UNDERSTANDING THE TRADITIONAL FOOD SYSTEM OF FIRST NATIONS IN CANADA IN THE CONTEXT OF BIODIVERSITY

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ABSTRACT

The health and well-being of Indigenous Peoples, including their nutritional status, is poor compared to the general Canadian population. There are many causes of these disparities, including racism, poor access to health resources, and the nutrition transition. Before colonization, most First Nations across Canada consumed diets purely composed of Traditional Foods (TF) that were hunted or collected from the natural environment. TF are important for their nutritional quality, food security, and culture. However, rates of TF consumption have decreased in recent years contributing to poor dietary outcomes. The diversity and quantity of TF consumed is thought to be primarily dictated by the ecological biodiversity in the surrounding environment; however, this relationship remains untested in Canada. The objective of this study was to gain a better understanding of First Nations modern food systems by evaluating the relationship between ecozone biodiversity and nutritional outcomes in the form of dietary diversity in First Nations individuals across Canada. We used dietary data and household data collected by the First Nations Food, Nutrition and Environment Study and multiple biodiversity databases for analyses. Spearman's correlations were used to investigate the relationship between dietary diversity and nutrition. A statistical model was used to evaluate the relative predictive power of biodiversity and multiple other predictive variables in determining dietary diversity. We found that individuals who consume more TF have more nutrient rich diets, and therefore, dietary diversity is a good indicator of nutrition outcomes. We also found that in contrast to previous research and assumptions, in the context of First Nations living in Canada, biodiversity has a negative relationship to dietary species richness. It was also determined that variables related to culture, and accessibility of TF were the most important factors in predicting positive nutritional outcomes. These preliminary results provide key areas for interventions essential for increasing access to TF.

ETHICS STATEMENT

Primary research was not conducted for this study. Since the data from the First Nations Food Nutrition and Environment Survey (FNFNES) involves sensitive information regarding the individuals who participated in the study, I have been granted permission from the head researchers and followed their confidentiality guidelines. All participants have been anonymized, and no personal information has been used or revealed in this thesis work.

POSITIONALITY

I acknowledge my position as a non-Indigenous Canadian performing research on Indigenous topics and with data from First Nations communities across Canada. I recognize the limitations in my perspective and that my interpretation of the data is inspired by the Western scientific perspective that I have obtained throughout my formal education. I pay respect to Traditional Knowledge, those who hold it, and those who provided their time and resources to this study. While understanding the limitations in my knowledge, it is my goal that the research done in this thesis coincides with how Indigenous peoples of Canada experience their food systems.

STATEMENT OF AUTHORSHIP & COLLABORATION

CHAPTER 1: The research questions and thesis topic were developed by HK and refined through conversations with HMC and TK.

CHAPTER 2: HK performed the literature review and drafted the manuscript with guidance from HMC and TK. HMC and TK provided their own knowledge and perspective and guided the style of writing as well as suggested concepts. SDW and JK provided comments and insight into their respective fields.

CHAPTER 3: HK collected data, performed the statistical analysis, analysed the results, and drafted the manuscript. DK and MH each provided a technique for gathering biodiversity data. CL and GHC provided their own methodology for calculating dietary diversity data using measures traditionally used for biodiversity. TK provided guidance on the use of the r program for statistical analysis and correct statistical methods. HMC and XH assisted with statistical methodology and interpretation. Results were compiled by HK and modified through consultations with HMC.

CHAPTER 4: The discussion was researched, conceptualized, and written by HK. HMC, TK, SDW, and JK provided feedback through their own expertise and knowledge, bringing increased focus to the concepts discussed.

Co-authors: HK = Hannah Klassen; HMC = Laurie Hing Man Chan; TK = TiffAnnie Kenny; SDW = Sonia D. Wesche; JK = Jeremy Kerr; DK = Daniel Kraus; MH = Murray Humphries; CL = Carl Lachat; GHC = Giles Hanley-Cook; XH = Xuefeng Hu

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ACRONYMS

Dietary Diversity	DD
Dietary Diversity Score	DDS
Indigenous and Northern Affairs Canada Remoteness Index Zone	INACRIZ
United States Geological Survey	USGS
Body Mass Index	BMI
Healthy Eating Index	HEI
Household	HH
First Nations Food, Nutrition, & Environment Survey	FNFNES
Food and Agricultural Organization	FAO
Household Dietary Diversity Score	HDDS
Quantitative Index for Dietary Diversity	QUANTIDD
Food Variety Score	FVS
Simpsons Index of Diversity	SID
Dietary Species Richness	DSR
Mean Adequacy Ratio	MAR
Traditional Foods	TF
Species Richness	SR
Principal Component Analysis	PCA
Dominance Analysis	DA
Food Security	FS

1. Introduction

1.1 Research Context

Indigenous people represent 4.3% of the Canadian population, with 60.8% self-identifying as First Nations (1). The First Nations People of Canada are composed of over 600 nations with over 60 languages spoken (1). The diversity in culture and traditions varies significantly between nations. First Nations populations make up approximately 2.6% of Canada's total population, but experience health disparities at a disproportionate rate to non-Indigenous Canadians (1). Experiences of racism, poor access to healthcare, and poor living conditions on government-based Indigenous reserves have made Indigenous health and well-being a major concern over the past century (2). Cardiovascular diseases and other nutrition-related chronic diseases have reached alarming levels in the First Nations population in Canada, with rates of obesity and type 2 diabetes occurring at rates double that of other Canadians (3). The rise in these illnesses can be attributed to the increasing difficulties in Indigenous communities to maintain nutritionally adequate diets and namely the nutrition transition that has occurred (3,4).

Traditional Indigenous diets in Canada were subsistence-based, meaning that individuals harvested, collected, and hunted TF from the immediate environment throughout the year (5). TF provide key nutrients like vitamin E, vitamin B-6, zinc, iron, and vitamin D, and a high protein content not commonly found in MF (6). As such, TF provided sufficient energy and nutrients to Indigenous peoples in Canada since time immemorial. With colonialism came the introduction of highly processed market foods (MF) and the nutrition transition towards consuming more foods with high caloric density and low nutritional value compared to TF (4,7). Due to the isolated nature of some Indigenous communities, the shipment of fresh foods into the communities is a lengthy and expensive process (4). As a result, many people cannot afford fresh produce and must rely on cheaper, highly processed foods, resulting in remote and geographically isolated communities having individuals with nutritionally inadequate diets (4,8). Over the years, starting with a loss of culture from forced assimilation and later on, losing access and availability to TF due to environmental changes, Indigenous Peoples in Canada have been consuming TF less frequently (4, 9). The reduction in TF use also decreased physical activity as hunting, fishing, gathering, and processing TFs require an energy expenditure needed for good health (9,10). An increase in metabolic syndromes and other nutrition-related chronic diseases resulted from this transition (9,10). Some of these diseases include obesity, type two diabetes, and cardiovascular disease, all of which contribute to a lower life expectancy (10). This shift has also been noted globally. For example, over the past 60 years, local Indigenous populations in Fiji shifted from mainly subsistence-based diets to the majority of diets being based on imported foods (11). While TF provides an average of only 4.6% of daily calories in current First Nations diets (12), studies show that daily nutrient intakes are significantly higher and intakes of saturated fat are lower for those who consume TF (12). These are significant findings as they show the benefit of consuming even a small portion of TF daily.

A commonly used metric for evaluating dietary quality is Dietary Diversity (DD). Dietary diversity is defined as the number of different foods consumed over a specified period of time (13,14). Methods for evaluating adequate nutrition are an evolving field as techniques with higher specificity are developed. Although DD scores are often recognized as a good measure of diet quality, there are a few inconsistencies in results showing lack of correlation between DD and nutrition indicators. These inconsistencies can be attributed to the variance of nutrient content in each food or food group and the increased consumption of non-nutritious foods. Therefore, the DDS may not be a good indicator of adequate nutrient intake in the Canadian population as many diets include foods with varying degrees of nutritional benefits (processed market foods) (15). However, DDS is a good measure of nutritional adequacy when considered in the context of diets comprised of healthy foods with ecological benefits. Therefore, when considering diets composed of Traditional Foods (TF), which are nutritionally rich and diverse in nutrient content (16), DD can effectively be used as a score. TF are commonly defined as foods of cultural significance which are obtained from the environment, often using traditional methods of hunting, fishing, and gathering and using Traditional Knowledge (TK)(10). Since these foods are already known to be nutrient-rich, having a higher DDS should be a good indicator of a nutritionally adequate diet (6,16).

Another global indicator used to understand dietary adequacy and human health is Food Security (FS) (4). Food security as defined by The Food and Agriculture Organization of the United Nations, is “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meet their dietary needs and food preferences for an active and healthy lifestyle" (4). However, food security and sovereignty have different meanings as it relates to Indigenous food systems. Settee et al., produced four guiding principles to translate Indigenous ways of understanding food systems (17). The principles explain how Indigenous food security extends beyond the ability to have sufficient resources and acknowledges the reciprocal relationship with the earth, the community, and oneself (17). This understanding recognizes components necessary for a subsistence diet and the importance of Indigenous social and cultural norms associated with TF (4). Food insecurity is much higher in Indigenous populations at 33% compared to the non-Indigenous Canadian population at 9%, with communities in geographically remote locations experiencing the highest rates (8,18).

In tandem with the shift towards the consumption of processed foods, rapid environmental changes have made subsistence practices increasingly challenging (5). Traditional subsistence plays a significant role in food security and nutritional adequacy for Indigenous communities in Canada (5). Globally, policies and solutions for food security have focused on cultivated foods despite approximately 1 billion people using TF in their diet (19,20). Even though the food crop production has increased by 300% since 1970 (21,22), there are still over 840 million people worldwide who experience hunger, and even more experience micronutrient deficiencies (22). While global food demand is increasing, biodiversity loss and reductions in farmable land are being exacerbated by climate change (3,21,22). Although conjectured as being critical components of the food system, the contribution of TF and ecological biodiversity to nutrition and food security is often overlooked (24).

Biodiversity is critical for ecosystem resiliency which in turn is critical for combatting further climate change damage (25,26). More generally, biodiversity holds economic value by providing goods and services to the general population, a pattern commonly defined as ecosystem services (25). Measuring and tracking biodiversity is more important than ever as anthropogenic activities impact biodiversity, the health of ecosystems, and subsequently human health and nutrition (25). According to ecosystem service theories, adequate nutrition is closely tied to direct access to nutritious foods in the environment. These findings are extensively researched in highly biodiverse locations with long growing seasons, plenty of natural resources, and the year-round availability of foods. It has often been hypothesized that this finding extends beyond tropical locations into various spheres, whereby ecological biodiversity directly affects the diversity and, therefore, quality of diets. Biodiversity has many definitions and is notoriously difficult to define in relation to human well-being outcomes. One common method for evaluating biodiversity is by calculating the relative abundance or counting the number of species in a region (27). This method is broad with many critiques, the most prominent being that not all species perform the same tasks in the environment or have the same impact. Gamfeldt et al. suggest an alternative approach called Functional Diversity (FD) whereby biodiversity is evaluated based on the functions performed by the species in service to the ecosystem (28). There is redundancy in nature whereby certain species perform similar functions and are therefore not essential for overall ecosystem wellbeing (28). Therefore, FD is an interesting alternative to Species Richness (SR), as a region with high SR may not have high-performing species essential for the wellbeing of that environment, but the SR tool does not have the ability to test for ecological function of species present (27,28). Despite the critiques, SR of the species or taxonomy present in a region have been deemed one of the best tools available for estimating biodiversity and is therefore, the definition of biodiversity used throughout this paper (27).

Ecological constraints suggest that the choice of TF is limited to the availability of species living in that region (29). Based on this assumption, the division of Canada into ecological regions should represent the availability, and therefore consumption, of TF in each region. For example, peoples living in the Pacific Maritime ecozone would have access to aquatic species not available to landlocked communities (29). Location within an ecozone is also important to consider, as communities located at transition zones between ecosystems will have access to a greater variety of TF (29). The common argument is that a higher diversity of regionally available species and, therefore, available foods should result in improved food security and higher DD (11,30,31). Understanding the ecological connections to Indigenous diets is critical as TF are an important aspect of their diet (29). However, it is still being determined whether higher levels of biodiversity in the immediate environment result in improved nutritional health and well-being for these populations (31).

For this research, SR is calculated at the ecozone level to reflect regional biodiversity. Ecozones are a type of ecosystem classification method and are the highest form of classification in Canada (32). There are 15 terrestrial ecozones in Canada, divided up based on ecosystem features such as composition, structure, and function (32). Since ecozones are the largest geospatial division of land in Canada, some regions are expansive and include both terrestrial and aquatic ecosystems (32). Each ecozone is characterized by distinct bedrock features that differ from adjacent ecozones (32). The variations in bedrock impact ecosystem function and alter the organisms that naturally occur there, making each ecozone functionally different (32). Therefore, ecozone classification captures the range of diversity in specific Canadian regions. Eleven of Canada's 15 terrestrial ecozones were used in this research (the northern territories were not included in the study): the Pacific Maritime, Boreal Cordillera, Montane Cordillera, Taiga Plains, Boreal Plains, Prairies, Boreal Shield, Taiga Shield, Hudson Plains, Mixedwood Plains, and the Atlantic Maritime (12).

1.2 Gaps in knowledge

The importance of biodiversity for ecological functioning has been established (19,25). Biodiversity improves ecosystem resilience to environmental changes, increases productivity, and improves the health of organisms within the system (25). It is often conjectured that the same principles apply to the diets of people who consume foods from their local ecosystem. A more diverse environment is assumed to increase the diversity of diet via improved accessibility to TF and a more diverse diet is often considered to be more nutrient-rich (11,16,30,31). As climate change alters ecosystem health and TF access, it becomes increasingly important to quantify the strength of this relationship. These relationships have been studied in selected populations in diverse locations, for example: Indigenous communities in Fiji, agricultural households in Malawi, and rural households in Tanzania, Cameroon, Ethiopia, Zambia, and Nicaragua (11,14,30,33,34). However, the relationship between biodiversity and DD or dietary quality has yet to be studied in less ecologically diverse locations or in high-income countries like Canada (5,6,22). As such, the relationship between regional biodiversity and dietary quality in Canada needs to be clarified. This project attempts to fill this gap by determining whether these known ecological concepts can be applied to human health and nutrition. This thesis focuses on TF dietary diversity as an indicator of nutritional quality for First Nations people living in Canada, recognizing the significant contribution of TF to total nutrient consumption (8,13,16). TF are also collected from the immediate environment, testing the direct pathway between ecozone biodiversity and the diversity of foods consumed. Establishing the relative importance of regional biodiversity and other predictive variables for the dietary quality of Indigenous populations is critical to further our understanding of connections between ecological biodiversity and human nutrition.

The availability and accessibility of TF sources are not the only predictors of human's dietary patterns. Although ecological factors may play a role, it is unclear how prominent that role is as many confounding factors contribute to consumption patterns. The variables predicting the dietary outcomes are complex and relative among different groups of people, including age, gender, and cultural communities. Food choices and nutritional outcomes depend on many factors, including socioeconomic status, lifestyle factors, social and cultural structures, and the accessibility of various foods. All these variables interact with each other across different scales, creating complexity when attempting to understand their relationship. These variables have been discussed in previous research qualitatively, but empirical evidence for their contribution to DD in First Nations communities is largely missing (36). Willows et al. explain the need for a more comprehensive understanding of the determinants of TF to improve the dietary patterns of Indigenous Peoples (36). For example, the idea that food consumption is both ecologically and culturally determined has been considered in qualitative reports but rarely has their relationship been confirmed empirically (29). Tremblay et al. tackled the cultural concepts in detail (29), and this research aims to quantify the ecological relationships to DD.

The final gap in knowledge concerns the geographic area and population of focus of dietary research in Indigenous populations in Canada. Most existing studies have been conducted among Inuit in Arctic Canada, and very few focus on First Nations in Canada (4,7). Research outputs stemming from the First Nations Food Nutrition and Environment Study (FNFNES) are some of the few papers that focus dietary studies on Indigenous communities in diverse and southern regions across Canada (10,37). Therefore, this research will contribute to increasing the studies completed in First Nations communities across Canada.

1.3 Research Objective

A significant challenge for First Nations communities across Canada has been maintaining nutritionally adequate diets throughout the various changes to the Indigenous food system. Among those changes includes a reduced availability and accessibility of TF. With climate change further reducing the accessibility of TF, it is critical to understand how future ecological changes will impact the diets of Indigenous Peoples. To develop interventions aimed at improving the food security and dietary quality of First Nations Peoples, it is imperative to understand which variables are important for predicting dietary outcomes. Therefore, this research aims to determine the relative importance of ecozone biodiversity in predicting DD and the dietary quality of First Nations populations in Canada.

To effectively translate ecological knowledge into proper management and understanding of food systems, nutrition, and public health measures, some key questions need to be answered. This thesis will address the previously mentioned gaps in knowledge by furthering the understanding of ecology's role in human health and diet. The specific objectives are to use data from existing databases to answer the following questions:

1. What is the relationship between ecozone biodiversity and the DD of First Nation populations living on reserve in Canada?
2. What is the relationship between DD and the nutritional quality of diets of First Nations living on reserve in Canada?
3. How strong are the associations between ecozone biodiversity and DD when compared with other covariates, such as socio-economic and demographic factors?

1.4 Thesis Structure

Chapter one discusses the background, context, and rationale that informed the research. This first chapter outlines the objectives of the research, gaps in current knowledge, and lays out the questions that will be answered in the subsequent chapters. Chapter two situates the thesis work in the existing body of knowledge. This chapter explores the current understanding of the relationship between traditional food use and biodiversity in Canada and globally, as well as exploring the intricacies of First Nations traditional food systems in Canada. Chapter three is the manuscript, including the methodology, results, and discussion. Finally, chapter four discusses the results of the three research questions in detail, elaborating on areas for future study and concluding with the significance of this research.

2. Review of Literature

Studying the complex relationship between biodiversity and dietary diversity requires expertise in the related but distinct fields of ecological biodiversity and human health and nutrition. This section begins by outlining Indigenous health and food systems to situate the research. Next, the importance of biodiversity and presumed benefits to human health are discussed. Finally, the global understanding of the relationship between biodiversity and DD is reviewed. Understanding the current knowledge on these topics guides the research questions and subsequent methodologies.

2.1 Dietary Diversity in Canadian Indigenous populations

Rates of food insecurity and inadequate nutrition are higher in Indigenous households across Canada than in non-indigenous populations (8,18). Food insecurity has been linked to poorer health conditions like infections and chronic diseases, and increases in psychological distress (7). Diverse diets have been shown to improve nutritional status and contribute to food security (5, 8,22). DD as an indicator is frequently used to measure the quality of diets in population studies and has proved effective in predicting nutrition-related health outcomes (13,14).

There are many factors that contribute to predicting dietary outcomes in Canada's Indigenous populations. One important set of variables are ecologically related and include seasonality, regional variance, and biodiversity. In this study, regionality is represented by ecozones (39). Since TF are collected from the local ecosystem, the types of species available in specific regions determine which species are likely to be consumed (39). There are several key reasons why biodiversity would majorly influence DD. First, diversity of diet is necessary when relying on the environment for food sources, as availability changes by season, migration patterns, and environmental changes. Relying heavily on one species, such as caribou, leaves a community sensitive to environmental changes (4). Should this resource become scarce or obsolete, their ability to adapt is severely diminished compared to communities with a diverse knowledge of the species in their region and a variety of species in their diets, as they have a higher capacity to adapt to changes in species availability (4). These trends are seen with seasonality as well. When communities harvest and consume more species, maintaining a healthy diet is easier throughout the lean seasons (4). Traditional knowledge and practices surrounding storing and preserving foods also accounts for the lean season (40). The continuation of these cultural practices is crucial for consumption of TF year-round.

2.2 Traditional Foods

TF could be a key resource for improving DD and food security among Indigenous populations. While many contemporary diets depend on MF, or foods purchased in retail environments, Indigenous food systems rely on both MF and TF (7,12). TF commonly consist of locally available plant and animal species such as berries, fish, birds, and mammals (39). TF constitute a significant source of micronutrients and food security, accounting for 30-93% of Indigenous People's total dietary energy (5). TF are nutrient-rich foods containing essential nutrients like vitamin D, iron, magnesium, and high protein content (10). Inuit communities in Arctic Canada were found to have higher quantities of micronutrients and protein in their diets when there were TF in their diets (41). Interestingly, the increased protein from TF was paired with a reduction in carbohydrate consumption and, therefore, an overall decrease in MF (41). With global Indigenous communities using over 200 wild species, TF could be a key component for fighting nutrient deficiencies and global hunger (19,22,24). Throughout the year, depending on many variables like seasonal availability, socio-economic variables, and individual variants, the relative contribution of MF's and TF's to an individual's diet changes (7). Despite the relative importance of MF for adequate caloric consumption, MF are often expensive and have high caloric density with low nutritional value compared to TF (7,10). These trends signify the importance of ongoing TF consumption.

TF may be critical for food security amongst Canadian Indigenous Peoples, particularly those in remote areas (42). Studies completed in Inuit communities in Northern Canada discovered that five out of six households were food insecure (43). Individuals reported a mix of food accessibility issues. For MF, over 50% of women in Nunavut and Labrador stated they could not buy all the food they needed from the store (43). However, there are also barriers to accessing TF, with many Inuit reporting inability to fish or hunt due to expenses (43). Food security hinges on TF accessibility as days without TF consumption increases refined carbohydrate consumption and reliance on MF (43). However, MF are not always accessible as cost increases in northern and remote locations (43). For increased food security, consumption of TF is paired with traditional practices like sharing, an important tenet of Indigenous food systems. For example, cultural events like community feasts and TF sharing networks mitigate access barriers to TF for elders or others who are unable to hunt (43). Unfortunately, in recent years, lack of sharing has been cited as a barrier to accessing TF (12,42).

Maintenance of traditional subsistence practices is critical for improving rate of food security and nutritional inadequacies (5). Apart from being a method for gathering food, subsistence holds deep cultural and spiritual roots in First Nations traditions. Consumption of TF and the practices associated with them are a critical component of Indigenous peoples' connection to nature, facilitating spirituality, deepening their connection to their history, and overall well-being (5,8,10). The role of culture in dietary choices amongst Indigenous Peoples is complex, and only recently has research attempted to understand these complexities (8,29). Indigenous Peoples have lived this way for centuries, passing down the traditional knowledge necessary for surviving directly off the land and ocean (5). Since the establishment of colonization, Indigenous Peoples have faced numerous challenges in continuing subsistence as their primary method for food security (5). The shift towards consuming processed foods in tandem with rapid environmental changes has made subsistence practices increasingly challenging (5,10).

2.3 Ecological/Ecozone Biodiversity

It is well-known among ecologists that diversity plays a role in ecological resilience (25). Biodiversity improves ecological functioning by providing genetic diversity, diversity in species, and functional diversity (25). This is due to the insurance effect of biodiversity (25). High levels of biodiversity within a region enable resilience in responses to various environmental disruptions due to differing responses from each species (25). Therefore, regions with higher Species Richness (SR) have systems with increased resistance to environmental changes assuming the species have varied responses to system changes (25). Biodiversity is also critical for the health of the ecological network. Although Indigenous Peoples only consume a small portion of the total biodiversity found in an area, all organisms (consumed, or not) play a direct role in the functioning of the ecosystem either through the food chain or symbiotic relationships (25).

The mechanisms driving the relationship between ecological biodiversity and DD are thought to be due to improved ecological performance (26). The reasons for a diverse region being more productive are still debated, however, there are a few main reasons for this thinking. Firstly, increasing the number of species in a region increases the probability that some species will be important players in the ecological functioning of that region (26). This theory can also be applied to nutrition and is partly why a diverse diet is seen as more nutritious (26). As you increase the variety in foods consumed, the probability increases that the individual will consume foods differing in nutrients and therefore have an adequate diet (26). Therefore, if the number of food choices available increases, their probability of accessing and consuming a nutritionally rich and diverse diet increases (26). Another explanation is the complementary effect, whereby species interactions improve ecological functioning and yield (26). These interactions occur due to symbiotic relationships where the presence of one species improves outcomes for other species. As well as resource partitioning, where competition for resources is reduced due to species utilizing different organisms and nutrients (26). This concept has been applied to agricultural settings, resulting in an understanding of beneficial groupings of plants for higher yields. For example, the functional differences between squash, corn, and beans allow for resource efficiency and greater output when planted in a single field (26). In ecological settings similar relationships occur, and the more diverse an area, the greater odds that beneficial relationships are happening and increasing ecological productivity.

2.3.1 Climate Change and Biodiversity

Due to various changes in the biophysical environment resulting in loss of biodiversity and changing migration patterns, game animals are becoming increasingly difficult to procure (10). Some factors, including climate change, environmental degradation practices like mining and agriculture, and an overall increase in environmental pollutants, have altered the accessibility and availability of TF (44). Hunting periods have changed due to climate variables and altered migratory patterns, further reducing accessibility (44,45). Many species are acutely impacted by environmental changes (46). As weather patterns shift and environmental conditions change, some can adapt, but many cannot (46). Biodiversity itself is an important factor for adapting to climate change and variability in weather patterns (44). For example, an Indigenous coastal community in British Columbia saw a rapid decline in fish harvest as 98 species of fish were forced to move from their current habitat to find cooler waters as the sea water continued to increase in temperature (46). Inuit People have also observed changes in the abundance and size of commonly consumed terrestrial animals and vegetation like berries (47). Another example is the Karuk People losing access to salmon and acorns, among other TF (46). This loss resulted in an increase in heart diseases and diabetes, mainly due to the types of foods replacing the nutritionally important TF (46). Species at higher trophic levels rely on lower trophic levels for food. Therefore when vegetation like lichen is impacted, it has a significant impact on the animals like caribou who depend on that food source (48). Thus, even the smallest changes in biodiversity can impact food security. The changing temperatures can also bring species to the region that are not native-like Pacific salmon, which can outcompete regional species like Arctic cod and become invasive (49). Considerations for climate change resilience in food systems are often a result of conjecture from these understood ecological phenomena.

2.4 Biodiversity's contribution to Dietary Diversity in Global populations

Positive associations between ecological biodiversity and DD have been shown in highly biodiverse locations around the world (11,13,14,50). A study performed across West, East, and Central Africa analyzed the relationship between deforestation and child DD (13). They discovered that children living in areas with forest loss had lower DD and consumed fewer foods from nutrient-rich sources commonly found in forested areas (13). Similar findings occurred in Malawi, where forest loss was associated with a lower DD in children and lower consumption of foods rich in vitamin-A (13). These findings follow similar results to other studies noticing the association between forest cover and dietary quality (13,14). One reason tree cover is highly related to DD is the direct pathway between access to foods residing in the forest and consumption of those foods (14). A study in Fiji identified farm biodiversity's role in DD outcomes. This study also found that households with higher farm diversity experienced higher DD and improved nutrition (11). When they examined the use of TF specifically, the importance of subsistence food practices and the ability to access TF was noticed as an important component of dietary intake (11). MF are also an important component of DD results in Fiji. Much like Indigenous Peoples in Canada, MF are less nutrient-rich, meaning incorporating TF in their diet is critical for dietary quality (11).

Studies performed in highly diverse locations also found a positive association between food security and TF or foraged foods diversity (33,37,51,50). In Burkina Faso, 92% of the study population reported foraged foods as being necessary for food security (50). This study also found a positive relationship between DD and the number of foraged foods consumed (50). Similar findings occurred in Botswana, where access to TF was positively associated with both food security and DD (51). Many families depend on wild foods for food security (33). This need will only increase as resources become scarcer through human-made pressures on the environment and climate change events like extreme weather patterns becoming more common. Despite these challenges, TF have been cited as a potential resource for alleviating poverty and adapting to the increasing demand for food (33).

2.5 Variables contributing to Dietary Diversity

Even though a TF is available in an ecological territory, that does not mean it is consumed. A study performed in Benin found that out of all 61 wild plant foods known by the local people, only 8 were consumed (52). This means that other factors, besides ecological diversity, are responsible for the consumption of foods by local people. This section outlines the variables that could impact dietary diversity. Table 1 describes all the variables taken from FNFNES that are hypothesised to predict dietary diversity outcomes and shows which variables were turned into scores. Creating a hypothesis regarding which variables will affect DD is complex when the previous research is conducted in low- and middle-income countries and in highly ecologically diverse locations (11,13,14,53). These locations, therefore, face different cultural, ecological, and demographic challenges than Indigenous Peoples in Canada. However, Indigenous Peoples in Canada also face other challenges than the rest of the Canadian population, experiencing higher rates of various chronic diseases, general health disparities, and disparities in access to nutritious foods (2,54). Although it is assumed that these variables in Table 1 will be factors in determining DD, modelling trials could inform us otherwise.

Table 1: Variables initially tested against DSR using Spearman's correlations

Variable & Category	FNFNES Code	Scoring Method
Demographic: Gender	Gender	Ordinal: 0/1
Demographic: Age	Age	Interval scale
Demographic: Activity level	Q13: PA level compared to others same age	Ordinal: More active, less active, about average, don't know
Demographic: Smoker	Q14a: did you smoke cigarettes yesterday? Q14b: number of cigarettes smoked yesterday?	Ordinal: 0/1
Social Determinants: Household #	Q1: Total # or ppl in the household Q1A: HH members <15 years old Q1C: HH members 66+	Nominal Ordinal Interval Ratio
Social Determinants: Employment	Q2A: # of people employed full time Q2A: # of people employed part time	Ordinal
Social Determinants: Income	Q3: main source of income Q3other: other source of income	Nominal Ordinal Interval Ratio
Social Determinants: Education Level	Q4: number of school years completed *Highest level of education received	Nominal Ordinal Interval Ratio
Social Determinants: Hunter/Gatherer	Q5A → Q5D: participants hunting/gathering practices	Nominal: score out of 4
Social Determinants: Hunter/Gatherer in the household	Q6A → Q6D: household member hunting/gathering practices	Nominal: score out of 4
Social Determinants: Food Security	FS status: Secure, Moderate, Severe	Nominal Ordinal Interval Ratio
Ecological: Climate Change as a barrier	Q9A, Climate 1 → Climate 19	Nominal: score out of 19
Ecological: Barriers to TF	Barrier 4, Barrier 7, Barrier 12, Barrier 23, Barrier 24, Barrier 25	Nominal: score out of 6
Ecological: Seasonality	Traditional food survey	
Ecological: Garden Access	Q5E: planted a garden last year? Q6E: other HH planted a garden?	Ordinal: 0/1
No Ecological Barrier	Barrier 16: no barrier/have enough TF	Ordinal: 0/1
Cultural: positive perceptions with TF	advTF1 → advTF30, Climate 16	Nominal: score of 31
Cultural barriers	Barrier 1-3, Barrier 5, Barrier 6, Barrier 13, Barrier 20-22 Q8C: worried whether TF food would run out Q8D: the TF that we got didn't last and we couldn't get anymore	Nominal: score out of 11
Cultural: Advantage of MF	AdvMF1 → AdvMF15	Nominal: score of 15

2.5.1 Demographic Variables

The impact of Gender on DD is complex. In Spain, a high-income country, women were found to have more diverse diets as they were more health-conscious (55). However, a study completed in a highly agriculturally diverse location in Kenya found that women had higher DD in households led by men (56). Similarly, a study in Tanzania found many gender-based cultural barriers to attaining a high DD for women who were the sole providers for their families (57). In the Canadian context, women do not face the same barriers to owning land and growing crops. Gender also impacts DD in terms of hunting practices. Traditionally, hunters were male, meaning that men were more likely to have access to TF (58). Finally, men tend to consume more food than women increasing their odds of a larger DD and confounding results. Therefore, gender must be considered when creating the model. Age of participants must also be considered. A consistent finding across studies is that DD decreases with age (3,56,59). However, this may not be true in Indigenous communities as the older generations tend to consume more TF (60). One major reason is that the younger generation has not taken over hunting roles as the older generation retires from those activities (60).

2.5.2 Socio-economic Variables

Interestingly, most papers reviewed found no association between socioeconomic indices and DD (56,59). However, one study performed in Malawi noted that wealthier households were more likely to have a more diverse diet in terms of types of foods consumed and frequency of different food groups consumed (61). Wealth could be a factor for access to TF due to the cost of hunting gear and the flexibility to have time to hunt (43,60). Some other barriers to consuming TF cited by Beaumier & Ford include knowledge of MF, high hunting costs, and budgeting skills (60).

Many studies performed in low-middle income countries with diverse environments have proven a positive association between DD and education, particularly with women (56,59). In contrast, other studies find no association at all (11,62). Despite the inconsistent results, education level will still be tested as a covariate for DD, as education is associated with educated food choices and a higher household income. Household size has inconsistent impacts on DD. In some studies, household size is negatively associated with DD due to having more individuals to feed

(56,59). Other studies found that larger households could provide more services, income, and ability to hunt or gather foods (11). A related variable that could have a more significant impact is the number of dependents living in the household and therefore not contributing to the household. However, O'Meara et al. found no association between dependents and DD (11).

2.5.3 Cultural Variables

The practice of food consumption is inherently a social practice based on cultural meanings. This is particularly true for Indigenous consumption of TF, as harvesting from their immediate environment is rooted deeply in their spirituality, connection to the land, connection to their ancestors, and perspective on life (29). Therefore, different Indigenous groups in Canada have their own ties to the land, cultural practices, food preferences, and knowledge base, leading to consuming different foods (29). For example, different Indigenous groups have different practices and connections to specific TF. This means that two groups within the same ecozone may have different dietary patterns (29). Baudron found that different ethnicities with differing food traditions abiding in the same area had different dietary outcomes despite having access to the same amount of forest cover (14). This variation highlights the importance culture plays in determining dietary patterns. Another example in Northern Ontario comes from a study performed in the Wapekeka region. They found that despite the relative abundance of caribou and black bears on their traditional land, neither are commonly hunted as they are not desired food choices (63). However, these species are highly prized by other Indigenous nations who may not have this abundance (63). These examples show the significance of culture in determining the TF consumed, regardless of species availability.

Tremblay et al. discovered that culture plays a much more significant role in determining food choices than ecological determinants (29). The social environment that individuals operate within greatly influences the types of foods consumed and the importance placed on traditions and food practices. When TF practices are a component of cultural norms, a strengthened cultural identity is shared between a group of people, and the use, cultivation, and consumption of these foods increases (62). When family duty and obligation to provide your children with healthy and culturally appropriate foods are present, this too guides the use of TF (62).

According to the dietary behaviour models, social pressures, moral obligations, and even emotions contribute to the dietary choices individuals make (62).

The absence of hunters within the household is a recognized cultural barrier to TF. Women who did not have access to a hunter mentioned having a decrease in TF access (60). In tandem, community members were concerned with the reduction in people able to hunt full-time due to age or illness and the poor replacement by younger generations (60). Lack of knowledge is a critical cultural barrier as it relates to hunting practices, knowledge on types of TF, and preservation methods (60).

Another cultural barrier is sharing. Beaumier & Ford discuss a weakening in food sharing and a decline in the practice of traditional activities (60). First Nations individuals also cite these barriers in the FNFNES data (12). Historically, country foods have been shared amongst households, a tradition that results in food security for multiple people. There has been a decrease in food sharing in recent years due to the increasing hunting costs, shortages of TF, and scarcity of big catches like caribou (60). This has reduced many families' access to TF, and some women have been cited as fearing community judgment as one reason for not asking for TF (60).

2.5.4 Ecological Variables: Regional variation, seasonality, and climate change

Due to Indigenous People's deep connection between their culture and the environment, their diets are likely influenced by both cultural and ecological variables (29). Ecological boundaries determine diversity due to the availability of certain foods. For example, coastal communities have access to marine plants and animals that inland ecozones do not have access to (29). This is also true for Arctic regions where resources are limited further to the species that can survive in those landscapes. In contrast, communities living on the edge of forests or highly biodiverse locations have increased access to various species (13). The connection between regional biodiversity and diversity of diet has not been studied in less biodiverse locations and therefore a direct comparison cannot be made to Canada. However, we predict that biodiversity will have a positive relationship with DD.

Seasonal variations in the availability and accessibility of wildlife are substantial factors contributing to local dietary patterns (11,14,29). However, seasonal effects can be mitigated through traditional preservation techniques (40). Finally, climate change and the degradation of environmental conditions have been cited as impacting the access and availability of TF (60). Some environmental conditions discussed include sensitive hunting and gathering techniques, for example, relying on ice in Arctic communities (60). Other human activities, including exploiting natural resources, overfishing or destroying ecosystems, cause species depletion (16).

3. Manuscript: Understanding the Traditional Food System of First Nations in Canada in the Context of Biodiversity

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A version of this chapter has been submitted to the journal Ecology and Society for publication.

3.1 Abstract

The health and well-being of Indigenous Peoples, including their nutritional status, is poor compared to the general Canadian population. There are many causes of these disparities, including racism, poor access to health resources, and the nutrition transition. Before colonization, most First Nations across Canada consumed diets purely composed of Traditional Foods (TF) that were hunted or collected from the natural environment. TF are important for their nutritional quality, food security, and culture. However, rates of TF consumption have decreased in recent years contributing to poor dietary outcomes. The diversity and quantity of TF consumed is thought to be primarily dictated by the ecological biodiversity in the surrounding environment; however, this relationship remains untested in Canada. The objective of this study was to gain a better understanding of First Nations modern food systems by evaluating the relationship between ecozone biodiversity and nutritional outcomes in the form of dietary diversity in First Nations individuals across Canada. We used dietary data and household data collected by the First Nations Food, Nutrition and Environment Study and multiple biodiversity databases for analyses. Spearman's correlations were used to investigate the relationship between dietary diversity and nutrition. A statistical model was used to evaluate the relative predictive power of biodiversity and multiple other predictive variables in determining dietary diversity. We found that individuals who consume more TF have more nutrient rich diets, and therefore, dietary diversity is a good indicator of nutrition outcomes. We also found that in contrast to previous research and assumptions, in the context of First Nations living in Canada, biodiversity has a negative relationship to dietary species richness. It was also determined that variables related to culture, and accessibility of TF were the most important factors in predicting positive nutritional outcomes. These preliminary results provide key areas for interventions essential for increasing access to TF.

3.2 Introduction

Indigenous Peoples in Canada experience many health disparities when compared to the non-indigenous population. Experiences of racism, poor access to healthcare, and poor living conditions on government-designated Indigenous reserves have made Indigenous health and well-being a significant concern over the past century (2). Among these health disparities are the increasing difficulties for Indigenous Peoples to maintain nutritionally adequate diets (4).

Traditional Indigenous diets in Canada were subsistence-based, meaning that individuals harvested, collected, and hunted TF from the immediate environment (5). With colonial influence came the introduction of highly processed market foods (MF), changing their diets substantially and growing more dependent on foods not traditionally consumed (4). MF most frequently purchased from the store tend to have high caloric density and low nutritional value compared to TF, particularly in remote locations where MF are limited (7). Due to the remote locations of some Indigenous communities, the shipment of fresh foods into the communities is a lengthy and expensive process (4). As a result, many people need help to afford fresh produce and must rely on cheaper, highly processed foods, resulting in remote and geographically isolated communities having nutritionally inadequate diets (4,8). Over the years, starting with a loss of culture from forced assimilation and later on, losing access and availability to TF due to environmental changes, Indigenous Peoples in Canada consumed TF less frequently (4,5). This trend is known as nutrition transition and occurs when a region shifts from a traditional nutrient rich diet to a Western inspired diet (37). In the Indigenous context of Canada this meant moving from consuming a pure TF diet which provided sufficient energy and nutrients to energy-dense and nutrient-poor MF (10). The reduction in TF use, also resulted in a decrease in physical activity as hunting, fishing, gathering, and processing TF require an energy expenditure needed for good health (10). With the transition to mainly consuming MF with high caloric content, and a decrease in energy expenditure, came an increase in metabolic syndromes and other nutrition-related chronic diseases (10,37). These include obesity, insulin resistance, diabetes, and cardiovascular disease, all of which contribute to a lower life expectancy (10). This shift has also been noted globally (11).

The switch from a subsistence-based diet to one with more processed MF is concerning due to the nutritional importance of TF (6). TF provide key nutrients like vitamin E, vitamin B-6, zinc, iron, and vitamin D, and a high protein content not commonly found in MF (6). One report utilizing the First Nations Food Nutrition and Environment Survey (FNFNES) data discovered that in the diets of residents in 92 First Nations communities', TF provide only 4.6% of daily caloric intake (12). However, when TF were consumed, daily nutrient intakes were significantly higher and simultaneously intakes of saturated fat were lower (12). These are significant findings as they show the importance of consuming even a small portion of TF frequently.

Dietary diversity (DD) can be measured by various metrics. The selection of which DD metrics to use primarily depends on the type of foods being measured, the categories included in the index, and the period for data collection (2). A commonly used metric for evaluating dietary quality is the Dietary Diversity Score (DDS) (13,14). The DDS is frequently modified for variables like gender and age, typically operates on a 24-hour-recall but can be used for a period of up to 15 days, and uses 6-14 food groups (52,64). However, there are some inconsistencies in the relationship between DDS and nutrition indicators. These inconsistencies can be attributed to the variance of nutrient content in each food or food group. Since the Western world's diets contain foods of varying nutritional benefits (i.e. market foods) DDS does not always capture nutritional quality adequately (15). However, DDS is a particularly good measure of nutritional adequacy when considered in the context of the consumption of Traditional Foods (TF) as they are known to be highly nutritious and, therefore, increasing consumption of TF will improve nutrition outcomes (6,12).

New indicators for measuring the biodiversity of diets were tested by Lachat et al., including the Simpsons Index of Diversity (SID), Dietary Species Richness (DSR), and Nutritional Functional Diversity (NFD) (65). SID involves measuring the weight of consumed species in grams compared to the total weight of all species consumed within 24 hours (65). DSR consists of counting the number of different TF species the individual consumes (65). Finally, NFD uses a functional dendrogram to calculate and reflect the nutritional diversity in the composition of each food consumed (65).

It is also necessary to note the nature of these indicators. DDS does not consider nutrient content or quantities of foods consumed and therefore is not an accurate measure of dietary quality (15),(66). Instead, it only reflects how diverse the diet is. Comparatively, DSR, SID and NFD are all positively associated with micronutrient adequacy, with DSR being most consistently associated with diet quality (65). Both SID and NFD consider more components than counting the number of species consumed, but DSR accurately captures nutritional quality compared to the other DD indices (65). For further information on all indices utilized in this research see Table 2.

Another global indicator of dietary adequacy and human health is food security (4). Food security, as defined by The Food and Agriculture Organization of the United Nations (FAO), is "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meet their dietary needs and food preferences for an active and healthy lifestyle" (4). Settee et al., explained how Indigenous food security extends beyond the ability to have sufficient resources and acknowledges the reciprocal relationship with the earth, the community, and oneself (17). This understanding acknowledges components necessary for a subsistence diet and the importance of Indigenous social and cultural norms associated with TFs(4). Food insecurity is much higher in Indigenous populations at 33% compared to the non-Indigenous Canadian population at 9%, with communities in geographically remote locations experiencing the highest rates (8,18). Traditional subsistence practices play a significant role in supporting food security and nutritional adequacy for Indigenous Peoples in Canada (5).

According to ecosystem service theories, adequate nutrition is closely tied to direct access to nutritious foods in the environment (11,16,30,31). These findings are extensively researched in highly biodiverse locations with long growing seasons, plenty of natural resources, and the availability of country foods year-round (11,14,30,33,34). It has often been hypothesized that this finding extends beyond tropical locations into various spheres, whereby ecological biodiversity directly affects the diversity and quality of diets (24). Biodiversity is important for ecosystem resiliency, which is critical for combatting climate change damage (25,26). Biodiversity holds economic value by providing goods and services to surrounding populations, commonly termed 'ecosystem services' (25). One of those services is the provision of TF. Ecological constraints suggest that the choice of TF is limited to the availability of species living in that region (29). The common argument is that a higher diversity of regionally available species and, therefore, available foods results in improved food security and higher DD (11,30,31). Understanding the ecological connections to nutrition outcomes is important as TF are a critical aspect of First Nations diets (29). However, it is unclear whether higher levels of biodiversity in the environment result in improved nutrition outcomes in First Nations populations (31). Table 2 outlines the types of biodiversity indicators considered.

Table 2: Overview of dietary diversity and biodiversity indices used in this study

		Definition	Efficacy	Data needed	Purpose
Dietary Diversity Indices	Traditional Food Dietary Diversity Score (TFDDS)	Total number of unique traditional foods consumed over a 24-hr recall period	DDS developed by the FAO is widely used as an indicator of a healthy diet (19). Doesn't capture the biological contribution of species to diets (1)	FNFNES 24-hr recall	Contribution of daily consumed TFs to dietary quality. Answers the question: What is the relationship between DD and biodiversity?
	Dietary Species Richness (DSR)	Number of different species an individual consumed over a specified time frame (1)	Integrates biodiversity, nutrition, and health aspects of the food system (1) Positively associated with MAR	FNFNES Traditional Food Survey	Contribution of TF to dietary quality
	Dietary Species Richness Parts (DSR Parts)	Number of different species and species parts an individual consumed over a specified time frame (1)	Has not been evaluated as an indicator of dietary quality outside of this study	FNFNES Grams TF intake FFQ	How consumption of all animal parts of TF contributes to dietary quality
	Simpsons Index of Diversity (SID)	Measures the diversity in nutrient composition of species consumed (1)	Positively correlated with micronutrient adequacy (1)	FNFNES Traditional Food Survey	An additional metric for determining TF nutritional composition
Biodiversity Indices	Simpson's Index of Diversity (SID)	Measures both species richness and evenness composition of communities (24)	Most appropriate tool when the primary objective is ranking sites based on biodiversity	N/A	Understand the relationship between DD and ecozone biodiversity
	Ecological Functional Diversity (FD)	The variation or distribution of functional traits in a community/region	Important determinant of ecosystem function. Useful for exploring biodiversity beyond species level		Relationship between DD, Dietary quality and FD of the TF consumed in each ecozone
	Ecological Species Richness (ESR)	Count data for the number of unique species in a specified region	As it only considers species presence, it is not the most robust indicator. However, it is still a frequently used and cited index for biodiversity	Natureserve, Birdlife, Range Maps	Understand the relationship between DD and ecozone biodiversity

While global food demand is increasing, biodiversity loss and reductions in farmable land are being exacerbated by climate change (3,21,22). Although conjectured as being critical components of the food system, the contribution of TF and ecological biodiversity to DD and nutritional quality is often overlooked (24). These relationships have been studied in unique populations in diverse locations, for example, Indigenous communities in Fiji, agricultural households in Malawi, and rural households in Tanzania, Cameroon, Ethiopia, Zambia, and Nicaragua (11,14,30,33,34). However, the relationship between biodiversity and DD or dietary quality has yet to be studied in less ecologically diverse locations or in high-income countries like Canada (5,6,22).

Although ecological factors may play a role, it is still being determined how prominent that role is as many confounding factors contribute to consumption patterns. All variables tested and included in this study are listed in Table 1. The variables predicting the dietary outcomes are complex and relative among different groups of people, including age, gender, and cultural communities. Food choices and nutritional outcomes depend on many factors, including socioeconomic status, lifestyle factors, social and cultural structures, and the accessibility of various foods. These variables have been discussed qualitatively, but empirical evidence for their contribution to DD in First Nations communities needs to be tested (36).

The final gap in knowledge concerns the cultural and geographic scope of dietary research among Indigenous populations in Canada. Most of the studies have been conducted among the Inuit in Arctic Canada, and very few focus on the First Nations in Canada (4,7). Research outputs stemming from the FNFNES data are some of the few that focus on dietary studies in Indigenous communities in diverse and southern regions across Canada (10,37). Therefore, it is important to improve our understanding of this understudied phenomenon amongst the population of First Nations individuals living in Canada..

To successfully translate ecological knowledge into effective management and understanding of food systems, nutrition, and public health measures, some key questions need to be answered. This research's main objectives are to determine dietary diversity's ability to measure nutritional quality and to understand the relative importance of ecological biodiversity and other key variables in predicting DD in First Nations populations in Canada.

Below are guiding research questions to answer the main objectives:

1. What is the relationship between ecozone biodiversity and the DD of First Nation populations living on reserve in Canada?
2. What is the relationship between DD and the nutritional quality of diets of First Nations living on reserve in Canada?
3. How strong are the associations between ecozone biodiversity and DD when compared with other covariates, such as socio-economic and demographic factors?

3.3 Methodology

Multiple methods of analysis and data sources were utilized to answer our main objectives. To assess the diversity and quality of individuals' diets by ecozone, we calculated the dietary diversity and quality indices, and investigated their relationships using correlation analyses. A statistical model was developed to assess the relationship between DSR outcomes and various indicators of interest including biodiversity, demographic, socioeconomic, cultural, and ecological factors. We used correlations and regressions to determine which variables are predictive for DD outcomes and evaluated their relative importance. Figure 1 depicts the relationship between the guiding questions for this study and the methods which have been used to answer them.

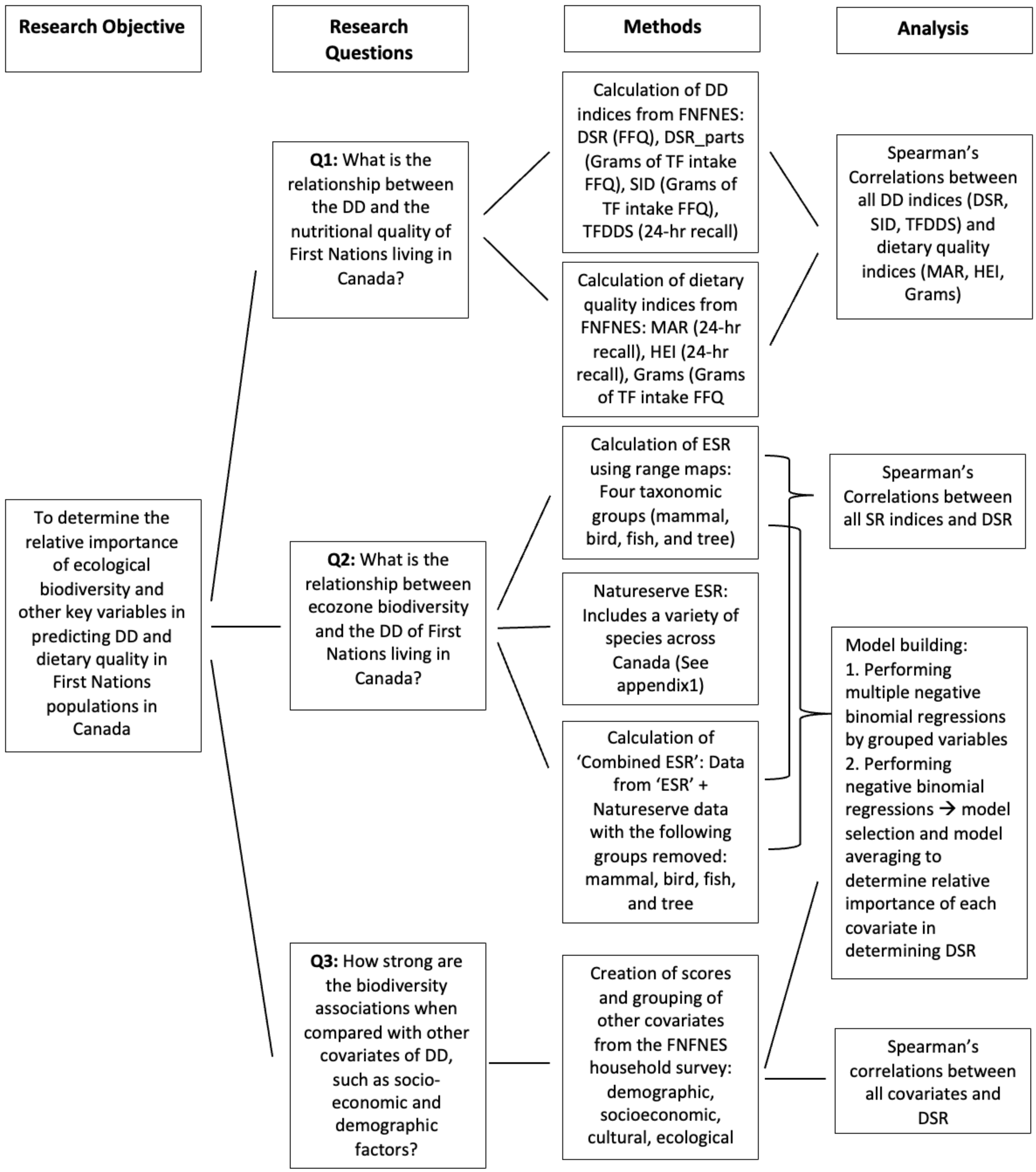

Figure 1. A methodological framework displaying how objectives are linked to the methods used for assessment and analysis.

3.3.1 Data Sources

3.3.1.1 Ecological Species Richness sources and methodologies

Ecological biodiversity has many different definitions. Certain diversity indices are better suited for specific analyses, as there is no universal understanding regarding which index is the most appropriate (27). Choosing a biodiversity index that accurately measures the relationships being studied is critical. For this study, the measure must accurately determine the biodiversity trends across each Canadian ecozone to match the dietary diversity data. Ecozones are divisions based on key ecosystems related to landforms, climate, and species (67). Out of Canada's 15 terrestrial and five marine ecozones spanning both provincial and territorial boundaries, eleven ecozones were used in this research (68).Ecological Species Richness (ESR) was chosen based on data limitations and ESR adequately representing species distribution across ecozones (27,28).

The first ecozone biodiversity data we used came from NatureServe, a non-governmental organization, that works collectively with provincial and territorial Conservation Data Centres (CDCs) to monitor, manage and study Canada's biodiversity (69). Each CDC maintains Element Subnational Tracking records (ESTs) which are complete lists of species known to exist within their jurisdiction. Tracking all species is not feasible due to the extensive range of biodiversity in Canadian ecosystems. Instead, CDCs create tracking lists focused on rare species or species of conservation concern. Therefore, the first data obtained for our model was SR count data for each ecozone that had been extracted from various NatureServe CDCs. Preliminary results showed that there was a negative relationship between ESR and all dietary diversity indices. See Appendix 1 for details concerning the Natureserve data.

Since the Natureserve data contains many species, such as insects, that are not relevant to food consumption, we used two other methods to measure the species richness (SR) of key traditional food species. The first method utilized a technique described by Kraus et al. (70). This technique utilizes ArcGIS to calculate SR from a variety of sources utilizing spatial distribution. The species datasets in the form of shapefiles were overlaid with ecozone boundaries from the Government of Canada. Then duplicates of each species sighted within each ecozone boundary were removed and the total number of species occurring within each ecozone was generated. The analysis is based on the presence or absence of each species. Therefore, the final SR count does not include species distribution or the number of occurrences. This method was utilized to calculate bird SR, with the data coming from BirdLife International. BirdLife International provides species distribution data from 2017, where each shapefile consists of polygons representing bird distribution across Canada's ecozones. For our analysis, bird species data was labelled possibly extant, probably extant, and extant, ignoring the other classifications of presence. These classifications describe the level of certainty that the species exists in that area based on available data. This source is a mix of data from published and unpublished data sources, meant to give a general understanding of species distribution. Mammal and fish SR obtained from the International Union for the Conservation of Nature and tree species data from the United States Geological Survey provided strange outputs with some ecozones showing zero mammals and some aquatic ecozones having very few fish species.

To calculate the SR for the taxonomic groups' mammals, fish, and trees, we used a third method that involved the use of range maps to estimate the distribution range. The data for fish distribution was obtained from species presence/absence lists for native fish species across North America and included spatial variation in regional SR for all freshwater species, endemic, and widespread distribution patterns (71). The mammal distribution was from a contour map of species density which involved the number of mammals per quadrat (72). The species data comes from an original source in the archives of the American Philosophical Society (72). As this data was from 1964, they cross-referenced it with a mammalian taxonomy study completed in 1993 (72). After this, their mammalian dataset included 721 species across North America (72). Finally, tree SR range maps came from the Government of Canada, Atlas of Canada 6th edition. Canada has about 180 tree species, most of which are present in Southern Ontario and along the St. Lawrence River; however, the highest SR is in the Lake Erie Lowlands ecoregion. SR from all range maps was calculated by evaluating the highest SR contour line that passed through each ecozone. The values from the contour line for each taxonomic group were summed. The final ESR values include the range map data from mammals, fish, and trees and the ArcGIS calculations for the bird species.

3.3.1.2 First Nations Food, Nutrition, and Environment Study

Dietary data used in this study comes from the First Nations Food Nutrition and Environment Survey (FNFNES). The FNFNES is a comprehensive study including a household questionnaire, a 24-hour recall of household diets (Automated Multiple-Pass method (12)), a Food Frequency Questionnaire (FFQ) capturing the seasonal consumption of TF over the course of a year (12), and various contaminant measures. Therefore, it contains all the required dietary data, nutrition data, and variables to create a comprehensive model illustrating the factors that predict dietary outcomes in First Nations households. Detailed methodology for this study has been outlined elsewhere (12). Briefly, the FNFNES is a comprehensive study spanning ten years from 2008 - 2018 to collect dietary and environmental health data in 92 First Nations communities across Canada. A systematic random sampling of households occurred by community, with 125 households from each community being randomly selected to participate (12). A total of 6,487 participants completed the various surveys utilized in this study (12). Data used in the current study include the household questionnaire, 24-hr dietary recall, FFQ, Grams of TF Intake (based on the FFQ), and INACRIZ and food cost, spanning 11 terrestrial ecozones occurring within Canada's provinces. INACRIZ is a remoteness indicator that groups all First Nations communities into four zones according to the existence of year-round access roads, distance to the nearest service center, and climatic factors (73). For confidentiality purposes, the FNFNES data is restricted to use at the or provincial level to avoid identifying specific communities.

3.3.1.2.1 Inclusion Criteria and Data Treatment

To be included in the FNFNES study, the individual had to be a minimum of 19 years old and self-identify as a First Nations person living on reserve. For this study, pregnant and breastfeeding women were included, and their nutrition adequacy indices were calculated assuming they do not have different nutrition requirements compared to other women in their age bracket. This decision was made because including pregnant and breastfeeding individuals would not significantly alter the results or the goal of the analysis. The number of pregnant individuals was also small at of 5.7% of the female interviewees and 3.7% of the total interviewee population.

The 287 participants who reported consuming a DSR beyond the 95% confidence interval (DSR equal to or higher than 23), are considered outliers and were excluded from the analysis. Twelve individuals were removed as they reported not having consumed any food, only water or alcohol, during the 24-hr recall. Another 23 individuals were removed due to missing age data. After accounting for the missing data, the total sample size was 6161 participants. The sample size varied in each correlation analysis due to missing data for specific variables. The smallest sample size was 5742.

The final regression model included 6,083 participants. In each ecozone, there were more female than male participants. The participant rate is representative of both the land mass of each ecozone and the First Nation population size. Large ecozones like the Boreal Shield and the Boreal Plains contained 19 and 18 research sites respectively, while smaller ecozones like the Taiga Plains and Boreal Cordillera contained 3 and 2 sites, respectively (Table 3). The largest discrepancy occurred in the Boreal Cordillera, with 77% of the participants being females, and only 71 participants total. The Boreal Shield had the most participants at 1247. Appendix 2 contains further dietary records regarding types of TF, MF, and nutrient profiles.

Table 3: Descriptive statistics of FNFNES data used

	Female	**Male**	**Total Participants**	**Number of Interview Sites**
Pacific Maritime	263	143	406	9
Boreal Cordillera	55	16	71	2
Montane Cordillera	172	105	277	6
Taiga Plains	77	46	123	3
Boreal Plains	806	377	1183	18
Prairies	360	197	557	8
Boreal Shield	792	455	1247	19
Taiga Shield	171	69	240	5
Hudson Plains	220	98	318	5
Mixedwood Plains	456	213	669	6
Atlantic Maritime	664	328	992	12
Total	4,036	2,047	6,083	93*

*One First Nation community in the Saskatchewan region occupied reserves in two ecozones (Boreal Plains and Boreal Shield), therefore, they were split into two sites by the ecozone boundary. Therefore, there are 92 interview sites but this one is counted twice, once in both ecozones it occupies (12).

3.3.2 Dietary Indices Used in Modeling

The following sections describe how the various DD and dietary quality scores were calculated.

3.3.2.1 Traditional Food Dietary Diversity Indices

Based on the available data, DSR, SID, and a Traditional Food DDS were calculated and tested against dietary quality indicators to determine the best dietary diversity indicator (Table 2).

The first indicator calculated was Dietary Species Richness (DSR). The data used for this index comes from the FNFNES Food Frequency Questionnaire (FFQ). This questionnaire accounted for the frequency of consumption and type of TF consumed seasonally over one year. The categories of TF included fish, shellfish and sea mammals, wild game, wild birds, wild berries or fruit, wild plants 1 (leaves, roots, shoots, and herbs), and wild plants 2 (mushrooms, trees, corn, beans, and squash). If a TF was consumed one or more times, it was given a score of 1. Following the same pattern, the SR was scored by adding all TF consumed at least once over a year. 'DSR Parts' was also calculated, which includes the number of different animal parts consumed. This measure increased the specificity of the DD indicator since First Nations individuals often consume more than one part of an animal containing different nutrients (40,74). Therefore, instead of counting the consumption of moose as one, an individual might consume different parts, with this score accounting for the consumption of up to three different moose parts (kidney, liver, and meat). This score was used only for comparison purposes to understand the role that part consumption has on dietary outcomes, while DSR is used in all analyses.

Simpsons Index of Diversity (SID) was calculated as described by Lachat et al. (65). Data taken from the FNFNES included the amount of TF intake (g) per day based on the FFQ and the % total weight in grams from each species in an individual's diet.

$$SID = 1 - \sum (n^2)$$

SID = Simpsons Index of Diversity (a number without units)

n = species abundance distribution

n is calculated by dividing the weight of one species consumed by the total weight of all species consumed. The n is then squared, and all values are summed and subtracted from 1.

The Traditional Food Dietary Diversity Score (TFDDS) was calculated using the FNFNES 24-hour recall data. Since a 24-hour recall only considers consumption patterns over a day, consumption of TF was very low, with the highest TFDDS being 7. See table 2 for specifics on these measures.

3.3.2.2 Dietary Quality Indices

We used three indicators, Healthy Eating Index (HEI), the Mean Adequacy Ratio (MAR) and the amount of traditional food consumed in grams, to understand the nutritional quality of the diets.

HEI is a multidimensional measure of diet quality that measures adequacy, moderation, variety and balance (75). The HEI values based on 24-hour dietary recall were previously reported by the FNFNES team (12,75). Intake is presented as the number of servings and is proportional to Canada's food guide's recommended serving size based on age and sex (75). Adequacy components include eight food categories (total vegetables and fruit, whole fruit, dark green and orange vegetables, total grain products, whole grains, milk and alternatives, meat and alternatives, and unsaturated fats) (75). Moderation components include intake of saturated fats, sodium, and "other food" – foods that don't fit into the other eight categories (75). The FNFNES technical report included the calculation and use of the HEI as an index for measuring individual diet quality (12). The Mean Adequacy Ratio (MAR) was calculated by averaging the Nutrient Adequacy Ratio (NAR). NAR measures an individual's nutrient intake level as a percentage. The NAR was calculated based on Canada's Dietary Reference Intakes and more specifically the values associated with the Recommended Dietary Allowance (RDA). The RDA is the average daily dietary intake level sufficient to meet an individual's nutrient requirement based on age and sex. The RDA is the target intake level for each nutrient. When calculating the NAR, it was capped at 100% (or 1) as going over the RDA does not necessarily equate to better health. The MAR was calculated by summing the NAR values obtained per individual, dividing by the number of nutrients used in the NAR calculations and multiplying by 100. Therefore, MAR is a comprehensive indicator representing the total nutrient intake and overall dietary adequacy (76).

The nutrition data for each individual was extracted from the FNFNES 24-hr recall data. The nutrients included in the MAR indicator were determined based on a literature search concerning typically used and nutritionally important nutrients, paired with an analysis of the available FNFNFES nutrient data. The following nutrients were the most commonly cited nutrients of importance; vitamin A, vitamin C, vitamin B6, iron, zinc, calcium, thiamine, riboflavin, niacin, folate, vitamin B12, and energy/protein (77,78,79). Lachat et al., utilized vitamins A, C, Folate, Calcium, Iron, and Zinc due to their own data limitations and based on the understanding that those 6 vitamins adequately represent a nutrient-rich diet (65). Based on these resources and a reasonable amount of missingness within the nutrient data these are the nutrients utilized in the NAR calculations: grams of protein, fibre, calcium, iron, magnesium, potassium, sodium, zinc, vitamin C, riboflavin, thiamin, niacin, vitamin B6, vitamin B12.

$$NAR = \frac{daily\ nutrient\ intake}{recommended\ amount\ of\ nutrient\ (RDA)}$$

$$MAR = \frac{Sum\ of\ NAR}{Number\ of\ Nutrients}\ X\ 100$$

The amount of TF consumed (g) is the final measure calculated and was utilized to understand the connection between abundance, diversity, and nutritional adequacy. Since DSR only captures the number of different TF consumed, understanding the relationship between the variety of foods consumed and quantity will help to address the assumption that increased variety equates to a greater amount of TF consumed (g). The calculation of this indicator involved data from the FNFNES Grams of TF intake taken from the Food Frequency Questionnaire, which only includes traditional foods consumed.

3.3.3 Other Confounding Variables for Dietary Quality

All confounding variables were derived from the FNFNES Questionnaire Data. Out of the 148 variables included in the questionnaire, 118 relevant variables were initially utilized either as individual variables or used to create a unique combined score (Table 4). These variables were sorted into 4 categories: cultural, socioeconomic, demographic, and ecological. These categories of indicators are derived from factors known to impact nutritional quality and influence dietary choices and are commonly assessed in dietary studies. Demographic factors include lifestyle, age, health factors, and gender. Cultural variables like individual preferences, the importance placed on cultural practices, and the social environment. Socioeconomic variables include household income, number of dependents in the house, location of the house, and proximity to retail food outlets. Finally, the ecological impacts include variables such as garden access, the number of species available to them in their immediate region, and climate change impacts. This research utilizes these four categories of factors contributing to dietary choices to understand each variable's relative importance to the diversity of traditional food consumption.

We also developed 11 secondary variables or scores due to an overwhelming number of variables and their co-correlation relationships (Appendix 3). For example, when considering the perceived advantage of market foods, there are 12 variables associated with that question. A combined score was developed to reflect individuals' responses and the importance of general patterns rather than overly specific variables. For example, the combined score for the perceived advantage of market foods includes two variables: availability/convenience, and variety. The rest of the variables were scored in the 'other' category. This means that the rest of the variables that fall under this category were scored out of 1 if the participant agreed with one or more of the following variables: healthy/nutritious, labelling, fresh, taste, food safety, cheaper, portioned, other MR advantages, or locally grown. This was done to diminish participant bias which can be seen through the dramatic drop-off in positive responses past the first few response variables for each question.

Table 4: All potential indicators of dietary diversity from FNFNES data and their score

Variable used in Regression	FNFNES Questionnaire variable/meaning	Category/Score
	Demographic	
Age	Age of participant	19-30 31-50 51-70 70+
Gender	Gender of participant	0/1
Household members	Total number of household members	Count data 1-19
Kids	Are there children < 18 yrs old living in HH?	0/1
Health barrier	Health barrier to accessing TF	0-2
Road access	Type of road access	Year-round, Fly-in, fly in_winter road
Nearest service centre (km)	Distance from the nearest service centre in km	Continuous
INACRIZ	Indigenous and Northern Affairs Canada Remoteness Index Zone	1 - 4
	Socioeconomic	
HH employment	Number of people in HH employed full-time	0 – 10
Income source	Main source of income for participant	Workers comp/EI, wages/salary/self-employed, social assistance, pension/seniors benefits, other
Poor access to TF	The TF that we got just didn't last, and we couldn't get any more	Often, sometimes, never, don't know/refused
Financial barrier	Financial barrier to accessing TF 'lack of money to buy'	0/1
No barrier	No barrier to accessing TF/have enough TF	0/1
FS	Food Security Status	Secure, moderate, severe
School completed	Number of years of school completed	Continuous
Logistical barriers	Logistical barriers to accessing TF	0/5
Cost of food basket	Cost of weekly food basket to feed a family of four using National Nutritious Food Basket tool (data collected from FNFNES)	160.98 – 454.71
	Cultural	
Individual hunter	Participant hunted, fished, collected wild plant food, or seafood in the last year	0/4

Household hunter	Participant or household member hunted, fished, collected wild plant food, or seafood in the last year	0/4
Cultural advantage	Perceived cultural advantages to TF's: family time, sharing, spirituality etc.	0/4
Cultural barriers	Cultural barriers to consuming TF	0/2
TF Preference	Would your household like to have more TF?	0/1
Perceived advantage of MF	Does your household view MF as important for a variety of reasons	0/3
Perceived advantage of TF	Does your household view TF as important for a variety of reasons	0/6
Lack of sharing	Barrier to TF access: lack of sharing	0/1
	Ecological	
Garden access	Did you or a HH member plant a garden in the last year	0/2
Climate change barrier	Noticed climate change in your region	0/8
Noticed climate change in the last 10 years	Have you noticed climate change in trad territory in the last 10yrs?	Yes, no, do not know
TF availability not affected	Availability not affected	0/1
Ecological barrier	Ecological barrier to consuming TF	0/4
Ecological Species Richness (ESR)	Natureserve, ArcGIS + Range maps	Continuous

Description of the variables included in the initial rounds of stepwise regressions after correlations to determine basic relationships

3.3.4 Statistical Analysis

All data analyses were performed using R (R Core Team, 2022). Spearman's correlations were performed to determine the strength and direction of association between all three DDI's, (DSR, SID, and TDDS) and indicators of nutritional adequacy (MAR, HEI, and grams of TF consumed). Predictive models were used to explain the links between ecological variables, demographic variables, socioeconomic variables, cultural variables, and dietary species richness. Two different modelling approaches were used. The first was a negative binomial regression model as described by Tata et al. (34). The negative binomial regression was selected as DSR is over-dispersed count data (see Appendix 4). The first four regressions were conducted with the four groupings of variables: demographic, socioeconomic, cultural, and ecological. Systematically, insignificant variables were discarded from the model until only the significantly related variables remained. The significant variables from these initial rounds of categorical regressions were then included in the model, and the same process commenced. This process continued until the model included only variables with a p-value < 0.05.

The equation for a negative binomial regression is as follows:

$$Var(Y_i|X_i) = \mu_i + \alpha{\mu_i}^2$$

The second modelling method utilized model selection and averaging. The basis of model selection is to compare a set of ecological models to see how well they match a model that includes all necessary information about the entirety of the system (80), termed the 'true model'. This method results in AIC values which can be used to rank the models being assessed where the model with the lowest AIC value most accurately approximates the true model (80). However, since all the models being compared in this method utilize the exact same information, it is impossible to choose a distinct best model. This is why model averaging is necessary (80). Model averaging takes all models with an AIC delta weight < 5 and obtains a weighted average of the model's predictions (80). In combination, these methods provide a confident estimation of the best model from the initial set of parameters.

A different method for choosing the initial variables for the negative binomial regression was used for our second analysis. Via stepwise regressions, statistically significant variables were chosen. However, unlike the first methodology, variables were chosen based on what information they contribute to the model, regardless of previously found statistical insignificance. The initial variables for this model can be found in Figure 2. Limiting the variables used in the initial model is imperative (80). Therefore, this model removes variables that give similar information including, for example, two of the three remoteness indices. StepAIC was completed on the best fit model as determined by model selection and averaging (81). The output included the coefficient for each predictor and, therefore, the relative predictive power of each variable in relation to the others within this model.

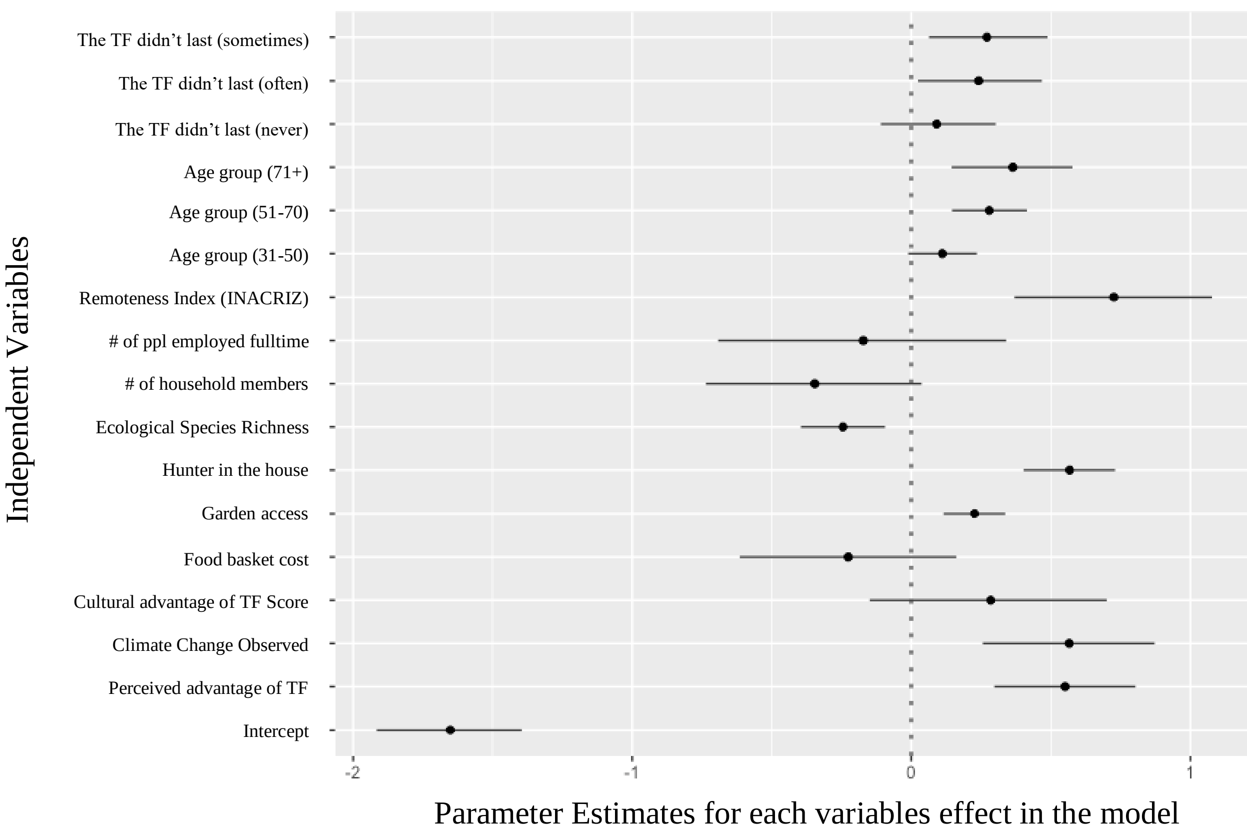

Figure 2: Visualization of regression coefficients of the independent variables included in the model

3.4 Results

The ESR data across the 11 ecozones are presented in Table 5 and Figure 3. Natureserve ESR ranged from 323 in the Hudson Plains to 3043 in the Boreal Shield. The calculated ESR values had a narrower range ranging from 302 in the Boreal Cordillera to 586 in the Boreal Shield. Boreal Shield showed the highest diversity by the two indices, but the order of the other ecozones did not show a consistent trend. Natureserve ESR has a much larger ESR range due to the inclusion of many taxonomic groups other than the four represented in the calculated ESR. The species tracked in each ecozone also varied, meaning that some ecozones have a higher ESR due to types of species being tracked (Appendix 1). Bird SR was the highest, followed by mammals, fish, and trees. The highest SR for birds, fish and trees were also found in the Boreal Shield.

Table 5: Ecological species richness final data

Ecozone	Mammal SR	Bird SR	Fish SR	Trees SR	ESR^1	Natureserve ESR
Pacific Maritime	80	263	60	64	467	396
Boreal Cordillera	50	160	60	32	302	338
Montane Cordillera	70	250	60	64	454	1668
Taiga Plains	45	182	60	32	324	229
Boreal Plains	60	258	80	32	440	1635
Prairies	60	266	80	64	480	1481
Boreal Shield	50	281	150	95	586	3043
Taiga Shield	45	165	100	16	321	1131
Hudson Plains	45	176	120	32	368	323
Mixedwood Plains	65	259	160	95	574	1248
Atlantic Maritime	50	234	120	64	468	2091

^{1} $ESR\ is\ the\ sum\ of\ the\ first\ four\ columns\ (mammal, bird, fish, and\ tree\ SR)$

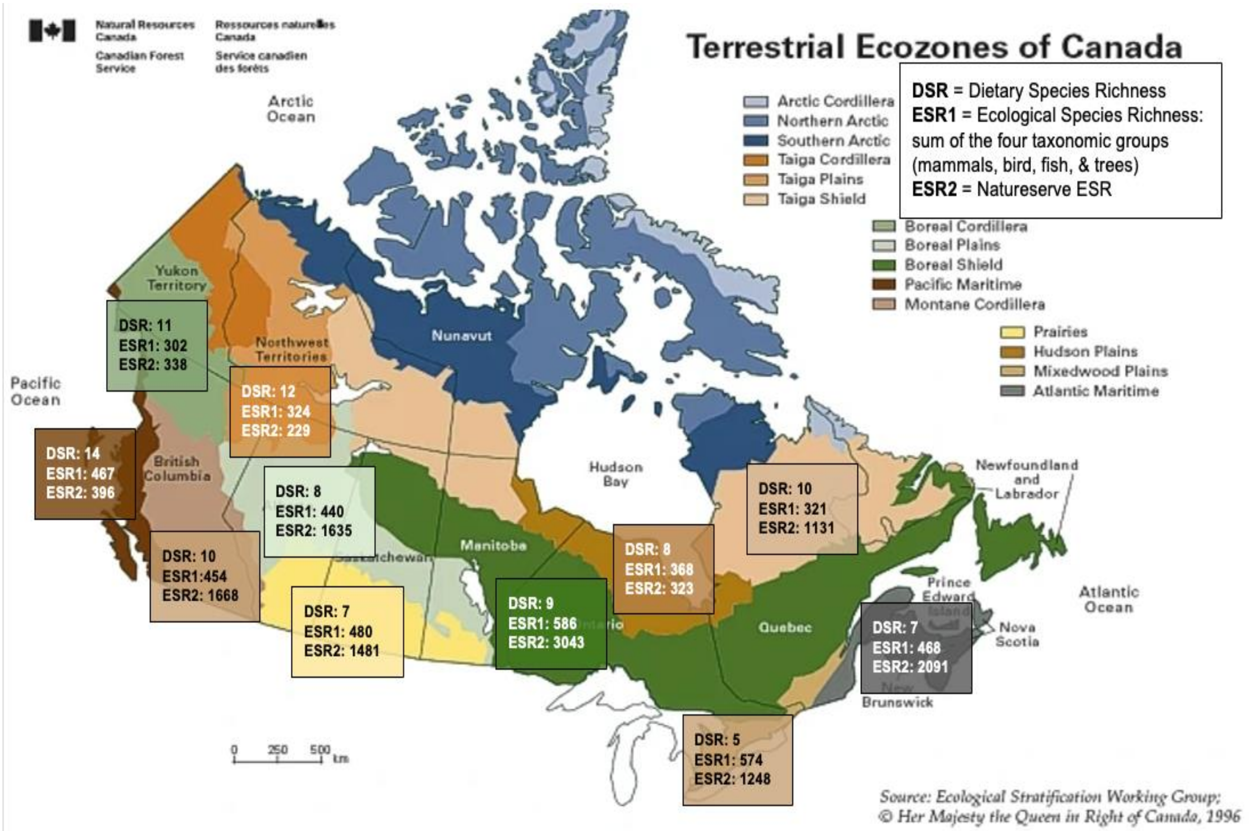

Figure 3: Map of Canada’s ecozones including DSR and ESR values

Table 6 shows the three dietary diversity indicators (6a) and the three dietary quality indicators (6b) across ecozones. The Pacific Maritime has the highest average DSR and average SID but has a lower TFDDS. The highest TFDDS is found in the Taiga Shield and the Boreal Cordillera, meaning that people in these ecozones consume more TF daily. The DSR across ecozones are also shown in Figure 4. Across ecozones, animal DSR was consistently higher than plant DSR, except in the Mixedwood Plains and the Prairies, where more plant than animal species were consumed. The Pacific Maritime had the highest average DSR at 14, with the Taiga Plains, Boreal Cordillera, and Taiga Shield, and Montane Cordillera following closely with average DSRs of 12, 11, 10, and 10, respectively. The Mixedwood Plains had the lowest average DSR at 5.

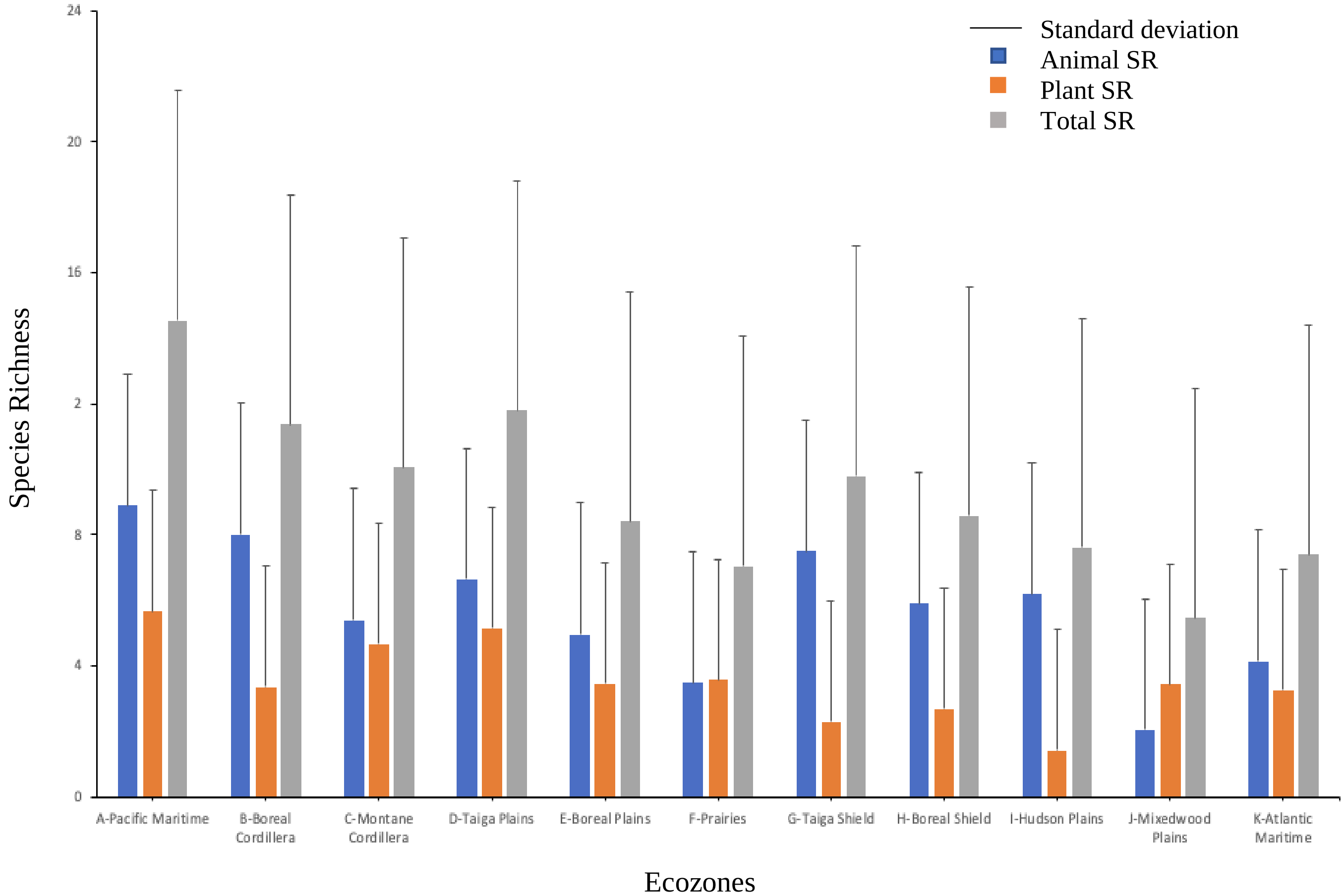

Figure 4: Average Dietary Species Richness (DSR) across ecozones

Table 6b shows that the average HEI and MAR are consistent across ecozones, falling within the 46 – 51 and 0.78 – 0.88 ranges, respectively. Figure 5 also shows the average HEI by ecozone. Revealing that the Mixedwood Plains and Boreal Cordillera have the highest average HEI, followed by the Hudson Plains. The Taiga Plains has the lowest HEI, and the rest fall within the middle ranges. Average consumption rate in grams shows large variation, with the Mixedwood Plains and the Atlantic Maritime having very low rates at 20.9, and 21.5, respectively. The highest consumption rate (g) is the Taiga Plains, Boreal Cordillera, and Taiga Shield, with average rates of 97.1, 89.6, and 89.5, respectively. The large standard deviations show the variability in responses. For all categories, many responses fall outside of the average response due to different dietary patterns and the number of outliers who consume TF at rates above the mean. The results concerning the relationship between dietary diversity indices and nutrition indicators showed no discernable difference between DSR and DSR Parts (Table 7). The consumption trends across ecozones did not change drastically when organ parts were included. Pacific Maritime still has the largest DSR and the Prairies, Hudson Plains, and Mixedwood Plains have the lowest (Appendix 5a and 5b).

Table 6a: Average values for the dietary diversity indicators (DSR, SID, TFDDS)

	DSR		**SID**		**TFDDS**	
	Avg	**St.dev**	**Avg**	**St.dev**	**Avg**	**St.dev**
Pacific Maritime	14.553	9.08	0.772	0.185	0.363	0.791
Boreal Cordillera	11.359	6.36	0.603	0.215	0.757	0.888
Montane Cordillera	10.072	9.72	0.607	0.234	0.393	0.73
Taiga Plains	11.854	7.81	0.563	0.274	0.447	0.841
Boreal Plains	8.431	6.53	0.595	0.271	0.345	0.704
Prairies	7.0454	6.34	0.6	0.289	0.203	0.569
Boreal Shield	8.583	6.17	0.641	0.266	0.375	0.826
Taiga Shield	9.808	5.87	0.618	0.24	0.864	1.17
Hudson Plains	7.624	4.63	0.673	0.21	0.403	0.795
Mixedwood Plains	5.466	5.72	0.515	0.315	0.097	0.362
Atlantic Maritime	7.394	7.15	0.553	0.324	0.099	0.383

Table 6b: Average values for the dietary quality indicators (HEI, MAR, Quantity (g))

	HEI		**MAR**		**Consumption rate (g)**	
	Avg	**St.dev**	**Avg**	**St.dev**	**Avg**	**St.dev**
Pacific Maritime	49.3	12.2	0.833	0.155	74.3	104
Boreal Cordillera	51.6	12.6	0.865	0.147	89.6	67.2
Montane Cordillera	49.3	11.1	0.789	0.160	76.7	110
Taiga Plains	46.0	11.2	0.830	0.156	97.2	130
Boreal Plains	48.9	12.4	0.83	0.162	34.6	57.2
Prairies	48.1	12.4	0.843	0.156	30.9	98.3
Boreal Shield	49.5	12.4	0.859	0.138	54.1	92.0
Taiga Shield	48.9	11.4	0.859	0.112	89.5	98.3
Hudson Plains	50.7	12.9	0.887	0.116	48.1	78.9
Mixedwood Plains	51.6	13.9	0.862	0.147	20.9	42.8
Atlantic Maritime	48.3	13.1	0.853	0.16	21.5	40.9

Table 7: Spearman’s correlation results between nutritional indicators and dietary diversity indicators

Nutritional Indicators	Dietary Diversity Indicators	Spearman’s Correlation Coefficient	P Value
DSR	TF Gram	0.741	< 0.001*
	MAR	0.071	< 0.001*
	HEI	0.136	< 0.001*
DSR Parts	TF Gram	0.744	< 0.001*
	MAR	0.070	< 0.001*
	HEI	0.133	< 0.001*
SID	TF Gram	0.478	< 0.001*
	MAR	0.076	< 0.001*
	HEI	0.144	< 0.001*
TFDS	TF Gram	0.336	< 0.001*
	MAR	0.122	< 0.001*
	HEI	0.152	< 0.001*

*Variables with significant p values

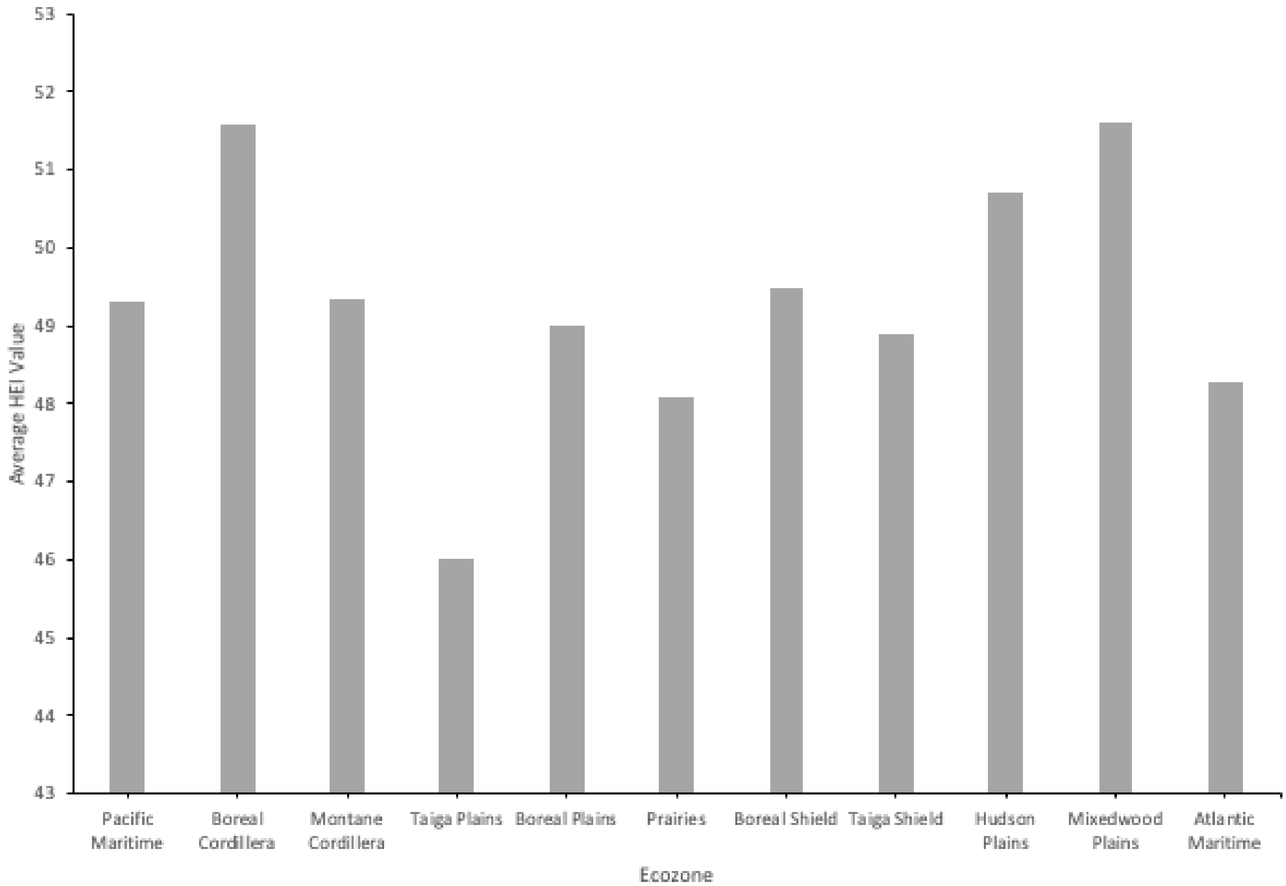

Figure 5: Average Healthy Eating Index (HEI) by ecozone

Spearman’s correlation between the nutritional indicators (DSR, SID, and TFD) showed a significant correlation with the dietary diversity (DD) indicators (TF Gram, MAR, and HEI) (Table 7). TF Gram showed the strongest correlation with each of the DD indicators. Although DSR and HEI are positively correlated, these results show variation between ecozones. A high average DSR does not directly equate to an equally high average HEI value. For example, the Mixedwood Plains has one of the highest average HEI values but the lowest average DSR (Table 6a & 6b). Comparatively the Pacific Maritime and Boreal Cordillera have high average HEI values corresponding to high average DSR. The Taiga Plains has the highest consumption rate of TF (g) but one of the lowest HEI and MAR values. This is an anomaly compared to the rest of the results showing a positive relationship between dietary diversity indicators and nutrition indicators. The Taiga Shield is another interesting case as it has an equally high consumption rate (g) as the Boreal Cordillera but has a lower average DSR (9.8, and 11.4 respectively) (Table 6a & 6b).

Spearman’s correlation between DSR and all 31 relevant variables showed that all but six variables (number of HH members, number of kids, cultural barriers, lack of sharing, TF availability not affected, and ecological barriers) were significant (Table 8). ESR was negatively correlated to DSR (r= -0.187). Therefore, the ESR and the following confounding factors were included in the regression model; age, access to TF, garden access, presence of a hunter, the advantage of TF, climate change, remoteness (INACRIZ), number of people employed full time, number of household members, food basket cost, and cultural advantage TF score. Figure 2 shows the visualization of the regression coefficients of the included variables. ESR and number of household members were the only two factors that are negatively associated with DSR. The variables that cross the estimate line at zero, i.e., their relationships with DSR were not significant, were removed from the model. They are ‘number of people employed fulltime’, ‘food basket cost’, ‘number of household members’, and ‘cultural advantage TF score'. Table 9 describes the correlation coefficients, standard error and P value for each variable included in the final model. Correlation coefficients were used instead of R2 values as R2 is incompatible with negative binomial regressions. In this regression model, ESR has the lowest predictive value at -0.0004. Similar low and negative predictive values were found when correlations and regressions were performed with both measures of ESR (ESR and NatureServe ESR). The demographic variables included in the final model are as follows; Age, the total number of household members, and remoteness (INACRIZ) (Table 9). This means that on average older individuals will consume more Traditional Foods. The baseline category was 18 – 30; therefore, those aged 71+ are most likely to consume TF compared to 18–30-year-olds, followed by 51–70-year-olds and 31–50-year-olds. The number of individuals in the house is negatively related, meaning that households with more individuals have lower DSR. One unit increase in INACRIZ results in a 0.113 increase in DSR. The second most important predictive variable is describing a household's access to TF. Households that describe themselves as sometimes or often running out of TF and not being able to obtain anymore have higher DSR. Garden access is the next variable with the most predictive power, followed by having access to a hunter. Finally, knowing the advantages of TF and noticing climate change in their region are of similar predictive capabilities. Due to the phrasing of the question, this question is evaluating individuals' ability to notice climatic and environmental shifts and is not a good indicator of the precise environmental changes in the region. This variable is therefore measuring time spent in nature or traditional knowledge rather than the impacts of climate change on accessing TF.

Table 8: Correlation results between DSR and all relevant dependent variables

Independent Variable	P value	Spearman's Correlation
		DSR
Age group	< 2.2e-16*	0.153
Gender	2.90e-09*	0.078
# of HH members	0.927	-0.001
# of kids	0.391	-0.011
Health barrier	0.003*	0.039
Road Access	< 2.2e-16*	0.138
Nearest Service Centre (km)	< 2.2e-16*	0.214
Remoteness (INACRIZ)	< 2.2e-16*	0.2
HH employment	0.005*	0.037
Income source	8.10e-06*	0.059
Poor access to TF	< 2.2e-16*	0.23
Financial barrier	0.018*	0.031
No barrier	2.34e-10*	0.083
Food Security	0.011*	-0.033
School completed	0.005*	-0.037
Logistical barrier	< 2.2e-16*	0.135
Cost of food basket	< 2.2e-16*	0.157
Individual is a hunter	< 2.2e-16*	0.412
Household member is a hunter	< 2.2e-16*	0.29
Cultural advantage	5.39e-08*	0.072
Cultural barrier	0.405	-0.011
TF preference	< 2.2e-16*	0.249
Perceived advantage of MF	0.022*	0.028
Perceived advantage of TF	< 2.2e-16*	0.235
Lack of sharing	0.797	0.003
Garden access	< 2.2e-16*	0.188
Climate change observed	< 2.2e-16*	0.233
Noticed climate change in the last 10 years	< 2.2e-16*	0.209
TF availability not affected	0.087	-0.023
Ecological barrier	0.176	-0.018
Ecological Species Richness	< 2.2e-16*	-0.187

Table 9: Negative binomial regression results with DSR as the dependent variable

	Categories	Coefficient	Std. error	P value
Ecological Species Richness		-4.17-04	1.12e-04	< 0.001*
Age	71+	0.367	0.044	< 0.001*
	51-70	0.29	0.026	< 0.001*
	31-50	0.105	0.024	< 0.001*
Poor access to TF	Sometimes	0.283	0.038	< 0.001*
	Often	0.254	0.04	< 0.001*
	Never	0.057	0.036	0.112
Garden access		0.226	0.023	< 0.001*
Household member is a hunter		0.153	0.009	< 0.001*
Perceived advantage of TF		0.134	0.01	< 0.001*
Climate change observed		0.117	0.013	< 0.001*
Remoteness (INACRIZ)		0.113	0.009	< 0.001*
# of household members		-0.021	0.004	< 0.001*

Table 10 outlines the differences between model one and model two. The results from each model are similar. However, model two is more refined, as model one includes redundancies within the included variables. For example, it contains both individual hunter and having a hunter in the household. Model one also contains all three remoteness indices. Variables that were positively associated with DSR include being a hunter yourself, not having a barrier to TF, noticing climate change in the region over the past 10 years, household preference for TF, and having a cultural preference for TF. All these variables are represented by similar variables in model 2 and, therefore, were no longer required. Road access type was negatively associated with DSR, and service centre distance was positively associated. Both indicators show that remoteness equates to higher rates of DSR. The same results were found with the INACRIZ remoteness index which was used for model 2 as the remoteness index that captured the most information.

Table 10: Final statistical models describing covariates responsible for determining DSR

Variable Code	Variable meaning	Direction of association	Model
Q3 (Income source)	Main source of income for participant	(+)	1
Indiv_hunt (Individual is a hunter)	You are a hunter, and/or fisher, and/or collect wild food, and/or collect seafood, and/or planted a garden. Therefore, those who have direct access to TF consume more TF.	(+)	1
No_bar (no barrier)	No barrier to TF/ have enough TF. Therefore, those who reported no barrier to accessing TF, consume more TF.	(+)	1
Q9A (Noticed climate change in the last 10 years)	Have you noticed climate change in traditional territory in last 10 yrs. Therefore, those who notice climate variables changing in the environment consume more TF.	(+)	1
Q8A (TF preference)	Would your household like to have more traditional food? Therefore, wanting to consume more TF (either relying on TF or viewing them as important food sources) increases consumption of TF.	(+)	1
CULT_ADVTF_SCORE (Cultural advantage)	Cultural advantage traditional food score. Therefore, the more cultural importance placed on TF in the household, the more TF consumed.	(+)	1
Roadaccess (Road Access)	Type of road access (indicator of remoteness). Therefore, those who live in more remote locations consume more TF.	(-) – winter_fly in (+) year round	1
Servicecentrekm (Nearest Service Centre (km))	Distance from the nearest service centre in km, therefore an indicator of remoteness. Therefore, those who live in more remote locations consume more TF.	(+)	1
CLIM_CHNG (Climate change observed)	Have you noticed a variety of climate change indicators in your region, Therefore, how much time is spent in nature and noticing changes in the environment increases the consumption of TF.	(+)	1 & 2
House_hunt (Household	Your household has a hunter, and/or fisher, and/or collect wild food, and/or collect seafood, and/or planted a garden.	(+)	1 & 2

member is a hunter)	Therefore, those who have direct access to TF consume more TF.		
INACRIZ (Remoteness index)	Indigenous and Northern Affairs Canada Remoteness Index Zone. Therefore, those who live in more remote locations consume more TF.	(+)	1 & 2
ADVTF_SCORE (Perceived advantage of TF)	Perceived advantage of traditional food score. Therefore, the perceived importance placed on the consumption of TF increases the quantity of TF consumed.	(+)	1 & 2
Agegroup (Age group)	19-30, 31-50, 51-70, 71+ Therefore, the older age groups consume higher rates of TF.	(+)	1 & 2
Q8D (Poor access to TF)	The TF that we got just didn't last, and we couldn't get anymore. Indicating a reliance on TF and a proxy for income. Therefore, relying on TFs increases the quantity of TF consumed.	(+)	1 & 2
Q1 (# of household members)	Total number of household members and therefore an indicator of household wealth. Therefore, having more family members (a potential access barrier) means that individual consumes less TF.	(-)	1 & 2
Garden (Garden access)	You or a household member planted a garden last year. Therefore, having direct access to TF and other food sources increases rates of TF consumption.	(+)	1 & 2
ESR (Ecological Species Richness)	Total count data of species in each Canadian ecozone. Informing on the relationship between biodiversity and TF dietary diversity. Therefore, consumption of TF generally increases in areas with lower ESR.	(-)	1 & 2

[1] *Relative importance of these variables is not applicable because they were removed during the model selection phase*

The concept of types of species being consumed based on their behaviours was explored. Table 11 highlights the types of species (generalist, specialist, and/or ruderal) that are commonly consumed by the province. This table includes data for the 10 species most frequently consumed in each province with overlapping labels as a species can be both a generalist/specialist and ruderal. The TF most consumed across ecozones include large mammals like moose and deer, fish, and wild berries like strawberries and blueberries. Most of the species consumed are generalists or ruderal. The tables in Appendix 6 show the types of foods most commonly consumed, consumption rates, and species type. The tables in appendices 7 and 8 explain each species category in more detail and why a species falls within each category.

Table 11: Types of species included in the top 10 most consumed species by province

	Type of Species		
Province	**Specialist**	**Generalist**	**Ruderal**
British Columbia (1)	3	5	3
British Columbia (2)	2	6	4
Manitoba	0	9	5
Ontario (1)	0	9	4
Ontario (2)	0	6	4
Alberta	0	7	5
Atlantic Maritime (1)	0	6	3
Atlantic Maritime (2)	1	7	4
Saskatchewan (1)	1	8	2
Saskatchewan (2)	0	7	6
Quebec	0	8	4

Table 12 shows the relationship between the median number of TF items reported and the HEI by ecozone. The number of TF reported ranged from the lowest of 5.6 in the Mixedwood Plains to the highest of 17 in the Pacific Maritime. About 30 to 40% of individuals reported consuming higher numbers of TF compared to the median. The average HEIs were very similar at around 50 across all ecozones. In general, the average HEI improved minimally for those consuming more TF than the median number. However, in the Taiga Plains, the average HEI of those with DSR higher than the median was lower than the average HEI. Spearman's correlations between animal SR and MAR showed a higher correlation value (0.09) when compared to plant SR and MAR (0.081). When evaluating the consumption of animals and plants out of the total TF consumption, animal SR was positively correlated to MAR, and plant SR was not (Table 13).

Table 12: Description of TF consumed by ecozone and the corresponding HEI values

Ecozone	**Median TF reported**	**% of individuals with DSR higher than median**	**Average HEI**	**Average HEI of those higher than median**
Pacific Maritime	17	41.6%	49	50.5
Boreal Cordillera	12	42.5%	51.5	54.8
Montane Cordillera	11	28.4%	49.4	54.7
Taiga Plains	12.5	41.4%	48.4	47.9
Boreal Plains	8.7	34.7%	48.9	51.1
Prairies	7	37.6%	48.2	50.5
Taiga Shield	11.7	34.6%	47.9	50.7
Boreal Shield	9	40.4%	49.6	50.7
Hudson Plains	8	40%	50.5	53
Mixedwood Plains	5.6	30.2%	50.8	52.9
Atlantic Maritime	8	37.4%	48.3	50.7

Table 13: Pearson's correlations between animal SR + plant SR and MAR

Animal SR & MAR	
P value	< 0.001*
Correlation	0.09
Plant SR & MAR	
P value	< 0.001*
Correlation	0.081
Animal SR/total TF consumption & MAR	
P value	< 0.05*
Correlation	0.034
Plant SR/total TF consumption & MAR	
P value	0.26
Correlation	-0.01

Outliers (DSR > 23) had an average DSR of 29, where 43% of those TF were plants, and 57% were meat. The rest of the population consumed an average of 37.33% plants and 61.33% meat. Despite consuming more wild animals than plants, plant DSR was negatively correlated with FS status ($p < 0.001$) and animal consumption was not related ($p = 0.37$). Therefore, the more plants an individual consumes, the more food insecure they were. Food Security status was only negatively associated with DSR consumption in the summer season ($p < 0.05$), and with total DSR ($p < 0.05$). Where individuals became more food insecure based on summer consumption patterns. Individuals consumed more TF in the summer than in any other season (Figure 6 & Figure 7). Figure 6 shows the immense variability in TF consumption, with some individuals consuming upwards of 50 TF in the summer. The average FS status for the general population (2.56) and the outliers (2.54) were very similar. Two represents moderately secure and three represents secure, meaning that on average the population was moderately to securely rated for food security and there was no difference for individuals who consumed more TF.

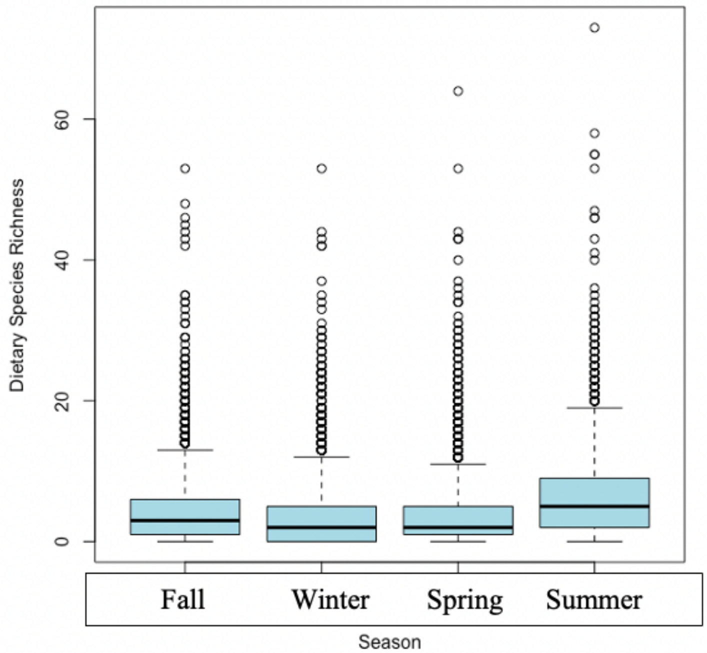

Figure 6: Boxplot showing the variation of all Dietary Species Richness (DSR) data divided by season

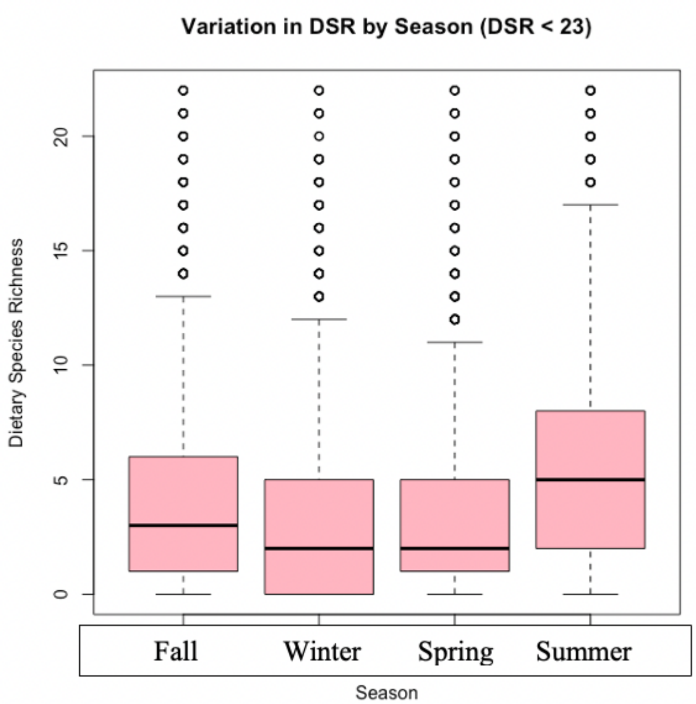

Figure 7: Boxplot showing the variation in Dietary Species Richness (DSR) divided by season with outliers removed

3.5 Strengths and Limitations

This study is exploratory in nature. Various datasets and multiple different techniques were utilized throughout the study to mitigate limitations as they arose. However, as a study that is working with existing datasets to identify a pattern between ecological, dietary, and nutritional data in Canada, there is much room for further research and improved methodology. As such, there are three key limitations with this study.

The first limitation of this study is the scale. Canada is a large country with many nations, all with varying cultures and confounding variables to accessing TF. Baudron et al., observed significant variability in diets for communities living in similar environments with similar access to biodiversity, concluding that nutrition-related interventions need to be created specifically for each community (14). Therefore, when interpreting the results in this study, we must be careful to not over-conflate the findings.

The second limitation of this study was poor access to biodiversity data. We used a few measures to mitigate the availability of regional biodiversity data. The first source was from a trusted collection of data from researchers across North America (NatureServe). However, this source included confounding species like moths and spiders that overpowered the edible species in a region. For example, according to the NatureServe data the Pacific Maritime has an ESR of ~700 while the Atlantic Maritime has an ESR of ~23000. This discrepancy could be due to variance in the taxonomic group included in each ecozone, the variety within each taxonomic group, and how much research was done in each area. Another indicator made up of four major taxonomic groups was created to combat the inconsistencies in the NatureServe data. Using mammals, birds, fish, and trees represents the general biodiversity in each ecozone and most importantly provides a comparison in average rates of ESR between each ecozone. The use of ArcGIS was ideal for calculating ecozone ESR from raw data. Unfortunately, we did not have access to datasets with the necessary biodiversity data. As such, this method relied on the use of range maps. The range maps offer a wealth of information calculated by trusted researchers, giving an excellent estimate of Ecozone ESR. However, ecozones are large land areas, making it challenging to estimate SR using range maps as a species could occur in only one area of the ecozone and is not found in any other. The fish range map also only included freshwater species.

Although the difference would be small, coastal ecozones would have higher rates of fish species than the range map shows and therefore a slightly higher total ESR. The studies that show the strongest association between regional biodiversity and DD utilize indicators of regionality like forest cover access, indicating that it is both a biodiverse location and that individuals have direct access to that food source (14). Therefore, the preferred method would be to use ArcGIS to find ESR with increased regional specificity. Due to confidentiality purposes, this was not possible. Finally, SR is not the most robust measure of biodiversity. Morris et al. recommend Simpson's Index of Diversity as the most appropriate tool when the primary objective is ranking sites based on biodiversity (27). Functional diversity was another method in consideration since it accounts for the functional differences in each species (27). Despite the proven efficacy of both SID and FD, data availability had to be considered.

Thirdly, FNFNES is a rich data source from comprehensive surveys, however, its primary objective differed from this study. Therefore, the exact variables and methodology for collecting data were sometimes insufficient for the requirements of the analysis, and as such, there were missing data points of interest. For example, seasonality could not be included in the regression even though it is an important factor as there is variation in DSR levels throughout the seasons.

The data received from FNFNES was also this study's greatest strength. The quality and content found within each survey, questionnaire, and food recall gave robust results. A sample size of 6488 participants provides information that represents First Nations Peoples in Canada with reasonable accuracy. Another strength was the expertise of incredible natural scientists and social scientists who participated in this project. The topic at hand required varying knowledge and expertise from very different fields, and the multidisciplinary nature lent itself to using novel methodologies and understanding of the material.

3.6 Discussion

This assessment supports First Nations health and nutrition in Canada by highlighting key factors that increase consumption of TF. We have produced the first model that presents the statistical importance of variables (primarily ecological) in determining nutrition outcomes in First Nations in Canada. We found that biodiversity had a low and negative association with TF dietary diversity. Other factors, including age, the total number of household members, remoteness (INACRIZ), household's access to TF, garden access, presence of a hunter, knowing the advantages of TF and noticing climate change in their region, were more significant in predicting DSR.

3.6.1 The relationship between ESR and DSR

Based on previous studies in highly biodiverse locations, we anticipated a positive association between DSR and ESR (11,14,30,33,34). According to the correlations and subsequent regressions, ESR has a weakly negative predictive relationship with DSR. As can be seen in Figure 3, the negative relationship between ESR and DSR is only a general trend and does not hold true in every ecozone. For example, both Maritime ecozones have approximately the same ESR, are ecologically diverse, and have access to both marine and terrestrial species. The difference is that the average DSR for the Atlantic Maritimes (7) is half that of the Pacific Maritimes (14). However, the Pacific Maritimes extends the length of Canada's west coast meaning it has expanses of northern territory largely untouched by manmade infrastructure and agriculture, while the Atlantic Maritime is a major agricultural hub, with mass destruction of ecosystems and loss of biodiversity. Another example is the Mixedwood Plains. Despite being one of the most ecologically diverse regions in Canada, the Mixedwood Plains has had many anthropogenic changes, has a large population size, and is an agricultural hub, resulting in alterations to the biodiversity (82). Most species consumed in this ecozone are generalists or ruderal, meaning that they are highly adaptable to anthropogenic changes. For example, deer thrive in edge habitats that humans have disturbed and is a commonly consumed TF species across Canada (Table 11, and Appendix 6). With 80% of the most frequently consumed species having highly adaptive and some having invasive tendencies, it can be inferred that these species have survived habitat destruction throughout urbanization. It is possible that the species most frequently consumed today may not represent the species consumed centuries ago.

These results reveal variables that confound the relationship between nature and direct access to TF for sustenance, including human interference in ecological systems. There are three main ecological patterns of interest when evaluating the effects shown in Figure 3. First is the north-south gradient, where ecological biodiversity declines further north due to climactic and resource barriers (83). This is a well-documented effect and corresponds to the ESR gradient seen in Figure 3 where ESR tends to be lower in northern provinces.

Secondly, access to biodiversity is just as important to consider as the quantity of biodiversity in the area. For example, the most southerly ecozone, the Mixedwood plains, is well documented as the most highly biodiverse ecozone in Canada. However, it is also the most populated, as Canadians tend to live along the continental United States border (82). This equates to increased urbanization, destruction of ecozones, and humans having reduced access to forest cover in urban areas. In these regions, it is important to consider whether individuals can participate in hunting and gathering practices, even if the ESR is high in that region. Additionally, urbanization, destruction of habitats, and reduced direct access to forest cover in urban areas limit TF access.

The third regional consideration is agriculture. The principal field crop areas extend from the Prairies eastward to the Boreal Shield, Mixedwood plains, and the Atlantic Maritimes. These regions make up most of the agricultural production in Canada, resulting in the large-scale destruction of ecosystems and a variety of changes to biodiversity. Loss of specific species or loss of access to species due to habitat destruction could explain why DSR is lower in these regions despite the high ESR. Therefore, the negative relationship between ESR and DSR is most likely a result of these unique ecological patterns and human interferences in ecological systems, rather than a reflection on the significance of biodiversity in First Nations health and wellbeing. Addressing these current ecological constraints are key intervention areas for improving DSR rates.

3.6.2 Dietary diversities contribution to nutrition outcomes

A positive association was found between all DD indicators and the dietary quality indicators. Therefore, increasing TF consumption improves nutritional outcomes. The strongest correlation was between grams of TF consumed and dietary quality. This is significant as it shows how the number of different TF consumed increases the amount (g) of TF consumed and should contribute to FS. The data used for the DD indicators included only TF while the nutrition indicators encompassed individuals' whole diets, with TF making up only a small portion of their daily intake. Therefore, regardless of the other foods in the diet, the positive relationship shows that consumption of any TF increases the nutritional quality of that diet (12).

Previous research outlines the importance of TF for improved food security without quantifying the current relationship (11,30,31). The negative correlation between total DSR and FS status reveals that there are barriers to consuming enough TF required to improve individuals FS status. Individuals in the outlier category who have higher rates of DSR do not have improved food security . On average, outliers consume more plant TF than 95% of the population, most likely due to a lack of access to other food sources, including meat TF. There could also be a cause-and-effect relationship where individuals are consuming more TF because they are food insecure, or because individuals are consuming small quantities of a variety of herbs that are not heavily contributing to FS outcomes. A limitation with the FNFNES FFQ relates to the use of plants for medicinal purposes or tea. This is a confounding factor when considering the nutritional value associated with DSR. As seen in Appendix 6, 30.7% of the population of First Nations living in Alberta consume mint. However, it is unclear whether that is used in tea, for other medicinal purposes, or eaten. The nuance in different uses cannot be determined with the available data but is necessary to understand each TF contribution to overall energy and FS.

These results reveal how critical the consumption of even a few TF is for improved nutritional outcomes. Despite TF being a potential solution to food insecurity in First Nations communities, we know that rates of consumption will need to increase to improve FS status. Therefore, improved access to TF and addressing barriers to TF harvesting and consumption is needed.

3.6.3 The relationships between the predictive variables and DSR

Health and nutritional outcomes for First Nations peoples living in Canada are largely impacted by social, economic, and environmental factors (84). The final model shows that all of the significant variables have similar predictive power. However, the low correlation values reveal that other, potentially more significant variables have yet to be considered. From the model’s results there are two significant findings. First, consumption of TFs can be predicted in part by variables describing a reliance on TFs to supplement their diets due to poor food access. Logistical variables like access, knowledge and demographic variables are impeding an increase in DSR, while good access to TF through having access to a hunter and/or a garden improve TF rates. The only socioeconomic indicator remaining in the final model was an indicator of poor access to TF "the TF we got just didn't last, and we couldn't get any more". The individuals who replied sometimes or often were predictive of having a higher DSR. This indicates that households who consume more TF tend to run out of TF before they would like to, showing reliance on TF as an important food source. The total number of HH members has a negative relationship with DSR, where households with fewer members consume more TF. Households with fewer members may consume more TF themselves, whereas, in households with more people, the TF are dispersed evenly among HH members, limiting quantities. Another explanation is that households with more members have more financial strain and less time to participate in hunting, fishing, and gathering that is required to gather large enough quantities of TF to satisfy their families. Age is another related variable as older age groups tend to consume more TFs. This is a sensitive population that may experience access and financial barriers, therefore, relying on TF sources. Finally, the remoteness index INACRIZ has a positive relationship with DSR. Those who live in more remote communities have increased odds of consuming TF, indicating a reliance on TF as an important dietary source. The farther from a service centre the individual is, the more difficult it is to access other food sources (4,8). This usually means that theMF available are more expensive and of lower quality due to traveling long distances (4,8).

The second important finding is that culture is perhaps the most significant indicator of TF consumption as most predictors in the final model are culturally related. For example, having a hunter in the family increases rates of TF consumption and hunting methods are generationally taught traditional practices. The remoteness index is also cultural. Traditional knowledge and culture are more easily maintained in rural and remote locations (85). Despite having fewer TF available in the environment, remote communities also have direct access to nature. Finally, the perceived advantage of consuming TF greatly increases the odds that you or your family will consume TF. Knowing the cultural and nutritional value of consuming TF is as important of a predictor for determining high DSR as having the physical capabilities to hunt.

The difference in organs consumed between provinces show that access to a TF does not equate to consumption of those organs. The differences in organs consumed between provinces provides an example for how culture plays a role in dietary patterns and the types of TFs consumed. For example, in the Mixedwood Plains, 164 individuals consumed moose meat, and five individuals consumed moose liver, but zero individuals consumed moose kidney. However, in the Taiga Shield, Hudson Plains, Boreal Cordillera, Taiga Plains, and the Boreal Plains, more people consume moose kidneys than livers. These results suggest that access to culturally significant TFs is more important than overall biodiversity in determining dietary diversity. A study performed in the Democratic Republic of Congo found that living in a highly biodiverse location did not contribute to improved nutrition outcomes (31). One reason for this is the need for more knowledge on local indigenous plants and the nutritional benefits of these plants (31). In the case of First Nations living in Canada, there are significant knowledge barriers to accessing TF. First, traditional knowledge was lost due to forced assimilation. Secondly, older generations have noticed a lack of interest and uptake in consumption of TF by the younger populations. Age is the variable with the greatest predictive power, with the 71+ category predicting higher rates TF consumption. Both practices associated with TF and the consumption of TF is lower in younger age-groups, suggesting the decline of knowledge transfer and the overall significance of TF in younger generations diets (60,63). This age gap in TF consumption highlights the importance of maintaining both the skills required to obtain TF and the importance placed on TF in diets for cultural and nutritional benefits.

3.6.4 Concluding Remarks

This study adds to the growing literature describing the intricacies of First Nations' health and well-being in Canada. The insight in this study brings further understanding to some of the reasons these health disparities exist as they relate to human nutrition. Access to TF is an undeniably important contributor to First Nations' health, nutrition, and food security. On average, households that consume higher quantities of TF are doing so due to poor access to food sources and are in regions with lower ESR Our findings suggest that households, on average, need increased access to TF as they would like to consume more TF than are available to them. These results inform policymakers that there are more significant barriers to accessing TF than ecological availability. Households that know the cultural importance of TF consumed more TF, as did older individuals, and households with hunters and gatherers, indicating that culture is a significant predictor of TF consumption. Reduced access through environmental destruction, knowledge loss, and reduced emphasis on TF importance has caused a decrease in TF consumption and a gap in TF knowledge in younger generations.

Increased accessibility of TF is also reliant on maintaining environmental and biodiversity conditions. All variables included in the final model contribute to the findings that ecozone biodiversity rates do not predict improved dietary outcomes. However, the general trend of ESR having a negative relationship to DSR throughout the ecozones reflects the distribution of species, multiple routes of lost knowledge on TF practices, access barriers from ecological and cultural destruction (and subsequent supplementation with available species), and households' reliance on TF in remote communities where there is typically a lower ESR. Therefore, the model results show diet adaptation due to the loss of culture, traditional knowledge, and biodiversity. These results inform policymakers that ecosystem maintenance and protection of species is a critical component of improved FS, nutrition, overall well-being, and culture. The maintenance of traditional practices, reinvigorating youth with traditional knowledge, and improving ecological accessibility to TF are the most significant indicators for improving DSR rates.

4. Discussion

The objectives of this study were to quantify dietary diversity outcomes in First Nations communities as they relate to ecological theories. These relationships were evaluated to provide insight into the various factors impacting dietary outcomes in First Nations populations across Canada The recommendations from this study include prioritizing the consumption of TF to address disparities in health, food security, and mitigate the effects of the nutrition transition. This includes interventions aimed at prioritizing ecological conservation, removal of access barriers to TF like cost, and improving community cultural programs surrounding sharing resources and teaching younger generations the importance of hunting and traditional subsistence practices. In the context of food security and nutrition interventions for First Nations in Canada, an increase in TF is consistently recommended (86). As discussed by Skinner et al., improved food security and nutrition interventions are desperately needed in Indigenous communities across Canada (63). These issues are persistent and ongoing without any clear method for improving these outcomes. Substantial changes to the current food systems are needed and this incorporates access to both MF and TF (63). This study contributes to the mounting evidence showing the importance of cultural and environmental programming, with the goal of impressing on policymakers the significance of these programs in the face of few other viable solutions.

4.1 What Biodiversity's Relationship to Dietary Diversity Provides to Policy Makers

Populations in Malawi, Bangladesh, Ethiopia, and Tanzania all saw a distinct positive relationship between regional biodiversity and dietary diversity (14,33). One common theme throughout is "access". In these papers, regional biodiversity represents direct access to wild food sources. For Bangladesh and Ethiopia, direct forest access and the density of forest cover were significantly associated with higher rates of dietary diversity. As discussed, regional biodiversity in Canada and particularly with the biodiversity indicator we used, does not represent direct or consistent access to those species. Access to TF is not only determined by availability in the ecosystem as it is also determined by confounding barriers like knowledge, resources (both monetary and biodiversity-related), cultural preferences, and climactic variables.

The relationships discovered between ecozone biodiversity and TF dietary diversity in Canada is an opportunity to learn about the complexities of Canada's ecological and cultural landscape. It is not an invitation to disregard the significance of biodiversity in Indigenous food systems. The general trend is a negative predictive relationship between ESR and DSR. Research in the Democratic Republic of Congo, Zambia, and Indonesia found an inverse relationship similar to our results (14,31). Certain communities in Nicaragua consumed many wild foods while others consumed none, patterns that were independent of wild food availability. Factors like knowledge of wild foods availability, gathering techniques, nutritional quality and cultural preferences were used to explain these findings, where Indigenous populations consumed more wild foods than non-Indigenous (14). These findings are like comparing Canada's Indigenous population's diet to the non-indigenous population. As non-Indigenous populations would not have the cultural and traditional knowledge of TF, they would not put energy into collecting, storing, and consuming these foods, even if they exist in abundance. The important results from the study in the DRC and Nicaragua are that individuals who traditionally use their land and have knowledge of foods to consume are significantly more advantaged than those who do not possess this knowledge or traditions. Canada's First Nations have lived off the land from time immemorial and therefore, have the knowledge and tools required to utilize these resources. As discussed by Powell et al., individuals who recognized the power of a diverse diet and connected it to diversity in their farm or nearby ecology had more diverse diets (57). In a highly biodiverse location in the Democratic Republic of the Congo, knowledge of locally available species was determined to be the main barrier to consuming more wild foods (31). Similar patterns could be appearing in Canada as loss of traditional knowledge occurred over the past century, resulting in declining rates of TF in diets.

The significance of these results is revealed in Canada's unique environmental and situational confounding factors in accessing TF, particularly in Canada's highly biodiverse ecozones. Environmental recommendations should consider the model results under the assumption that biodiversity is still critical for the following reasons. Firstly, the climactic changes that have already caused poor access to TF sources must be halted and reversed. There are countless ecological barriers to accessing TF, including species loss, mass habitat destruction, and altered migration routes. A biodiverse system is more resilient to climactic changes, which will only increase in the coming years (25,26). A stable environment that is not as susceptible to changes in the environment will be able to provide resources and continued access to TF. Secondly, the nutritional and potential food security benefits from increased consumption of TF should encourage the environmental protection of biodiversity and ecosystems across Canada. Finally, the accessibility of TF needs to be evaluated and understood as a main factor in the inverse relationship between DSR and ESR. DSR rates may also relate to the types of species available in the region. Studies suggest key species are important both for ecosystem health and potentially as key nutritional species (28). Future studies should focus on identifying these culturally and nutritionally important species and direct access to them rather than total SR. It would be important to look at First Nations Peoples living in cities or near city centres and their access to purchasing TF or participating in hunting, gathering, and fishing. Conversely, it is important to evaluate the needs of remote communities and their reliance on TF while not obtaining enough to be food secure. From these results, it appears as though they cannot obtain enough TF to satisfy the needs of their family while contending with poor access to overpriced market foods and having a much smaller ESR than the Southern communities. Both situations are indicative of a failing food system not accounting for the detriment caused by reduced biodiversity, inaccessibility of TF, and loss of key TF sources.

Finally, biodiversity, as considered in this context, is attempting to quantify an Indigenous traditional food system. However, the maintenance of the environment is significant to Indigenous peoples beyond the scope of this study and our understanding of biodiversity as Western scientists. Our findings are significant as they reveal the significance of culture, traditional knowledge, and adaptability of species to anthropogenic changes. However, these findings were unnecessary to understand the significance of biodiversity and a healthy ecosystem in the lives of Canada's First Nations peoples. The inherent importance of biodiversity in Indigenous food systems must not be undermined or forgotten.

4.2 Do Traditional Foods Contribute to Improved Nutrition Outcomes?

TFs contain many essential nutrients including but not limited to vitamin D, iron, and magnesium, and are high in protein (6,9). Findings suggest that when TF are consumed, MF consumption decreases and, along with it, processed foods high in sugar, saturated fats, and foods with high-caloric density and poor nutritious value (9,12). Not only do TF improve dietary outcomes, but they also improve cardiovascular fitness as traditional practices of collecting TFs require high cardiovascular expenditure (9). Despite the overwhelming health benefits, rates of TF consumption have been dropping due to various access barriers. As a result, First Nations living in Canada have poorer health outcomes when compared to non-Indigenous Canadians due to dietary inequalities, poor access to nutritious foods, and an overwhelming issue of food insecurity. The lower consumption of TF seen is directly related to the increase in obesity and nutrition-related chronic diseases (9). A study completed in 2019 found that obesity rates are rising at a much faster rate in First Nations communities than in the general Canadian population or the Inuit populations (9). Nutritional benefits are found even when TF were consumed the low rate of 4.6% total caloric energy per day, showing that any consumption of TF is significant (12). Current findings are pushing for increased access to TF as a way of combatting nutritional inadequacies and climbing rates of food insecurity (9,10,12).

The results in this study converge with other research done on TF and show the significance of consuming even a small portion of TF daily. Consuming any TF increases the nutritional quality of that diet while reducing the amount of saturated fats, sugars, and carbohydrates consumed, mostly in the form of MF. Our results further proved the nutritional significance of TF, as every dietary diversity indicator was positively correlated to each indicator of nutrition. Since the nutrition indicators incorporated individuals' entire diet, the significant correlation shows that the consumption of any TF improves dietary quality despite what else that individual ate. These results are significant for understanding the importance of TF in First Nations diets and how critical it is to increase the consumption of TF. Policymakers can make dietary recommendations based on sound knowledge that increasing TF will improve First Nations diets even without addressing any other aspect of their diet. Despite the model results showing a negative relationship between DSR and ESR, biodiversity and ecosystem health is important for First Nations' health and nutritional outcomes. Objective one proved that including any TF in one’s diet improves dietary outcomes. With species loss increasing, the maintenance and protection of biodiversity are critical for the health and well-being of First Nations Peoples.

The findings in this study contribute to the growing concerns in the literature of late. The negative relationship between FS and TF dietary diversity is of particular importance to policymakers. It is not that FS is negatively related to increased TF consumption because TF increase food insecurity. Instead, it’s a complex and circular relationship where individuals have poor access to all food sources, are heavily relying on the TF they do have access to even though it is not enough, and as a result, remain in a food insecure state. As exhibited by research done in northern Manitoba, individuals recognized that traditional activities like hunting, fishing, gardening, and gathering used to provide self-sufficiency. Still, recently many Indigenous peoples of Canada cannot afford healthy foods (84). Financial, regulatory, and environmental barriers to TF have increased in recent years, making healthy diets and food security more difficult (84). This is significant for future policy as the current use of TF is not significant enough to improve food security rates despite TF being a critical component of First Nations’ own definition of food security and sovereignty.

4.3 The Role of Culture in Inspiring Nutrition Related Interventions

This study shows the significance that culture plays in determining dietary outcomes, indicating the priority areas other than ecological, for intervention. Interventions surrounding community economic development and local food production and networks have been suggested as methods for improving food sovereignty (87). The empirical evidence in this study points towards similar interventions and policies.

The model shows that consumption is most critically determined by the maintenance of cultural practices, coinciding with findings from Tremblay et al., (29). This is the priority area that should be of primary interest for interventions. First, having access to someone who hunts, gathers, or fishes greatly increases your odds of having a high DSR. These individuals have direct access to TF sources without purchasing from a market or having foods shared with them from neighbours. This cultural practice requires traditional knowledge and skills specific to each community. Other key cultural variables are ‘TF advantage score’ and ‘we ran out of TF and can’t get more. Both indicators reveal similar outcomes. The perceived advantage of consuming TF greatly increases the odds that you or your family members will consume TF. This result is culturally significant since this perceived importance would have been taught or handed down through generations. However, cultural barriers are causing a decrease in TF consumption. A decrease in uptake of traditional practices, like hunting and then sharing TF throughout the community, has been noticed (60,62). Those without a hunter in the household who rely on the culture's traditional generosity are often already sensitive populations (low-income, elderly, or with poor health) (84). According to a study conducted in northern Manitoba, programs that included sharing TF increased food sovereignty and sharing had a more significant relationship to FS than remoteness indices (87). To provide for sensitive populations, the cultural significance of these community events and traditional food practices must be maintained.

Age is also culturally related since the older age groups are predictive of consuming more TF. These individuals typically retain cultural practices and therefore place importance on TF in their diet. In remote communities, it may be easier for cultural practices to be maintained and not lost to newer MF. Remote communities both have more direct access to nature and are less influenced by less traditional practices, making it easier to maintain cultural ways of living and prioritize TF. Therefore, having the knowledge concerning the cultural and nutritional value of consuming TF is as important of a predictor for determining high DSR as having the physical capabilities like being a hunter/gatherer. Interventions aimed at increasing community engagement in traditional food systems and providing incentives to participate are recommended as interventions, particularly since youth engagement is declining (60,84).

The results from objective three also suggest that TF are used for needs-based sustenance due to low income and remoteness. Typically, First Nations reserves are the most remote and poorest communities in Canada, with 4% of First Nations people lacking road access (84). The remoteness index (INACRIZ) having a positive relationship shows that those living in more remote locations are more likely to consume more TF. A community could be 350 - 920 km from a service centre or have no year-round access to a service centre and would, therefore, rely more on TF for sustenance. Another variable, 'the TF that we got just didn't last, and we couldn't get anymore' highlights the dependence on TF and disappointment when the household cannot obtain anymore. Individuals 70 or older predicting higher DSR outcomes indicate a reliance on TF as, statistically, elderly individuals are more sensitive and have less access to resources. Finally, families with more members being predictive of fewer DSR consumption is also an indicator of poor access to TF, and there not being enough for the whole family. All these indicators converge into a pattern showing poor access to TF and the wish to consume more. The significance of these results is in revealing the importance of culture, explaining the unique food landscape of Canada, and the underlying suggestions of what else could be significant predictors of DD rates.

4.4 Areas for Further Study

This is the first study in Canada to attempt to quantify the relationship between regional biodiversity and dietary diversity. Therefore, many areas for future research have been identified. One question that garners further exploration is whether specific foods and access to food sources are more critical for First Nation health and wellbeing than the overall TF diversity of their diet. It has been well documented that TF sources are incredibly nutrient-rich and are an essential component of First Nations diets. However, it would be interesting to look further into the specifics of types of foods that are most nutritionally and culturally beneficial. For example, these findings outlined that those living in more remote areas and living in areas with less biodiversity equates to increased consumption of TF sources. This reveals that the importance for First Nations people is not necessarily the number of different TF they consume but the availability of their favourite/most nutritionally rich/most culturally important TF. This can be related back to the ESR findings where having more biodiversity does not equate to more TF, so the larger predictive factor may be the biodiversity and bioavailability of important TF and not overall biodiversity as previously assumed. To begin to test this theory, animal and plant SR was calculated separately, and various correlations were performed within both the outliers and the general population. Performing Pearson's correlation between Plant DSR and FS status, it was found that there was a weak negative correlation between the two variables. This shows that as individuals consume more TF plant species, they become more food insecure and vice versa. There was no statistical significance found between animal DSR and FS status, although its correlation value was also negative. Although not definitive, due to the weak correlation, these results allude to what the rest of the results are suggesting; That those who have a higher DSR are, on average, consuming more plant species which, although nutritionally beneficial, does not necessarily contribute to improved food security. Plants could also represent medicines or teas and therefore are not contributing to dietary quality or food security. This also coincides with the finding that those consuming higher quantities of TF may be doing so out of need as they have poor access to other food sources and must rely on plant TF, despite their low caloric value.

Interestingly, plant DSR was positively correlated with MAR, as was animal DSR but with weaker values.

Another example can be seen when evaluating the outliers. The individual with the highest DSR score (78) mostly consumed plant items, making up 12.8% of their TF intake. This means that they were most likely a gatherer and did not have much access to games. This individual also has severe food insecurity. Outliers consume more plants on average than the rest of the population, meaning that generally, the increase in traditional food consumption is coming from an increase in plant consumption. Further research will need to be conducted concerning the importance of specific TF types for improved nutrition outcomes and their potential association with food-insecure households.

Another question that arose regards the type of biodiversity indicator used. It would be important to calculate functional diversity or SID to understand how different measures of regional biodiversity impact DSR outcomes. Functional diversity is particularly important as it reveals the diversity of roles that each species has in that environment. Therefore, informing on the resiliency and ecosystem services available, rather than just the diversity of species presence. SID would provide a more accurate measure of biodiversity distribution. The calculation of both measures would provide different understandings of regional biodiversity and its relationship to DSR. Along with indicator type, applying a more regional approach is needed. The access barriers to TF will change dramatically based on the geographic location of each Nation. Evaluating biodiversity at a more regional level would provide a more detailed understanding of biodiversity's relationship to each community. The ecozone level shows a general pattern, providing key information to be applied at a large scale. However, for maximum impact at the community level, a detailed understanding of TF access is required.

4.5 Conclusion

Results of our analysis show that noticing climatic changes in your region, having access to a hunter, living remotely, being 70 or older, not being able to access enough TF as you would like, having fewer household members, and having access to a garden are all more statistically significant than ecozone biodiversity in predicting DSR outcomes. These results are complicated.

Without further studies, it is difficult to conclude how all these components interact or why one is more predictive than the other. However, it can be deciphered that humans' dietary choices are difficult. Barriers to accessing TF are only getting more complex as traditional knowledge decreases and other nutrient-poor food sources are made more accessible. Along with cultural interventions, the health of the environment needs to be prioritized to enhance biodiversity rates and revert some of these climate change indicators being noticed by the participants.

This study contributes to methodological approaches used in both ecological and social sciences. Cross-disciplinary studies and particularly social and environmental studies are increasingly important as we attune our understanding of human health and well-being to being interconnected with the world around us. Utilizing biodiversity measures as dietary diversity measures to better represent the ecological impact on humans' diets is a new and exciting method. This study's use of a negative binomial regression to answer a question asked qualitatively is a significant contribution. The information gleaned through this method has provided insight into one potential understanding for how variables interact to predict dietary outcomes.

This study is also of academic significance as it adds to the growing literature describing the intricacies of First Nations' health and well-being in Canada. The insights in this study provide a detailed analysis and introduce a few reasons that these health disparities exist as they relate to dietary quality. Access to TF is an undeniably important contributor to First Nations health and nutrition and as these findings suggest households on average, do not have adequate access to the amounts of TF that they would like to consume or need to consume to be food secure. Most households use TF out of necessity and in regions with lower ESR on average. These results inform us that there are more significant barriers to accessing TF than environmental availability. However, ecological restoration and improved rates of biodiversity are critical for households to become food secure through access to TF. Households that knew the cultural importance of TF consumed more TF, as did older households and households with hunters and gatherers. Therefore, the maintenance of traditional practices, the passing down of wisdom, and the importance of these practices are the most significant indicators of maintaining a high DSR of TF and improved nutrition outcomes. These results suggest that adaptability and resourcefulness are more important than having a surplus of species to choose from. In remote communities, it may be easier for cultural practices to be maintained and not lost to newer MF. Remote communities both have more direct access to nature and are less influenced by less traditional practices, making it easier to maintain cultural ways of living and, therefore, the priority of consuming TF. Despite having fewer TF available in the environment, the remote communities have maintained the significance of traditional ecological knowledge and can adapt to environmental changes.

Finally, this study provides further evidence for policymakers and practical methods for improving dietary diversity rates in First Nations communities in Canada. A program tested in northern Manitoba showed that communities with a country food program had improved FS status (87). This program emphasizes both cultural and environmental tactics. Focusing on conservation techniques like not catching fish during the spawning season or hunting during the calving season greatly improved biodiversity in the area, even re-establishing a caribou herd (87). This is critical for improving access to TF as wildlife decimation forces individuals to travel farther distances, which is both costly and time-consuming, to obtain TF. Some of the cultural interventions in place include training and employing First Nations individuals to hunt, fish, and gather as well as traditional preservation methods like smoking meat (87). TF are then distributed throughout the community with a focus on priority households. These interventions promote cultural values, skills, traditional knowledge, and conservation and have been highly effective in one case study (87). The results from our study suggest similar community-led interventions focused on environmental and cultural restoration. Our results should inform policymakers that encouraging and focusing on training the younger generations in traditional practices and teaching ecological management techniques aimed at species restoration could be the best methods for increasing TF DSR in First Nations populations. Some barriers to community-driven programs have been noted. For example, programming costs and the ability of culturally relevant food interventions to provide regular increased access to TF have yet to be sufficiently evaluated (86). However, with the mounting evidence pointing towards the significance of culturally and environmentally geared programming, the barriers to initiating these programs should be mitigated.

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Appendices

Appendix 1: Overview of Natureserve data

Ecozone	Informal Taxonomy	NS Status	Legal Status
Pacific Maritime	Dicots, Mosses, Lichens, Other Moths, Other Beetles, Spiders and other Chelicerates, Terrestrial Snails, Freshwater Snails, Bumble Bees, Butterflies and Skippers, Adder's-tongues, Grapeferns, and Moonworts, Monocots, Amphibians, Lichens, Spikemosses and Quillworts, Dragonflies and Damselflies, Tiger Beetles, Clubmosses, Leptosporangiate ferns, Other crustaceans, Other Molluscs, Other Marine Invertebrates, Reptiles, Sponges, Starfish, Turtles, Worms, leeches, and other annelids,	G1 G2 G3 G4 G5 GNR GU T1 T2 T3 T4 T5 TNR TU	COSEWIC: 'DD' COSEWIC: 'E' COSEWIC: 'T' CSEWIC: 'E, T' COSEWIC: 'NAR' COSEWIC: 'Nonactive' COSEWIC: 'SC' COSEWIC: 'XT' COSEWIC: 'E' USESA: 'E' COSEWIC: 'E' USESA: 'E, XN' COSEWIC: 'NAR' USESA: 'DL' COSEWIC: 'E' USESA: 'PT' COSEWIC: 'E' USESA: 'E, PT' COSEWIC: 'E' USESA: 'T' COSEWIC: 'SC' USESA: 'E' COSEWIC: 'SC' USESA: 'T' COSEWIC: 'SC' USESA: 'T, XN' USESA: 'E' USESA: 'E, T' USESA: 'T' USESA: 'T, SAT' USESA: 'DL'
Boreal Cordillera	Dicots, Mosses, Bumble Bees, Butterflies and Skippers, Tiger Moths, Adder's-tongues, Grapeferns, and Moonworts, Monocots, Amphibians, Grasshoppers, Lichens, Spikemosses and Quillworts, Other Flies and Keds, Dragonflies and Damselflies, Tiger Beetles, Clubmosses, Leptosporangiate ferns		
Montane Cordillera	Adder's-tongues, Grapeferns, and Moonworts, Amphibians, Amphipods, Bumble Bees, Butterflies and Skippers, CaddisFlies, Clubmosses, Dicots, Dragonflies and Damselflies, Freshwater Mussels, Freshwater Snails, Giant Silkworm and Royal Moths, Horsetails, Isopods, Leptosporangiate ferns, Lichens, Liverworts, Mayflies, Monocots, Mosses, Other Beetles, Reptiles, Robber Flies, Spikemosses and Quillworts, Stoneflies, Terrestrial Snails, Tiger Beetles, Turtles		
Taiga Plains	Adder's-tongues, Grapeferns, and Moonworts, Amphibians, Bumble Bees, Butterflies and Skippers, Clubmosses, Dicots, Dragonflies and Damselflies, Freshwater Mussels, Leptosporangiate ferns, Lichens, Liverworts, Mason Bees, Monocots, Mosses, Other Beetles, Spikemosses and Quillworts, Tiger moths		

Boreal Plains	Adder's-tongues, Grapeferns, and Moonworts, Amphibians, Amphipods, Ants, Wasps and Sawflies, Bumble Bees, Butterflies and Skippers, Clubmosses, Crayfishes, Dicots, Dragonflies and Damselflies, Flower Flies or Hoverflies, Freshwater Mussels, Freshwater Snails, Giant Silkworm and Royal Moths, Isopods, Leptosporangiate ferns, Lichens, Liverworts, Mason Bees, Monocots, Mosses, Notodontid Moths, Other Bees, Other Beetles, Other Moths, Papaipema Moths, Reptiles, Spiders, Spikemosses and Quillworts, Tiger Beetles, Turtles
Prairies	Adder's-tongues, Grapeferns, and Moonworts, Amphibians, Amphipods, Bumble Bees, Butterflies and Skippers, Crayfishes, Dicots, Dragonflies and Damselflies, Freshwater Mussels, Freshwater Snails, Giant Silkworm and Royal Moths, Horsetails, Leptosporangiate ferns, Lichens, Liverworts, Mayflies, Monocots, Mosses, Other Bees, Other Beetles, Other Moths, Papaipema Moths, Predaceous Diving Beetles, Reptiles, Sphinx Moths, Spikemosses and Quillworts, Stoneflies, Terrestrial Snails, Tiger Beetles, True Bugs, Cicadas, Hoppers, Aphids and Allies, Turtles
Boreal Shield	Adder's-tongues, Grapeferns, and Moonworts, Amphibians, Bumble Bees, Butterflies and Skippers, Caddisflies, clubmosses, crayfishes, Dicots, Dragonflies and Damselflies, Flower Flies or Hoverflies, Freshwater Mussels, Freshwater Snails, Fungi, Giant Silkworm and Royal Moths, Grasshoppers, Ground Beetles, Hornworts, Horsetails, Leptosporangiate ferns, Lichens, Liverworts, Mayflies, Monocots, Mosses, Other Bees, Other Beetles, Other Moths, Papaipema Moths, Predaceous Diving Beetle, Reptiles, Sphinx Moths, Spiders, Spikemosses and Quillworts, Stoneflies, Terrestrial Snails, Tiger Beetles, Tiger Moths, True Bugs, Cicadas, Hoppers, Aphids and Allies, Turtles

Taiga Shield	Adder’s-tongues, Grapeferns, and Moonworts, Amphibians, Bumble Bees, Butterflies and Skippers, clubmosses, Dicots, Dragonflies and Damselflies, Flower Flies or Hoverflies, Horsetails, Leptosporangiate ferns, Lichens, Liverworts, Mason Bees, Monocots, Mosses, Other Beetles, Other moths, Spiders, Spikemosses and Quillworts, Tiger Beetles
Hudson Plains	Adder’s-tongues, Grapeferns, and Moonworts, Amphibians, Bumble Bees, Butterflies and Skippers, Clubmosses, Dicots, Dragonflies and Damselflies, Flower Flies or Hoverflies, Leptosporangiate ferns, Lichens, Monocots, Mosses, Spikemosses and Quillworts, Tiger Beetles
Mixedwood Plains	Adder’s-tongues, Grapeferns, and Moonworts, Amphibians, Ants, Wasps, and Sawflies, Bumble Bees, Butterflies and Skippers, Clubmosses, crayfishes, Dicots, Dragonflies and Damselflies, Freshwater mussels, Freshwater snails, Giant Silkworm and Royal Moths, Grasshoppers, Ground Beetles, Isopods, Hornworts, Horsetails, Leptosporangiate ferns, Lichens, Liverworts, Monocots, Mosses, Other Beetles, Other moths, Papaipema Moths, Reptiles, Spiders, Spikemosses and Quillworts, Terrestrial Snails, Tiger Beetles, True Bugs, Cicadas, Hoppers, Aphids and Allies, Turtles
Atlantic Maritime	Adder’s-tongues, Grapeferns, and Moonworts, Amphibians, Bumble Bees, Butterflies and Skippers, Clubmosses, Dicots, Dragonflies and Damselflies, Freshwater Mussels, Ground Beetles, Hornworts, Horse and Deer Flies, Horsetails, Leptosporangiate ferns, Lichens, Liverworts, Mayflies, Monocots, Mosses, Other Bees, Other Beetles, Other Molluscs, Other Moths, Reptiles, Spikemosses and Quillworts, Terrestrial Snails, Tiger Beetles, Turtles

Appendix 2: Dietary records from the FNFNES

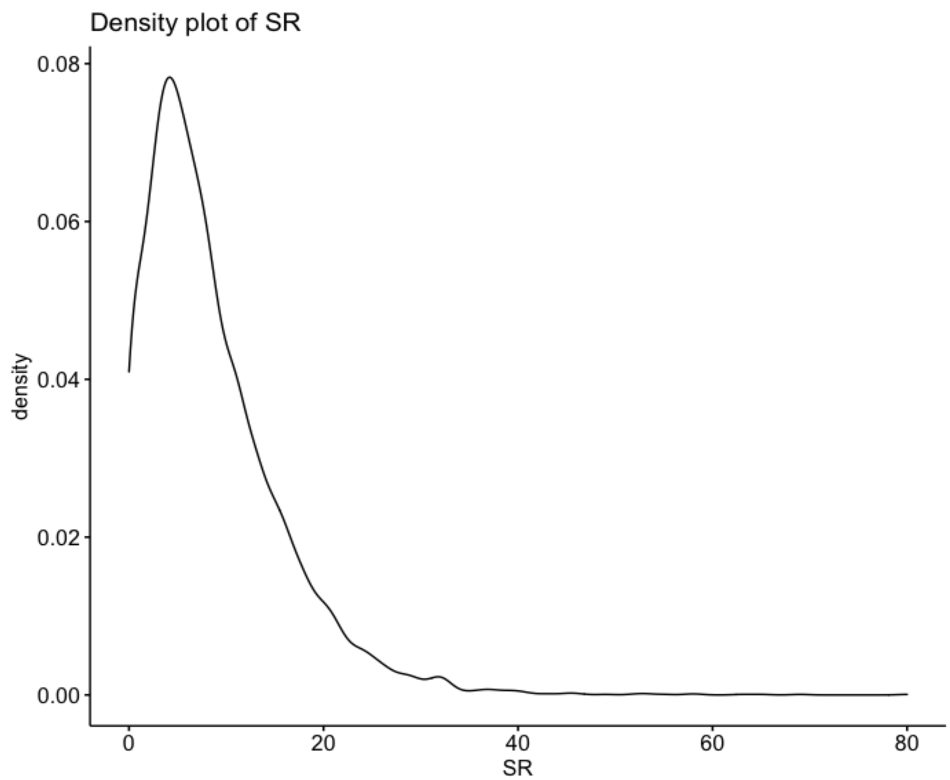
		MF	TF		
			Grams_TF	**Frequency TF**	**Nutrient Profile**
Categories of Foods	**Beverages**	Milk products, coffee, sugar sweetened beverages, & juices	Tea		
	Food	Meat, Artificial Sweetener, Bannock, Breads, Candies, Cereal, Dairy Products, Dessert, Nuts, Fruits, Vegetables, & Other Processed foods	Game meat, Fish, Fruits, Vegetables, Grains (corn), Herbs/Spices, Shellfish, & Wild Birds		Fat, FE, Fibre, Folate, Grams, K, Kcal, Linoleic, Linolenic, MG, MUFA, NA, Niacin, P, Protein, PUFA, RIBO, Thiamin, TSAT, TSugars, VITA, VITB6, VITB12, VITC, VITD, ZN
Quantity of Types		**77**	**198**	**226**	**42**
Sites		**93**	**93**	**93**	

Appendix 3: Scores created from FNFNES data for regressions

Variable used in Regression	FNFNES Questionnaire variable/meaning	Score
Health barrier to accessing TF	Barrier 9: physical/health reasons Barrier 11: too lazy	0-2
Logistical barriers to obtaining TF	Barrier1: lack of equipment/transportation Barrier2: lack of hunter Barrier3: lack of time Barrier7: difficult to access Other_BAR: Barrier4 (lack of availability), Barrier5 (lack of money to buy), Barrier6(lack of knowledge), Barrier8(government/firearms regulations, Barrier9 (physical/health reasons)	0/5
Individual is a hunter	Q5A: Participant hunted or set snares last year? Q5B: Participant fished last year? Q5C: Participant collected wild plant food last year? Q5D: Participant collected seafood last year?	0/4
Someone in the house is a hunter	Q6A: Other HH member hunted or set snares last year? Q6B: Other HH member fished last year? Q6C: Other HH member collected wild plant food last year? Q6D: Other HH member collected seafood last year?	0/4
Perceived cultural advantage of TF	AdvTF6: cultural/educational AdvTF11: family time AdvTF21: sharing AdvTF26: spiritual reasons	0/4
Cultural barrier to consuming TF	Barrier6: lack of knowledge Barrier22: lack of sharing	0/2
Perceived advantage of market foods	AdvMF1: availability/convenient AdvMF2: variety AdvMR_Other (score of 0/1 if they had at least one of the following): AdvMF3 (healthy/nutritious), AdvMF4 (labelling), AdvMF5 (fresh), AdvMF7 (taste), AdvMF8 (food safety), AdvMF9 (cheaper), AdvMF10 (portioned), AdvMF12 (other MR advantages), AdvMF15 (locally grown)	0/3
Perceived advantage of traditional foods	AdvTF1: healthy/nutritious AdvTF2: natural/safe AdvTF3: availability AdvTF4: cheap/free AdvTF7: variety OTHER (score of 0/1 if they had at least one of the following: AdvTF9 (medicinal), AdvTF10 (physical activity), AdvTF12 (fresh), AdvTF13	0/6

	(prepare way you want), AdvTF14 (no parts wasted), AdvTF16 (everything good), AdvTF17 (last longer), AdvTF18 (get more meat), AdvTF20 (other TF advantages), AdvTF22 (gives energy), AdvTF23 (stress reliever to hunt), AdvTF24 (self-sufficiency) AdvTF25 (acquiring skills), AdvTF27 (survival) AdvTF28 (know where it comes from), AdvTF29 (body used to it), AdvTF30 (practicing rights)	
Garden access	Q6E: Other HH member planted a garden last year? Q5E: Participant planted a garden last year?	0/2
Have you noticed any of the following climate change indicators in your region	Climate1: Less availability of TF Climate2: General comments on weather changes Climate3: Decreased accessibility to TF (harder to get) Climate4: Growth of TF affected Climate5: Animal cycles/habitats affected Climate7: Contamination/pollution observed Climate15: Shorter hunting/growing season OTHER_Adjusted for low response rate: Climate8 (illness/disease observed), Climate10 (animals food supply affected, Climate11 (different species observed), Climate14 (other climate effects on TF availability), Climate17 (Difficult to hunt when too hot/cold), Climate18 (Quality of TF affected)	0/8
Ecological barrier to consuming TF	Barrier2: lack of hunter Barrier24: seasonal/weather effects Barrier25: poor soil or planting conditions Barrier12: pesticides/contaminants	0/4

Appendix 4: Density plot of DSR



Appendix 5a: Traditional food parts (organs) consumed by ecozone

		P. Maritime	Boreal Cordillera	Montane Cordillera	Taiga Plains	Boreal Plains	Prairies
		n=486	n=80	n=313	n=152	n=1248	n=577
Game 1 (Deer Meat)	(n)	296	8	113	29	548	376
	Frequency	6419	48	5946	501	7326	4993
Game 2 (Deer liver)	(n)	102	2	34	2	53	43
	Frequency	1007	6	715	3	474	769
Game 3 (Deer kidney)	(n)	15	1	13	0	40	30
	Frequency	419	4	185	0	360	426
Game 4 (Elk meat)	(n)	20	0	71	41	381	226
	Frequency	487	0	1411	456	5688	3008
Game 5 (Elk liver)	(n)	10	0	9	4	22	17
	Frequency	270	0	200	5	99	371
Game 6 (Elk kidney	(n)	4	0	4	2	26	19
	Frequency	20	0	69	3	135	292
Game 7 (Moose meat)	(n)	231	80	268	149	1034	262
	Frequency	4564	9452	17746	14175	40095	4028
Game 8 (Moose liver)	(n)	65	44	52	40	173	18
	Frequency	486	385	554	497	1814	319
Game 9 (Moose kidney)	(n)	14	57	43	45	198	18
	Frequency	160	604	641	404	1943	308
Game 10 (Caribou meat)	(n)	15	43	20	13	57	13
	Frequency	108	989	194	104	322	68
Game 11 (Caribou liver)	(n)	1	5	1	0	4	1
	Frequency	1	28	24	0	11	4
Game 12 (Caribou kidney)	(n)	1	8	1	0	6	3
	Frequency	1	36	12	0	27	11
Game 20 (Black bear meat)	(n)	15	6	35	9	33	6
	Frequency	80	26	406	182	121	21
Game 21 (Black bear fat)	(n)	2	24	34	12	19	5
	Frequency	12	393	928	153	130	22
Seamammal 1 (Harbour seal meat)	(n)	10	1	0	0	0	0
	Frequency	72	2	0	0	0	0
Seamammal 2 (Harbour seal fat)	(n)	6	0	0	0	0	0
	Frequency	53	0	0	0	0	0
Total	(n)	807	279	698	346	2,594	1,037
	Frequency	14,159	11,973	29,031	16,483	58,545	14,640

Appendix 5b: Traditional food parts (organs) consumed by ecozone

		Boreal Shield	Taiga Shield	Hudson Plains	Mixedwood Plains	A. Maritime
		n=1317	n = 272	n=321	n=681	n=1039
Game1 (Deer Meat)	(n)	309	5	5	269	237
	Frequency	2959	6	47	4240	2365
Game 2 (Deer liver)	(n)	17	0	0	11	27
	Frequency	110	0	0	153	120
Game 3 (Deer kidney)	(n)	12	0	0	2	9
	Frequency	29	0	0	12	53
Game 4 (Elk meat)	(n)	24	1	1	10	0
	Frequency	317	1	6	61	0
Game 5 (Elk liver)	(n)	1	0	0	0	0
	Frequency	6	0	0	0	0
Game 6 (Elk kidney	(n)	1	0	0	0	0
	Frequency	4	0	0	0	0
Game 7 (Moose meat)	(n)	1000	166	310	164	538
	Frequency	22757	1327	6527	1627	10786
Game 8 (Moose liver)	(n)	241	16	49	5	20
	Frequency	2344	52	348	12	136
Game 9 (Moose kidney)	(n)	185	28	69	0	11
	Frequency	1734	73	399	0	73
Game 10 (Caribou meat)	(n)	224	262	100	17	2
	Frequency	9471	23586	1539	96	8
Game 11 (Caribou liver)	(n)	81	55	7	0	0
	Frequency	927	433	51	0	0
Game 12 (Caribou kidney)	(n)	87	132	8	0	0
	Frequency	1065	1256	70	0	0
Game 20 (Black bear meat)	(n)	47	42	26	13	11
	Frequency	358	237	92	153	25
Game 21 (Black bear fat)	(n)	32	36	7	2	1
	Frequency	405	821	17	3	1
Seamammal 1 (Harbour seal meat)	(n)	0	4	0	0	2
	Frequency	0	10	0	0	3
Seamammal 2 (Harbour seal fat)	(n)	1	2	0	0	0
	Frequency	24	24	0	0	0
Total	(n)	2,262	749	582	493	858
	Frequency	42,510	2,7826	9,096	6,357	13,570

Appendix 6: Top 10 most frequently consumed TF by province (grams of TF intake FFQ)

British Columbia (1)

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species type (ruderal?)
Moose Meat	461	92.9%	30.97	107.	Generalist
Sockeye salmon	309	62.3%	9.63	43.4	Specialist
Blue huckleberries	258	52%	1.55	7.33	Specialist
Soapberries	247	49.8%	1.57	7.38	Ruderal
Blueberries	191	38.5%	1.08	5.19	Generalist
Raspberries	175	35.3%	0.76	3.85	Ruderal
Wild strawberries	160	32.3%	0.57	2.43	Generalist/ Ruderal
Moose Kidney	132	26.6%	1.24	5.13	Generalist
Moose Liver	132	26.6%	1	5.13	Generalist
Chinook Salmon	126	25.4%	2.28	14.37	Specialist

British Columbia (2)

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species type
Sockeye salmon	425	85.7%	7.47	31.7	Specialist
Deer meat	424	85.5%	9.19	45.2	Generalist/Ruderal
Moose meat	336	67.7%	12.3	78.6	Generalist
Halibut	287	57.9%	2.47	10.8	Generalist
Chinook Salmon	281	56.7%	4.38	24.1	Specialist
Wild strawberry	264	53.2%	0.82	3.67	Generalist/ Ruderal
Raspberries	259	52.2%	0.88	4.58	Ruderal
Blueberries	258	52%	1.15	5.48	Generalist
Salmonberries	256	51.6%	0.85	4.58	Ruderal
Elk meat	244	49.2%	3.34	15.4	Generalist

Manitoba

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species Type
Walleye/Pickerel	464	65.7%	3.72	15.8	Generalist
Moose meat	463	65.6%	5.59	22.1	Generalist
Blueberries	335	47.5%	2.41	11.5	Generalist
Geese	302	42.8%	2.36	11.6	Generalist/ Ruderal
Deer meat	295	41.8%	3.97	19.6	Generalist/Ruderal
Ducks	268	37.9%	3.2	17.4	Generalist/Ruderal
Raspberries	204	28.9%	1.24	5.76	Ruderal
Lake whitefish	196	27.8%	2.04	9.31	Generalist
Northern pike	189	26.8%	1.04	5.33	Generalist
Wild strawberry	170	24.1%	1.02	3.59	Generalist/ Ruderal

Ontario (1)

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species Type
Walley/pickerel	455	81.3%	10.83	40.3	Generalist
Moose meat	428	76.4%	9.26	30.8	Generalist
Blueberries	357	63.8%	2.69	13.1 13.068	Generalist
Canada Geese	246	43.9%	3.83	20.1	Generalist/ Ruderal
Lake whitefish	234	41.8%	5.18	22.7	Generalist
Northern pike	182	32.5%	3.07	15.9	Generalist
Raspberries	165	29.5%	1.17	4.60	Ruderal
Lake sturgeon	161	28.8%	0.97	4.71	Generalist
Wild strawberry	145	25.9%	1.15	3.86	Generalist/ Ruderal
Deer meat	132	23.6%	1.25	6.16	Generalist/ Ruderal

Ontario (2)

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species Type
Moose meat	413	47.5%	4.9	22.7	Generalist
Walley/Pickerel	400	46%	2.24	10.3	Generalist
Corn/hominy	391	44.9%	1.37	7.02	n/a
Deer meat	262	30.1%	1.74	8.69	Generalist/Ruderal
Beans, kidney	251	28.9%	0.93	5.13	n/a
Canada Geese	229	26.4%	3.53	14.8	Generalist/ Ruderal
Wild strawberry	225	25.9%	1.26	5.23	Generalist/ Ruderal
Squash	223	25.7%	0.56	3.35	n/a
Blueberries	202	23.2%	1.5	5.23	Generalist
Raspberries	191	21.9%	0.9	3.05	Ruderal

Alberta

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species Type
Moose meat	471	77.3%	14.24	63.4	Generalist
Saskatoon berries	332	54.6%	1.31	5.14	Generalist
Raspberries	314	51.6%	1.17	4.49	Ruderal
Blueberries	258	42.4%	1	4.49	Generalist
Mallard	229	37.6%	2.23	10.6	Generalist/ Ruderal
Deer meat	222	36.5%	1.24	5.35	Generalist
Strawberries	217	35.6%	0.8	2.99	Generalist/ Ruderal
Wihkes	188	30.9%	0.02	0.059	Ruderal
Mint	187	30.7%	0.02	0.118	Ruderal
Lake whitefish	179	29.4%	1.14	5.56	Generalist

Atlantic Maritime (1)

Traditional Food	# of people who consumed	% of total population	Consumption rate Grams	95th percentile	Species Type
Lobster	235	53.7%	1.59	6.9	Generalist
Moose meat	234	53.4%	6.87	34.2	Generalist
Blueberries	213	48.6%	0.25	0.945	Generalist
Strawberries	191	43.6%	0.19	0.756	Generalist/ Ruderal
Atlantic Salmon	189	43.2%	0.64	2.69	Generalist
Fiddlehead	171	39%	0.63	2.94	Ruderal
Raspberries	149	34%	0.12	0.504	Ruderal
Corn/hominy	114	26%	0.48	1.96	n/a
Beans	109	24.9%	0.56	2.94	n/a
Smelt	107	24.4%	0.34	1.74	Generalist

Atlantic Maritime (2)

Traditional Food	# of people who consumed	% of total population	Mean grams consumed	95th percentile	Species Type
Moose meat	322	54.9%	5.57	23.5	Generalist
Blueberries	322	54.9%	0.58	1.98	Generalist
Lobster	287	48.9%	1.74	7.32	Generalist
Atlantic salmon	240	40.9%	1.03	4.04	Generalist
Strawberries	216	36.8%	0.33	1.51	Generalist/ Ruderal
Raspberries	182	31%	0.24	0.756	Ruderal
Scallops	167	28.4%	1.48	7.80	Specialist
Atlantic cod	155	26.4%	1.5	8.09	Generalist
Blackberries	144	24.5%	0.19	0.63	Ruderal
Deer meat	143	24.4%	1.35	5.69	Generalist/Ruderal

Saskatchewan (1)

Traditional Food	# of people who consumed	% of total population	Mean grams consumed	95th percentile	Species Type
Moose meat	524	84.7%	9.61	51.7	Generalist
Blueberries	424	68.5%	1.06	4.73	Generalist
Walleye	334	53.9%	6.79	35.8	Generalist
Lake whitefish	310	50.1%	5.61	26.3	Generalist
Northern pike	301	48.6%	4.96	28.4	Generalist
Mallard	263	42.5%	1.25	5.71	Generalist/ Ruderal
Lake trout	242	39%	3	16.3	Generalist
Prairie dog	242	39%	3	16.3	Generalist
Raspberries	217	35.1%	0.2	0.789	Ruderal
Caribou meat	209	33.8%	13.42	124	Specialist

Saskatchewan (2)

Traditional Food	# of people who consumed	% of total population	Mean grams consumed	95th percentile	Species Type
Deer meat	257	60.8%	3.65	15.6	Generalist/Ruderal
Moose meat	242	57%	5.07	21.8	Generalist
Saskatoon berries	242	57%	0.72	3.55	Generalist
Elk meat	208	49.2%	3.28	12.5	Generalist
Blueberries	191	45.2%	0.51	2.37	Generalist
Raspberries	166	39.2%	0.43	2.37	Ruderal
Cherries (pin/chokecherries)	158	37.4%	0.34	1.58	Ruderal
Mallard	145	34.3%	0.84	3.73	Generalist/ Ruderal
Rabbit meat	87	20.6%	0.57	2.52	Generalist/ Ruderal
Corn/hominy	83	19.6%	0.66	3.49	n/a
Rat root (wihkes)	83	19.6%	0.04	0.164	Ruderal

Quebec

Traditional Food	# of people who consumed	% of total population	Mean grams consumed	95^{th} percentile	Species Type
Blueberries	312	54.5%	1.36	5.52	Generalist
Moose meat	301	52.5%	4.2	18.7	Generalist
Goose, Canada	204	35.6%	1.92	11.9	Generalist/ Ruderal
Walleye (yellow pickerel)	151	26.4%	0.69	3.49	Generalist
Raspberries	139	24.3	0.61	2.49	Ruderal
Rabbit/hare	137	23.9%	0.63	3.26	Generalist/ Ruderal
Maple syrup	132	23%	0.59	3.16	Ruderal
Beaver meat	131	22.9%	0.45	2.75	Generalist
Caribou meat	127	22.2%	1.55	9.04	Generalist
Atlantic salmon	126	21.9%	0.56	2.9	Generalist
Strawberries	126	21.9%	0.52	2.07	Ruderal

Appendix 7: Typically consumed animal TF and a description of their habitat, diet, and adaptability to human disturbed areas

*Generalists are species that either lives in diverse ecosystems or has a varied diet and can survive and adapt in many regions.
*Specialist species have distinct habitat and diet requirements.
*Ruderal species are species that thrive in disturbed areas and, therefore, despite the human interruption in their habitat, adapt and even take over the other species in the area.

Traditional Food – Animals	Species Type	Explanation
Moose Meat (*Alces alces*)	Generalist	Consume a wide variety of plant species. They also rely on forest cover and therefore, do not perform well in deforested areas, therefore non-ruderal[1].
Sockeye salmon *(Oncorhynchus nerka)*	Specialist	Consume a specified diet of zooplankton, insects, and mollusks. However, they have large habitat ranges; temperate and polar, salt and fresh[2]
Deer meat *(Odocoileus spp.)*	Generalist/ Ruderal	Deer thrive in disturbed areas including[3] fires, logging, and even residential areas
Halibut *(Hippoglussus stenolepsis)*	Generalists	Consume a wide array of mainly fish, but also cephalopods and smaller invertebrates[4]
Chinook Salmon *(Oncorhynchus tshawytscha)*	Specialist	Their diet consists of a variety of planktons, fish, insects, mollusks, crustaceans etc. They also live in both fresh and salt water in a variety of temperatures[5]
Elk meat *(Carvus canadensis)*	Generalist/ Ruderal	As foragers, very similar to deer, Elk consumes grass, shrubs, and tree seedlings that fill in after natural disturbances. They survive on human disturbed lands[6]
Walleye/Pickerel *(Sanders Vitreus)*	Generalist	Exhibit flexibility in diet and habitat needs. Individual specialisation based on availability was seen, but show overall adaptability to their environment[7]
Rabbit meat *(Lepus spp.)*	Generalist/ruderal	A herbivore that consumes many different wild grasses, weeds, bark, and buds. With the increase of agriculture, they have adapted to consuming crops[8]
Ducks *(Aix sponsa)*	Generalist/ Ruderal	Both aquatic and land habitat and survive on aquatic vegetation, insects on land, and use agriculture fields for seeds. Can survive on disturbed lands if proper breeding locations are in place[9]
Lake whitefish *(Coregonus clupeaformis)*	Generalist	Has generalist feeding behaviour[10]
Northern pike *(Esox lucius)*	Generalist	Diverse diet of mainly fishes but also benthic invertebrates, amphibians, or mammals if

		opportunity arise. An opportunistic feeder, they adapt to what prey fish are present (invasic tendencies)[11]
Canada geese *(Branta canadensis)*	Generalist/Ruderal	Habitat generalists, they have adapted to human landscapes[12]
Lake sturgeon *(Acipenserspp)*	Generalist	Generalist benthic feeders that can vary greatly between habitats[13]
Mallard *(Anas platyrhynchos)*	Generalist/Ruderal	Both aquatic and land habitat and survive on aquatic vegetation, insects on land, and use agriculture fields for seeds therefore, adapting to and thriving on disturbed lands and even benefitting from human habitats[14]
Lobster *(Homarus americanus)*	Generalist	Their diet is consistent across different habitats; mollusks, echinoderms, polychaetes, and crustaceans[15]
Atlantic Salmon *(Salmo salar)*	Generalist	Generalist carnivore; invertebrates, insect larvae, other insects, small fish[16]
Smelt *(Osmerus mordax)*	Generalist	Generalist feeders and invasive in some territories[17]
Scallops *(Pecten magallenicus)*	Specialist?	Consume plankton and other small organisms (only filtered foods). Highly sensitive to anthropogenic changes in their environment[18]
Atlantic Cod *(Gadus morhua)*	Generalist	Generalist predator[19]
Lake trout *(Salvelinus namaycush)*	Generalist	Trophic generalist with omnivore feeding patterns[20]
Prairie dog	Generalists	Consume whatever plants grow in their habitat – live in grasslands. Keystone species, however, are seen as pests to farmers and are eliminated in agricultural areas[21]
Caribou meat *(Rangifer ssp.)*	Generalist	Generalist foragers. Habitats decreasing due to human presence increasing in sub-arctic and arctic regions[22]
Beaver meat *(Castor canadensis)*	Generalist	Choosy generalist, where the diet is made up of many different species, but the bulk of the diet is only a few species[23]

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Table 28: Typically Consumed Plant TFs and A Description of their Habitat, Diet, and Adaptability to Human Disturbed Areas

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Appendix 8: Typically consumed plant TF and a description of their habitat, diet, and adaptability to human disturbed areas

Traditional Food Plants	Species Type	Explanation
Corn/hominy		Planted*
Salmonberries *(Rubus spectabilis)*	Ruderal	A ruderal species found in the Pacific Northwest of North America[1]
Blue huckleberries *(Vaccinium spp)*	Specialist/ Non-ruderal	Can have difficulties growing at elevations below 2000 ft. and occurs in limited landscapes. Human disturbances (deforestation, trampling, and herbicides) cause poor berry growth[2]
Soapberries *(Shepherdia canadensis)*	Ruderal	Is a common woody species found in Ruderal [3] deciduous woodlands.
Blueberries *(Vaccinium myrtilloides)*	Generalist	Resilient to fire and grows in disturbed sites[4]
Raspberries *(Rubus idaeus)*	Ruderal	Lives in a variety of anthropogenic (man-made or disturbed habitats), forest edges, forests, meadows and fields, shores of rivers or lakes, shrublands or thickets, swamps, wetland margins[5]
Wild strawberries *(Fragaria spp.)*	Generalist/Ruderal	Occurs in a wide range of habitats: mixed woods, swamps, edges of woods, cedar swamps, rocky woodland, damp ledges[6]
Beans, kidney *(Phaseolus vulgaris)*		Planted*
Squash		Planted*
Saskatoon berries *(Amelanchier alnifolia)*	Generalist	A hearty shrub or small tree capable of adapting to a wide range of soils and climatic conditions[7]
Wihkes *(A. calamus)*	Ruderal	This strain in particular is more adaptive than A. americanus and A. calamus will continue to replace americanus as wetlands continue to be destroyed[8]
Mint *(Mentha SSP.)*	Ruderal	Habitat: Anthropogenic (man-made or disturbed habitats), meadows and fields, shores of rivers or lakes, swamps, wetland margins [9]
Fiddlehead *(Matteauccia struthiopteris)*	Ruderal	Habitat: Rich woods, often in alluvial or mucky swamp soils. Anthropogenic (man-made or disturbed habitats), forests, shores of rivers or lakes[10]
Blackberries *(Rubus spp.)*	Ruderal	Wild blackberries are often found growing as weeds in home landscapes, along roadsides, forestlands, coastlines, riparian areas, brushlands, and disturbed areas[11]

Cherries (pin/chokecherries) *(Prunus virginiana L.)*	Ruderal	Canopy removal can create open conditions and bare mineral soil, allowing for the establishment of *Pinus virginiana*. These conditions can include meadows and fields, shrubland woodlands, forest edges, old pastures, clearcuts, and eroded areas (man-made and otherwise)[12]
Maple syrup	Ruderal	A tree that can establish on disturbed sites, particularly land that's gone through human changes like plowing, soil alternation, and even landfills[13]

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