A CASE FOR THE COMMERCIAL HARVEST OF WILD EDIBLE FUNGI IN NORTHWESTERN ONTARIO

by

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ABSTRACT

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Key Words: wild edible fungi, non-timber forest products, *Morchella* spp, morel, *Cantharellus* spp, chanterelle, Tricholoma spp, matsutake, pine mushroom, *Boletus* spp, boletes, lobster mushroom, foraged food.

This undergraduate thesis explores the feasibility of a commercial wild edible mushroom industry in Northwestern Ontario. Commercially relevant fungi reviewed in this thesis include chanterelles, matsutake, boletes, lobster mushrooms and morels. The commercial harvest of wild edible fungi has occurred in the Northwest Territories, Yukon and British Columbia since the early 1990's. The productivities (kg/ha) of wild edible fungi in Northwestern Ontario are comparable to those in Northwest Territories, Yukon and British Columbia. A number of factors that might hinder a commercial harvest of wild edible fungi in Northwestern Ontario include limited accessibility to harvest sites, perishability of fruiting bodies, lack of local markets, lack of local harvesting traditions, and a lack of entrepreneurship in this endeavour.

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INTRODUCTION

Wild edible fungi (WEF) are highly valuable commercial products and choice edible foods that are typically foraged or harvested in landscapes such as the Boreal forest. Wild edible fungi such as chanterelles (*Cantharellus* spp.), matsutake mushrooms (*Tricholoma* spp.) and boletes (*Boletus* spp.) are ectomycorrhizal in that they form symbiotic relationships with specific host tree species (Ehlers, 2007; Berch and Wiensczyk, 2001; Arora, 2008). Lobster mushrooms [*Hypomyces lactiflourum* (Schwein.) Tul. & C. Tul.], are the result of a mycoparasitic fungus that parasitizes other ectomycorrhizal fungi (Rochon *et al.*, 2009). Morels (*Morchella* spp) are known to fruit, *i.e.* produce mushrooms, in high concentrations in areas where wildfire has burned the previous year (Keefer *et al.*, 2010). The fruiting patterns of each of these WEF is, moreover, influenced by numerous other biotic and abiotic factors such as precipitation, temperature, soil moisture, forest stand density and more (Visser, 1994; Pinna *et al*., 2010). Attempts at cultivating these types of WEF have largely proven too complex to be fruitful (Pilz *et al*., 2003). Thereby, most of the international WEF supply originates in “wild” landscapes such as the Boreal forest.

The export market for WEF produced and harvested in Canada is worth millions of dollars (Tedder, 2008; Dzyngel, 2012; Yun & Hall, 2004). Most of Canada’s WEF exports originate in British Columbia. In the early 2000’s, British Columbia exported an annual average of $14 million worth of WEF to Europe and Japan (Tedder and Mitchell, 2003). In lieu of such commercial importance, WEF endemic to British Columbia have garnered significant scientific and government attention via research, reports and government panels. There is little literature on the abundance, distribution, harvesting practices and markets for WEF endemic to Northwestern Ontario (NWO). Personal communications and literature have suggested that there are comparable quantities of WEF in NWO as there are in BC and the rest of Canada (Dzyngel, 2012; Drombolis, pers. comm. Nov. 21, 2019; Forbes, pers. comm. Jan. 16, 2020; Alexander pers. comm. April 3, 2020; Duchesne and Weber, 1993; Duchesne *et al.*, 1999). The Boreal forest's range encompasses most of NWO and provides ideal habitat for WEF (Pinna *et al*., 2010). Commercial harvests have been successful in other regions within the Boreal forest in the Northwest Territories (NWT) and Yukon (Obst, pers. comm. Jan. 17, 2020; Obst, 2015; Kenney, 1996; CBC, 2019). There is reason to believe that a commercial WEF harvest could be successful in NWO.

OBJECTIVES

This thesis will endeavour to understand the factors surrounding a potential commercial WEF industry in NWO. Can harvesting and selling WEF support a small business enterprise in NWO or merely provide supplementary income to the harvester/ buyer? Could a processing and distribution enterprise be established to promote the commercial WEF industry in NWO, or would the regional supply of WEF and number of harvesters limit such an endeavour? The governments of BC, Yukon, Northwest Territories and Alaska all have studied and published reports on the feasibility of a commercial WEF harvest within their respective jurisdictions. NWO has not received the same attention. The author will endeavour to understand the differences that surround commercial WEF harvests in BC, Yukon and NWT in relation to the factors surrounding NWO's social, ecological and economic landscape.

Thunder Bay is in a strategic location, as a gateway to NWO and the main connection between Western Canada and Eastern Canada. As such, it would seem reasonable to suggest that a buyer's network and supply chain could be organized from Thunder Bay where the potential for growth in the NWO commercial WEF industry is yet to be realized. This information will be sought after through literature review and interviews with local harvesters, buyers and organizations.

PROPOSAL

This thesis will propose that the harvest and sale of wild edible fungi in NWO can support a small business enterprise.

WILD EDIBLE FUNGI ECOLOGY AND HABITAT

Members of the kingdom of Fungi are heterotrophic, *i.e.* they cannot produce their own nutrients like plants do. Fungi are separated into three categories based on how they obtain nutrients: saprotrophism, parasitism and symbiotic mutualism (Boa, 2004). Saprotrophic fungi, like morels, feed on dead or dying organic matter. Parasitic fungi, like lobster mushrooms, feed on living organisms such as plants, insects or fungi. Symbiotic mutualistic fungi, as is the case with ectomycorrhizal fungi, receive and provide nutrients in a mutually beneficial way for both partners within the relationship (Boa, 2004). However, the availability of these nutrients does not suffice alone to facilitate fungal fructification.

Fungi are sensitive to many biotic and abiotic factors. Visser (1994) stated that, just as there is succession in forest stands, so too is there succession amongst their ectomycorrhizal fungal partners. The overall species composition and structure of the jack pine stand ectomycorrhizal community was recorded as richest between 41 and 65 years of age with a clear distinction between early-stage - *Suillus* spp - and late-stage fungi – *Tricholoma* spp (Visser, 1994). Biotic factors such as forest stand type, structure and age are widely recognized as major determinants in fungal habitat. Ehlers (2007) found that chanterelle productivity was highest in Douglas-fir stands aged 35 to 75 years of age. Moreover, forestry operation activities such as commercial thinning were noted as having a negative effect on chanterelle productivity (Ehlers, 2007). Abiotic factors such as slope, aspect, elevation, soil classification, drainage regime, soil moisture regime, precipitation levels and temperature are also widely recognized as having a large influence on fungal productivity. Pinna *et al*. (2010) notes that certain soil moisture levels can stimulate bolete and *Lactarius* spp. fructification and productivity while dampening the fructification of other fungi present in the soil. Fructification by some fungal species can be delayed by approximately one week with every 1°C increase in soil temperature (Pinna *et al*., 2010). Obst and Brown (2000) noted that low precipitation levels in 1999 were correlated with lower morel productivity in NWT. However, abiotic characteristics such as soil texture and precipitation are the least variable and most understood of WEF ecology and habitat (Pinna *et al*., 2010). The WEF reviewed in this paper fall within a small range of soil conditions.

The complexity of WEF ecology and habitat is apparent in the literature. This complexity is such that commercial endeavours to artificially cultivate chanterelles, matsutake, boletes and lobster mushrooms has eluded financial success (Pilz *et al*., 2003). Moreover, predictive models based on rigorous scientific data of WEF ecology and habitat have largely fallen short of confidence intervals required to satisfy scientific certainty and probability measures (Bravi and Chapman, 2006; Yang *et al*. 2006; Kucuker and Baskent, 2015; Ehlers, 2007). Nonetheless, WEF continue to fruit in abundance.

CHANTERLLES

Chanterelles have a long history of being harvested and eaten by Eastern Europeans and people of Karelian descent (Boa, 2004; Pilz *et al.*, 2003). They are known for their peppery and floral or nut-like flavour (Pilz *et al.*, 2003). Fruiting bodies are various in colour, tough in texture and slow in growth where fruiting can persist for approximately 44 days on average (Pilz *et al.*, 2003). Taxonomically, they occur within the family Cantharellaceae (Rochon *et al.*, 2011). The edible genera within Cantharellaceae that occur in Canada include *Cantharellus*, *Craterellus* and *Gomphus*. And, the most common, out of the 40 known species of Cantharellaceae to occur in North America are:

> The yellow chanterelle (*Cantharellus cibarius* Fr.), the Pacific golden chanterelle (*Cantharellus formosus* Corner), the red or cinnabar chanterelle (*Cantharellus cinnabarinus* Schw.), the smooth chanterelle (*Cantharellus lateritius* (Berk.) Sing.), the small chanterelle (*Cantharellus minor* Peck), the black craterelle (*Craterellus cinereus* Pers.), the black trumpet or horn of plenty (*Craterellus cornucopioides* (L. : Fr.) Pers.), the flame-colored craterelle (*Craterellus ignicolor* Pers.), the autumn craterelle (*Craterellus tubaeformis* Quelet), the fragrant craterelle (*Craterellus odoratus* Schw.), the fragrant black trumpet (*Craterellus foetidus* Smith), and the pig's ear gomphus (*Gomphus clavatus* S.F. Gray). (Pilz *et al.*, 2003)

Due to the large variety of genera and morphologies within the Cantharellaceae, all genera of the Cantharellaceae will hereafter be referred to as chanterelles. The golden chanterelle is the most easily recognizable, well-known, widespread and commercially valuable member of the Cantharellaceae, as seen in Figure 1 (Buyck *et al.,* 2016; Redhead *et al.*, 1997). Red, pink and blue chanterelles and trumpets are also commonly harvested species.

Figure 1 the red or cinnabar chanterelle and the golden or yellow chanterelle on the left, the pink chanterelle on the right (Forbes Wild Foods, 2020)

Chanterelles are ectomycorrhizal and associate with a wide range of hosts including *Betula* spp, *Populus* spp, *Quercus* spp, *Pinus* spp, *Picea* spp, *Abies* spp and *Tsuga* spp (Rochon *et al.*, 2011; Pilz *et al.*, 2003). Chanterelles tend to fruit in large clusters at specific stages of their hosts growth (Pilz *et al.*, 2003). For example, Pilz *et al.,* (2003) have suggested that chanterelle fruiting first occurs when host species are between 10 and 40 years of age and are most productive between 40 to 60 years of age. However, productivity is variable from region to region and year to year with host conditions remaining one of many contributing factors. The most common habitat characteristics of chanterelles in NWO, notwithstanding associated host habitats, are recognizable as:

- Semi-mature to mature jack pine stands and other conifer-type stands
- High moss and lichen cover – *Pleurozium schreberi* and *Cladonia rangiferina*,
- Well-drained, sandy soil,
- Nutrient poor and low pH soil
- Glacial till formations – moraines and eskers,
- High percentage canopy coverage,
- Cool and moist organic layer (Rochon *et al.*, 2011; Pilz, 2003).

However, chanterelle productivity is, again, highly variable and such habitat characteristics are no guarantee of chanterelle occurrence. Ehlers (2007; 2009) studied Pacific golden chanterelle ecologies in order to provide input towards BC's forest sustainability plans (FSP). The report defines several significant indicators of productive chanterelle habitat including associated tree species, percent canopy coverage – 77%, soil type – podzolic, elevation – 300masl, and, moisture regime – mesic. However, chanterelle productivity was and continues to be highly variable and could not be predicted with enough certainty to be satisfactory for inclusion within BC's FSPs. And yet, forest management can affect WEF as timber harvests such as clear-cuts and thinned stands are noted for disrupting WEF productivity (Boa, 2004).

Regarding sustainability, the effects of harvesting chanterelles on subsequent years productivity has been studied by Norvell and Roger (1994; 1998) in a 120-year Western hemlock stand in the PNW. Over the course of ten years, control and harvest plots were monitored to this end. The results showed that harvesting does not significantly affect productivity over the course of ten years. Pilz and Molina (2002) have suggested that the harvest of WEF can be associated with an increase in spore dispersal if open-air baskets are used for collection and unopened fruiting bodies are not harvested – *i.e.* typical harvester practice. The sustainability of WEF is, therefore, at the mercy of forest management plans and practices including silvicultural treatments, rotation ages and harvest methods (Pilz and Molina, 2002).

MATSUTAKE

Matsutake, also referred to as pine mushrooms, are highly prized WEF. They are a delicacy and cultural symbol within Japan and have been for centuries (Hosford *et al.*, 1997). For example, a haiku by the Japanese poet Chigetsu (1634-1718):

Coming down the mountain

Through the drizzle

To the scent of the first mushrooms.

As such, Japan has the highest demand and pays the highest value for matsutake (Luoma *et al*., 2006). Japanese matsutake, *Tricholoma matsutake* (S. Ito & Imai) Singer, are prized for their specific flavour, odour and appearance (Freedman and Freedman, 1987). Of all the species of *Tricholoma* that occur in North America, such as *Tricholoma caligatum* (Viv.) Ricken*, Tricholoma flavovirens* (Pers.:Fr.) Ryv.*, Tricholoma pessundatum var. montanum* (Fr.) Gillet*,* it is *Tricholoma magnivelare* (Peck) Redhead that is regarded as the species that most resembles the flavour, odour and appearance of the prized Japanese matsutake,(Figure 2) (Hosford *et al.,* 1997; Redhead, 1997; Yun *et al.,* 1997; Visser, 1995). Whereas most *Tricholoma* spp are considered similar in commercial value, all will hereafter be referred to as ‘matsutake.’

Figure 2 Unopened T. magnivelare (Peck) Redhead are stated to sell for higher prices in Japan (Davidademac, 2011)

Japan imports millions of dollars worth of matsutake every year. From 1996 to 2001, Japan imported an average of approximately 390,000 kg or $12.3 million worth of matsutake from Canada - approximately 15% of Japan’s total matsutake imports – with prices ranging from

$7 to $220 per kg (Luoma *et al.*, 2006; Tedder and Mitchell, 2003; Tedder 2008). The high commercial value of matsutake has generated much interest in PNW and BC. Research in BC has shown that the commercial value per hectare for matsutake - $1492/ha - can be greater than that of timber in some regions (Tedder and Mitchell, 2003; Tedder, 2008). Such commercially relevant matsutake sites are well-known to harvesters where large numbers of matsutake fruit in clusters, also known as shiros, in association with host mature conifers (Ehlers *et al*., 2007). However, these mature conifer stands associated with matsutake shiros are typically harvested as per the stand's optimal net present timber value. As a result, forest management plans can target highly productive matsutake sites for timber harvest unwittingly (Ehlers *et al*., 2007). Forest management plans and other resource management plans such as the Nass South Sustainable Resource Management Plan and Caribou Chilcotin Land Use Plan make direct efforts to optimize the value of both resources – *i.e*. delaying timber harvests until matsutake production declines (Vaughn and Chapman, 2003; Hamilton, 2012; Ehlers *et al.,* 2007). This requires that harvest operations be aware of and do not disrupt areas of ideal matsutake habitat (Ehlers *et al*., 2007).

The ecological characteristics of matsutake endemic to NWO are like those of the chanterelle:

- Well-drained, sandy soil,
- Cool, moist and thin organic layer,
- Nutrient poor soil,
- Glacial till formations,
- Semi-mature to mature jack pine stands or mixed conifer – mixed-wood forests (Visser, 1995),

- High percentage canopy coverage (Hosford *et al.*, 1997; Berch and Wiensczyk, 2001; Ehlers *et al*., 2007).

The sustainability of matsutake harvests, again, mirrors that of the chanterelle in that forest management practices have a larger effect on habitat than harvesting does (Hosford *et al.*, 1997). However, specific harvest techniques are known to negatively affect matsutake productivity such as ‘raking,’ in which ground litter is raked back to search for matsutake fruiting bodies, and harvesting unopened fruiting bodies (Luoma *et al.,* 2006). The decline in Japanese matsutake productivity has been linked to a decline in Japanese black and red pine forests due to nematode pathogens, change in local uses of forests and change in forestry practices (Hosford *et al.*, 1997). Japanese immigrants to BC and PNW working in the forestry industry are noted as harvesting matsutake as early as the 1930’s, thereby, introducing this WEF to a new market in their new local communities (Berch and Wiensczyk, 2001).

In NWO, Jonathan Forbes of Forbes Wild Foods has worked with Indigenous communities around James Bay to encourage matsutake harvests in the surrounding mature Jack pine forests (Elton, 2010; Forbes, pers. comm., Jan. 16, 2020). They are reported as having collected approximately 700kg of matsutake in one season (Elton, 2010; Forbes, personal communication, Jan. 16, 2020). Further efforts involving Quebec and the communities of Chisasibi and Wemindji First Nations within the James Bay region have confirmed these levels of abundance. Biopterre (2013) estimated that a volume of 5,000 kg or approximately $100,000 worth of matsutake could be harvested within the James Bay region in partnership with local Cree communities.

BOLETES

The *Boletus edulis* Bull. species complex – *Boletus edulis sensu lato* – is comprised of *Boletus aereus* Bull*.*, *Boletus pinophilus* Pilat & Dermek*, Boletus aestivalis* Paulet, among the others (Treindl and Leuchtmann, 2019). The *B. edulis s. l*. have a long history of being harvested, marketed and eaten in Europe, Africa and Asia and, as such, have many common names: ceps, porcini, penny buns, panza and pig-leg mushrooms (Arora, 2008; Oria-de-Rueda *et al.,* 2008; Sitta and Floriani, 2008). *Boletus edulis* Bull., as seen in Figure 3, is the most widely recognized species within the species complex and its name is commonly used in relation to other species within the genus. Thus, the *B. edulis s.l*. will hereafter be referred to only as "bolete." Related genera and allied species, such as *Suillus* spp, commonly referred to as slippery Jacks, are commonly mistaken for boletes due to their similarities in shape and size. However, slippery Jacks can be easily distinguished by their slimy caps where the slime acts as a purgative if digested uncooked (Boa, 2004). Most boletes are edible and only a small fraction of species within the genus are known to be poisonous, such as *Boletus satanas* Lenz which can be easily identified by its red tubes underneath the cap - *i.e*. pileus (Boa, 2004).

Figure 3 Boletus edulis is commonly referred to as porcini in Italy (Wood, 2020)

There are a large variety of boletes and their varied occurrence around the world – from sub-tropical to sub-arctic – making it difficult to generalize across regions. Most are ectomycorrhizal and occur in association with a variety host tree species (Arora, 2008; Oria-de-Rueda *et al*., 2008; Sitta and Floriani, 2008). Bolete hosts relevant to NWO, include *Abies* spp, *Pinus* spp, *Picea* spp, *Betula* spp (Hall *et al.*, 1997). They are known to fruit in clusters, as with chanterelles and matsutake, and occur widely throughout NWO (Drombolis, pers. comm. Nov. 21, 2019; Alexander, pers. comm. April 3, 2020). Alexander (pers. comm. April 3, 2020), a recreational harvester, stated that he sold approximately $600 worth of boletes to the Maltese Grocery in Thunder Bay in the 2019 season.

The global demand for boletes is generally focussed in Italy, France, Germany and U.S.A. The global supply and harvest of boletes occurs in China, India, Pakistan, Eastern Europe – including the Baltic states, Finland and to a lesser extent North and South America. Boa (2004) notes that boletes harvested and exported from Eastern Europe and Finland are cheaper than exports from North America, and, thus, North American boletes have a difficult time competing on the European market.

Boletes are commonly sold dried as the drying process does not diminish flavour or aroma (Zhang *et al*., 2018; Nofer *et al*., 2018). The drying process is stated to increase the total concentration of aromatic, volatile compounds creating a richer and more desirable flavour (Zhang *et al.,* 2018). The most effective method of drying to achieve this is also the easiest and most commonly applied – convective drying at 70°C to 80°C (Nofer *et al*., 2018). This is unique among WEF and is favoured by chefs and restaurants as an affordable and accessible WEF option in the off seasons (Hall *et al.*, 1997).

LOBSTER MUSHROOMS

Lobster mushrooms are the product of mycoparasitism whereby the host, either *Russula* spp or *Lactarius* spp, is parasitized by *Hypomyces lactifluorum* (Rochon *et al.*, 2009). *H. lactifluorum* occurs within the *Hypocreales* family of the *Ascomycota*. The *Hypomyces* genus is comprised of several mycoparasitic species, however, the lobster mushroom is the only known edible fungus that is parasitized. Moreover, the literature suggests that lobster mushrooms do not occur outside of North America (Rogerson and Samuels, 1994). *Hypomyces lactifluorum's* mycelium covers the pileus, gills and stipe of its host with a red-orange crust, as seen in figure 4. The host continues to grow but ceases spore production. *Lactarius deliciosus* (L.: Fr.) S.F. Gray, commonly known as the saffron milkcap and *Russula brevipes* are the most common Boreal hosts of *H. lactifluorum*. In order to understand lobster mushrooms, it is crucial to understand *R. brevipes, L. deliciosus* and *H. lactifluorum*. Moreover, *R. brevipes* and *L. deliciosus* are ectomycorrhizal fungi with specific hosts trees including *Betula* spp, *Populus* spp, *Picea* spp and *Pinus* spp (Visser, 1995; Rochon *et al.*, 2009).

Figure 4 H.lactifluorum parasitism of L. deliciousus (FFN, 2018)

Rochon *et al.,* (2009) studied the ecology of lobster mushrooms in a Jack pine stand in Quebec's Boreal forest. The study suggested that gaps in the canopy and increased sunlight exposure stimulated lobster mushroom patch density. The overall productivity of lobster mushroom at the study site was recorded as 21.6kg/ha (Rochon *et al.*, 2009). The ecological characteristics of its habitat were recorded as:

- Sandy, nutrient-poor soil
- Fluvial and/ or glacial deposit landforms – *e.g.* moraines and eskers
- Low pH soil (Rochon *et al.*, 2009)

Lobster mushrooms are widely regarded as highly delicious WEF. Their flavour is regarded highly compared to the flavour of their hosts alone. Foragers will often leave *R. brevipes* and *L. deliciosus* unpicked to this end (Laperriere *et al*., 2017). Laperriere *et al.* (2017) analyzed the metabolic profile of *R. brevipes* before and after parasitism by *H. lactifluorum* and noted that the flesh of the host undergoes significant change in terms of lipid and terpenoid content as illustrated in figure 5.

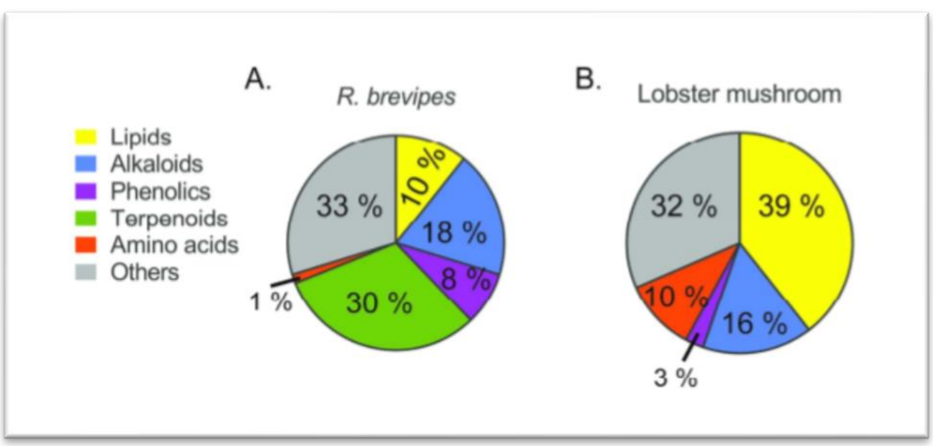

Figure 5 Change in metabolic profile of R. brevipes after parasitism by H. lactifluorum (Laperriere et al., 2017)

MORELS

Morels occur within the genus *Morchella* of the phylum *Ascomycota*. There is uncertainty within the literature about whether morels exist as ectomycorrhizal fungi or saprophytic fungi or both (Keefer *et al.*, 2010). The most common species occurring within the Boreal forest of Canada include *Morchella esculenta* Fr. – blond morel, *Morchella elata* Fr. – black morels, and *Morchella angusticeps* Peck - *Morchella conica* Pers. is falsely named in Figure 6 (Obst, 2015). These are true morels. False morels from the genus *Gyromitra* are related to morel species but contain a toxin that can damage the kidneys if ingested (Brozen, 2019).

Figure 6 Common morel species formerly recognized as a single species - M. conica (Obst 2015)

Morel fruiting bodies occur in early- to late-spring. They are widely known to occur in abundance in previously burned areas for approximately three years following said burn – *via* prescribed burn or forest fire (Keefer *et al.*, 2010). This has led some to label morels as phoenicoid fungi – *i.e.* fungi stimulated by fire disturbances. The premises behind this are as follows:

- Fire and heat stimulate morel ascospore production.
- Fire and heat reduce the presence of inhibitory compounds and competition with other fungi and bacteria.
- Fire and heat alter soil pH and carbonate concentrations in favour of morel fruiting (Duchesne and Weber, 1993)

The Boreal forest is prone to frequent fire disturbance and is strongly associated with fire-prone tree species such as jack pines – *Pinus banksiana* Lamb. – and *Picea* spp (Pinna *et al*., 2010; Scoular *et al.,* 2010). Moderate to severe wildfires are suggested to have optimal effects for subsequent seasons morel productivity (Wiita and Wurtz, 2004). Other ecological parameters for morels include sandy and well-drained soils, nutrient poor and low pH soils (Obst and Brown, 2000).

Numerous studies and reports have documented morel harvests and productivity across North America including BC, Yukon, NWT, Saskatchewan, Ontario and Alaska. Kenney (1996) recorded an approximate productivity of 1547kg/ha in the Yukon following four separate 1995 fires all of which were larger than 50,000 ha. Obst and Brown (2000) in NWT estimated approximately 2340kg/ha two years after the 165,000-ha fire at Tibbitt Lake, NWT. In Alaska, morels were seen, “thicker than grass,” by a local after the 1990 Tok fire (Wurtz *et al.,* 2005).

COMMERCIAL VALUE OF WILD EDIBLE FUNGI

The average annual value of WEF exports from Canada have been estimated by numerous reports at anywhere between $10 million to $100 million (Alexander *et al.,* 2010; Boa

2004; Cai *et al.*, 2011; De Geus and Berch, 1997; Kenney, 1996; Tedder and Mitchell, 2003). As the WEF industry functions within an informal market structure, there are many unrecorded and "under-the-table" financial interactions within the commodity chain outside of international export and import records (Alexander *et al.*, 2010). As a result, it is difficult to assess the commercial value of the WEF industry in its entirety. For example, the amount of time harvesters spend harvesting, the cost of equipment for harvesting, the price buyers pay for the harvest at any given time, the cost of processing, storing and shipping by the distributor, etc. are all financial factors involved in commercial WEF harvests that are not typically recorded (Alexander *et al.,* 2010; Tedder, 2008).

Roadside stands and farmer's markets are the setting for many commercial transactions outside of the international market. Moreover, many individuals and families will harvest WEF for recreational or subsistence purposes (Boa, 2004). Pilz *et al.*, (2003) stated that only a small number of individuals make large profits from selling WEF due to year to year variation of productivity. Most of the commercial value from the sale of WEF is experienced at local levels where the direct cash input is spread across local businesses and services (Obst and Brown, 2000). Many of the local communities that benefit from the commercial WEF industry are remote and reliant on industries such as timber where WEF harvests have been noted to increase economic resilience when market prices for natural resources such as timber drop (Pilz *et al.*, 2003). Outside of local markets, global demand for WEF, namely chanterelle, matsutake, boletes and morels are widely regarded as greater than the supply and, thus, the WEF industry in Canada has continued to grow (Kenney, 1996; Boa, 2004; Tedder, 2008).

THE WILD EDIBLE FUNGUS INDUSTRY: WITH EMPHASIS ON MORELS

The general structure of the WEF industry in Canada is hierarchical, as seen in figure 7. There are only a small number of major distributors of WEF in Canada including West Coast Wild Foods Ltd., Ponderosa Mushrooms, and Forbes Wild Foods (Obst, pers. comm. Jan. 17, 2020; Forbes, pers. comm. Jan. 16, 2020). These distribution firms manage large quantities of WEF and have export licenses to access international markets in U.S.A, Japan, France, Italy and Germany (Kenney, 1996; Obst and Brown, 2000). WEF supply retained by distribution firms are either sold to restaurants, wholesale or grocery companies within Canada (Forbes, pers. comm. Feb. 21, 2020). Buyers act as middlemen between harvesters and larger distribution firms. Buyers set up buyer stations near harvest areas where WEF are weighed, graded, bought, then shipped to distribution firms. Buyers are suggested to have a large influence on harvester behaviour and have been regulated in British Columbia and areas of the PNW as a result (Kenney, 1996). For harvest areas in the range of 50,000 ha, hundreds of harvesters can be involved (Forest Foods, 2018). Only small percentages of WEF harvests are fully realized in areas such as Alaska, NWT and Yukon because of, among other factors, small local populations and low numbers of migrant workers.

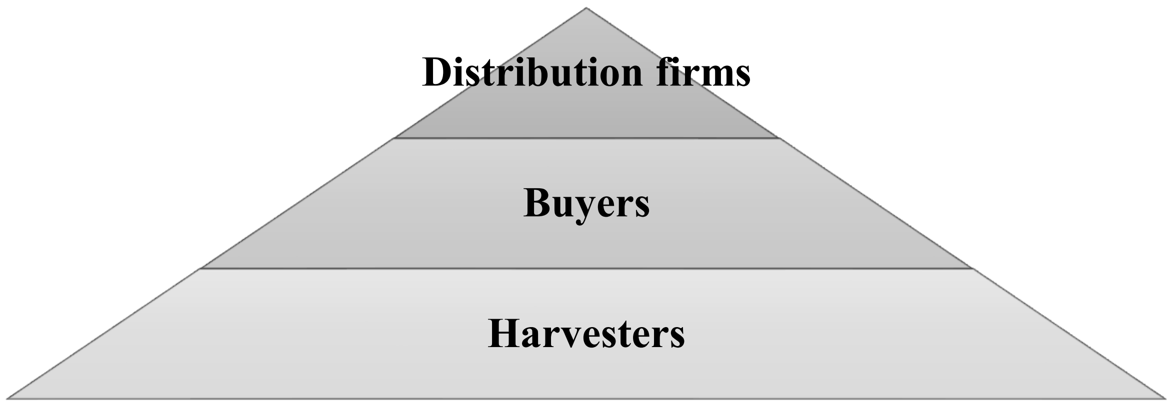

Figure 7 Hierarchical structure of the WEF industry in Canada (Kenney, 1996)

The morel mushroom industry has been well documented across North America. Government reports have been funded to study the feasibility and sustainability of the industry in Alaska, Yukon, NWT, and British Columbia.

ALASKA

The Alaskan study done on the feasibility of a morel mushroom harvest concluded that the harvest would not be able to sustain a small business enterprise. Wurtz *et al.* (2005), and Wiita and Wurtz (2004) listed several reasons why they believed an Alaskan WEF industry would not be financially sustainable:

- The highly unpredictable nature of WEF fruiting patterns,
- The small timeframe within which morels fruit in Alaska (2-4 weeks) – where long daylight hours (20 hours) are suggested by the author to quicken morel growth at the expense of commercially-relevant quality (Wurtz *et al.*, 2005),
- The risk of perishability,
- The lack of accessibility and proximity to burn sites,

- The lack of public awareness about WEF and morels, and
- The lack of an established buyers' network with only one commercial distributor in Alaska and a small handful of restaurants willing to work with morels (Wiita and Wurtz 2004).

These reasons, however, are the nature of the game. Morel productivity can and has been predicted through delineating previous year's wildfire areas (Obst and Brown, 2000; Duchesne *et al.*, 1999; Forest Foods, 2018; Government of BC, 2020; Saskatchewan, 2020). The risk of perishability can be mitigated through the drying process – sun-dried or drying racks (Kenney, 1996; Obst and Brown, 2000; Nofer *et al*., 2018; Forbes, pers. comm. Feb. 16, 2020). Workshops and Government guides have been successfully implemented in British Columbia and NWT towards facilitating greater public awareness and involvement in the sustainable harvest of WEF (Obst and Brown, 2000; Government of BC, 2020).

YUKON

The Government of Yukon, Department of Economic Development and Department of Renewable Resources funded a project in 1996 to study the feasibility of a morel mushroom industry. The report produced is comprehensive. The WEF industry was already growing in the early 1990's with concerns over sustainability and management guiding the project's purpose. The industry in 1996 consisted of migrant harvesters and buyers from B.C. and the PNW and local harvesters (Kenney, 1996). The report listed areas where wildfires had burned in the previous year along with highlighting the most accessible areas via proximity to roads and highways. The Yukon experienced four 50,000 ha wildfires in 1995. All four burn sites were accessible by road and/ or nearby an urban centre, had access to clean drinking water and had safe camping sites (Kenney, 1996). The report stated that local harvesters and local small-scale buyers did not have much industry experience. However, the presence of more experienced buyers and harvesters from BC and the PNW, through association, provided guidance (Kenney, 1996). The report, also, noted that the morel harvest had a significant positive effect on local economies with an influx of cash brought in from outside directly into local pockets or businesses – *e.g.* gas stations, rental properties, restaurants and bars (Kenney, 1996).

The Government of Yukon has continued to publish reports and provide information on their website which assist in species identification, best harvest practices and guide harvesting activities in general. The website also contains archived wildfire maps, such as in figure 8, with wildfire boundaries and area in relation to major highways. News articles on Yukon's annual morel harvest suggest that locals, along with migrant harvesters, continue to experience success with one local noting that he made $400 per day harvesting (CBC, 2019).

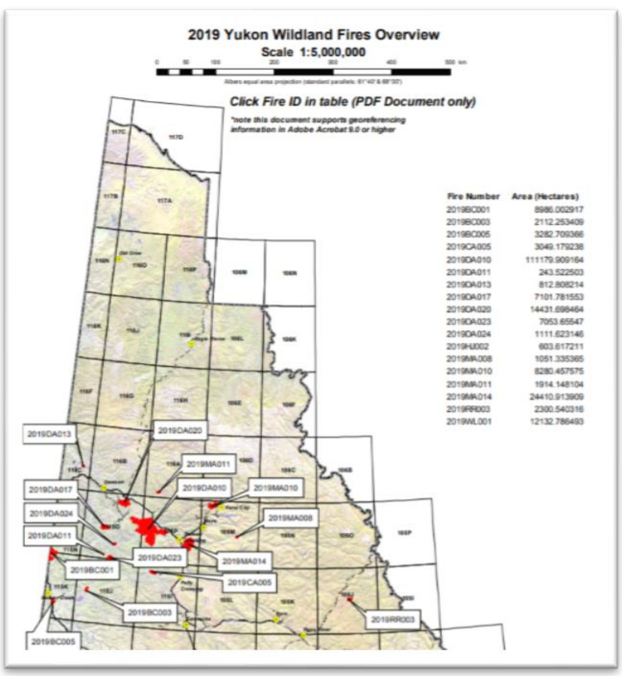

Figure 8 Yukon wildfire map of wildfire boundaries in 2019 (Yukon, 2019).

NORTHWEST TERRITORIES

The Government of NWT began research on the feasibility of a morel mushroom harvest in 1999. The Tibbit Lake wildfire of 1998 burned over 100,000 ha of forested land and intersected with accessible roads (Obst and Brown, 2000). This provided the ideal scenario with which to assess viable morel habitat and if a morel harvest could benefit the local economy. Obst and Brown (2000) researched the morel harvest in 1999 and recorded ecological, climatic and economic data along with the social and political factors associated with the WEF industry. The report stated that a commercial harvest would be sustainable and profitable in NWT. Out of the approximate 100,000 ha of burned area, only 1.3% of that was harvested (Obst and Brown, 2000). The total amount of fresh morels harvested was recorded as approximately 3,000 kg. Ecological habitat characteristics of the morels harvested were in agreement with the literature: upland, well-drained, sandy sites with jack pine and white spruce associations. Obst and Brown (2000) estimated that the total Tibbitt Lake burn area produced approximately 1.1 million kg of morels. The morel fruiting season and harvest occurred over a two-month period starting at the beginning of June. Obst and Brown (2000) hypothesized that secondary and tertiary flushes of morel fruiting occurred due to the thawing of the permafrost's active layer adding soil moisture in the later, drier half of the season. The harvested morels were noted by buyers as being of high quality (Obst and Brown, 2000).

There were ten buyers present at the Tibbitt Lake burn – all of whom were from either BC or the PNW. Fifty commercial harvesters partook in the harvest while other locals took part in the harvest for personal use (Obst and Brown, 2000). The ten buyers bought \$56,000 worth of morels. Thirty-six thousand dollars of this went directly into local harvester's pocket as cash. Expenses incurred during the harvest (~\$15,000) were largely spent in Yellowknife, thus, benefitting the local economy. Only a small portion of expenses were spent outside of the NWT and went either to BC or the PNW (Obst and Brown, 2000).

The NWT morel mushroom industry has grown since their first documented commercial harvest. The NWT Department of Industry, Tourism, and Investment [ITI] has funded workshops, community consultations, presentations in communities all over NWT to promote the harvest and urge locals to participate in it (Obst, 2015; Obst, 2016). Obst (2016) stated that in 2014, NWT experienced the largest area of wildfires in Canada at approximately 3.4 million ha as seen in figure 9. The subsequent years harvest earned approximately $1.4 million where $1.1 million was paid directly to local harvesters (Obst, 2016). The total income experienced in all local NWT communities from the 2014 and 2015 morel harvests was reported at approximately $4 million by Obst (pers. comm. Jan. 17, 2020)

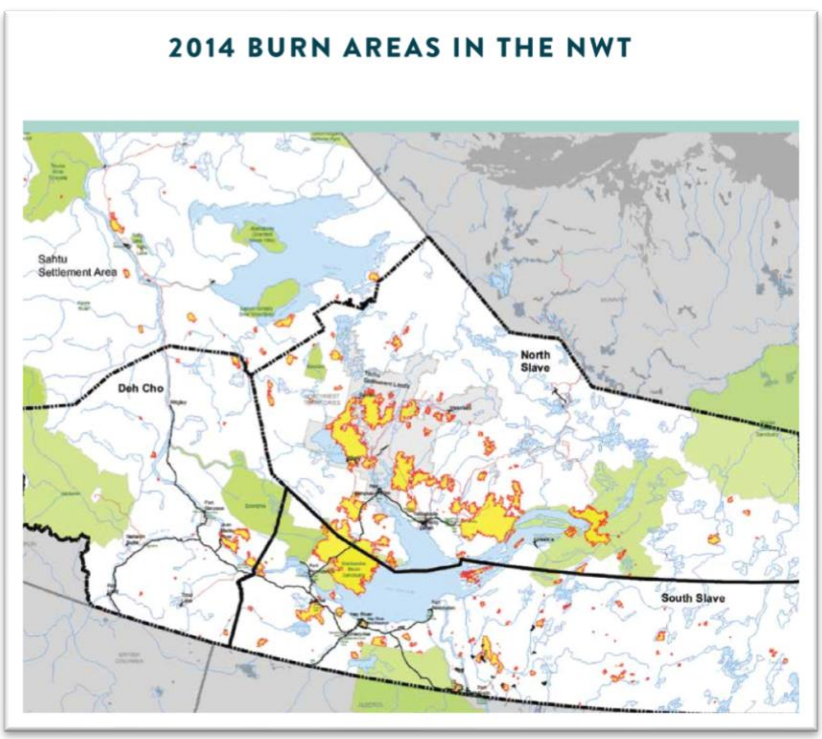

Figure 9 Survey of wildfires in NWT that are predicted to produce morel (Obst, 2016)

BRITISH COLUMBIA

In 1994, the BC Pine Mushroom Task Force was appointed to study WEF harvest amongst rising concern, interest and increased participation (Kenney, 1996). As no previous data on WEF in BC had ever been recorded, the Task Force's study relied entirely on interviews (Kenney, 1996). Recommendations made to the Government of BC included the creation of a license system for buyers, the continued collection of data on harvest volumes and sales, and the establishment of an administrative body to oversee the industry (Government of BC, 2020). These recommendations, however, were deemed infeasible in an industry that was as erratic and unpredictable as the WEF themselves (Kenney, 1996).

Since 1993, numerous studies have been documenting the BC WEF industry in terms of its commercial, ecological and social components. Ehlers (2007) and Ehlers & Hobby (2010) have described the ecology, management and commercial development of chanterelles in various regions on Vancouver Island. De Geus and Berch (1997) have described BC's matsutake industry. Numerous non-timber forest product [NTFP] studies have occurred throughout B.C. to promote their management alongside timber management objectives (Duchesne *et al.*, 1999; Tedder and Mitchell, 2003; Tedder, 2008). Forest management plans have come to include the protection of matsutake habitat within the provisions of their harvest operation guidelines as a result (Duchesne *et al.*, 1999; Bravi and Chapman, 2006; Ehlers *et al*., 2007; Ehlers, 2009; Vaughn and Chapman, 2003). The Government of B.C. has taken a large public education role on the WEF harvest. Their website (www.gov.bc.ca) has a comprehensive section on 'mushroom picking' with emphasis on morel mushrooms. There are GIS maps with data on the last three years of burns, guides on best harvesting practices; public safety in campsites, on burns, and road use; along with general environmental stewardship information (Government of BC, 2020).

In 2018, several First Nations territories initiated WEF harvesting permits in response to the increase in harvester numbers. The 2017 Elephant Hill Fire covered 192,000 ha and saw over 1,000 WEF harvesters the following year (Forest Foods, 2018). Nisga'a FN, Twilhqot'in National Government and Secwepemc FN set up identical permit systems towards the goal of ensuring environmental sustainability, safety among harvesters, and community development (Forest Foods, 2018; TNG, 2020). They also provide essential maps and information to assist in a successful WEF harvest such as seen in figure 10. The green areas within figure 10 illustrate the extent of previous years burns that are open to harvesting while the red areas illustrate culturally important sites or environmentally sensitive sites where no harvesting is permitted (TNG, 2020) Harvester permits cost $20.00 and buyer permits cost $500.00 (TNG, 2020). Most harvesters interviewed by the Pine Mushroom Task Force in 1994 believed that a form of administration would benefit the WEF industry and encourage sustainability (Kenney, 1996). Where regulatory action on the provincial scale failed, regional communities have had success.

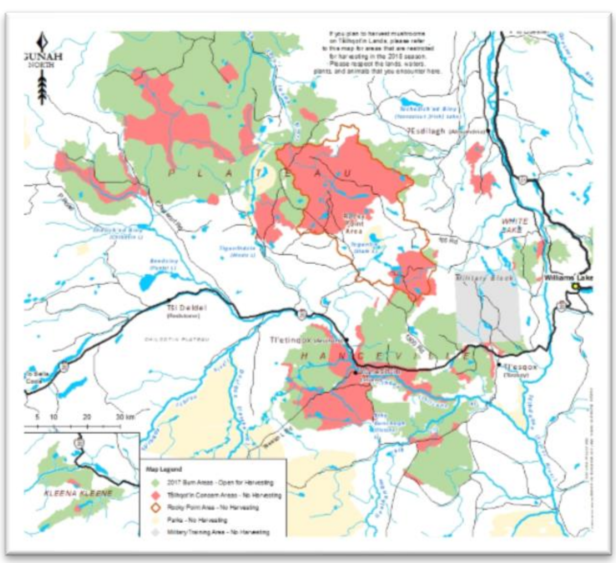

Figure 10 Map of previous years burn area and with areas in red where no harvesting is permitted within the TNG territory (TNG, 2020)

THE REST OF CANADA

In Quebec, the association for the marketing of non-wood forest products (ACPFNL) formed in 2006 to encourage harvesters, processors and marketers to get involved in the NTFP industry which includes WEF (JNH, 2013). The ACPFNL has stated that annual harvests of WEF in Quebec are estimated at 50,000 kg for all species with lobster mushrooms and chanterelles in largest quantity (JNH, 2013). The ACPFNL has published a $40 book available for purchase on their website to guide harvesters, buyers, processors and marketers in the Quebec WEF industry. Other organizations such as Biopterre – Centre de Development des Bioproduits – provide WEF identification guides for Northern Quebec species, WEF preservation instructions and best harvest practice guides (Biopterre, 2019). On the local level, smaller groups and organizations actively participate in educating, harvesting and selling WEF including Foret y gouter Inc. (foretygouter.com), and Champignons Forestiers de la Mauricie (mycomauricie.com).

Nova Scotia, New Brunswick, Manitoba and Saskatchewan have brief WEF guides and reports on their respective websites (Murrin, 2008; NACC, 2013; Saskatchewan, 2020). Saskatchewan's website provides maps of the previous year's wildfire boundaries for those interested in the morel harvest. The author could not find scientific literature or any government reports on the commercial WEF industry in Alberta, Manitoba or Saskatchewan. However, in Newfoundland, Murrin (2008) reported that several tons of matsutake, boletes and hedgehog mushrooms were harvested, sold and exported to Europe and U.S.A. in the previous year (Murrin, 2008).

CONSIDERATIONS FOR COMMERCIAL WILD EDIBLE FUNGI HARVESTS IN ONTARIO

It is well-known that there are many areas of ideal WEF habitat within Ontario – many of which are harvested for non-commercial purposes (Forbes pers. comm. Jan. 16, 2020; Drombolis pers. comm. Nov. 21, 2019; pers. comm. Alexander; PHO, 2019; Dzyngel, 2012; Duchesne *et al*., 1999; Mohammed, 1999). Foraging, in general, is noted as rising in popularity as well (Forbes pers. comm. Jan. 16, 2020; Alexander pers. comm. April 3, 2020). PHO (2019) published a brief regarding the risks involved when buying and ingesting WEF sold at farmers markets and restaurants in response to this rise in popularity. They provide a table of common WEF found within Ontario, notes on their habitat and poisonous fungi that are often mistaken for their counterparts - Appendix I.

Ontario's WEF industry pales in comparison to that in PNW, BC, Yukon and NWT. Forbes (pers. comm. Jan. 16, 2020) has promoted annual WEF harvests in communities around James Bay and along the Trans-Canada Highway and is aware of annual harvests in the region surrounding Sault Ste. Marie. However, the wide range of variability and inaccessibility to productive sites, again, are noted as major hindrances to the commercial WEF industry gaining momentum in NWO. Alexander (pers. comm. April 3, 2020) has harvested WEF recreationally and for the purposes of selling. In the summer of 2019, Alexander sold approximately $600 worth of boletes alone to the Maltese Grocery in Thunder Bay, Ontario. Moreover, he has and continues to work with Thunder Bay's Salvation Army shelter, driving people who want to learn about and harvest WEF to productive WEF sites every year (Alexander pers. comm. April 3, 2020).

There is one known study on the commercial potential of a WEF harvest in Renfrew County, Ontario (Duchesne *et al.*, 1999). The author could not locate the study but found many references to it in other research. Duchesne *et al*. (1999) reports that morels were producing at approximately 2860kg/ha in a jack pine stand in Petawawa Forest. Dzyngel (2012) attempted to map productive WEF sites in the White River Forest using personal experience and regional GIS data from the Northern Information Technology and Geomatics Cooperative (NITGC). He identified and harvested several highly productive chanterelle and morel sites towards the conclusion that small-scale foraging operations would be sustainable. The areas of burn site morels that Dzyngel (2012) harvested were noted as similar in productivity as to that of burn morels in the literature – *i.e*. approximately 10 kg/ha. However, Dzyngel (2012) did not assess WEF markets in the region such as buyers, distributors and the supply chain's final sale. Scandia Mat of Canada Ltd is a wholesale distributor of WEF in Ontario. They are noted as managing, buying and selling approximately 135 tonnes of WEF annually with only about 135 kg of this supply originating in Ontario (Mohammed, 1999). Mohammed has published several reports and books to promote the non-timber forest products (NTFP) industry in Ontario. Mohammed (1999), like Forbes, notes that Ontario's WEF industry is hindered by several factors including:

- Lack of access or restriction of access to productive sites such as when the MNRF restricts access in the event of wildfires;
- A general lack of transportation infrastructure in NWO; and,
- A lack of tradition of WEF harvesting.

Wurtz *et al*., (2005) suggested that a commercial WEF harvest would not be feasible in Alaska for similar reasons. Wurtz *et al*., (2005) further cited the inability to predict WEF abundance and distribution and WEF's high rate of perishability as contributing factors. In

Yukon and NWT, successful commercial WEF harvests have been occurring since the early 1990's under the same constraints as Alaska and NWO. Obst and Brown, (2000) and Obst (2015; 2016) along with Kenney (1996), have cited numerous efforts that have contributed to the success of NWT's commercial WEF harvest. They included:

- Public education – presentations, workshops, community consultations;
- Networking – contacting buyers from B.C. and PNW, shipping airlines and customs authorities, local restaurants and food-distributors;
- Investment – personal investments into start-up equipment such as drying racks, baskets; and,
- Experience – learning from harvesters and buyers from BC and the PNW.

The following sections will describe, in further detail, factors constraining commercial WEF harvests as informed by the morel mushroom industries in Alaska, Yukon, NWT, and British Columbia including WEF predictability, site accessibility, perishability, public education and market networks.

PREDICTABILITY

Morels have been predicted to occur in areas one year after a wildfire with a 95% confidence interval in Yosemite Park (Larson *et al.,* 2016). Yang *et al*. (2006) predicted matsutake presence with 70.4% accuracy at best using logistic regressions on spatial distribution maps. Bravi and Chapman (2006) predicted matsutake presence in the West Chilcotin Forest, BC within confidence limits between 59% - 83%. *Lactarius* spp. occurrence was predicted with a 73% accuracy using a similar logistic regression analysis by Kucuker and Baskent (2015). Chanterelle productivity and occurrence models have been tested and refined towards the goal of incorporating WEF into forest management plans on Vancouver Island by Ehlers (2007). However, the models predicted occurrence and productivity with poor accuracy.

Factors involved in the understanding of WEF productivity and fructification are highly complex. In order to predict WEF with certainty, scientific predictive models must define all elements of climatic, soil and forest stand conditions to satisfy inflexible confidence interval requirements that are only true for local regions (Pinna *et al*., 2010). And yet, the literature suggests that, despite lacking 95% confidence intervals, harvests of chanterelles, matsutake, boletes, lobster mushrooms and morels around the world have and will continue to enjoy success.

The morel industry functions within clear parameters where sites are chosen based on fire maps, word of mouth, and factors around accessibility. British Columbia has the most comprehensive mapping system available to this end (Government of BC, 2020). Moreover, harvesters are not static. In the case of chanterelles, pine mushrooms, lobster mushrooms and boletes, their occurrence is less predictable but in no way are they less abundant. Local harvesters are known to keep knowledge of productive habitats to themselves or amongst their cohort (Pilz *et al*., 2003; Boa 2004; Ehlers, 2007). It is also common for individuals to happen upon productive WEF sites without intentionally looking for them, such as on hikes (Alexander, pers. comm. April 3, 2020; Drombolis, pers. comm. Nov 21, 2019). Thereby, the unpredictability of WEF fruiting patterns and productivity can be remedied by the knowledge and mobility of its harvesters.

ACCESSIBILITY

The extent of potential WEF habitat and productive sites are often far greater than the capacity of the WEF industry to harvest. For example, Obst and Brown (2000) noted that approximately 1% of the 100,000 ha Tibbit Lake burn was harvested in NWT. The 192,000 ha Elephant Hill burn in BC attracted only 1,000 harvesters for the season – an unattainable average of 192 ha to harvest per harvester (Forest Foods, 2018). The location of buyer stations and harvester camps is as much influenced by the size and productivity of potential WEF sites as they are by the degree of accessibility these sites have to highways, roads and urban areas (Obst, 2015; Kenney, 1996; Boa, 2004). As such, the WEF industry can be constrained by the allowances of regional transportation infrastructures.

It is widely recognized that NWO suffers from a lack of transportation infrastructure, especially in relation to far-north communities only accessible by fly-in or winter ice roads. The Trans-Canada Highway through Thunder Bay is the only major highway connecting Western Canada to Eastern Canada. Moreover, most wildfire burns in Ontario – potentially productive morel sites - occur far north of the Trans-Canada in the Boreal forest (NRCAN, 2019). However, the stretch of Trans-Canada Highway across NWO is by no means short at 1,470 km from Sudbury to Kenora.

The long history of forestry in NWO has required the construction and maintenance of thousands of kilometres worth of forest service roads that branch all throughout the Boreal forest (OMNR, 2020). Many of these forest service roads are active with maps archived within the OMNR's database of crownland uses (OMNR, 2020). Government of BC (2020) recommends caution when using forest service roads regarding WEF harvesting. Active forest service roads must accommodate for large logging trucks and deactivated forest service roads are deactivated for reasons such as erosion control, landscape restoration, protection of sensitive wildlife, streams or ecosystems. The infrastructure provided by forest service roads in addition to the large stretch of Trans-Canada Highway across NWO, provides more than adequate access into the Boreal forest towards the potential identification of productive WEF sites (Dzyngel, 2012; Drombolis, pers. comm. Nov. 21, 2019).

PERISHABILITY

Wiita and Wurtz (2004) stated that the remoteness of potentially productive morel sites was such that WEF harvests would risk spoilage in transportation back to potential markets – *i.e.* the high rate of perishability of WEF. Morel mushrooms along with other WEF are susceptible to spoilage by bacteria and insects (Obst & Brown, 2000). Moreover, WEF lose approximately 10% moisture within the first 24 hours and 18-20% within the first 36 hours (Wiita and Wurtz, 3004). This can become significant in terms of price paid per unit of weight. Thus, fresh WEF are typically moved from harvest site to final sale – *i.e.* wholesaler, processor, grocer – as quickly and efficiently as possible. Buyers and harvesters often set up drying stations on site or cold-boxes to accommodate for the perishability and to compensate for the loss of wet weight – especially in remote areas (Obst and Brown, 2000; Forbes, pers. comm. Jan. 16, 2020).

On-site drying stations, or heat boxes, will often consist of ‘drying tents.’ Drying tents contain stacks of screens and accommodate airflow via fan or natural ventilation (Obst and Brown, 2000; Forbes, pers. comm. Jan. 16, 2020). On hot, sunny days, WEF can be dried on rocks in the open air if the site permits it. A second process called ‘flash-drying’ involves time spent at a higher temperature – 70-80°C – via woodstove, furnace fans, or fires (Obst and Brown, 2000). This process can take up to three days. The drying process results in a weight reduction ratio – from fresh to dry - of 10:1 (Kenney, 1996). Due to the labour involved in the drying process, dried WEF are often sold at a higher price than fresh WEF (Kenney, 1996).

The effect of the drying process varies per WEF species. Morels are the easiest and fastest of WEF species to dry due to their hollow structure (Kenney, 1996). The drying process can often be associated with a decrease in quality, however, Tian *et al*., (2015) found that the drying process increased total taste-active amino acids and sulphur compounds in shiitake mushrooms – *Lentinula edodes* (Berk.) Pegler. Boletes are known for retaining their quality after being dried as well (Nofer *et al*., 2018). Zhang *et al*., (2018) studied the aromatic compounds of porcini in both fresh and dry states and found that the drying process increased the total volatile compounds, thus, contributing to a richer and more desirable flavour.

EDUCATION

Education is cited as a factor contributing to the success of the annual morel harvest in NWT (Obst and Brown, 2000; Obst, 2014). Obst and Brown (2000) stated that WEF were not traditionally harvested by locals within the region. To promote and educate locals within the region about WEF, walking WEF workshops and presentations were held to promote the industry (Obst and Brown, 2000; Obst, 2014; Obst, 2015). As a result, more locals have participated in the harvest, more morels have been harvested and the value of NWT's commercial WEF industry has risen since its beginnings in the 1990's.

British Columbia, Yukon, NWT, Saskatchewan, Manitoba, Quebec, New Brunswick and Nova Scotia have all provided documents or brochures on their websites to present WEF best harvesting practices, safety tips and to assist in WEF identification (Murrin, 2008; NACC, 2013; Saskatchewan, 2020; Obst, 2014; Yukon 2020; Biopterre, 2019). Moreover, BC, Yukon, NWT and Saskatchewan all provide up-to-date maps and information on previous years wildfire boundaries and areas to assist harvesters and buyers in finding potentially productive morel sites and towards protecting restricted areas such as private property, parks and some First Nations land (Yukon, 2019; Government of BC, 2020; Saskatchewan, 2020).

Thunder Bay's demographic, unlike Yukon and NWT, has a large percentage of first, second and third generation immigrants from cultures with strong WEF harvesting traditions such as Finland, Italy, Poland, Ukraine, Germany and other European countries (StatCan, 2016; Boa, 2004). Such cultures have traditionally harvested for both recreational and subsistence purposes (Boa, 2004). However, second and third generations have generally not required WEF for subsistence purposes and, thus, the tradition of WEF harvesting has weakened (Alexander, pers. comm. April 3, 2020; Drombolis, pers. comm. Nov. 21, 2019). Alexander (pers. comm. April 3, 2020) was first introduced to WEF harvesting traditions by his uncle of Italian descent. Others, like Drombolis (pers. comm. Nov. 21, 2019), learned on their own.

Thunder Bay has many resources with which to educate the public on WEF and WEF harvesting. Several individuals, organizations and conservations authorities already provide workshops and classes on endemic WEF including Ontario Nature, Thunder Bay Field Naturalists, Lakehead Region Conservation Authority and Alexander (Alexander, pers. comm. April 3, 2020 Drombolis, pers. comm. Nov. 21, 2019; PHO, 2019). Dr. Leonard Hutchison, resident mycologist within the faculty of Natural Resources Management at Lakehead University, Thunder Bay, is one of the primary leaders of these workshops, presentations and walking tours. Moreover, Dr. Hutchison fields regular requests for fungus identification in the form of emails sent with attached photos, or in-person visits to his office or lab.

THE MARKET

The international market demand for WEF is concentrated in Europe, U.S.A. and Japan with approximately two-thirds of BC WEF harvests going to export (Keefer *et al*., 2010). Schlosser and Blatner (1995) stated that Europe exhibits the highest demand for international bolete supplies, U.S.A. for morels and chanterelles, and Japan for matsutake. Forbes (pers. comm. Jan. 16, 2020) stated that the majority of the 700 kg harvest of matsutake in the James Bay region was exported to Tokyo. Domestic markets for WEF supply are focussed in large urban centres such as Vancouver, Toronto and Montreal where final sale occurs in grocery stores and restaurants (Keefer *et al*., 2010. Forbes, pers. comm. Jan. 16, 2020; Drombolis, pers. comm. Nov. 21, 2019; Alexander, pers. comm. April 3, 2020; Obst and Brown, 2000; Kenney, 1996).

Due to the variability, remoteness and perishability of WEF, market supply of WEF is irregular and, as such, market destinations must be sought out by buyers and/ or distribution firms with this caveat. A survey done by Schlosser and Blatner (1995) stated that 61% of WEF suppliers had to develop their own markets. Drombolis (pers. comm. Nov. 21, 2019) stated that he, too, had to develop his own market through networking between harvesters in areas such as Dryden and restaurants in Toronto and Montreal. Due to the high risk of perishability, market destinations for fresh WEF must be confirmed and moved quickly. Such is the role of buyers and distribution firms.

WEF markets in smaller urban centres and remote communities where WEF are often harvested are not large (Forbes, pers. comm. Jan. 16, 2020). Forbes (pers. comm. Jan. 16, 2020) stated that morels are eaten locally in the communities he visited along the Ontario portion of the Trans-Canada Highway, around Kirkland Lake and in the James Bay region but the tradition is not strong. Moreover, Alexander (pers. comm. April 3, 2020) states that, though he has a large supply of WEF ready to sell, the demand in Thunder Bay is not large. Buyers in the Thunder Bay region have been in the form of restaurants and grocery stores with the largest and most frequent buyers being Maltese Grocery and the Tomlin restaurant (Alexander, pers. comm. April 3, 2020). The Maltese Grocery has largely purchased boletes while the Tomlin restaurant has bought chanterelles and lobster mushrooms from Alexander (pers. comm. April 3, 2020). Other restaurants in the Thunder Bay region, such as the Nook restaurant, have also purchased WEF from Alexander in the past, but are not noted as regular buyers (Alexander, pers. comm. April 3, 2020). Forbes (pers. comm. Jan. 16, 2020) stated that he works with several groups that actively harvest WEF throughout the spring, summer and fall seasons. They ship their harvests to Forbes' business, Forbes Wild Foods, which acts as a buyer, processor and distributor for WEF within Ontario (Forbes, pers. comm. Jan. 16, 2020). If a WEF harvesting business or distribution enterprise were to be formed in the Thunder Bay region, then a market network of wholesalers, restaurants and grocery stores would have to be established outside of the Thunder Bay region to facilitate final sale of the commodity; at least, at the outset. Again, the international demand for WEF is noted as larger than its supply (Kenney, 1996; Boa, 2004; Tedder, 2008).

RECOMMENDATIONS FOR WILD EDIBLE FUNGI HARVESTERS IN NORTHWESTERN ONTARIO

The establishment of a small-scale foraging operation to harvest WEF in NWO would be profitable. It is acknowledged through personal communication and literature review that there are abundant productive and commercially relevant WEF sites within NWO (Dzyngel, 2012; Drombolis, pers. comm. Nov. 21, 2019; Forbes, pers. comm. Jan. 16, 2020; Alexander pers. comm. April 3, 2020; Duchesne and Weber, 1993; Duchesne *et al.*, 1999). Previous research has suggested that the WEF industry in Ontario has been hindered by constraints such as unpredictability, inaccessibility, high risk of perishability and a lack of harvesting traditions within Ontario (Forbes, pers. Comm. Jan. 16, 2020; Mohammed, 1999). However, NWT and Yukon have enjoyed successful commercial WEF harvests since the early 1990's with these same constraints (Obst, 2016; Kenney, 1996; CBC, 2019).

The challenges presented to WEF harvesters in NWO, as suggested by Mohammed (1999) and Forbes (pers. comm. Jan. 16, 2020), are addressed by the individual's knowledge of productive WEF sites, their mobility between and within such sites and their market network. The risk of perishability of WEF can be addressed by processing. Drying WEF in remote sites can be achieved efficiently and affordably with drying racks and fire pits. The equipment needed to create drying apparati are commonplace and variable in that one could use a window screen or a bread rack to the same effect – anything that will promote air flow. If a highly productive WEF harvest season is foreseeable, then the individual seeking to establish their own small-scale WEF enterprise may find that the extent of harvestable area greatly exceeds their capacity to harvest it. Alexander (pers. comm. April 3, 2020) addresses this disparity by bringing individuals from Thunder Bay's Salvation Army shelter. Obst (2000, 2014, 2015) addressed this through organizing numerous community consultations, presentations and walking workshops to promote larger involvement. Distribution firms in Finland, like Dalla Valle OY, have distributed leaflets, advertised in local newspapers, and regularly send out emails to their 15,000 website subscribers about why, when and how to harvest WEF (Cai *et al*., 2011). The author would recommend a similar method as the one used by Dalla Valle OY. When supply is established, the venture becomes entrepreneurial in that market destinations and connections must be established to facilitate final sale.

The individual seeking to establish their own small-scale WEF enterprise has many tools and people willing to help them. For example, Forbes of Forbes Wild Foods actively seeks out Ontario WEF harvesters to buy from. Alexander (pers. comm. April 3, 2020) has stated that he is willing to teach and accompany people interested in WEF harvesting. Obst (pers. comm. Jan. 17, 2020) stated that working for distribution firms in BC, such as West Coast Wild Foods LTD., Ponderosa Mushrooms and Untamed Feast Wild Mushroom Products, helped his understanding of the industry's harvesters, buyers and market networks. Drombolis (pers. comm. Nov. 21, 2019) met many people within NWO who harvested or had knowledge of productive WEF sites that were willing to sell and ship to him for cash.

If the individual seeking to establish their own small-scale WEF enterprise does not have prior knowledge of productive WEF sites, they can look to the ecology of the desired WEF species for assistance. Many of the commercially valuable WEF endemic to NWO are associated with similar habitat characteristics such as well-drained, sandy, nutrient-poor, low pH soils along with mature jack pine host tree associations. There are many online tools with which to locate the geographic convergence of such conditions. For example,

- Canada's National Forest Inventory (NFI) online map can be used to locate forest stand types. Appendix II illustrates the relative occurrence of jack pine across Ontario with the highest densities occurring in NWO.
- Ontario's Crown Land Use Atlas can be used to locate major highways, roads and forest service roads within proximity to chosen sites.
- Online soil survey maps can be found through the Canadian Soil Information Service. Appendix III illustrates the location and boundaries of the soil types and drainage patterns within the Thunder Bay region.

- iNaturalist's online community and map archives public observations of wildlife and vegetation. It can be used to locate associated vegetation and the targeted WEF themselves (inaturalist.org).

The author noted that Ontario's wildfire maps are not comprehensive in their illustration of wildfire boundaries and area in relation to regional infrastructure, parks and First Nation reserves. BC, Yukon, NWT and Saskatchewan all provide wildfire maps towards supporting the morel harvest. Future work could focus on presenting Ontario wildfire data in a similar way. Moreover, Ontario fire rangers have privy access to many burn sites productive with morels that are inaccessible except by fly-in. It would benefit the Ontario morel harvest to find a way to partner with Ontario fire rangers or create connections with individual fire rangers who harvest morels in such sites. Also, provincial government departments could be persuaded to invest in the NWO commercial WEF industry as it is shown to have direct economic benefits for small resource-dependant communities – *e.g.* Ontario's Ministry of Agriculture, Food and Rural Affairs; the Ministry of Natural Resources and Forestry; or, the Ministry of Economic Development, Job Creation and Trade. This type of collaboration was a benefitting factor in the NWT commercial WEF industry's success.

CONCLUSION

The proposal stating that the harvest and sale of WEF in NWO can support a small business enterprise is validated by the literature review along and personal communications. The success of such an endeavour would depend upon the quality of entrepreneurship, and, as such, the proposal's validity remains speculative. However, the literature review and personal communications have suggested that there is a large supply of WEF in NWO to correspond with a larger demand for WEF at, both, the international and domestic levels. The potentially productive WEF areas within NWO are such that their extent may exceed the capacity of a single harvester to realize. In this respect, it would also seem reasonable to suggest that a WEF distribution firm could be established in NWO to facilitate the movement and processing of large volumes of WEF to international markets, *i.e.* U.S.A., and large urban centres such as Toronto, Montreal and Winnipeg. There is a large potential for NWO to strengthen food security and the economic resilience of its remote and resource-dependent communities through the commercial WEF industry.

PERSONAL COMMUNICATIONS

Alexander, J. Recreational WEF harvester and supplier to Maltese Grocery and Tomlin Restaurant, Thunder Bay, ON. April 3, 2020.

Drombolis, P. co-owner of Eat the Fish, Thunder Bay, Ontario. November 21, 2019

Forbes, J. Owner of Forbes Wild Foods, Toronto, Ontario. January 16, 2020

Obst, J. Retired consultant at Arctic Ecology & Development (AED) Consulting. January 17, 2020.

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APPENDIX III: TABLE OF WEF ENDEMIC TO ONTARIO PROVIDED BY PHO

Table 1 Wild edible fungi endemic to NWO

Edible Species	Common name	Ontario fruiting season	Habitat	Other parts of the world where gathered	May be mistaken with
*Armillaria spp.**	Honey mushroom	Fall	On wood or stumps	Widely sought, prized in Central and Eastern Europe	Deadly Galerina (*Galerina autumnalis*): deadly[40]
Boletus edulis	King bolete or porcini	Mid-summer to fall	On the ground under conifers or in mixed woods	Widely sought, prized in Central and Eastern Europe	Some bolete species can cause gastrointestinal symptoms[4]
Calvatia gigantea	Giant puffball	Late summer to fall	In fields, woods, gardens, banks of streams	Widely sought	Button-stage of destroying angel (*Amanita virosa*): deadly[41]
Cantharellus cibarius	Chanterelle	Mid-summer to fall	On the ground in woods	Widely sought, prized in Central and Eastern Europe	False chanterelle (*Hygrophoropsis aurantiaca*): gastrointestinal symptoms;[4] Jack O'Lantern (Omphalotus olearius): poisonous[42]
Entoloma abortivum	Hunter's hearts	Mid-summer to fall	On or near rotting wood in mixed woods[4]	Entoloma abortivum	Hunter's hearts
Fistulina hepatica	Beefsteak fungus	Late summer to fall	On oak and other hardwoods	–	*Hapalopilus nidulans*: poisonous
Grifola frondosa	Hen of the woods	Mid-summer to fall	On the ground in mixed woods in southern Ontario	Southern Europe and East Asia	Any somewhat similar species are too leathery in texture for consumption
Hydnum repandum	Hedgehog mushroom	Mid-summer to fall	On the ground in mixed woods	Southern and Central Europe	*Bankera fuligineo-alba*: inedible, not poisonous43
Lactarius deliciosus	Orange milk cap / Delicious Lactarius	Mid-summer to fall	On ground under conifers	Southern, Central and Eastern Europe	*Lactarius chrysorheus*: poisonous, severe gastrointestinal symptoms4
Laetiporus sulphureus	Chicken of the woods	Mid-summer to fall	On standing moribund or dead oak or other broadleaf trees	Central Europe	Cinnabar polypore (*Pycnoporus cinnabarinus*): non-poisonous44; *Hapalopilus* nidulans: poisonous
Leccinum aurantiacum	Orange bolete	Mid-summer to fall	On ground under birch and poplar trees	–	Some bolete species can cause gastrointestinal symptoms4
Lepista nuda	Blewit	Late summer to fall	On ground in woods	Western and Central Europe	Genus *Cortinarius*: variably poisonous45

Macrolepita procera	Parasol	Mid-summer to early fall	On the ground in grassy areas and open woods	Central- and Eastern Europe and East Asia	Small-statured species in the *Lepiota subincarnata* group ("Fatal Dapperling"): deadly; and the green-spored *Chlorophyllum molybdites*: gastrointestinal symptoms
Marasmius oreades	Fairy ring mushroom / Scotch bonnet	Early summer to fall	In grass and open areas	–	*Leucocybe candicans, L. connatum, Clitocybe rivulosa*, found in forests and forest margin grasses: poisonous
Pleurotus ostreatus	Oyster mushroom	Spring to early summer	On dead longs, stumps, and standing trees	Widely sought	Angel's Wings (*Pleurocybella porrigens*): generally regarded as edible, questionable toxicity[46]
Tricholoma magnivelare	Matsutake / pine mushroom	Mid-summer to fall	In 2-needle pine barrens, pine and spruce plantations	East Asia (especially Japan and Korea)	*Entoloma subsinuatum*: poisonous

APPENDIX II: JACK PINE FOREST OCCURRENCE IN ONTARIO

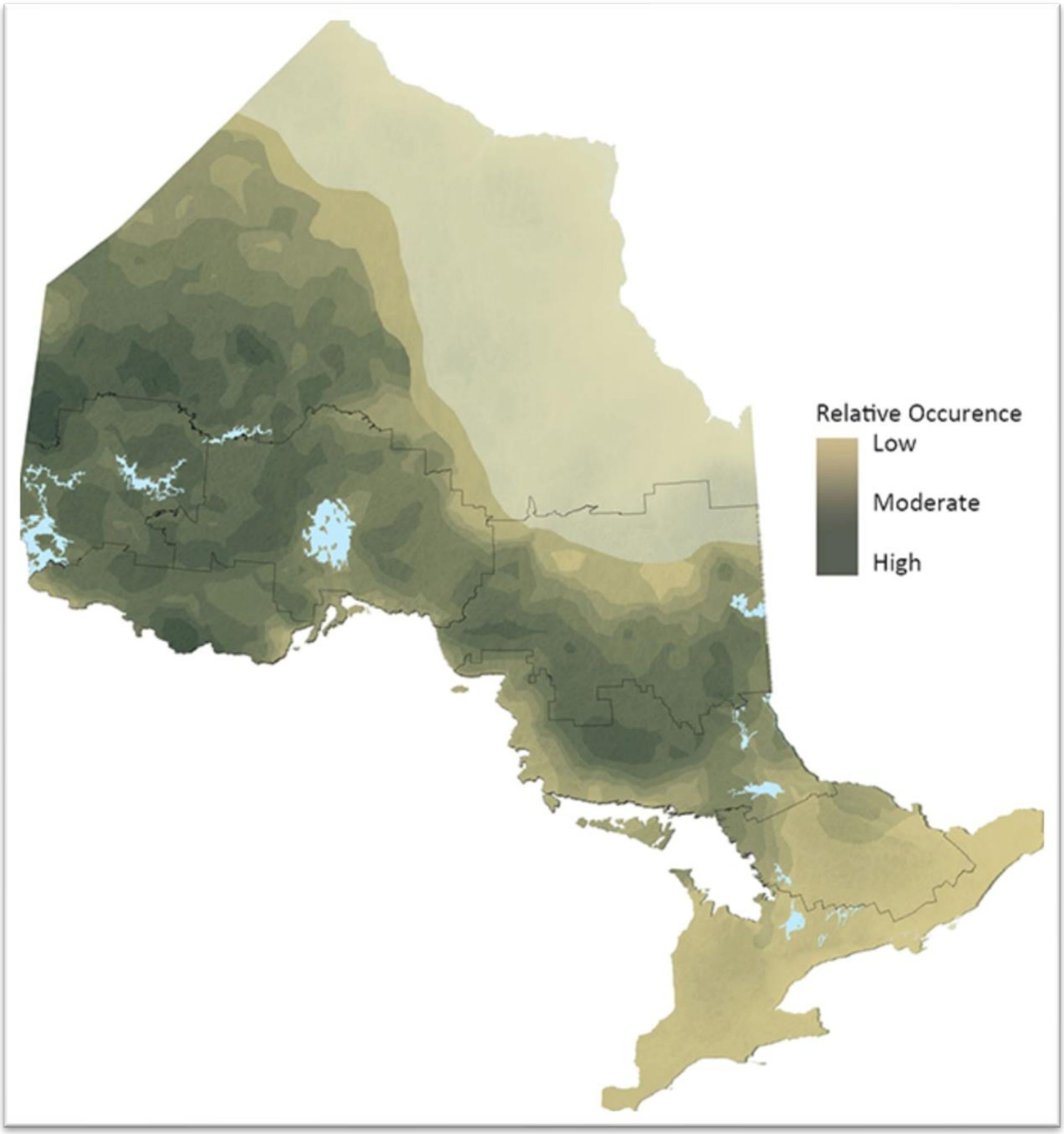
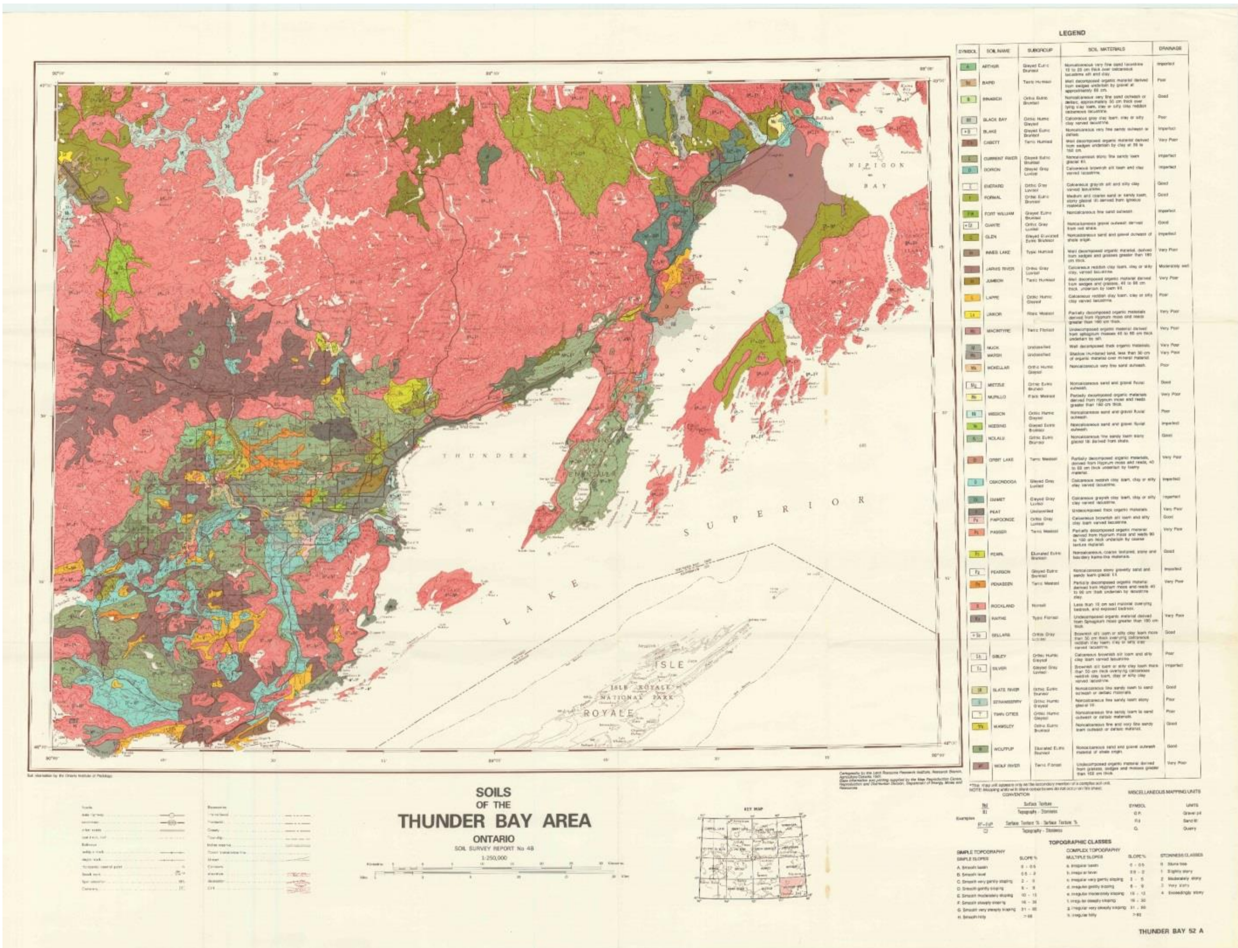
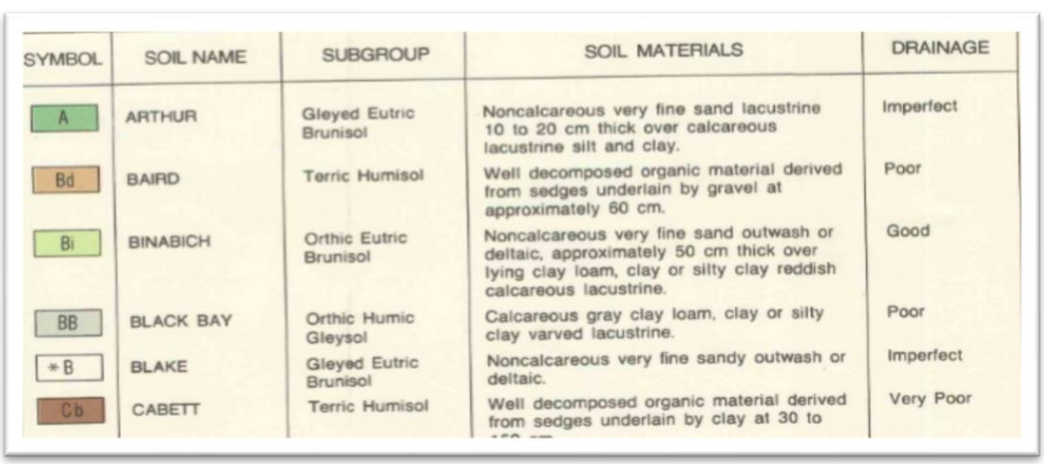


Figure 11 Relative occurrence of jack pine dominated forests in the rest of Ontario in relation to Ontario's forest types (MNR, 2016)

APPENDIX III: MAP OF SOIL TYPE AND DRAINAGE PATTERNS AROUND THUNDER BAY





SYMBOL	SOIL NAME	SUBGROUP	SOIL MATERIALS	DRAINAGE
A	ARTHUR	Gleyed Eutric Brunisol	Noncalcareous very fine sand lacustrine 10 to 20 cm thick over calcareous lacustrine silt and clay.	Imperfect
Bd	BAIRD	Terric Humisol	Well decomposed organic material derived from sedges underlain by gravel at approximately 60 cm.	Poor
Bi	BINABICH	Orthic Eutric Brunisol	Noncalcareous very fine sand outwash or deltaic, approximately 50 cm thick over lying clay loam, clay or silty clay reddish calcareous lacustrine.	Good
BB	BLACK BAY	Orthic Humic Gleysol	Calcareous gray clay loam, clay or silty clay varved lacustrine.	Poor
∗B	BLAKE	Gleyed Eutric Brunisol	Noncalcareous very fine sandy outwash or deltaic.	Imperfect
Cb	CABETT	Terric Humisol	Well decomposed organic material derived from sedges underlain by clay at 30 to	Very Poor

Figure 12 Map of soil types and drainage patterns surrounding Thunder Bay with the legend magnified (LRRI, 1981)