3	P1	M2	P2	m1	C	m2	i1	i2
Least Square Mean	7.7	8.4	8.5	8.6	9.2	9.9	10.1	10.8	11.2	11.4
Group	A	A	A	A	A	A	A	B	B	B
					B	B	B			

Table 7-3 Groupings of $\delta^{15}N_{dentin}$ values (‰) based on Least Square Means

These groupings run according to the age at which the tooth crown finished forming. The highest relative $\delta^{15}N_{dentin}$ values occur in the earliest forming teeth. The groupings by least square means indicate that a transition between the weaning diet and the adult diet occurred between the formation of the permanent canine and the 2nd permanent premolar.

For children in Ingersoll during the 19th century, the process of weaning began between 8 and 10 months, and was completed by 20 months. Variations in the $\delta^{15}N_{bone}$ and $\delta^{15}N_{dentin}$ values and the pattern of linear enamel hypoplasias confirm this, and are in accordance with other bioarchaeological studies done on similar populations as well as the medical edicts of the time.

7.3   Inter-Population Variation[23]

Figure 7-11 compares the means (± 1 SD) of the $\delta^{13}C$ and $\delta^{15}N$ bone collagen values for two contemporaneous cemeteries in the United Kingdom (Lukin Street, London, active

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[23] The inter-population comparison only includes individuals over the age of 10 in order to eliminate any influence of breastfeeding on isotopic compositions. There is statistically significant variation in $\delta^{15}N_{bone}$ values between Lukin Street and Sacred Heart, Lukin Street and St. Thomas, and Lukin Street and Kilkenny (p < 0.05).

1843-1854 and Kilkenny Workhouse, Ireland, active 1847-1851) and two contemporaneous cemeteries in Ontario (St. Thomas, Belleville, active 1821-1874, and Prospect Hill, Newmarket, active 1824-1879) with Sacred Heart (for this analysis, all samples are adults only).
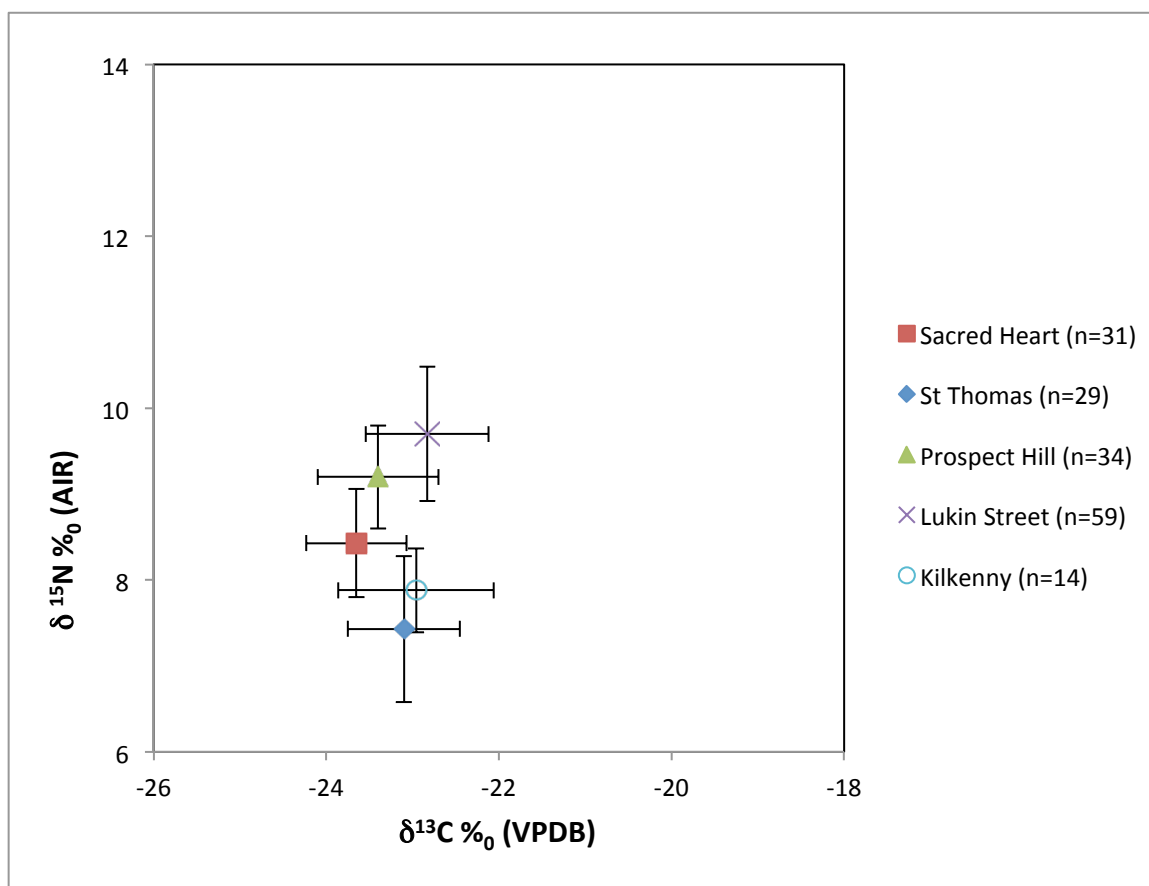
Figure 7-11 Mean bone collagen values from Sacred Heart, St. Thomas Cemetery in Belleville, Ontario (Katzenberg *et al.* 2000), Prospect Hill Cemetery in Newmarket, Ontario (Katzenberg & Pfeiffer 1995), Lukin Street Cemetery in London, England (Beaumont *et al.* 2013), and Kilkenny Workhouse in Ireland (Beaumont *et al.* 2013).[24]

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[24] The methods used in the above papers are comparable to Sacred Heart. All bone collagen values have been adjusted to reflect diet in the same manner that the Sacred Heart values were shifted.

The Kilkenny and Lukin Street populations are not necessarily baselines for the standard diet of landed Irish immigrants in Ontario, as both sites represent diets that were perceived as "low-status" and not considered fit for general consumption (Beaumont *et al.* 2013), but they are nevertheless informative proxies. At Kilkenny (prior to the Famine), potatoes were a main source of food energy, and the diet was essentially vegetarian: "the average Irishman consumed 12-14 lb of potatoes per day, supplemented by oatmeal when potatoes were out of season, dairy products, [and] eggs" (Beaumont *et al.* 2013) [25]. The relatively low range of the Kilkenny $\delta^{15}N$ values (mean $\delta^{15}N$=7.9‰ ± 0.5) is indicative of a vegetarian diet. Conversely, the diet at Lukin Street was more varied, with a likely large fish component. A much wider range of fruits and vegetables were available at the markets in London than at the Kilkenny workhouse, and fish were a cheap and abundant source of dietary protein. Since poorer tenements edged the land along the Thames, it is hardly surprising that the homes of many poor migrants were described as "smelling overwhelmingly of fish" (Beaumont *et al.* 2013). The significant difference in $\delta^{15}N_{bone}$ values observed between the Lukin Street population and that of Sacred Heart, St. Thomas, and Kilkenny reflects the significant contribution of fish to the diet. The diets at Kilkenny and Lukin Street, different though they are from each other, are both different from the omnivorous diets observed in the Ontario populations, where, as has been noted, a more diverse array of food was available.

No statistically significant variation in $\delta^{13}C_{bone}$ values is indicated among the populations, which indicates that the UK comparators for Ontario diets are not ideal baselines for expected Irish or British diets of the poor, possibly due to consumption of maize imported by Britain as an anti-Famine relief measure (Beaumont *et al.* 2013), and the consumption of fish with C_4-like isotopic compositions. In Ontario, the $\delta^{13}C_{bone}$ values of the Sacred Heart population ($\delta^{13}C_{bone}$: −23.7‰ ± 0.6) are similar to both the Prospect Hill values ($\delta^{13}C_{bone}$: −23.4‰ ± 0.7) and St. Thomas values (($\delta^{13}C_{bone}$: −23.1‰ ± 0.7). The Sacred Heart $\delta^{13}C$ values are the most negative of all five populations, indicating that, in

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[25] Beaumont also cites fish as a source of dietary input in coastal populations (2013), although this is likely not relevant to the Kilkenny population, as the entire county is landlocked.

Ingersoll, maize and other C_4 plants were a less important component of the food web than at the other two sites. It is also possible that the more negative $\delta^{13}C_{bone}$ values could be due to a disproportionate number of non-local individuals, particularly those who had recently migrated from Ireland (and there are many at Sacred Heart: see Chapter 4, Appendix A). Although the Kilkenny and Lukin Street samples reflect the consumption of imported maize and possibly fish that have C_4-like compositions, this does not refute the expectation that European migrants to the Sacred Heart population can be identified by more negative $\delta^{13}C$ values, as both cemeteries were active for the very brief period of time (Kilkenny: four years, Lukin Street: 11 years) during which relief-maize imported from North America was incorporated into the diet (Beaumont *et al.* 2013).

 Using the $\delta^{13}C_{bone}$ values of a Belleville diet reconstructed from foodstuffs, Katzenberg *et al.* (2000) estimated from $\delta^{13}C_{bone}$ values that meat food sources represented only a small contribution (~10%) to general diet of the St. Thomas population. Vegetables and baked goods accounted for the majority of the diet (representing 70% and 20%, respectively). The same kind of diet is also evident in the $\delta^{15}N_{bone}$ values of the adults at St. Thomas, whose mean $\delta^{15}N$ values are the lowest of all the populations discussed here, including the "vegetarian" diet at Kilkenny. It is also possible that the Kilkenny population reflects starvation (Beaumont *et al.* 2013), as a period of chronic nutritional stress (e.g., the Potato Famine) could result in relatively high $\delta^{15}N_{bone}$ values. This could account for the higher $\delta^{15}N_{bone}$ values of the Kilkenny "vegetarians" relative to the St. Thomas population, and the overlap of Kilkenny with the lower range of the omnivorous Sacred Heart diet.

7.4   Mobility

As was discussed in Chapter 4, the Dominion government courted Europeans in general, and English in particular, with the aim of settling the so-called frontiers with skilled labourers and gentrifying the urban centres with landed aristocrats. In the 1840s, there was an extraordinary increase of Irish emigrants due to the devastation of the Great Famine, many of whom settled in Upper Canada. Settlement further into the country

required a greater financial commitment, due to the increased travel expenses as a family traveled farther into the so-called "Hinterlands."

Acknowledging the contemporary trend of waves of Irish immigration into the then-frontiers of Upper Canada, the English-speaking Catholic population of the Sacred Heart sample, and the known presence of Irish-born individuals in the Sacred Heart cemetery, it is likely that many of the individuals sampled in this population may be landed Canadians of Irish origin.

An intra-individual analysis of $\delta^{13}C_{bone}$ values elucidates dietary sources relative to C_3 and C_4 plant consumption as they change over time. It has already been established that maize is the most significant C_4 plant in the food web for this population (millet, sorghum, and sugar cane do not contribute significantly to the local economy). Since dentin does not normally remodel after forming[26], but bone remodels constantly throughout life, when both tissues are sampled, it is possible to obtain two temporally different "snapshots" of a single individual, bone represents the last 10-25 years of life, whereas teeth represent the period of childhood during which the tooth formation occurred. Where the later-forming bone has relatively high $\delta^{13}C$ values compared to early-forming teeth, increased consumption of C_4 plants is inferred. Due to the relative paucity of C_4 plants in the United Kingdom diet, and the significance of maize to the North American food web, it is likely that individuals exhibiting a lifetime increase in $\delta^{13}C$ values started life in a region where maize was scarce and died in a region where maize was either consumed as part of the diet, or present in an earlier stage of the food chain (e.g., as animal feed).

Of the 49 individuals for whom both tissues were sampled, 15 (31%) showed a positive increase in $\delta^{13}C_{bone}$ values of the bone relative to the tooth (see Figure 7-12) ranging from +0.1 to +2.1‰, with an average increase of 0.9 ± 0.6 ‰. Maize was a significant weaning food, so it is expected that lifetime averages of $\delta^{13}C$ would decrease in a

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[26] Dentin can also remodel as a response to excessive wear or trauma to enamel. The teeth sampled for this study did not include samples with excessive wear or chipping.

stationary population, eating a consistent diet throughout life. The Kilkenny and Lukin Street populations referenced previously are indicative of the isotopic composition of the famine-stricken inhabitants of an Irish workhouse and an English mission. The contrast between those two datasets and the Sacred Heart population speaks to social class as well as mobility. The indivduals who migrated to Ingersoll were not the starving Irish of Lukin Street or Kilkenny, or of the contemporary imagination. Rather, they were likely from a higher social class, who had the means to emigrate successfully into the Canadian "Hinterlands," and whose isotopic composition is not reperesentative of the pauper's diet described by Beaumont *et al.* (2013).
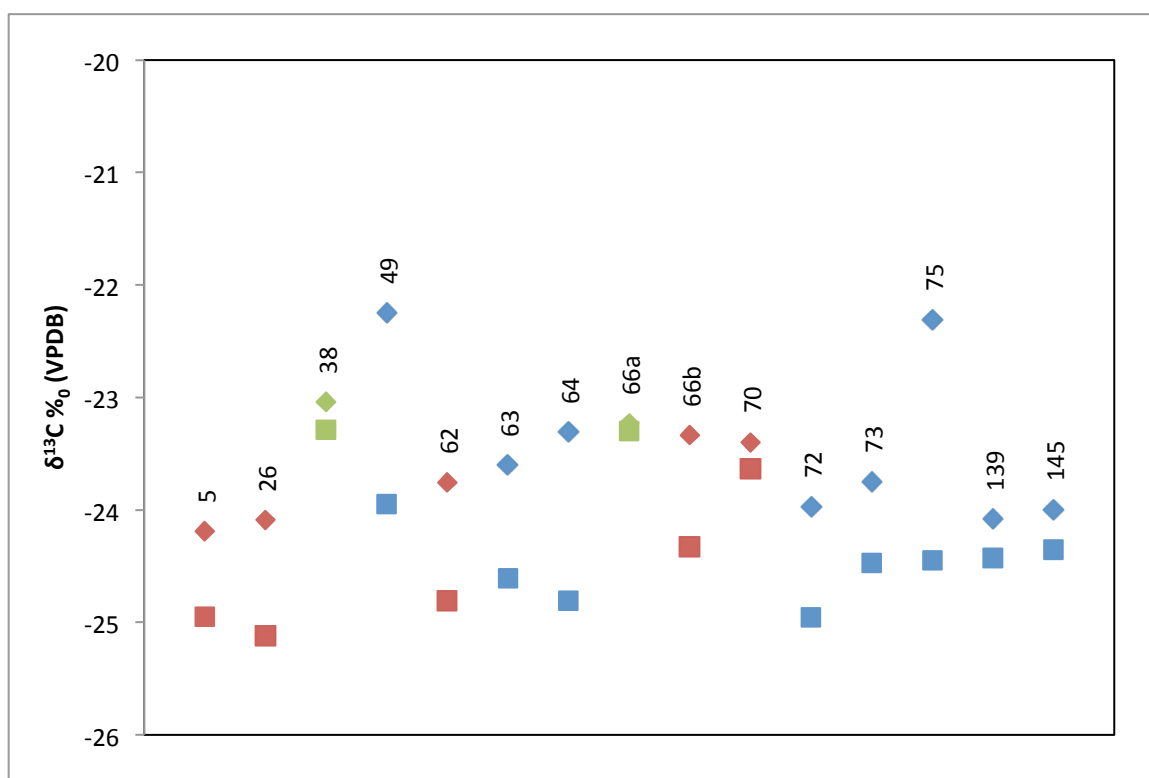
Figure 7-12 Intra-individual increase in δ^{13}C values, by tissue type and sex category. Red = females, blue = males, green = juveniles, square = δ^{13}C$_{bone}$, diamond = δ^{13}C$_{dentin}$

Sample ID	Sex	Age	$\delta^{13}C_{dentin}$ (‰)	$\delta^{13}C_{Bone}$ (‰)	Lifetime Increase (‰)
5	F	57.5	−25.0	−24.2	0.8
26	F	37.5	−25.1	−24.1	1.0
38	J	3.05	−23.3	−23.0	0.3
49	M	18	−24.0	−22.3	1.7
62	F	67.5	−24.8	−23.8	1.1
63	M	18	−24.6	−23.6	1.0
64	M	67.5	−24.8	−23.3	1.5
66a	J	1.8	−23.3	−23.2	0.1
66b	F	67.5	−24.3	−23.3	1.0
70	F	27.5	−23.3	−23.4	0.2
72	M	55	−25.0	−24.0	1.0
73	M	62.5	−24.5	−23.8	0.7
75	M	52.5	−24.5	−22.3	2.1
139	M	57.5	−24.4	−24.1	0.4
145	M	67.5	−24.4	−24.0	0.4

Table 7-4 Individuals displaying lifetime increase in $\delta^{13}C$ values. F = female, M = male, J = juvenile.

7.5   Possibly Related Individuals

Combined with Spence's data on groups of possibly related individuals and the spatial organization of the Sacred Heart cemetery, the results of stable isotope analysis can reveal patterns in diet and mobility within family groups. Spence (2012) identified possibly related individuals in the population through skeletal traits (metric and non-metric, see Appendix C) and their burial context. The map of the cemetery (Chapter 3) shows graves organized in rows and clusters; a family group may be marked by a vacant space between graves, indicating the limits of a plot but not necessarily indicative of a

biological relationship between individuals (e.g., a married couple buried side by side would not share inherited skeletal traits) (Spence 2012). Vacant spaces may also mark the location of a monument, or the space reserved for a family member who had not yet died at the time of the cemetery's closing (Spence 2012). A further consideration in the skeletal identification of family groups is the fact that close relatives may not be buried together due to marriage, adoption, social status, or other social phenomena.

Tests for statistically significant differences in the means of the δ^{15}N and δ^{13}C bone collagen values of the possibly related individuals were conducted using One-Way ANOVAs. There were no significant outliers within the trait cluster subsets. There were no statistically significant differences in δ^{15}N bone values among trait clusters, $F_{(5,26)} = 0.601$, $p = 0.7$. Similarly, there were no statistically significant differences in the means of δ^{13}C bone values among the trait clusters, $F_{(5,27)} = 1.801$, $p = 0.146$.

Trait Cluster	Individuals	Mean $\delta^{13}C_{bone}$ ‰	Mean $\delta^{15}N_{bone}$ ‰
Cluster 1	5, 9, 11, 12, 33	−24.0 ± 0.4	+8.7 ± 0.7
Cluster 2	119a, 125	−23.4 ± 0.7	+9.1 ± 0.9
Cluster 3	124a, 124b, 133, 144, 145	−23.4 ± 0.7	+9.4 ± 1.4
Cluster 4	62, 63, 64, 65, 66a, 66b, 67	−23.4 ± 0.2	+8.6 ± 0.9
Cluster 5	25, 26, 37, 71, 72, 73	−23.3 ± 0.8	+8.8 ± 0.5
Cluster 6	114, 115, 131a, 131b, 132a, 139, 140	−24.0 ± 0.5	+8.7 ± 0.5

Table 7-5 $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ values for clusters of possibly related individuals, ± 1 SD

The trait clusters with the most similar bone collagen values and nearly identical ranges are 1 and 6. These two trait clusters also have the most isotopically negative $\delta^{13}C_{bone}$ values relative to the other trait clusters. There are, however, no statistically significant differences in the bone collagen δ^{13}C and δ^{15}N values among the trait clusters, which indicate that family units did not have differential access to foods resulting from their

social or occupational status. Neither did they use food as a means of group identification, assuming that these trait clusters do indeed represent groups of genealogically linked individuals.

The greatest variation in $\delta^{13}C$ values is present in trait cluster 5 (SD = ± 0.8‰), which includes three individuals who exhibited a lifetime increase in $\delta^{13}C$ bone collagen values (samples 26, 72, 73), indicating a change in diet (likely accompanied by a change in location) towards more C_4 plant consumption.

The largest range in $\delta^{15}N$ bone collagen values, as well as the most positive $\delta^{15}N$ values, occurs within trait cluster 3 (SD = 1.4‰), likely a reflection of the diversity in age: 124a (unknown sex, newborn); 124b (female, 55-70 years old); 133 (unknown sex, 0.7 years old); 144 (unknown sex, newborn), and 145 (male, 60-75 years old). The more positive $\delta^{15}N$ values belong to the three subadults and likely indicate the breastfeeding trophic level effect.

7.5.1 Proximal Burials

Spence (2012) identified two sets of children, buried in separate coffins but in the same grave shaft. The first pair, samples 89a and 89b, are both young children (aged between 3 and 4.5 years), who were not identified as sharing a biological relationship through the skeletal evidence. 89a, the outlier identified earlier in this chapter, has significantly higher $\delta^{13}C$ and $\delta^{15}N$ bone collagen values than 89b, whose average $\delta^{15}N_{bone}$ values also fall below the mean of the Sacred Heart population (Figure 7-13). This is unusual, as the young age of 89b should place this individual in the elevated range of $\delta^{15}N_{bone}$ values of children who were being weaned, although may reflect an individual who had been weaned onto a low-protein diet at an earlier age than was typical of this population.

Individuals 127a (28 fetal weeks old) and 127b (35 fetal weeks old) were laid to rest side-by-side in the same coffin, were buried in unique positions relative to the rest of the population, with their heads to the north and feet to the south, rather than the typical east-west orientation (Spence 2012). Spence suggests that this may be tied to their burial in an area of the cemetery reserved for unbaptized infants, which may also include

stillbirths. 127a and 127b, whose deaths were contemporary, could not have been twins due to the differences in their skeletal development, and may have not even been siblings (Spence 2012). Their bone collagen values, however, are very similar (Figure 7-13), with a difference in $\delta^{13}C_{bone}$ values of $-0.2‰$ between 127a and 127b, and of $+0.1‰$ $\delta^{15}N$, which suggests they could have been siblings. The $\delta^{15}N$ values are in the median range of the Sacred Heart population, and are a reflection of the mother's diet and the pre-natal environment.

Individuals 69 (approximately 1.3 years old) and 70 (approximately 27 years old) share a close biological relationship (Spence 2012). They were both buried with their head facing east, contrary to the majority of Sacred Heart burials who are oriented towards Paradise in the west. The $\delta^{15}N_{bone}$ values of 70 are consistent with the mean range of the Sacred Heart population, indicating that her diet was not significantly different from the wider population. The child has elevated $\delta^{15}N_{bone}$ values relative to the rest of the population, which is consistent with the trophic level effect related to breastfeeding. Spence identified burial 70 as being skeletally different from the rest of the population[27], and burial 70 is among the individuals who exhibited a lifetime increase in $\delta^{13}C$ values (Table 7-4), although at only $+0.2‰$ it may not be indicative of the significant dietary shift that would accompany trans-continental migration.

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[27] With the exception of the infant (burial 69), with whom she shares a genetic lack of a 12th vertebrae, unique in this population to these two individuals, and indicating a close biological relationship.
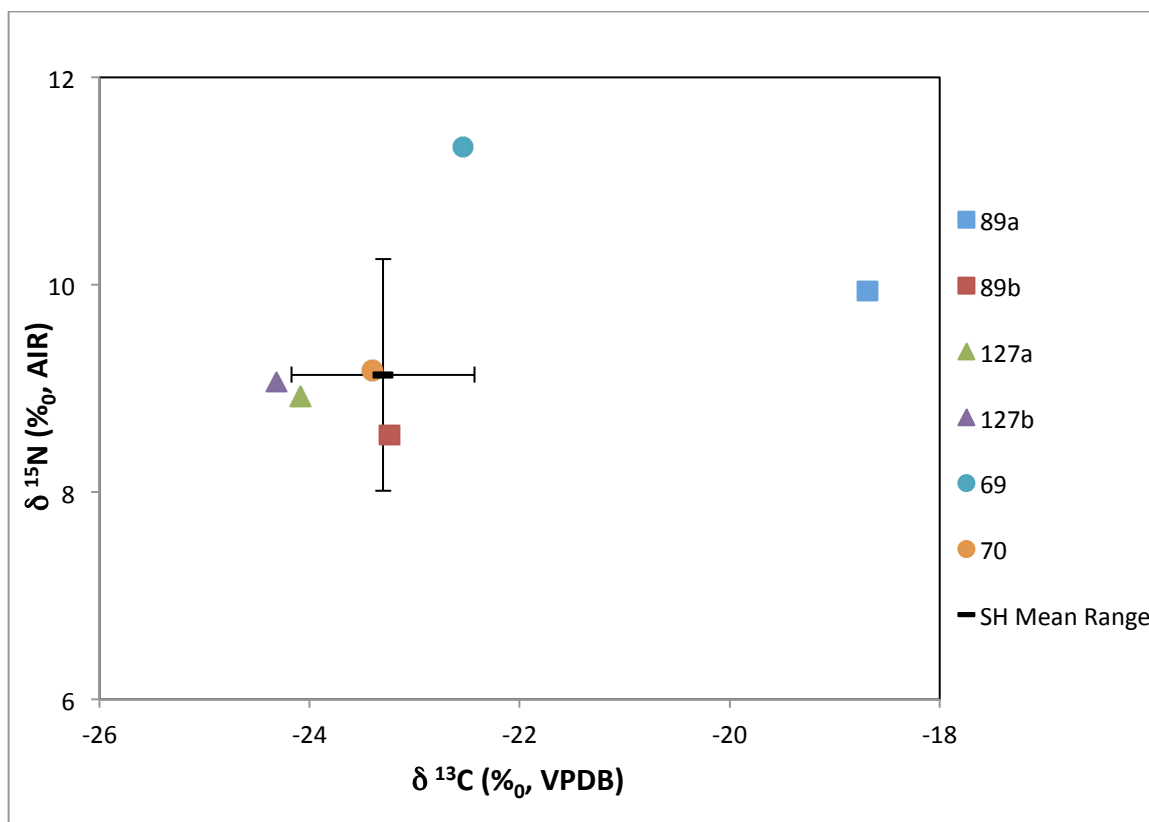
Figure 7-13 $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ results of individuals noted by Spence (2012) to likely have a familial relationship.

7.5.2 Migration and Family Groups

Within trait cluster 4, there is a close biological relationship between 62 (adult female) and 64 (adult male), which indicates that they were not spouses. Sample 63 (male teenager) shares traits with both 62 and 64; samples 66a (infant) and 66b (female adult), found in the same burial shaft, and 67 (child), do not share as many traits with the former group, and may be more loosely related or a separate family group (Spence 2012). In addition to the shared physiological traits, all of these individuals have higher $\delta^{13}C_{bone}$ values relative to $\delta^{13}C_{dentin}$ values, indicating an increase in the contribution of C_4 plants to their diet. This could be indicative of a family group migrating from a country (likely Ireland, in this population) with little C_4 plant consumption. There are no members of this trait cluster who do not exhibit a lifetime increase in C_4 consumption.

Within trait cluster 5, only 26 (female adult), 72 (male adult), and 73 (male adult) show a lifetime increase in $\delta^{13}C$ values. Spence notes that samples 71, 72, and 74 were related

biologically (Spence 2012). Interestingly, samples 72 and 73, both of whom are possible emigrés, were buried in a row immediately to the east of the row containing all members of the trait cluster 4 (samples 62, 63, 64, 65, 66a, 66b, and 67), all also thought to be of different geographic origins than the rest of the population.

Chapter 8

8   Conclusions

Carbon and nitrogen isotope analysis of individuals interred at the Sacred Heart cemetery in Ingersoll, Ontario, were used to identify patterns of diet, migration, infant feeding behaviour, and in some cases, biological relatedness. The $\delta^{15}N_{bone}$ values of the Sacred Heart population indicate a diet high in protein, combining farm animal meat and products, with a mix of C_3 and C_4 plants. The data are consistent with available historical sources indicating that a wide variety of foods were consumed on a daily basis. Domestic diet in Ingersoll was diverse, and included kept animals (pork, beef, mutton, and fowl), animal by-products (cheese, milk, eggs, and other dairy), and a variety of fruits and vegetables (Kenyon & Kenyon 1992). The most significant source of maize in the diet appears to be secondary consumption, as farm animals were raised on maize fodder. This interpretation is supported by a moderate positive correlation between $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ values indicating that trophic level was associated with C_4 plant consumption, and historical references to maize as a food that is only suitable to be eaten when nothing else is available. Direct consumption of maize was likely as corn flour or cornstarch in baked goods as several contemporary recipes call for its usage (Abonyi 1993; Katzenberg *et al.* 2000).

The results of the Sacred Heart population are similar to those of two contemporary Ontario populations: Prospect Hill (Katzenberg & Pfeiffer 1995) and St Thomas (Katzenberg *et al.* 2000). The diet at Sacred Heart is more similar to Prospect Hill. Access to food resources was fairly standardized within the population, and was not predicated on wealth or status.

There were no significant differences in $\delta^{15}N_{bone}$ or $\delta^{13}C_{bone}$ values between the sexes, indicating that access to food resources was not predicated on sex. The chronological patterning of $\delta^{15}N$ values of both bone collagen and dentin at Sacred Heart is similar to that of other 19th century Ontario population studies (Katzenberg 1991; Katzenberg & Pfeiffer 1995) and reflects adherence to advice in historic medical texts (Smith 1890;

Holt 2005). Infants were breastfed for most of their first year of life, with supplementation beginning at approximately 8 to 10 months. The milk of cows raised on maize fodder was a significant weaning food. The weaning process was completed before the child's second birthday, at approximately 18 to 20 months. The timing of the shift in $\delta^{15}N$ values that represents cessation of breastfeeding is associated with appearance of linear enamel hypoplasia, a non-specific dental pathology (Spence 2012) indicative of children experiencing physiological stress shortly after weaning, likely due to the loss of passive immunity from their mothers and increased exposure to the health risks in the greater environment. A dietary shift between post-weaning children and adolescents is likely due to a workforce specific dietary regime experienced by pre-teens as they entered the adult social sphere. Further study of the isotopic composition of carbonate would be useful in reconstructing a more precise diet.

Immigration contributed significantly to the population growth of Canada during the 19th century, and this is reflected in the Sacred Heart population. The $\delta^{13}C$ bone and tooth results identified 15 individuals (20% of total population) displaying a lifetime increase of C_4 plant contribution, indicating a significant dietary change. Individuals who migrated to Ingersoll were likely from a relatively affluent social class, as their isotopic composition is high in dietary protein and is distinct from the profiles at both the Kilkenny workhouse and the Lukin Street Mission. There is possible evidence of family groups migrating together. A group of 6 individuals with a close biological relationship and proximal burial[28] all experienced lifetime increases in $\delta^{13}C$ values. If they migrated together, then they traveled with either a pregnant woman or a young infant, as one of the travelers was less than two years of age at death. At least one other related family group[29] migrated together as well, although it is not possible to specify the age at which this occurred.

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[28] Samples 62, 63, 64, 66a, 66b, and 67

[29] Samples 26, 72, 73

Future research should include measurement of the bone structural carbonate and enamel $\delta^{13}C_{sc}$ and $\delta^{18}O_{sc}$ values. The $\delta^{13}C$ values of the inorganic phase of bone would provide additional data for intra-individual comparison that will elucidate the contribution of different macronutrients to the diet, as opposed to the focus on protein afforded by $\delta^{15}N_{bone}$ studies (Krueger & Sullivan 1984). $\delta^{13}C_{sc}$ values also provide an additional measure of trophic level, and provide an index of relative degrees of "herbivory" and "carnivory" in the human diet (Lee-Thorpe *et al.* 1989). Since oxygen isotopes in water vary due to climate and physical geography, it should also be possible to use the oxygen isotope composition of carbonate as a marker of migration by comparing juvenile and adult environments.

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Appendices

Appendix A: Stable Isotope Analysis of the Sacred Heart Sample

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
3		0.75	0.75	rib	-23.0	10.24	17.01	3.26	45.73	16.35
			0.75	lrm2	-22.49	11.14	10.79	3.12	40.76	15.24
5	f	50-65	57.5	rib	-24.19	9.45	13.69	3.26	45.28	16.21
			57.5	LRC	-24.95	9.67	13.25	3.13	41.75	15.58
9	f	35-45	40	rib	-24.25	8.59	6.33	3.24	41.61	14.99
			40	LRP2	-24.47	9.47	7.46	3.14	41.38	15.37
11		new born	0	rib	-24.07	9.53	19.08	3.18	43.88	16.08
12		7.5-8	7.75	rib	-23.27	7.86	22.89	3.23	46.96	16.96
			7.75	M2	-22.72	9.11	14.14	3.1	42.74	16.07
16		0.5	0.5	rib	-21.76	11.58	20.34	3.21	44.08	16.01
21		3-3.5	3.25	rib	-22.69	8.76	19.4	3.24	45.12	16.22
			3.25	llm2	-22.46	10.89	13.32	3.11	42.72	16
			3.25	lli2	-22.17	11.41	15.29	3.13	41.71	15.56
24	f	40-55	47.5	rib	-23.68	9.19	16.42	3.21	45.4	16.47
25		3-3.5	3.25	rib	-23.86	9.25	16.84	3.21	45.39	16.47
			3.25	m1	-23.52	9.94	14.69	3.25	43.53	15.6
26	f	30-45	37.5	rib	-24.09	8.94	21.97	3.23	46.19	16.69
			37.5	RP2	-25.12	8.92	14.12	3.27	43.17	15.39
27		0.125	0.125	rib	-21.6	10.07	15.47	3.27	45.16	16.13

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
33	m	50-75	62.5	phalanx	-24.24	8.29	18.24	3.21	45.12	16.38
34		0.5	0.5	rib	-22.13	10.1	14.94	3.25	44.81	16.06
35		1.6	1.6	temporal	-23.28	10.4	10.61	3.21	44.72	16.27
			1.6	lrm1	-23.14	11.43	12.43	3.31	39.95	14.06
36		4.5	4.5	rib	-22.3	7.99	15.52	3.21	45.38	16.47
			4.5	URP1	-22.14	8.5	11.21	3.12	40.73	15.2
37	f	15-17	16	rib	-23.1	8.3	10.23	3.24	37.95	13.64
			16	LLM3	-22.83	8.82	12.22	3.27	44.79	15.96
38		2.6-3.5	3.05	vertebra	-23.04	9.13	16.21	3.21	43.95	15.97
			3.05	llm2	-23.29	9.78	10.51	3.11	42.06	15.77
39		1.5	1.5	mandible	-22.77	9.88	16.56	3.2	44.62	16.25
			1.5	ulm2	-22.17	10.88	16.99	3.26	42.97	15.38
43		1	1	rib	-22.44	11.7	20.84	3.18	45.45	16.68
44		1	1	rib	-22.9	10.51	20.35	3.19	44.93	16.45
47	f	60-75	67.5	phalanx	-24.03	7.47	17.76	3.2	44.83	16.33
			67.5	URM2	-24.32	8.73	11.12	3.14	42.54	15.82
48		0.25	0.25	rib	-22.69	10.17	19.89	3.2	45.76	16.68
49	m	17-19	18	rib	-22.25	7.86	17.54	3.15	44.93	16.63
			18	LRM3	-23.95	7.67	11.38	3.26	43.46	15.52
50a		new born	0	rib	-23.21	9.44	15.67	3.23	44.45	16.03
51		new born	0	rib	-22.57	9.8	20.06	3.2	44.19	16.1
			0	ulm1	-22.57	11.34	14.45	3.24	43.72	15.73
55	m	60-80	70	phalanx	-23.94	8.26	17.24	3.18	44.81	16.43

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
			70	ULM2	-23.95	8.33	10.64	3.12	41.6	15.56
56		0.25	0.25	rib	-24.24	6.73	21.42	3.22	44.3	16.06
			0.25	lli1	-23.55	8.82	8.89	3.11	38.56	14.44
57		0.5	0.5	rib	-23.34	11.14	20.54	3.22	44.88	16.24
60	m	17-19	18	rib	-23.55	8.36	19.42	3.16	45.17	16.67
			18	ULM3	-23.25	7.31	13.71	3.12	42.69	15.94
61		40 fw	0	rib	-22.87	11.33	15.61	3.2	44.27	16.15
62	f	60-75	67.5	rib	-23.76	7.65	15.13	3.19	44.31	16.21
			67.5	ULM2	-24.8	7.9	11	3.13	42.66	15.91
63	m	17-19	18	rib	-23.6	8.38	20.24	3.2	45.99	16.77
			18	LM1	-24.61	8.34	13.88	3.26	43.17	15.42
64	m	60-75	67.5	rib	-23.31	8.64	16.13	3.18	44.45	16.32
			67.5	ULM2	-24.81	8.02	10.73	3.12	40.12	14.98
65		new born	0	vertebra	-23.62	10.26	15.04	3.21	45.51	16.56
66a		1.8	1.8	rib	-23.23	9.06	20.33	3.18	44.73	16.38
			1.8	uri1	-23.3	11.19	18.79	3.26	43.35	15.49
66b	f	60-75	67.5	Rib	-23.33	7.85	20.97	3.21	45.2	16.42
			67.5	URP1	-24.33	7.9	12.11	3.13	43.69	16.3
67		3.5	3.5	rib	-23.22	8.42	18.07	3.18	45.31	16.62
			3.5	lrm1	-22.97	8.89	16.96	3.11	42.44	15.91
69		1.3	1.3	rib	-22.54	11.33	18.94	3.17	44.8	16.48
			1.3	LRC	-22.07	12.56	12.55	3.12	42.11	15.72
70	f	25-30	27.5	phalanx	-23.4	9.17	19.74	3.18	45.56	16.69

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
			27.5	ULM2	-23.63	9.36	14.58	3.11	42.32	15.88
71	f	55-70	62.5	rib	-22.18	9.37	14.19	3.17	44.88	16.5
72	m	45-65	55	phalanx	-23.97	8.82	6.68	3.21	39.01	14.16
			55	LRC	-24.96	7.97	8.82	3.33	42.72	14.98
73	m	55-70	62.5	rib	-23.75	8.29	19.95	3.16	44.88	16.58
73			62.5	ULM1	-24.47	7.03	10.9	3.25	44.23	15.85
75	m	45-60	52.5	rib	-22.31	8.27	18.41	3.18	44.86	16.46
			52.5	LRM2	-24.45	8.09	14.01	3.23	44.5	16.07
85	m	55-70	62.5	rib	-23.17	8.2	14.73	3.2	44.19	16.12
			62.5	ULM2	-22.99	7.83	8.06	3.27	42.33	15.1
88	f	17-18	17.5	rib	-23.31	8.59	3.78	3.19	39.22	14.35
			17.5	URM3	-23.5	9.04	10.11	3.11	41.87	15.68
89a		3-4.5	3.75	phalanx	-18.69	9.94	18.55	3.17	44.8	16.49
			3.75	ulm2	-17.55	11.44	12.67	3.12	41.74	15.62
89b		3-4.5	3.75	rib	-23.24	8.55	16.93	3.17	40.84	15.03
			3.75	ulm2	-22.46	10.71	18.69	3.2	45.68	16.67
90	f	17-18	17.5	rib	-23.46	9.06	6.63	3.22	42.48	15.33
			17.5	ULM3	-23.36	7.7	10.65	3.27	41.91	14.94
93		0.75	0.75	rib	-22.98	11.06	21.68	3.19	45.14	16.52
95		new born	0	rib	-23.42	9.96	18.05	3.21	44.04	16
96		10-11.0	10.5	rib	-23.97	6.34	14.35	3.17	44.91	16.5
			10.5	lrm1	-23.94	6.92	12.12	3.14	41.98	15.58
98		new born	0	rib	-23.44	9.33	19.45	3.23	46.28	16.68

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
99		0.25	0.25	vertebra	-22.32	11.21	16.37	3.21	45.16	16.42
114	f	60-80	70	cranial	-24.1	8.35	21.93	3.17	44.58	16.39
			70	LRP2	-24.1	9.14	13.26	3.12	43.78	16.39
115	m	30-45	37.5	phalanx	-24.39	8.6	18.03	3.19	44.71	16.34
			37.5	ULM2	-23.88	8.39	10.33	3.23	41.47	14.96
119a	f	45-55	50	rib	-23.88	8.46	18.77	3.21	16.42	45.14
			50	URM2	-23.4	9.31	13.89	3.15	38.69	14.34
123		new born	0	rib	-23.94	8.69	15.71	3.23	45.02	16.25
124a		new born	0	rib	-23.38	9.17	14.92	3.19	44.71	16.34
124b	f	55-70	62.5	rib	-23.99	7.87	23.08	3.17	45.19	16.63
125		1.3	1.3	rib	-22.91	9.66	17.84	3.21	44.63	16.21
			1.3	urm1	-22.33	10.8	10.97	3.24	43.55	15.65
127a		28 fw	-0.231	vertebra	-24.09	8.92	13.43	3.23	44.26	15.96
127b		37 fw	-0.038	vertebra	-24.31	9.06	15.14	3.21	44.18	16.04
130		2	2	rib	-24.08	9.03	19.11	3.2	45.76	16.7
			2	um1	-23.79	10.46	14.25	3.2	44.64	16.25
131a		6-6.5	6.25	rib	-22.94	8.21	20.48	3.18	44.42	16.27
			6.25	URP1	-22.75	9.05	15.04	3.12	42.5	15.89
131b	m	55-70	62.5	rib	-24.17	8.64	18.29	3.18	43.35	15.9
			62.5	URM3	-24.27	9.8	14.61	3.11	42.41	15.93
132a		1.3	1.3	maxilla	-23.97	9.7	19.68	3.18	44.35	16.28
			1.3	lrm2	-23.29	10.88	12.02	3.21	44.73	16.24
133		0.7	0.7	rib	-23.28	11.01	20.95	3.18	45.23	16.59

Sample ID	Sex	Skeletal Age	Age (mean)	Sample	$\delta^{13}C_{diet}$ (VPDB)	$\delta^{15}N_{diet}$ (AIR)	Collagen Yield (%)	C/N Ratio	Carbon %	Nitrogen %
			0.7	urm1	-23.09	11.98	14.35	3.24	42.67	15.34
139	m	50-65	57.5	phalanx	-24.08	8.59	11.55	3.19	43.25	15.8
			57.5	LRP2	-24.43	9.28	17.08	3.22	44.25	16.02
140		3.9	3.9	sphenoid	-24.28	8.88	18.09	3.16	44.92	16.57
			3.9	urm1	-23.69	9.71	11.86	3.26	44.28	15.83
141	m	16-18	17	rib	-23.65	9.27	13.34	3.25	44.45	15.97
141			17	ULM2	-22.65	7.79	9.21	3.13	41.91	15.61
143		3.5	3.5	illium	-23.34	7.94	20.83	3.18	44.05	16.15
			3.5	urm1	-23.45	7.97	11.51	3.22	43.71	15.8
144		new born	0	rib	-22.23	10.53	18.54	3.2	45.22	16.48
145	m	60-75	67.5	phalanx	-23.99	8.25	19.88	3.17	40.86	15.03
			67.5	ULM2	-24.35	8.19	9.47	3.16	41.43	15.28
300		2	2	temporal	-23.68	8.64	8.64	3.18	42.14	15.45
			2	lrm1	-23.26	8.92	13.87	3.31	23.6	8.31

The $\delta^{13}C$ and $\delta^{15}N$ values are corrected for collagen – diet fractionation: –3.7‰ for carbon isotopes (after Vogel & van der Merwe 1978) and –3‰ for nitrogen isotopes (after DeNiro and Epstein 1981).

Appendix B: Irish Origin in Sacred Heart Grave Markers
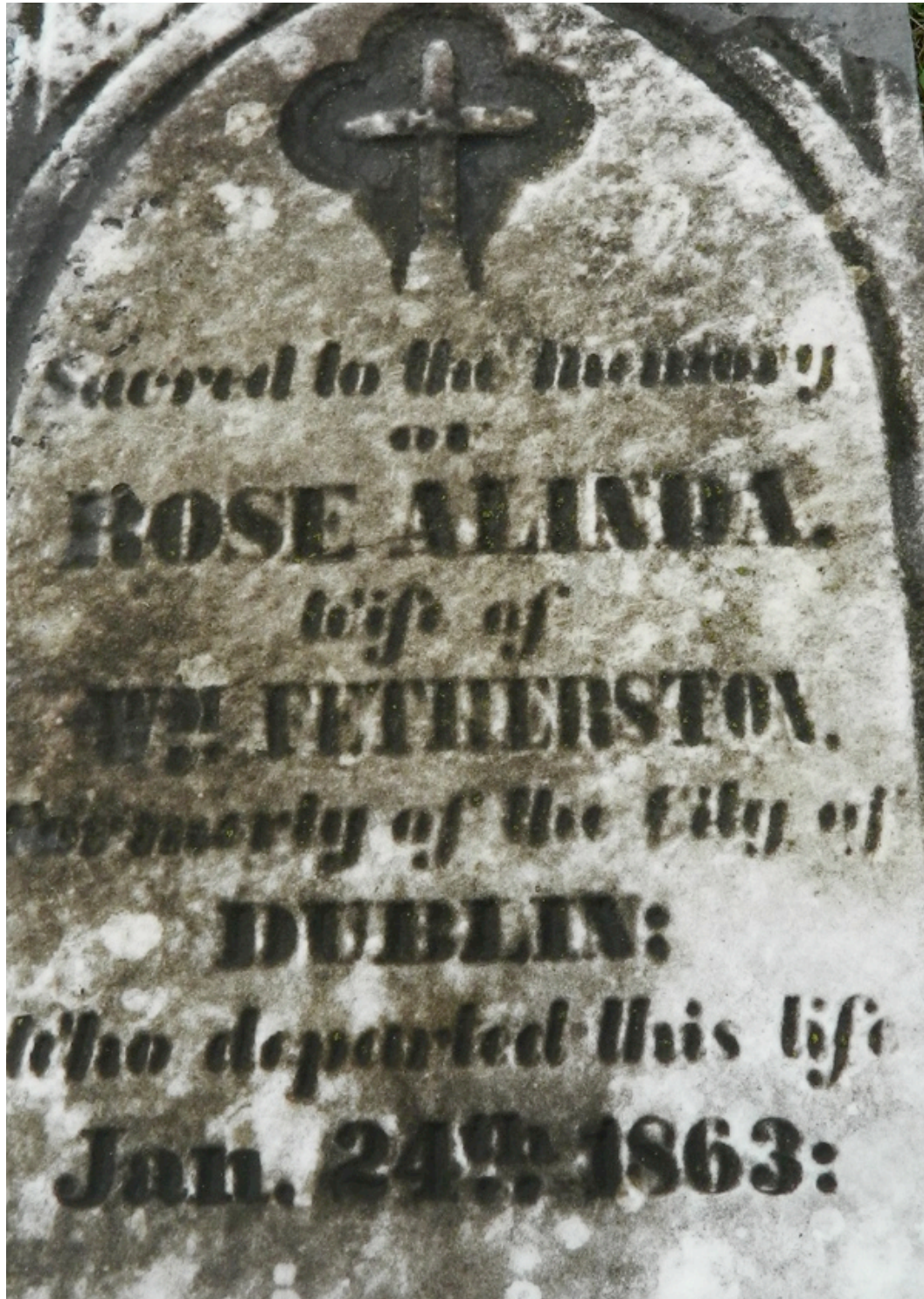
"Sacred to the memory of ROSE ALINDA, wife of William Featherston, Formally of the City of DUBLIN: Who departed this life Jan. 24th 1863"

(Personal photograph by Emily Wells, 2011)
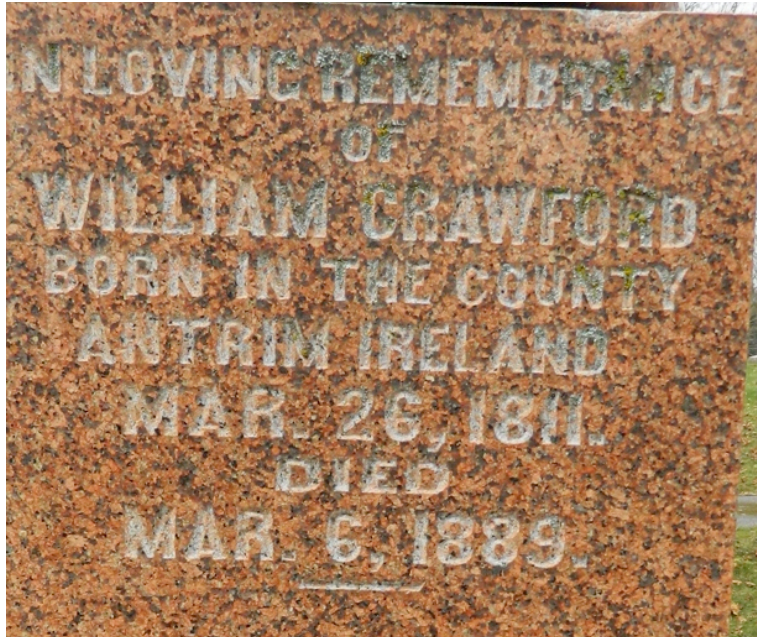
Above: "IN LOVING REMEMBRANCE OF WILLIAM CRAWFORD BORN IN THE COUNTY OF ANTRIM IRELAND MAR. 26, 1811. DIED MAR. 6, 1889"

Left: "MARY ANN HENNESSEY, WIFE OF JOSEPH NAGEY, DIED JUNE 17, 1887, AGED 72 YEARS, NATIVE OF SUTTON PARISH, WEXFORD COUNTY, IRELAND / JOSEPH NAGEY, BORN AUGUST 27, 1816 IN THE PARISH OF TINTERN, WEXFORD COUNTY, IRELAND, DIED JANUARY 1, 1887"

(Personal photographs by Emily Wells, 2011)

Above: "RICHARD RYAN, DIED DEC. 14, 1895, AGED 87 YRS. 10 MOS. NATIVE OF TIPPERARY IRELAND."

Left: "IN MEMORY OF ALICE, WIFE OF ROBERT PAUL, DIED NOVEMBER 8, 1880, AGED 76 YEARS. NATIVE OF COUNTY ARMAGH, IRELAND."

(Personal photographs by Emily Wells, 2011)
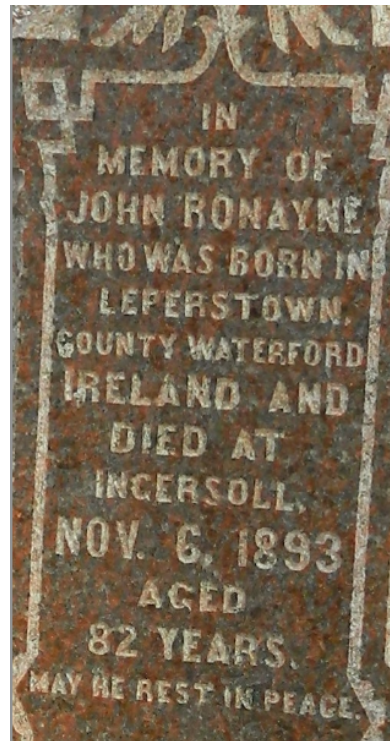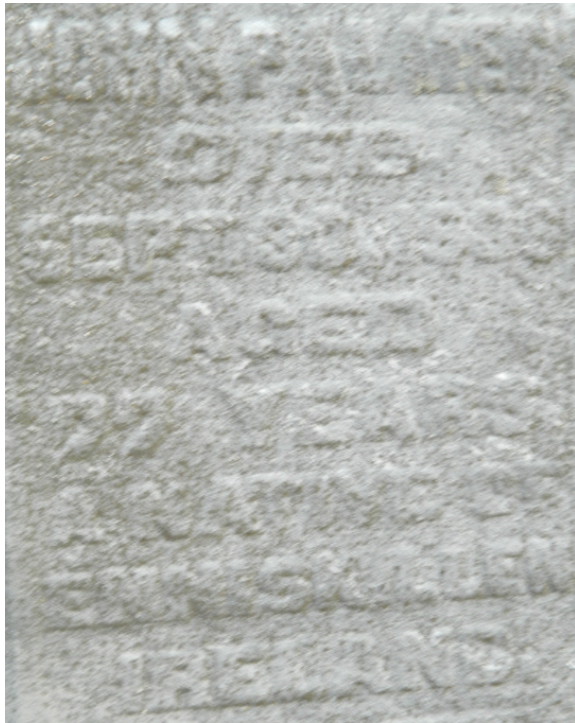
Left: "JOHN PALMER, DIED SEPT. 30, 1906, AGED 77 YEARS, A NATIVE OF ENNISKILLEN IRELAND"

Center: "IN MEMORY OF JOHN RONAYNE, WHO WAS BORN IN LEPERSTOWN, COUNTY WATERFORD, IRELAND AND DIED AT INGERSOLL, NOV. 6 1893, AGED 82 YEARS. MAY HE REST IN PEACE"

Right: "THE SOULS OF MICHAEL LENIHAN, DIED JANUARY 2, 1894, AGED 76 YEARS / CATHERINE, WIFE OF THE ABOVE, DIED DECEMBER 24, 1898, AGED 80 YEARS, NATIVES OF THE CO. LIMERIC IRELAND"

(Personal photographs by Emily Wells, 2011)
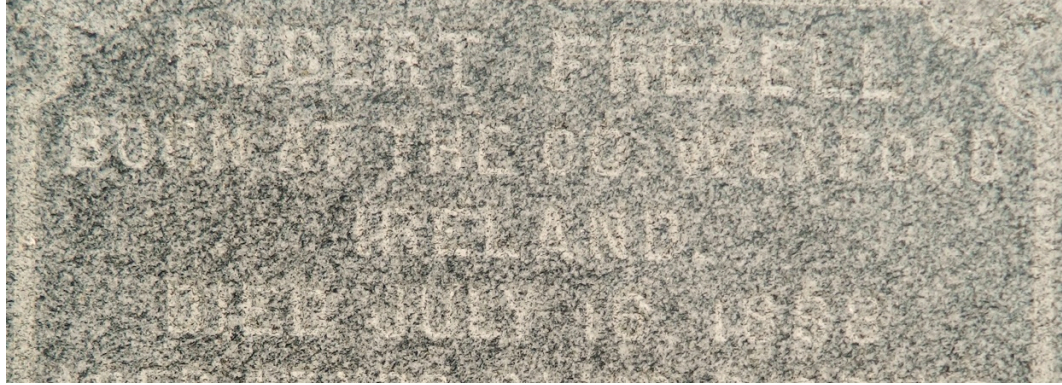
Above: ROBERT FREZELL, BORN AT THE CO. WEXFORD, IRELAND. DIED JULY 16, 1888

Below: Monuments in the Sacred Heart Cemetery in the Irish "Celtic Cross" style.

(Personal photographs by Emily Wells, 2011)

Appendix C: Trait Clusters identifying Possibly Related Individuals

Trait Cluster 1	5	8*	9	11	12	14*	15*	29*	30*	31*	33
coronal ossicle					x	x					
bifid rib					x						x
trochlear spur					x		x				
multiple supraorbital openings						x	x				
palatine torus	x		x								
lambda bone					x		x		x		
epipteric bone				x			x				
asterionic bone					x			x			
posterior condylar canal absent	x				x	x		x	x		x
mandibular taurus		x	x					x			

Trait Cluster 2	119a	120*	125
palatine torus	x	x	
parietal notch bone	x	x	
multiple supraorbital openings	x	x	

posterior condylar canal absence	x	x				
epipteric bone	x	x				
lambda bone	x		x			

Trait Cluster 3	**122***	**124a**	**124b**	**133**	**144**	**145**
coronal ossicles	x		x			
mandibular torus	x		x			
lambda bone	x		x			
parietal notch			x		x	

Trait Cluster 4	**62**	**63**	**64**	**65**	**66a**	**66b**	**67**
agenesis of 12th rib	x		x				
open foramen ovale	x		x				
trochlear spur		x	x				
metopic seture	x	x	x				
epipteric bone		x				x	x

Trait Cluster 5	**25**	**26**	**37**	**71**	**72**	**73**	**74***	**76***

lumbosacral shift					x	x		x	
mandibular torus					x		x		
asterionic bone		x			x	x			
lambda bone			x		x	x			
parietal notch bone		x	x			x			
epipteric bone		x	x	x					
metopic suture	x	x	x		x				
Trait Cluster 6	**131a**	**131b**	**132a**	**132b*[30]**	**113***	**114**	**115**	**139**	**140**
reduced UM3					x		x		
occipito-mastoid ossicle	x						x		
parietal notch bone	x	x							
lambda bone	x					x	x		
posterior condylar canal absent						x	x	x	x
pseudoarthrosis of anterior illium						x		x	

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[30] * Indicates individuals not included in the stable isotope analysis. Dr. Spence's skeletal analysis (2012) used data and observations from individuals who were not subsequently sampled for stable isotope analysis

Curriculum Vitae

Name: Emily Wells

Post-secondary   Western University
Education and   London, Ontario, Canada
Degrees: 2006-2010 B.A.

                     The University of Western Ontario
                     London, Ontario, Canada
                     2010-2014 M.A.

Honours and   Western University Social Science Alumni Award
Awards: 2010

                     Social Science and Humanities Research Council (SSHRC)
                     Joseph-Armand Bombardier Canada Graduate Scholarship
                     2011-2012

Related Work   Teaching Assistant
Experience: The University of Western Ontario
                     2010-2011

                     Digital Archivist
                     Ontario Archaeological Society
                     2012

                     Field Archaeologist
                     Archaeological Services, Inc.
                     2012-2014

Conference Presentations:
2012 "Isotopic Bioarchaeology of Children at the Sacred Heart Cemetery in Ingsersoll, Ontario." Poster Presentation at the Annual Meeting of the Society for American Archaeology, Memphis, TN.