

THE ECOLOGY AND ECONOMY OF MORELS IN BRITISH COLUMBIA'S EAST KOOTENAY

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Abstract

Morels (*Morchella*:Fr. ssp.) are widely known as being amongst the finest wild fungus foods; in Western North America, they are best known to fruit after wildfires. The summer of 2003 in the Kootenay Region was characterized by intense heat, smoke from wildfires and a backcountry travel ban. The spring of 2004 saw a major morel harvest in the East Kootenay. There are many unanswered questions concerning the *Morchella spp.*, and how the life cycle and ecology of this fungus interact with fire and other disturbances. This project aimed to increase our understanding of morel mushroom ecology and some of the economics of the morel harvest following wildfire. The research used ecological and ethnological survey methods together in order to gain both scientific data and contemporary ecological knowledge from the morel pickers.

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Abstract.....	2
Chapter 1: Introduction.....	6
1.1 The Issue Background & Opportunities.....	6
1.2 Research Objectives and Hypotheses.....	9
Research Questions:.....	9
Chapter 2: Literature Review.....	11
2.1 Mushrooms as NTFPs:.....	11
2.2 Background on Morels.....	15
2.3 Role in ecosystem.....	17
2.4 Human Uses.....	20
2.5 Cultivation (in vitro & agroforestry).....	24
3.0 Chapter 3: Methods.....	27
3.1 Introduction:.....	27
3.2 Ecological survey.....	27
3.3 Ethnographic Methods:.....	30
3.4 General Observations.....	31
Chapter 4: Results.....	33
4.1 Ecological Research.....	33
4.2 Nearest Neighbour Experiment.....	33
4.3 Morel Production.....	34
4.4 Ethnological Research.....	35
4.4.1 Picker Survey.....	35
4.4.2 Informal Conversations with Pickers, Buyers.....	39
4.3 Preliminary Results from Case Study Team.....	40
4.4 General Observations.....	41
Chapter 6: Conclusions.....	45
References.....	48
Appendix I - Research Consent Form and Morel mushroom Use Questionnaire.....	54
Appendix II – Ecological Data.....	64
Table I - Nearest Herb Neighbours.....	64
Table II – Nearest Shrub Neighbours.....	66
Table III – Nearest Tree Neighbours.....	68
Table IV – Morel Production vs. Duff Consumption.....	69
Figure I – Morel Production vs. Duff Consumption Class.....	69
Table V – Morel Production per Plot.....	70
Appendix III – Picker Survey Data.....	71
Section 1 – General Information.....	71
Figure 2: Picker Ethnicity.....	71
Figure 3: Picker Gender.....	71
Figure 4: Age Group Dispersion.....	72
Figure 5: Picker Experience.....	72
Section II - Socio-economic.....	73
Figure 6: Reason(s) to Pick.....	73
Figure 7: Pickers who picked in 2003.....	73
Figure 8: Picker Earnings.....	74
Figure 9: Percentage of yearly income derived from picking morels in 2004.....	74
Figure 10: Perceived Typical Daily Earnings.....	75
Figure 11: Best Single Days Earnings.....	75
Figure 12: Do you collect other NTFPs?.....	76
Figure 13: Why do you pick other NTFPs?.....	76
Figure 14: Do you pick other fungi?.....	77
Figure 15: What other fungi do you pick?.....	77
Figure 16: Who do you sell your fresh morels to?.....	78
Figure 18: Percentage of Morels Dried.....	79
Figure 19: Acceptable Price for Dry Morels per pound.....	80
Section III – Ecological Information.....	81

Figure 20: Habitat Preference	81
Figure 21: Elevation Preference.....	81
Figure 22: Preferred Aspect for Picking.....	82
Figure 23: Preferred Moisture Level	82
Figure 24: Preferred Neighbouring Trees	83
Figure 25: Awareness of Plant Associations.....	83
Figure 26: Awareness of Connection with Morel Production and Weather.....	84
Figure 27: Awareness of Indicators on Harvest Time and Volume.....	84
Figure 28: Are peripheral areas of fires more productive?	85
Figure 29: Are hotter areas of fires more productive?	85
Figure 30: Are you aware of Management Techniques?	86
Figure 31: Do you practice management techniques?	86
Section IV - Production System.....	87
Figure 32: Have you experienced problems with other pickers?.....	87
Figure 33: Awareness of Laws Governing Industry	87
Figure 34: Support for New Legislation	88
Appendix IV – Maps	89
Figure 35: Locator Map.....	89
Figure 36: Lamb Creek Fire Map.....	90
Figure 39: White River Middlefork Fire.....	93
Appendix V – Photos.....	96
Figure 42: Morels (<i>M. elata</i> group).....	96
Figure 43: Mass fruiting Morels (<i>M. elata</i> group) in Middlefork Fire.....	96
Figure 44: Measuring nearest neighbours.....	97
Figure 45: A giant in the <i>M. Elata</i> Group.....	97
Figure 44: Unproductive Area with Glaciolacustrine Soil.....	98
Figure 45: Morel Dryer in Lamb Creek.....	98
Figure 46: Morel (<i>M. elata</i>) in heavily burnt duff.....	99
Figure 47: Isabella Keefer in Morel Habitat in Mountain Pine Beetle Block Gold Creek.....	99

Chapter 1: Introduction

1.1 The Issue Background & Opportunities

Morels (*Morchella*:Fr spp.) are amongst the most valuable and highly sought-after wild edible fungi; their harvest represents a seasonal employment niche in the non-timber forest product (NTFP) sector for people throughout much of the world. Morels are widely known to fruit abundantly in the spring following wildfire events (Weber, 1995). The large number of wildfires in 2003 within the East Kootenay Region provided the opportunity for research on a variety of fire related topics with a rare opportunity for replication in a single season.

There is relatively little known about the ecology of morels in the post fire setting, other than the fact that most, but not all, wildfires in Western North America are known to produce abundant morel crops. Duchesne and Weber reported a morel biomass per hectare of 2860 kg (1993). When one regards the morel species complex, it rapidly becomes apparent that there are many questions concerning their ecology in fire zones, such as, what levels of fire intensity produce the most morel biomass or if there is homogeneity in morel production in the fire sites. On the other hand, there is a wealth of informal knowledge ranging from exquisite recipes to contemporary ecological knowledge from the mushroom pickers and buyers about where one is most likely to find productive morel habitat. Given the large annual harvest and the desirability of morels as a food product, the dearth of literature revealed an opportunity for further study of morels.

The smoky summer of 2003 led many to speculate that the spring of 2004 would see a spectacular bumper crop of fire morels in the region. This speculation also led the Royal

Roads University's (RRU) Centre for Non-Timber Resources (CNTR) and the Ktunaxa Kinbasket Treaty Council (KKTC) to seek funding for the Kootenay Morel Case Study (KMCS) in the East Kootenay as part of a three year program through the Sustainable Forest Management Network. The funding application was successful, although notice arriving in April of 2004 provided little lead time for detailed planning of the study.

The Kootenay Morel Case Study (KMCS) follows a methodology developed by Belcher and Ruiz-Perez (2001) with the goal of setting up internationally comparable non-timber forest product (NTFP) case studies. The team for this project is: Darcy Mitchell (RRU), Richard Winder (Natural Resources Canada), Tom Hobby (University of Victoria/RRU), Betty Shore, and the author as principal case writer. This method provides a series of descriptors, including: (1) background; (2) the characteristics of the product and production system; (3) ecological implications of production, socio-economic characteristics of the study area; policy; (4) characteristics of the industry, trade and marketing; and (5) outside intervention. In this thesis, the descriptors are augmented with additional ecological information to provide a more complete picture of the 2003-2004 event. So while the KMCS is being reported separately, portions of the study are integrated with this thesis because they integrally related to the thesis, which itself primarily contains information from the case study that is directly concerned with the ecology and management of the resource.

The study area for this project lies in the south-eastern corner of British Columbia. This area is within the traditional territory of the Ktunaxa Nation in British Columbia as outlined in the Statement of Intent for the BC Treaty Process (Ktunaxa Kinbasket Treaty Council [KKTC],

2004). The East Kootenay is defined by the Purcell and Rocky Mountain ranges flanking the wide trough of the Rocky Mountain Trench. Most of the region's 56,000 population live within the Trench (Regional District of East Kootenay (RDEK) 2004). Within this region, the study area is further defined by the locations of five major wildfires that occurred in the area in 2003. The fire sites are labelled by their locations: Lamb Creek, Plumbob Creek, White River Middlefork, Mission Creek and Tokumm/Verrendrye (Please refer to Appendix V for maps). The first three fire sites are located within the Rocky Mountain Forest District. The Mission Creek Fire is in the Kootenay Lake Forest District and the Tokumm/Verrendrye Fire site is within Kootenay National Park. A mountain pine beetle-kill area in Gold Creek near Cranbrook was also briefly surveyed.

An initial review of available literature revealed a dearth of ecological or socio-economic information on the morels. There were no published scientific studies on the ecology of morels in BC, and only a limited amount of literature from neighbouring States and Territories. There is a small body of literature that includes discussion on the commercial importance of morels in the Province (De Geus, 1992 & 1995; Wills & Lipsey, 1999). Wills and Lipsey (1999) report that the BC/Yukon morel harvest may be as large as 225,000 kilograms per year. It is believed that this commercial harvest only removes a small proportion of the total morel crop (Betty Shore, personal communication, May 15, 2005).

During the summer of 2003 over 250,000 hectares of forest land burnt in BC (Filmon, 2004). Unlike past fire seasons, many of these fires exhibited unpredictable 'extreme fire behaviour' with 334 residences being consumed and over 45,000 people evacuated (Filmon, 2004). Following this intense fire season, the BC Government appointed former Manitoba Premier,

Gary Filmon to lead the Firestorm 2003 Provincial Review. Central in the recommendations from the Filmon Report was the case for the reduction of fuels in the forests, especially surrounding urban interface areas. If this fuel reduction work does take place at a large scale, there is considerable opportunity for stimulating future morel harvests in these treated areas through the use of prescribed fire as a management strategy.

1.2 Research Objectives and Hypotheses

The ecological study was primarily carried out using a Nearest Neighbour Method, a method not known to have been previously applied to such a study as this. Additional data were collected in order to produce estimates of morel production. Other ecological data were collected using ethnological techniques. Morel pickers are subject experts on both the ecological and socioeconomic aspects of the resource. The ethnographic portion used a modified questionnaire that was originally developed by for huckleberry research conducted by KKTC. In addition to these formal techniques, the author spent time picking morels for the commercial market, in order to achieve a better understanding of the resource and the industry.

Research Questions:

A series of hypotheses were developed about the ecology of morels, specifically:

Ecological Research Hypothesis I: Regarding plant distribution:

H₀: Morel mushrooms have no association with vascular plants.

H₁: Morel mushrooms are distributed in association with certain vascular plants.

Ecological Research Hypothesis II:

H₀: Morels are evenly distributed across the landscape.

H₁: Morels are found in the highest density in specific habitats.

Regarding ethnographic techniques, the hypothesis was:

Ethnological Research Hypothesis I

H₀: Commercial morel pickers harvest morels throughout the landscape with no habitat preferences.

H₁: Morel pickers target certain ecological conditions while harvesting in order to maximize their profits.

The relative absence of basic data on morel pickers suggested that it would be germane to collect data that included: age, gender, ethnicity, place of residence etc. an important addition to testing the above hypothesis. Morel harvesters were also queried on the volumes of morels picked, and their knowledge and opinions of regulations.

Chapter 2: Literature Review

2.1 Mushrooms as NTFPs:

There is no single, widely accepted definition of Non-timber forest products (NTFPs) (Belcher, 2003). The Centre for Non-Timber Resources (CNTR) defines NTFPs as botanical and mycological products of the forest other than “sawlogs, pulpwood and similar forest products” (CNTR, 2005). NTFPs include a wide variety of resources including: floral greens, wild mushrooms, wild berries, medicinal plants, native plants for landscaping and restoration as well as a wide variety of other products (Brigham, Whiteside, Fraser & Clay, 1998; De Geus, 1992 & 1995; Tedder, Mitchell & Hillyer, 2002; Wills & Lipsey, 1999). From the late 1980’s onward, there has been increased attention given to NTFPs in BC. During this period, the wild mushroom industry has moved from its infancy to intermediate stages along with other NTFPs, and importantly, it is during this period that the profile of these resources has risen with a series of key widely distributed reports being published (De Geus, 1992 & 1995; Tedder et al., 2002; Wills & Lipsey, 1999). In May 2004, the Forest Practices Board published a Special Report entitled *Integrating Non-Timber Forest Products into Forest Planning and Practices in British Columbia*. The report stated that the Board’s main involvement with NTFPs has been through its public complaints program; the complaints were concerning the effects of timber harvesting on NTFPs and concerns about the sustainability of the harvest of NTFPs.

Wills and Lipsey (1999) estimate that the NTFP industry in BC in 1992 generated close to 32,000 jobs (full and part time), had corporate revenues of \$280 million and Provincial revenues over \$630 million. This report aggressively promoted the industry and was controversial at the time of publication, both in terms of the numbers and the strategy

presented. A revised version of the report was recently revised and re-publicized (Cognetics International Research Inc., 2004); many of its findings and methods remain contentious (Mitchell & Cocksedge, 2004).

NTFPs are becoming increasingly prominent in both rural development and forest conservation throughout the world. In the 1990's many development agencies were promoting NTFPs as a major part of the solution to global forest conservation because of the perception that NTFPs would be worth as much as the timber, eliminating the need for logging (Brian Belcher, personal communication, July 15, 2004). This perception has moderated, but there remains a high potential for reducing destructive uses of the forest yet providing income and subsistence for many (CNTR, 2005). Within the past few years, the sector is gaining prominence in Canada and the United States. Tropical countries and research agencies such as CIFOR are in the lead in NTFP research, with northern nations like Canada following (CNTR, 2005). In neighbouring states and provinces, a number of useful and comprehensive texts have emerged including *Nontimber Forest Products in the United States* (Jones, McLain & Weigland, 2002). First Nations have expressed serious concerns about the sustainability of this growing industry by (Gayton, 2000; Tedder et al., 2002; Turner, 2001). This recent period has also witnessed the development of the first institution expressly concerned with NTFPs, the Centre for Non-Timber Resources which officially opened at Royal Roads University in 2004. The opening of the centre may be seen as a major step towards the sustainable management of this resource.

NTFPs have been a valued part of British Columbia's economy since long before European contact, as many of the species of importance today were also intensively used and managed by First Nations (Turner, 2001). This close connection to the forest gives First Nations a special place in the management of NTFPs. Their formal role has yet to be defined, except in

the case of the Nisga'a, whose modern Treaty includes the management of NTFPs (Nisga'a Lisims, 2004). Until the BC Treaty Process is complete, or alternatively a Supreme Court decision is reached concerning the ownership of these resources, it is unclear in the current political and legal climate who owns this resource, or which parts of the resource. Property rights in the NTFP resources remain unclear in terms of First Nations entitlements, and to society at large (Tedder et al., 2002). There is provision for the regulation of NTFPs in the Forest Practices Code and the Forest and Range Practices Act on BC Crown lands. The only tenures currently employing this legislation are the Community Forest Licences. The Harrop-Proctor Community Forest Pilot Project located near Nelson, BC has gone the furthest of any Community Forest in the management of the resource. This group has conducted inventory and harvesting research, but as yet is not ready to implement wide scale harvesting of the resource (Evan Mackenzie 2004, personal communication, June 10, 2004). The vast majority of NTFP harvesting occurs on a highly informal basis, ranging from highly sustainable to the other extreme. For example, herbalist Diane Luchton of BC's West Kootenay has carefully managed her NTFP collection areas for over twenty years and has recently experienced trouble with commercial pickers "pillaging" these patches that are close to her heart, but not hers to defend as they are located on Crown lands (personal communication, October 19, 2004). This problem is analogous to some of the commercial berry pickers over-harvesting the black huckleberry resource in the East Kootenay, leaving few berries for the bears or the Ktunaxa Elders as described by Liz Gravelle in Gayton (2000). Such concerns of inappropriate harvesting speak to the need for the development of a legal framework for resource management; in addition these concerns speak to a need for more extensive collection of

baseline data on the resource along the lines of the current efforts in Harrop-Proctor and Northern Vancouver Island.

There is clearly a need to research both ecological and socioeconomic aspects of the NTFP industry because and to understand their linkage. By gaining a greater understanding of the various NTFP species, opportunities will be gained to pair the management of these species with timber and other values. This understanding will also give resource managers an enhanced ability to set appropriate harvest levels. A more complete data set on the socioeconomic aspects will likely help to give harvesters a greater voice in the management of these diverse resources. A continued absence of concrete information may lead to the deterioration of the resource(s), increased conflict and the possibility of ill-considered legislation.

Of the NTFP fungal species, the pine mushroom (*Tricholoma magnivelare*) may be the best understood NTFP mushroom species, but our understanding of the species is far from complete (Wiensczyk & Berch 2002). Chanterelles (*Cantharellus*, *Craterellus* & *Polyozellus spp.*) have seen recent attention by researchers (Ehlers n.d.; Pilz, Weber, Carter, Parks & Molina, 2004) and are likely the next best researched NTFP fungal species in the Pacific Northwest. Both of the above mushrooms are different from morels as they are obligatorily mycorrhizal (Weber, Pilz & Carter, 1996) and typically fruit every year alongside their plant hosts, providing conditions are suitable. In the case of morels, the scope of their trophic status is still not clear and they are only known in Western North America to fruit in commercially viable quantities in following wildfire and possibly insect attacks. Morels which fruit following wildfire are known as 'fire morels' (Weber et al., 1996). The fire morel sites are of the greatest known economic value, but highly ephemeral and therefore uniquely challenging to planned research

(Weber et al., 1996). The fire morels are the least well known of the morels (Weber et al., 1996).

2.2 Background on Morels

Morels belong to the Ascomycetes subdivision of fungi, and in to the order Pezizales (Arora 1986). This order of fungi has an exposed spore-bearing surface (hymenium) and their asci have 'lids' which open when the spores are forcibly expelled (Arora, 1986). This order also contains the highly valuable true truffles, which produce a underground or hypogeous ascocarp (O'Donnell, Cigelnik, Weber & Trappe, 1997). Morels are "epigeous apothecial ascomycetes" (O'Donnell et. al., 1997, p. 48), meaning that their fruiting body is above ground and has asci which hold the spores inside the cells until they are forcibly ejected. The morels and truffles are amongst the most highly prized fungi in the world (Pegler, 2003). Other than the truffles and morels, the majority of the well-known edible fungi belong to another order of fungi, the Basidiomycetes.

Arora (1986) states that morels belong to the family Morchellaceae, which contains three genera: *Morchella*, *Verpa* and *Disciotis*. The true morels are classified in the genus *Morchella*.: Fr (O'Donnell et. al., 1997), with representation throughout the world (Scott & Mohammed, 2004; Weber, 1995). There has been no definitive treatment of morels for any large part of the world (Weber, 1995). Weber (1995) argues that there are less than one dozen "good" species of morels. Her book divides *Morchella* into three groups centered on the following species: half-free morels (*M. semilibera*), black morels (*M. elata*, *M. angusticeps*) and common morels (*M. esculenta* & *M. deliciosa*). Arora (1986) follows a slightly different approach grouping only the black morels (*M. elata*, *M. angusticeps* & *M. conica*) into a species

complex. Kirk (2004) in Index Fungorum lists 197 species and subspecies in the genus. O'Donnell, Weber, Rehner & Mills (2003) undertook a genetic study from a global collection of around 600 samples; this study “nearly fully resolved phylogeny in which a monophyletic *Morchella* comprised two sister clades: the ‘yellow-tan-grey’ morels (*Esculenta* clade) and the ‘black’ morels (*Elata* clade) with 13 and 15 species respectively” (p.1). It is believed that North America is the centre of diversity for the genus (Pilz, Weber, Carter, Parks & Molina, 2004), with 13 endemics, four in the *M. Esculenta* clade and nine in the *M. Elata* clade; this and other evidence suggests that North America may be the ancestral home of *Morchella* (O'Donnell et al., 2003). Pilz et al. (2004) divides the morels of the Northwester US into five putative species, PS A, B, C, D, and E. Taxonomic uncertainty has caused investigators to report they were investigating multiple species when only one species was being investigated (Scott & Mohammed, 2004). This challenge furthers the difficulties of comparing the work of others, “as the comparison may or may not be valid depending upon the veracity of the taxonomic identification” (Scott & Mohammed, 2004, p. 44.). Identification of morels to species without the aid of molecular genetics is a great challenge as species within the groups may appear homogenous to the naked eye; thus a species group or clade approach simplifies research, although it may lack the detail necessary for a complete understanding of ecological behaviour of individual species.

2.3 Role in ecosystem

There is considerable uncertainty in the literature concerning the trophic status of morels. Morels are known to fruit in areas following fire (Weber et al., 1996); Dutch elm disease (Weber, 1995); in association with cottonwood (*Populus spp.*) (Betty Shore, personal communication May 1, 2004); old fruit trees (Weber, 1995); and in many other conditions. In Ower's patent titled *Cultivation of Morchella* (1989) a process is described which induces morels to fruit entirely as saprobe. Opinions range from morels being saprobic to facultatively mycorrhizal or a combination of both (Buscot & Kottke, 1990; Buscot 1992; Gramss, Gunther & Frische, 1999; Hobbie, Weber & Trappe, 2001; Lakhanpal, Shad & Sagar, 1991). Putative ectomycorrhiza have been observed on Casuarinaceae in Australia (Peter McGee, personal communication, January 3, 2005). The prospect that morels are facultatively mycorrhizal has been debated since at least 1936 (Dahlstrom, Smith & Weber, 2000). According to Buscot (1992), morels have two main strategies for fructification: they may "grow and fructify as saprophytes on recently disturbed soils" or

in forest ecosystems, morels form hypogeous sclerotial aggregates around suberized mature tree roots, which rest over winter and provide the nutrients for the vernal fructification. In association with *Picea abies*, the sclerotial aggregates also produce a new, subterranean, vegetative mycelium in spring, which is able to succeed as ectomycorrhizal partner to a specific primary mycobiont" (Buscot, 1992, p. 12).

Peterson, Massicotte & Melville (2004) states that relatively few ectomycorrhizal fungal species are known to "form sclerotia in the extraradical mycelium", though a few species have been studied in detail, other "mycorrhizal fungal species of *Gyrodon*, *Boletus*, *Austropaxillus*,

Cortinarius, and perhaps *Morchella*, are also known to form these structures” (p. 33). The preceding statement is indicative of the uncertainty surrounding the trophic status of morels.

The relationship described by Buscot (1992) is further complicated by his research indicating that mycorrhization “is promoted by a *Bacillus* which can be isolated from the ascospores” (p. 16). Morels are known to fruit in association with tuberous begonias (Volk & Leonard, 1990). In a paper concerning the degradation of soil humic extract by fungi, bacteria and commercial enzymes, Gramss et al. (1999) refers to morels as being an ectomycorrhizal. Hobbie et al. (2001) performed isotopic analysis on a host of fungi believed to be saprobic or mycorrhizal; their isotopic information confirms Buscot’s arguments that morels employ both trophic strategies.

Dahlstrom et al. (2000) describe an experiment in which they observed morels forming a “mycorrhiza-like” relation with four species in *Pinacea* in vitro without the addition of helper bacteria or primary colonizing fungi. Based on the results of their study, they postulate that morels may employ the following strategies:

- if only weakly mycorrhizal, morels would be “able to obtain a constant supply of fixed carbon”
- perhaps morels form mycorrhizae to “acquire nutrients from living trees but also to position themselves to decompose fine rots as they senesce or in the event of tree death”; or
- perhaps the “colonization provides no mycorrhizal benefit or may even act as a parasite”. (p. 283).

The authors also state that “These possibilities also have ecological significance in understanding carbon dynamics of the rhizosphere microbial community” (p. 283).

Regarding the strategies of *Morchella*, Volk (2004) suggests that after mass post fire fruitings that many of the ascospores germinate, form mycelia and then sclerotia by the end of the growing season, in this scenario they exist in the form of sclerotia, or cycle between sclerotia and mycelia and do not fruit until the next fire. This hypothesis, with minor modification, fits the pattern of morel fruiting in the East Kootenay. In that area, morels are known to fruit in low densities in many habitat types, but they only fruit in high density following fire and other disturbances. Morels commonly fruit in association with *Geopyxis carbonara* in the post fire setting (Obst & Brown, 2000)

Although references are not found within the literature, morels may act as part of a vernal dam, securing nutrients that might otherwise leach away during spring rains (Richard Winder personal communication, December 13, 2004). The vernal dam concept asserts that certain species may sequester large amounts of nutrients that are released for the general benefit of the ecosystem (Anderson & Eickmeier, 2000). It is well known that wildfires are often followed by major erosion, especially following salvage logging. Morels in their often great abundance following fires may be playing a key role in these ecosystems. This is perhaps the greatest concern with the sustainability of morel harvests, that being the potential loss of nutrients in the post-fire ecosystems.

In agricultural environments, morels are well known to fruit in association with fruit trees, in particular, apple, pear and peach trees (Weber, 1995). All of these trees are members of Rosaceae. None of the scholarly literature discusses this relationship, neither is there extrapolation to wild members of the family. Winder (personal communication December 15, 2004) suggests that there is a large chance that *Morchella* does form associations with Rosaceae, citing morel collections deposited in the Pacific Forestry Centre herbarium that were associated with ocean spray (*Holodiscus discolor*) and cherry laurel (*Prunus laurocerasus*).

2.4 Human Uses

Morels are undoubtedly best known as a gourmet wild edible “mushroom”. There are a number of publications that contain recipes for morels (Weber 1995; Lonick 1999; 2002, Ratzloff 1990) as well as a plethora of websites with recipes. Morels are not known to have been used by First Nations people in Canada prior to European contact; this is evidenced by their absence in Kuhnlein and Turner (1991), a highly comprehensive ethnobotanical text that includes a host of other fungi.

Human consumption of morels and the manipulation of habitat to maximise production dates back at least to the Middle Ages in Europe. At that time people were aware of the connection of morels to fire and employed it as a tool to increase production (Ratzloff 1990). Ramsbottom as cited in Weber (1995) reports from Germany that: “women who harvested and sold morels deliberately set small fires in an effort to increase morel production. It worked, but as major forest fires sometimes resulted, the authorities quickly banned the practice” (p. 170). The practice of burning for morels continues to date in India’s Himalaya Region: “Local people set

the ground on fire every year during October/November, assuming that such a practice will improve Morchella yield” (Prasad et al., 2002, p. 1098).

Along with their food uses, they are also known to be medicinal (Prasad et al, 2002, Maikhuri, Nautiyal, Rao & Semwal, 2000; Ratzloff, 1990). The Bhotiyas of India are known to use morels in the treatment of colds and coughs (et al., 2000). It is reported that the Bhotiyas prepare a decoction of *M. esculenta* with boiling water, and the locals in the Kullu District of Himachal Pradesh prepare their decoction with milk (Prasad et al., 2002). Morels are known as ‘sheep stomachs’ in China and are used as a stomach medicine (Ratzloff, 1990).

When considering Morchella from the ethnological perspective, the genus offers two intertwined values, those being income from sale and direct use as a prized food product. Wills and Lipsey (1999) estimated that the global trade of morels was approximately 225,000 kg per year; it is unclear whether this datum refers to fresh or dry morels.

Mushroom pickers may be categorised as either passionate mycophagists or ‘mushroomers’ and commercial pickers who pick for profit (Fine, 1998). The BC literature focuses on the latter group (De Geus, 1992 & 1995; Wills & Lipsey, 1999). In the state of Michigan, there is a substantial tourism industry associated with the morels that includes: picking competitions, picking guides (like fishing guides), morel festivals and more (Weber, 1995). There are clearly opportunities for this type of ecotourism in BC.

All the true morels are known to be edible (Arora, 1986; Groves, 1979; Weber, 1995). Despite their edibility, there are reports of adverse reactions to their consumption (Arora, 1986; Kenny, 1996; Weber, 1995). It appears that many of the reactions occurred because of improper preparation or identification. Kenny (1996) describes a case in Vancouver's Hyatt Regency where guests were served raw morels marinated in alcohol, within 20 minutes many of the guests at the police chief's retirement were ill. Kroeger (1991) in his article: "*Yum' said the police chief*" reported that the "symptoms were typical of raw morel poisoning"; the author surveyed 24 of the victims and: "20 of them reported nausea, 16 diarrhoea, 12 vomiting, 7 cramps, 4 rapid and severe sensation of bloating, and 2 a hive like rash (*sic*)" (p. 34)." Weber (1995) reports that there are higher levels of sensitivity to the black morels than to other morels.

Misidentification is one of the most serious threats to safe morel consumption. The closely related genus *Gyromitra* is known to contain gyromitrin, a compound that, under certain conditions, breaks down or metabolizes into monomethylhydrazine (MMH). MMH is a volatile, highly toxic compound that is not always thoroughly removed by cooking. The beefsteak morel (*Gyromitra esculenta*), also known as the brain mushroom, is the best known species in the genus; there have been deaths and poisonings associated with this species (Arora, 1986; Weber, 1995). *Verpa*, another closely related genus, is more easily confused with true morels; this species is considered 'edible with caution' and is known to cause stomach pains and delirium in some people (Arora 1986). Kenny (1996) reports that the US Food and Drug Administration (US FDA) undertook a study that revealed "21 percent of morels in the market were contaminated with toxic look alike species" (p. 5). In 1996 the US FDA re-issued an alert

pertaining to morel consumption; in this alert they report contamination of true morels with false morels (*Verpa* and *Gyromitra* species) (United States Food and Drug Administration [US FDA] 2004). This alert underscores the importance of properly trained pickers and buyers along with the possible need for regulations that protect public safety. Fortunately with a minimal amount of training, people can clearly distinguish between the true and false morels. The KKTC and RRU's CNTR held a workshop in April of 2004, at the very beginning of the morel season. In this workshop, participants from a wide array of skill sets learned the basics of morel taxonomy and picking in preparation for the season (Keefer, 2004).

Other than misidentification, a second type of concern with the consumption of wild fungi is that wild mushrooms are efficient at accumulating heavy metals (Isildak, Elmastas, Tuzen, 2004; Obst, Coedy & Bromley, 2001). Morels are especially efficient at accumulating lead (ibid.). Obst et al. (2001) in their study in the North Great Slave Region of the Northwest Territories found that the levels of heavy metals in some of their collections exceeded the annual tolerable levels of the World Health Organisation provisional tolerable daily intake. These findings run counter to the perception of wild fungi being a 'pure, healthful, natural' product. There are key areas in Southern BC where metals may be a concern; some of them are Greenwood, Trail and Kimberley. Greenwood was the location of the BC Copper Company smelter and may still have elevated levels of metals (Forward 1987). Trail, BC is well known for concentrations of metals in the soil. Kimberley is the site of the Sullivan Mine; a lead, zinc, and copper mine that operated for close to 100 years (TeckCominco, 2004). Given the results of Isildak and Obst, it is clear that areas with significant mining/smelting history should not be used for the gathering of wild mushrooms until further study proves these areas as being safe

with reasonable certainty. On the subject of metals, Winder (personal communication, February 14, 2005) points out that, “in some mushrooms, metals are bound into novel compounds that are not biologically active to human metabolism”. No information was found on the potential hazard of consuming morels from areas with fire retardant, a potential avenue for additional research. This need poses a significant challenge to overcome in an industry where pickers are free to pick wherever they want, as long as it is not within a protected area (Berch, 2004).

2.5 Cultivation (*in vitro* & agroforestry)

The earliest attempts of morel cultivation can be categorised somewhere in the area between true agriculture and gathering. This dichotomy is well documented in the case of many of the species of plants that were essential for the survival of First Nations people in the pre-contact era (Peacock and Turner, 2000). Weber (1995) describes a number of attempts of semi-cultivation as she calls it, the most interesting example being Roze (1888). In this case, Roze inoculated fields of Jerusalem artichokes (*Helianthus tuberosus*) with morels; the morels apparently attached themselves to the rhizomes of these plants (Weber, 1995). Richon and Roze as cited in Weber (1995) later reported the failure of their experiment. Both of these species are well known to be inulin containing plants (Max Planck Institute, 2004). Weber described another interesting episode in which Crown Zellerbach Company was experimenting with using paper mill sludge as a fertilizer on corn and beans, and a significant morel fruiting followed (Weber, 1995). The former study raises concerns of the possible bioaccumulation of dioxins and furans; which two chemicals are not (or “a risk which is not”) found in the literature in relation to morels. There is a Chinese website purporting to sell a patent for the cultivation of *M. esculenta* for a price of \$60,000 US. From the pictures on this website, it

appears that their method falls into the category of semi-cultivation (Chinarivers, 2004). The more recent experiments of morel cultivation are generally conducted *in vitro*.

The *in vitro* cultivation of morels would present an excellent opportunity to study the genus. Ower, Mills & Malachowski (1989) filed a series of three US Patents on the cultivation of morels. The patents are purported to describe the first ever successful attempt of growing morels indoors under environmentally controlled conditions; the previous attempts were only successful outdoors. This work was valuable in determining the life cycle of morels. It was confirmed in this work that morels form sclerotia, a “hard surfaced resting body of fungal cells resistant to unfavourable conditions, which may remain dormant for long periods of time and resume growth on the return of favourable conditions” (Ower et al., 1989 p. 4). The role of sclerotia as a nutrient sink is critical in the study of the morel life cycle (Volk & Leonard, 1990). Sclerotia are not found in other cultivated mushrooms, thus complicating the process, as sclerotia can either germinate as new mycelium or fruiting bodies, and the former is far easier to develop (Volk, 2004). Even when one is successful in cultivating the development of primordia, they are prone to abort (Volk, 2004).

Weber (1995) reported that in 1987 that the Neogen Corporation was working on refining Ower’s process. A recent phone call to Neogen revealed that the company is no longer involved in morel research (Neogen Corporation, personal communication, December 16, 2004). Ower’s patent was since sold to Terry Farms in Auburn, Alabama which opened a production plant (Hammond, 1999). A search on the worldwide web December 30, 2004

revealed no website for Terry Farms and no other companies advertising cultivated morels; may indicate this is indicative of a lack of commercial success for morel cultivation.

3.0 Chapter 3: Methods

3.1 Introduction:

Three primary methods were used to garner information during this project:

1. Ecological survey;
2. A Questionnaire for Pickers and associated ethnographic techniques; and
3. Observations of morel distribution made by the author while moving between plots and acting as a picker as well as picking with his family.

The first two were the primary methods, but it was apparent that the third method may reveal interesting patterns or trends and stimulate the discovery of questions to investigate. All data was entered in Microsoft Excel 2003.

3.2 Ecological survey

In order to cover a wide geographical area a method was required that would allow for the rapid collection of data in the plots. A further constraint for methodology was that the decision to proceed with this research was reached in late April of 2004, the beginning of the morel season. A 'nearest neighbour' sampling approach was adopted for extensive, rather than intensive, sampling. With the key question of possible plant associations, this method was preferred over intensive ecological plots. The method was tested and modified in the field prior to the commencement of the sampling program.

Plots were selected using two methods:

1. systematic: as the author travelled through the fires, areas with morels were located and plots were taken in these sites, the first morel sighted was always the plot centre;
2. systematic random: plots were selected in each fire being researched and accessible by road by first defining a corridor of 100 m on all roads, then letting Arc View 3.2 assign 10 random locations in each biogeoclimatic zone; the researcher then loads the waypoints into a GPS Unit and finds the points on the ground.

Based on past experience in the Kootenay Region, the Garmin Etrex handheld GPS unit typically has between 5-10 metre accuracy limiting its use to establish plot centre. Given this difficulty, the first morel sighted (if there were any) near the waypoint was used as plot centre in order to reduce bias.

It was intended that all fires would be surveyed using both methods. Upon finding plot centre by either method the following data is then collected within a 3.99 radius plot area:

1. the nearest 2 herb, shrub and tree species;
2. canopy cover (estimated in percent);
3. morel density (all specimens are counted in plot as well as a breakdown between species groups);
4. the presence/absence of the cup fungi *Geopyxis carbonara*;
5. percentage of the duff layer consumed (from 0 to 100 % of duff consumption, a visual estimate was made of consumption within the plot area that included the presence of ash and the estimated level of consumption of the duff);

6. fire intensity, a general estimate of the fire severity in the surrounding area this was a composite of crown and duff consumption; (high, medium, low)
7. overall morel production in general plot area;
8. photographs of plot centre and then site photos in the four cardinal directions; and
9. Geographic coordinates (in systematic plots).

A total of thirty-seven systematic and fifty random-systematic plots were taken. Analysis was conducted using the systematic-random plots for an unbiased measurement of productivity.

Due to many commitments and the short duration of the harvest season, not all systematic plot locations were visited. Vegetative analysis was conducted with both data sets, because it was necessary to ensure the presence of sufficient morel populations in the analyses. Regarding the difference in the two selection methods, a follow-up study is planned to compare vegetation in the two types of plots. Hence, it will be possible to test the putative plant indicators found in this study versus randomly selected vegetation typical of the area.

The wildfire sites that were surveyed for plant associations were: Lamb Creek, White River Middlefork, Plumbob, Tokumm Creek, Ram/Cabin and Carol Creek. At present, both the Lamb and Plumbob fire sites have been surveyed using the systematic method. The plot locations have been mapped on BC TRIM using Arcview 3.2 software.

All plants found within the plots were identified using macroscopic observation of foliage and floral characteristics. In most cases, the plant neighbours were identified to the species level. Due to the hybridisation of spruce (*Picea glauca* x *P. engelmannii*) in the region (Parish et al. 1996), spruce was only identified to genus.

3.3 Ethnographic Methods:

In order to capitalize on the informal ecological knowledge and to develop an understanding of the socio-economic aspects of the morel harvest, a number of techniques were employed, including a questionnaire, two focus sessions, and informal interviews. The questionnaire was originally developed for a Ktunaxa huckleberry use study at KKTC in 2001. In early May, 2004, the berry questionnaire was modified to suit the purposes of this study. In order to ensure ethical research was being conducted, the questionnaire and letter of consent were reviewed and approved by the RRU Ethics Committee prior to distribution. Please see Appendix I for the approved questionnaire and the letters of permission.

The questionnaire was only distributed at the buying stations where pickers were selected on the basis of being willing to participate in the research. The questionnaires were delivered at the various morel buying stations in Lamb Creek from a period beginning in late May until mid-July. Participants were approached as they arrived at the buying stations and orally informed of the purpose of the research and were informed that a small gift of either a \$5.00 gift certificate or an ethnobotanical handbook written by the author were being offered as an inducement to participate. Participants were then given the choice of filling out the questionnaire orally or by themselves. Following their completion, participants were then offered their gift and thanked for participating. A total of twenty-seven questionnaires were completed. Picker data was entered and processed in Excel 2003. In a number of questions pickers were provided the choice to provide their data in dollars, pounds or litres; all pickers provided data in either dollars or pounds. The pounds data was converted to dollars at the conservative price per pound of three dollars in order to integrate the data.

Two focus sessions with morel pickers were held, both on December 1, 2004 in Cranbrook. The first session was held at the KKTC office; it was primarily attended by Ktunaxa pickers and was attended by eight community members. The second session was held in the evening of the same day at the College of the Rockies and was attended by ten people. During both of these sessions, discussions were focussed on the pickers' experience and knowledge of morel harvesting and ecology.

Throughout the duration of this study, informal interviews and discussions were conducted with subject experts. These experts include: three mushroom buyers, experienced morel harvesters, and five biologists.

3.4 General Observations

Critical elements of this study were to understand both the resource and the overall culture of picking morels. Informal anthropological methods such as participating in the harvest were expected to be a valuable means of developing hypotheses and documenting the morel harvest. With the exception of Kootenay National Park, the researcher harvested morels throughout the different fires. This method of learning to think like a picker was invaluable in a number of ways, it:

- enhanced the researcher's skills at 'morel spotting';
- allowed for a large area to be covered, where patterns in morel distribution could be observed;
- gave the researcher an enhanced discourse with the morel pickers; and

- provided an abundance of morels to share within the KKTC office, thus promoting community interest in the research.

By picking morels commercially and selling them at buying stations, the research was able to bring to light several economic aspects of the harvest.

Chapter 4: Results

4.1 Ecological Research

The ecological research portion of this study included a total of 37 systematic plots and 50 systematic-random plots. Within the fire sites, there were a total of 27 plots in the Lamb Creek; eighteen in Plumbob Creek; nineteen in White Middlefork; ten in Mission Creek; and 23 in Tokumm/Verrendrye; there were eleven plots taken in the beetle kill area in Gold Creek (Please see Appendix V for photos). Analysis of the data revealed high levels of heterogeneity.

4.2 Nearest Neighbour Experiment

The data from nearest neighbour measurements (see Appendix II) were valuable in helping to describe the cohort of plants found with morels fruiting in the study area. Future visits to random control plots in the study area are planned to improve the statistical assessment of the putative indicators.

Fireweed (*Chamerion angustifolium*) and heart-leaved arnica (*Arnica cordifolia*) were the two most common herbaceous plants to occur as first neighbours, with 21 occurrences; the third most common species was pinegrass (*Calamagrostis rubescens*), with 19 cases. The four most common second neighbour herbs were: *Calamagrostis rubescens*, 13, aster (*Aster/Erigeron spp.*) eleven occurrences and *Chamerion angustifolium* and glacier lily (*Erythronium grandiflorum*) with four occurrences. It is likely that *Chamerion angustifolium*, *Calamagrostis rubescens* and *Aster* or *Erigeron spp.* all turn up prominently due to their abundance. In the case of *Erythronium*, it is known to contain fructooligosaccharides (Loewen 1998), these are inulin-like saccharides.

The most common shrub to occur as a first neighbour was birch-leafed spirea (*Spirea betulifolia*) with 18 occurrences, the second most common was prickly rose (*Rosa accicularis*) with seven occurrences, and the third most common was false azalea (*Menziesia ferruginea*) with six occurrences. *Spirea* and *Rosa* were the two most common with eleven and seven occurrences respectively and *Vaccinium membranaceum* the third most common with five occurrences. The prominence of *S. betulifolia* and *R. accicularis* as the most common first and second neighbours may speak to their relative abundance in these ecosystems; but it may also indicate an association with *Morchella*. (Please refer to Appendix II - Table II)

Abies lasiocarpa was the most common first neighbour with 19 occurrences; the second most common first neighbour species encountered was *Pinus contorta* with 18 occurrences. *P. contorta* also occurred as the most frequent second neighbour with 23 occurrences, the second most common second neighbour was *Picea X* with 15 occurrences (Please refer to Appendix II - Table III).

4.3 Morel Production

A key value that this research sought to quantify was that of overall morel ascocarp productivity in fire habitats morel production. Production data was separated in two classes: systematic-random plots and systematic plots which were separated between fire sites and Gold Creek. When this data was converted to morels observed per hectare the following production figures were obtained:

- Random fire plots 760/ ha

- Systematic fire plots: 420/ ha
- Systematic Gold Creek (beetle and logging disturbed) plots: 120/ ha (Please see Appendix II - Table V).

These results help to illustrate the variability of the morel crop. Surprisingly, the systematic plots had lower productivity than the random plots; this verifies that plot selection was unbiased. Regarding the Gold Creek plots, actual productivity may have been higher than the observed productivity, because dense pockets of fruiting observed during harvesting were not included in the small number of random samples assayed.

Although duff consumption data were recorded as percentages, they were categorized into ten equal classes to facilitate analysis. Overall and class means were calculated for the Middlefork, Mission and Tokumm/Verrendrye fires individually and then together as a group. (Lamb and Plumbob fires were omitted due to missing data). The results of this analysis illustrated that mean morel production was highest in class five and six (44 and 46 per plot respectively) and lowest in class one, two and ten (2, 9 and 13 respectively) (See Appendix II, Table III and Figure 1). Where there was sufficient data to calculate variances, the variance was highest in class seven (12,747) and lowest in class one and ten at 288. The data indicate that one is more likely to find an abundance of morels at the mid levels of duff consumption but also that production was highly variable under those conditions.

4.4 Ethnological Research

4.4.1 Picker Survey

The picker surveying resulted in a total of 27 questionnaires being completed. Data was not collected on the percentages of potential participants who declined to participate; about 75% of

all pickers approached agreed to answer the survey. It was found that the time between three and five o'clock was the most effective time to interview at the buying stations, as this was the period when the traffic was most brisk.

The General Information section of the questionnaire provided an interesting profile of the picker population (please see figures 1- 5, Appendix III). Concerning ethnicity: 74% of pickers were non-native; 11% Ktunaxa Nation members; and 15% were of other First Nations ancestry. The gender breakdown was 48% female and 52% male. The mean age group of the pickers was the age class 35-44 years and the median age group was age class 45-54 years old. Regarding number of years experience picking morels, 59% were first year, 19% were second year and 22% had five or more year's experience.

The socio-economic data illustrated the diversity of picker interests and the variable nature of earning potential (please see figures 6-19, Appendix III). Data from some pickers is anonymously displayed in some graphs; these numbers are in the order that the pickers were surveyed. Concerning why they pick, 67% exclusively pick for sale; 12% pick for personal use and sale; 6% pick for sale and sharing; 12% pick for all of the above reasons and three percent for other reasons. The average picker had earned \$1,877 with a standard error of 9.6; total earnings ranged from \$90.00 to \$7,500.00. A large majority of pickers (84%) reported earning less than 10% of their annual earning picking morels; 12% reported earning ten to 25% and 4% reported earning 26% to 50% percent. There was a wide range of average daily earnings \$125.00, the best pickers earn roughly \$150.00 per day; the average picker earns \$89.00

(standard error = 1.4). There was an even larger range in the best day's earnings \$356.00, the best day reported was \$381.00; the average best day figure was \$165.00 (standard error = 2.1).

A significant number of pickers (56%) reported collecting other NTFPs; of these people: 47% pick for personal use; 42% for sale and 11% pick for both reasons. NTFPs reported include: floral greens, antlers, berries, art material, fern fiddleheads and medicinal plants. One third reported picking other fungi; of these fungi, chanterelles were picked by all those people, other species reported being picked were boletes, false morels, pine mushrooms, lobster mushrooms and cauliflower mushrooms.

A majority (56%) of respondents reported that they sold to the same buyer every day. A minority (29%) generally sold to the same buyer, 10% sold to the highest bidder, and 5% found other outlets or uses for their morels. Almost half of those interviewed (49%) do not dry their own product; 44% dry theirs and 7% did not respond. Of those who dry their product, nine people dry less than 10%; two dry 11-25% and one dries 26-50%. The acceptable price for dry product to those surveyed ranged from \$9.00 to \$75.00 per pound with an average of \$41.91 (standard error = 0.92). In conversation, the more experienced people generally like to keep their dry product until the winter as they felt that prices are generally higher for product by this season.

While completing the ecological section, many of the pickers stated "it depends on season, weather and other variables" and were somewhat uncomfortable with the limits of the answers. While completing the questionnaires, it was clear that many of the pickers were not familiar

with the regional flora. These data are presented in Appendix III, Figures 20 to 31. The general habitat preference of the pickers was burnt but unlogged forest; 93% selected this type. High elevation sites were preferred by 49% of respondents, with no response being the next dominant category (33%). South was the preferred aspect for picking (49%), north and west both scored 23% with west scoring 10%. Wetter sites were preferred by 60% of respondents with 'no response' at 29% and 'dry' at 11%. Lodgepole pine (*Pinus contorta*) was the preferred associate with thirteen selecting this species, western red cedar was the next most preferred associate at twelve selections. Regarding the question of possible plant associations, 39% were aware of them; 36% did not respond and 25% were not aware. Plants that people reported being associated with morels are: wild rose (*Rosa spp.*) with 2 respondents, thimbleberry (*Rubus parviflorus*), bracken fern (*Pteridium aquilinum*), a little yellow flower most likely glacier lily (*Erythronium grandiflorum*), shooting star (*Dodecatheon pulchellum*), false azalea (*Menziesia ferruginea*), pine (*Pinus spp.*) and soopalalie (*Shepherdia canadensis*). Three people also mentioned cup fungi being associated. A large majority (96%) believe that there is a link between weather and morel production, the most commonly reported condition being rain followed by sunshine. A minority (29%) of pickers were aware of indicators for harvest time and volume; reported indicators included: Mother's Day, pinheads, morel pickers, following snowmelt and strawberries in flower. The majority (59%) of respondents felt peripheral areas of fires are more productive. A minority (29%) of pickers felt that hotter areas of fires are more productive; 54% feel they are less productive. Concerning management techniques, 44% of respondents were aware of them. Techniques mentioned included: cutting morels, leaving the small and poor quality specimens and harvesting mostly the clusters; 40% report practicing these types of techniques.

The production system questions focussed on the need for and feelings of the potential for regulation (this data is presented in Appendix III, Figures 32 to 33). A minority (26%) of pickers reported problems with other pickers, these include: competition; theft; accusations of being a thief; the claiming of territories and blocked roads. On the question of awareness of rules governing the industry, the awareness was low:

- 26% were aware of rules concerning harvesting;
- 19% were aware of rules concerning selling morels;
- 26% were aware of laws concerning the buying of morels; and
- 11% were aware of laws concerning processing morels.

Opinions on laws governing NTFPs were similarly low; the support for legislation was as follows:

- 19% for harvesting laws and 81% against;
- 19% for selling laws and 81% against;
- 22% for buying laws and 78% against; and
- 22% for processors laws and 67% against.

There are major hurdles for legislators to confront when considering selling legislation to pickers. It was apparent from the morel harvester's comments in this area that the concerns surrounding legislation are linked with concerns over taxation.

4.4.2 Informal Conversations with Pickers, Buyers

During these conversations, there were a number of recurring themes:

- pickers perceived that the buyers were fixing prices;

- the buyers stated that they had little control over prices;
- a number of pickers felt the buyers were too picky in the product they purchased.

Along with these frequent comments, there were a number of observations. The comments of some pickers and buyers made it clear that a number of pickers were not aware of, or did not care that they were handling a premium food product. One buyer reported finding morels that a picker had stuffed pebbles into; the buyer observed that in the time the picker took in this activity that they could have simply picked more morels and would have been paid! A number of people recalled the Canal Flats morel season of 1984 which some claimed to have earned upwards of \$200.00 per day in 1984 dollars.

At the Plumbob Creek Fire, there was rumour of a shooting related to a road blocked by a vehicle. When the Cranbrook RCMP were queried, they could not confirm the veracity of the story as there was no record of the incident. There were also similar rumours of aggressive bears that proved to be apocryphal. It appears that both of the above cases were urban/morel legends.

4.3 Preliminary Results from Case Study Team

The case study team is continuing to compile data concerning total productivity. Betty Shore (personal communication August 30, 2004) provided information on the total harvest, with reports from one buyer still forthcoming, her estimate is 222,000 kg. Roughly one third of this product was dried at the buying stations using portable driers. These figures do not include the product that the pickers dried personally for later sale. Once fully tabulated, the figures will be published with the Kootenay Morel Case Study paper.

4.4 General Observations

It was anticipated that in a short amount of time, it would be possible to form testable hypotheses, check them in the field, and be able to determine patterns in morel behaviour. It rapidly became apparent that the morels are indeed as mysterious as other pickers had insisted. Areas that had appeared, at initial inspection, to have high potential proved to have no morels and other areas that looked hopeless, from a harvester's perspective, had an abundance of morels. Despite this, a number of trends did become obvious.

In the area near Monroe Lake in the Lamb Creek fire, there were dry rocky areas with scattered mallow ninebark (*Physocarpus malvaceus*). Within 1m of virtually all these shrubs, morels were observed. In the areas of similar soils nearby there were no morels observed.

The early stages of the literature review and conversations with subject experts had indicated that higher levels of calcium were beneficial to morels. An initial hypothesis was formed that low lying areas with glaciolacustrine soils would be especially productive due to their high alkalinity. To the surprise of the author, no morels were observed in the first such site visited in the Plumbob fire area. The valley bottom of the White Middlefork is also characterised by the low lying areas being covered by soils appearing to be glaciolacustrine. During the field visits in this fire, few morels were found in the latter mentioned soil type, yet nearby side slope areas with soils that appeared to be colluvial or morainal had moderate to high productivity. It is hypothesized that the alkalinity is too high on these glaciolacustrine sites following fire.

Conversations with experienced pickers revealed that black cottonwood (*Populus trichocarpa*) was an excellent indicator for high productivity morel picking. Due to the relative lack of black cottonwood in the area, no cottonwood sites were surveyed in the systematic random plots. A small number were surveyed using the systematic method for plot selection.

Cottonwood stands are also locally known to be good areas for non-fire morels. Despite this, there were a number of low elevation areas with black cottonwood that were accessible for family picking. These areas all had moderate to high morel production, especially around the bases of black cottonwood trees and stumps. One such site was visited in the Lamb Creek fire area; at this site, morels were only found within 2m of the cottonwood stumps; no morels were found adjacent to the western larch (*Larix occidentalis*) or hybrid spruce (*Picea glauca* X *Engelmanii*). The one area where morels were not found in association with black cottonwood was the Plumbob Fire area mentioned above with glaciolacustrine soils.

A particularly confusing area to find morels was that of Kaufman Lake, a site near the treeline in the Tokumm/Verrendrye Fire in Kootenay National Park. The only area in the vicinity with consistent morels was near the lakeshore in an area with a northwest aspect. Large areas of the forest appeared to be high potential from the view of a helicopter; a search on the ground revealed large areas with nominal habitat. Within these areas, there were occasional patches of morels; all of which were located within two metres of exceptionally large spruce. No morels were to be found surrounding the non-dominant spruce or dominant subalpine fir (*Abies lasiocarpa*) and not all of the large specimens had morels associated with them.

The initial literature review and conversations with subject experts revealed numerous reports of morels fruiting in combination with insect-attacked trees. Currently in BC there is a widespread 'epidemic' of the mountain pine beetle (*Dendroctonus ponderosae*) infesting the vast lodgepole pine (*Pinus contorta* var. *contorta*) forests of the Interior. This outbreak is the largest infestation recorded in North America (BC Ministry of Forests 2004). This possibility of morel fruitings in combination with pine beetle attacked forest proved irresistible; two beetle polygons in my neighbourhood near Cranbrook were investigated with morels being found adjacent to killed lodgepole pine trees. A report of a mass fruiting of morels in Gold Creek was investigated; this site was a "beetle block" with mostly lodgepole pine removed. Two adults people picking at a leisurely pace for 1.5 hours collected 10 litres of morels. It was noted in this block that the best areas typically had birch-leaved spirea (*Spirea betulifolia*) as the nearest shrub, and were always near pine stumps and often on or adjacent skid trails. Picking morels in these sites is a far cleaner business than in the burns. The lack of ash and dust makes the morels from these sites a premium product. All of the morels found in these sites were in the *M. Elata* group.

An outcome of this study was the need for an additional year's data; currently funding is being sought to allow for this. Gathering one year of data was certainly worthwhile, but a second season of data is needed to strengthen interpretation of the results. Moreover, there is a need for nearest neighbour data from control plots that would allow the putative plant indicators to be statistically verified. A key opportunity missed during the 2004 field season was the opportunity to visit sites and conduct nearest neighbour plots using a randomly tossed ball or other item as plot centre. This key piece of missing information made the statistical analysis less powerful, as this method would have provided data to compare with that of the morel's

nearest neighbour data. It is hoped that in the late spring of 2005 that funding and time will allow for this data to be collected for analysis and use in the production of a journal article. If this were to happen, this opportunity would also allow for an additional year of data to be collected on morels to confirm the decline in morel production in year two that is noted in the literature and through local knowledge.

A challenge in the field research was the lack of a form for recording data. Though the method required relatively little data to be collected per plot, the lack of a form led to a challenge of inconsistent data collection and missing data. This form could either be printed on waterproof paper, or be entered on a palm device. This would be further streamlined by the use of a palm device or ideally with a combined GPS/palm device such as the Trimble Geo Xt. Such a device may conveniently be programmed with data entry sheets, has better than 5 metre accuracy, reduces missed data and eliminates labour consuming data entry.

Chapter 6: Conclusions

The ecological results, though interim, confirm the alternate hypothesis that morels are found in the highest densities in specific habitats. This result is also confirmed by the Picker's Survey, in which a number of informants specified focussing on certain habitats, elevations and tree species. In turn, the alternate hypothesis of morel pickers targeting certain ecosystems was also confirmed. Regarding the topic of the trophic status of morels, this study was not able to prove or disprove that morels have an association with vascular plants. Despite this, both the ecological and ethnological research, as well as the general observations, suggest that morels are associated with members of Rosaceae. The data confirms the assumption during data collection that morels are a difficult species for which to develop a fine predictive model. Gathering the first year data for the purpose of this thesis project was worthwhile, but there is still a need to collect an additional year's data. Further, there is also the need for nearest neighbour data from a control that would allow the data to be further tested statistically.

With the rejection of the alternative hypothesis that morels are evenly distributed across the land, there are interesting opportunities for management. A large amount of the burned areas have been salvage logged since the fire events. By furthering our understanding of morel fruiting and working with forest managers there is potential for synergy between the interests of morel harvesting and logging. Presuming that the moderately intensely burned areas are indeed most productive, the salvage logging of these areas could be delayed until following the first morel harvest season.

The confirmation that morels do indeed fruit in BC following insect attack has the potential to increase the morel harvest, especially when the Province is in the middle of a major mountain pine beetle infestation. Conversations with subject experts and pickers revealed a low awareness of this potential morel habitat type. The quality and possibility of these morels being widely distributed offers interesting potential for a morel harvest that doesn't depend on wildfires.

The Picker's Survey indicates that the 2004 morel harvest provided an important contribution to the regions economy. Many of Cranbrook's motels on the west side of the city were occupied by morel pickers. The pickers also required fuel, vehicle parts and repairs, food and other services; thus all who participated in the harvest contributed to the local economy.

Though still not fully understood, wildfires offer economic opportunities, despite their negative image in the media. They offer economic benefits that include the morel harvest, salvage logging, fire fighters wages, and benefits (in some cases) to the affected ecosystems. The fact that one may collect nearest plant neighbour data in the wildfire sites is also a significant result to much of society, proving that there is life after wildfire and that these areas are not 'destroyed'.

If BC does indeed adopt the recommendations from the Filmon (2004) report, there will likely be widespread fuel reduction programs that may involve the use of prescribed fire. It is germane to investigate the prescribed fire areas in the following spring to look for the presence, absence and possible abundance of morels. The duff consumption data from this study may be

applicable to these fires. If the burn managers were to obtain higher levels of duff consumption than observed following prescribed fire in the East Kootenay; there remains excellent potential for stimulating morel fruitings. It is understood that the Kimberly Nature Park is soon to see such a thinning project to reduce fuels and harvest beetle killed lodgepole pine; this work may be an ideal opportunity to explore these opportunities.

The techniques employed in this study proved a useful means of synthesising a wide array of different sources of information. This research problem has inspired an effort to follow-up this study and gain more ecological knowledge concerning this intriguing resource. In 2005, it is proposed to continue expanding this study by: conducting the aforementioned additional research in the sites visited in 2004, to expand the number of plots in mountain pine beetle-killed sites and to survey areas that were burnt using prescribed fire in the Rocky Mountain trench in 2004. A product of this work will be the production of journal articles to be submitted for publication.

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Appendix I - Research Consent Form and Morel mushroom Use Questionnaire

Research Consent Form for Michael Keefer’s morel study for Morel Pickers Questionnaire.

This research project is part of the thesis requirement for the degree of Master of Science in the Management and Environment Program at Royal Roads University. The purpose of my research is to improve society’s understanding of the ecology and economic importance of the morel harvest.

The student conducting this research is Michael E. Keefer. Michael can be reached at the Ktunaxa Kinbasket Treaty Council office at (insert contact info). My supervisor is Richard Winder, he may be reached at (insert contact info). The sponsor of this research is the Centre for Non-Timber Resources at Royal Roads University. The Director of the Centre is Dr. Darcy Mitchell Royal Roads University at (insert contact info).. Please contact either Dr. Winder or Dr. Mitchell if you have any questions about this project.

This document constitutes an agreement to take part in a research program, the objective of which to gain an improved understanding of morel mushrooms and their harvesting techniques from the perspective of the morel pickers.

The research will consist of a questionnaire that is foreseen to last between 20 and 30 minutes. The questions are concerning harvester production and knowledge of the ecosystems that support morel mushrooms.

Prospective research subjects are not compelled to take part in this research project. If an individual does elect to take part, she or he is free to withdraw at any time with no prejudice. Similarly if employees or other individuals elect not to take part in this research project, this information will also be maintained in confidence.

Information will be recorded in hand-written format and, where appropriate, summarized, in anonymous format, in the body of the final report. At no time will any specific comments be attributed to any individual unless specific agreement has been obtained beforehand. Completed questionnaires will be stored at the Royal Roads University Centre for Non-Timber Forest Resources office until March 31, 2006.

Do you consent to have your name mentioned in reports? ___yes ___no

If you answered yes, are there any conditions to the use of your name? If so, please state them:

Information gathered during this interview will be made available, in summary form, to the Centre for Non-Timber Resources who may use the information for research purposes. Information provided in written form to the Centre will not include any means of identifying the source of the information, unless permission to do so is received from you in writing.

A copy of my thesis will be housed at Royal Roads University and will be publicly accessible through the National Library of Canada.

By signing this letter, the individual gives free and informed consent to participating in this project.

Name: (Please Print): _____

Signed: _____

Date: _____

Morel mushroom Use Questionnaire

I. General Information

1. Age

- less than 10
 10-14 years
 15-19 years
 20-24 years
 25-34 years
 35-44 years
 45-54 years
 55-64 years
 65 years and over

2. I am:

- Ktunaxa
 Other First Nations
 Non-Native
 Gender (observation) M _ F _
 I live: Locally Other area

3. If you live in another area, where do you live while you are picking morels in this area?

- hotel or motel
 camper or other r.v.
 tent
 with friends or family
 other (specify)

Do you consider yourself a:

- novice picker
 somewhat experienced picker
 experienced successful picker

4. How many years have you picked morels for? _____

5. Why do you pick morel mushrooms?

- a) For personal use
 b) For sale
 c) To share
 d) all of the above
 e) Other (please describe):
-
-

6. How far do you travel on average each day to pick morels?

- km OR miles

7. Where do you pick morel mushrooms?

Locally

Other areas

If so, in which areas?

8. Other areas of British Columbia? yes no

If so, where?

9. Other provinces, territories or USA

If yes, where?

10. Did you pick morels in 2003? yes no.

11. If you answered yes to question 10, please answer the following questions:

a. How many morel mushrooms do you pick in 2003? (pounds, gallons, litres etc.)

b. How many days did you pick morels in 2003?

c. What was your average pick per day in 2003?

d. Where did you pick in 2003?

e. How many morel mushrooms have you picked in 2004?

f. What is your average pick per day in 2004?

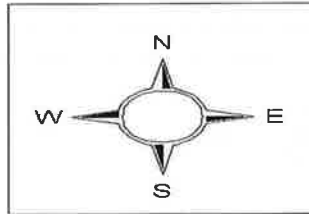
g. What is your largest total daily pick?

h. How many days have you picked this year?

i. How many more days do you anticipate picking this year?

II. Ecological Information

1. In the area(s) that you harvest morel mushrooms, which is the most common direction that the slopes face?



(Please shade or circle on the compass)

2. In the area(s) that you pick what are the site conditions that you find most productive?

- | | |
|---------------------------------------|--|
| <input type="checkbox"/> wet | <input type="checkbox"/> Steep |
| <input type="checkbox"/> dry | <input type="checkbox"/> Flat |
| <input type="checkbox"/> open | <input type="checkbox"/> low elevation |
| <input type="checkbox"/> open forest | <input type="checkbox"/> mid elevation |
| <input type="checkbox"/> dense forest | <input type="checkbox"/> high elevation |
| <input type="checkbox"/> old burn | <input type="checkbox"/> old clearcut |
| <input type="checkbox"/> new burn | <input type="checkbox"/> new clearcut |
| <input type="checkbox"/> loamy soils | <input type="checkbox"/> sandy soils |
| <input type="checkbox"/> rocky soils | <input type="checkbox"/> soils rich in rotten wood |
| <input type="checkbox"/> clay soils | |

Other _____

3. Which species of trees do you find picking under most successful:

- | | |
|---|--------------------------------------|
| <input type="checkbox"/> cedar | <input type="checkbox"/> larch |
| <input type="checkbox"/> white pine | <input type="checkbox"/> hemlock |
| <input type="checkbox"/> lodgepole pine | <input type="checkbox"/> Douglas fir |
| <input type="checkbox"/> aspen | <input type="checkbox"/> spruce |
| <input type="checkbox"/> black cottonwood | |

Other _____

4. Do you notice any other plants that are usually grow near morels? If yes, which plants?

5. Which of the following habitat types do you find most productive to pick in?

- recently salvage logged
- within burnt plantations
- in grassy areas
- within unlogged but burnt forest
- none of the above

6. Do you find peripheral areas of the fire

- more productive
- less productive
- no difference

7. Do you find areas where the fire was hottest:

- more productive
- less productive
- no difference

8. Are you aware of any natural signs that may tell you how many morel mushrooms there will be or when they will be ready to harvest? (i.e. grass size, leaf size...)

- Yes
- No

If "Yes", please describe:

9. Have you noticed any relationship between the weather and Morel mushroom production?

- Yes
- No

If "Yes", please describe:

10. Are you aware of any traditional or contemporary techniques to manage the morel mushroom picking sites? (e.g., picking only the larger morels)

- Yes
- No

If yes, please describe?

III. Socio Economic Information

1. If you answered yes to question 7, do you use any management practices at the morel mushroom patches that you described above?

- Yes
- No

If yes, please describe?

2. Do you typically go morel mushroom picking with a group of people?

- Yes, with my family
- Yes, with my friends
- Yes, both family and friends
- No, I pick on my own

If yes, how many people are with you on a typical trip?

3. If you pick with your family, which members of your family pick with you?

- Husband/wife
- Children
- Others

4. How much of your yearly income do you normally derive from commercial morel picking?

- Less than 10 percent
- 10-25 percent
- 26-50 percent
- 51-75 percent
- More than 75 percent

5. Do you commercially pick other wild mushroom species?

- Yes No

6. If you answered yes to question 5, please answer the following question: What other species of mushrooms do you commercially pick?

- Chanterelle Brain mushrooms
- Boletes Pine mushrooms
- Other, please specify _____

7. What is (are) your other sources of income?

8. Do you harvest any other non-timber forest products (antlers, berries, wild vegetables, medicinals, floral greenery (i.e. pussy willow, falsebox) etc)?

a. No Yes If yes, please answer the following questions:

b. Yes, for personal use. If yes, which products?

c. Yes, for sale. If yes, which products?

d. Both for sale and personal use. If yes, which products?

9. Do you sell your morels to:

the same buyer every day

usually to the same buyer, but sometimes to other buyers

whichever buyer is offering the highest price that day

other answer

10. Do you or other members of your family dry or otherwise preserve any of your morel harvest for later sale?

Yes

No

a. If yes, about percentage do you dry or otherwise preserve

<10%

11-25%

26-50%

51-75%

76-100%

11. How do you dry your morels?

in the sun

other (how?) _____

12. Which members of your family work with you on processing

Husband/wife

Brother/Sister

Children

Others _____

13. To whom do you usually sell your processed morels?

local stores or restaurants

personal acquaintances

other (who?) _____

14. How many pounds/kilograms of fresh morels does it take, on average, to produce a pound of dried morels?

pounds kilograms

15. If you sold fresh morels for \$3.00 a pound, how much would you expect to receive for dried morels?

III. Production System

1. Have you experienced problems with other morel pickers when you were out harvesting?

Yes

No

If yes, what sort of problems? _____

2. Have you noticed any relationship between the weather and Morel mushroom production?

Yes

No

a. If "Yes", please describe:

3. Are you aware of any laws that control:

a. Harvesting yes no

b. Selling yes no

c. Buying yes no

d. Processing yes no

4. Do you think there should be laws governing: a. Harvesting yes no

If so, what types of laws?

b. Selling yes no

If so, what types of laws?

c. Buying yes no

If so, what types of laws?

d. Processing yes no

If so, what types of laws?

Other Comments?

Thank you for participating in the survey.

Appendix II – Ecological Data^[SH1]**Table 1 - Nearest Herb Neighbours**

Species	Number of First Neighbour Occurrences	Mean Distance (cm)	Standard Error	Number of Second Neighbour Occurrences	Mean Distance (cm)	Standard Error	Fire Sites
<i>Agropyron repens</i>	1	3	-	-	-	-	1
<i>Arnica cordifolia</i>	21	69	1.5	4	26	1.6	3
<i>Aster/Erigeron sp.</i>	3	86	4.5	11	72	1.8	2
<i>Calamagrostis canadensis</i>	-	-	-	3	82	1.8	1
<i>Calamagrostis rubescens</i>	19	46	1.8	13	58	1.9	4
<i>Calochortus apiculatus</i>	-	-	-	1	23	-	1
<i>Carex sp.-</i>	2	38	4.8	2	67	0	3
<i>Chamerion angustifolium</i>	21	31	1.6	5	84	2.9	4
<i>Clintonia uniflora</i>	2	99	-	3	140	3.8	1
<i>Equisetum arvensis</i>	-	-	-	5	127	5.3	2
<i>Erythronium grandiflorum</i>	-	-	-	5	108	3.4	2
<i>Festuca idahoensis</i>	-	-	-	2	6-3	1.6	1
<i>Fragaria virginiana</i>	3	25	1	3	120	4.6	2
<i>Graminae</i>	2	13	2.7	1	76	-	1
<i>Hieracium albiflorum</i>	1	2.5	-	1	226	-	2
<i>Lupinus serricious</i>	-	-	-	1	41	-	1
<i>Mitella breweri</i>	2	15	-	-	-	-	1
<i>Osmorhiza chilensis</i>	-	-	-	1	18	-	1
<i>Petasites palmatus</i>	-	-	-	4	95	1.6	1
<i>Poa canadensis</i>	1	5	-	-	-	-	1

Table I - Continued

	Number of First Neighbour Occurrences	Mean Distance (cm)	Standard Error	Number of Second Neighbour Occurrences	Mean Distance (cm)	Standard Error	Fire Sites
<i>Poa pratensis</i>	1	41	-	-	-	-	1
<i>Pyrola picta</i>	1	43	-	-	-	-	1
<i>Saxifragaceae</i>	-	-	-	2	61	-	1
<i>Senecio triangularis</i>	1	89	-	-	-	-	1
<i>Taraxicum officinale</i>	1	15	-	1	25	-	1
<i>Thalictrum occidentale</i>	1	58	-	4	119	3.5	2
<i>Trifolium spp.</i>	-	-	-	1	43	-	1
<i>Valarium sitchensis</i>	-	-	-	1	131	-	1
<i>Viola spp.</i>	2	38	-	3	47	4.1	1
<i>Xeriphyllum tenax</i>	4	178	5.8	-	-	-	2

Table II – Nearest Shrub Neighbours

Species	Number of First Neighbour Occurrences	Mean Distance (cm)	Standard Error	Number of Second Neighbour Occurrences	Mean Distance (cm)	Standard Error	Fire Sites
<i>Alnus crispa</i>	3	133	5.3	1	338	-	3
<i>Amalanchier alnifolia</i>	2	66	5.7	-	-	-	2
<i>Arctostaphylos uva-ursi</i>	2	11	0.9	1	25	-	2
<i>Cornus stolonifera</i>	1	26	-	-	-	-	1
<i>Ledum groenlandicum</i>	-	-	-	2	118	5.1	1
<i>Linnaea borealis</i>	1	36	-	-	-	-	1
<i>Lonicera involucrata</i>	-	-	-	1	127	-	1
<i>Lonicera utahensis</i>	-	-	-	2	173	3.3	2
<i>Mahonia aquifolium</i>	3	17	1.6	2	80	7.4	1
<i>Menziesia ferruginea</i>	6	117	4	1	81	-	3
<i>Rhododendrum albiflorum</i>	1	356	-	1	142	-	1
<i>Ribes oxyacanthoides</i>	1	140	-	-	-	-	1
<i>Ribes spp.</i>	1	40	-	-	-	-	1
<i>Rosa accicularis</i>	7	38	2	7	70	2.5	4
<i>Rubus parviflorum</i>	2	114	3	4	134	5	2
<i>Salix spp.</i>	4	118	6.6	1	43	-	3
<i>Sambucus racemosa</i>	-	-	-	1	51	-	1
<i>Shepherdia canadensis</i>	-	-	-	3	154	6.4	1
<i>Spirea betulifolia</i>	18	85	2	11	92	2	2
<i>Symphoricarpus albus</i>	3	49	3.3	3	28	3	1
<i>Vaccinium caespitosum</i>	1	8	-	-	-	-	1

Table II - Continued

Species	Number of First Neighbour Occurrences	Mean Distance (cm)	Standard Error	Number of Second Neighbour Occurrences	Mean Distance (cm)	Standard Error	Fire Sites
<i>Vaccinium membranaceum</i>	2	184	4	5	183	4.6	2
<i>Vaccinium scoparium</i>	1	23	4.7	2	48	3.5	2
<i>Vaccinium spp.</i>	1	43	-	-	-	-	1

Table III – Nearest Tree Neighbours

Species	Number of First Neighbour Occurrences	Mean Distance (cm)	Standard Error	Number of Second Neighbour Occurrences	Mean Distance (cm)	Standard Error	Fire Sites
<i>Abies lasiocarpa</i>	19	91	1.6	10	145	2.3	4
<i>Larix occidentalis</i>	5	168	2.9	1	325	-	2
<i>Picea X</i>	16	98	2.1	15	158	2.1	4
<i>Pinus contorta</i>	18	84	1.7	23	161	2.2	4
<i>Populus tremuloides</i>	2	11	2.1	-	-	-	2
<i>Populus trichocarpa</i>	3	162	4.5	1	200	-	1
<i>Pseudotsuga mensiesii</i>	4	130	3.1	5	192	1.6	2
<i>Thuja plicata</i>	1	69	-	-	-	-	1
<i>Tsuga heterophylla</i>	2	56	3	2	358	11	1

Table IV – Morel Production vs. Duff Consumption

Duff Consumption *					
	Class 1	Class 2	Class 3	Class 4	Class 5
Middlefork	0-5	-	49	5	12
Mission	4	25	-	20	4
Kootenay	16	34	38	52	46
mean	6-83333	29-5	43-5	25-6667	666667
sdev	8-12917	6-36396	7-7782	24-0069	300972
std error	1-64612	1-45648	1-6102	2-82884	9279078

* Class 1=0-20%, Class 2=21-40%, Class 3=41-60%, Class 3=61-80% and Class 5=81-100%
Duff Consumption

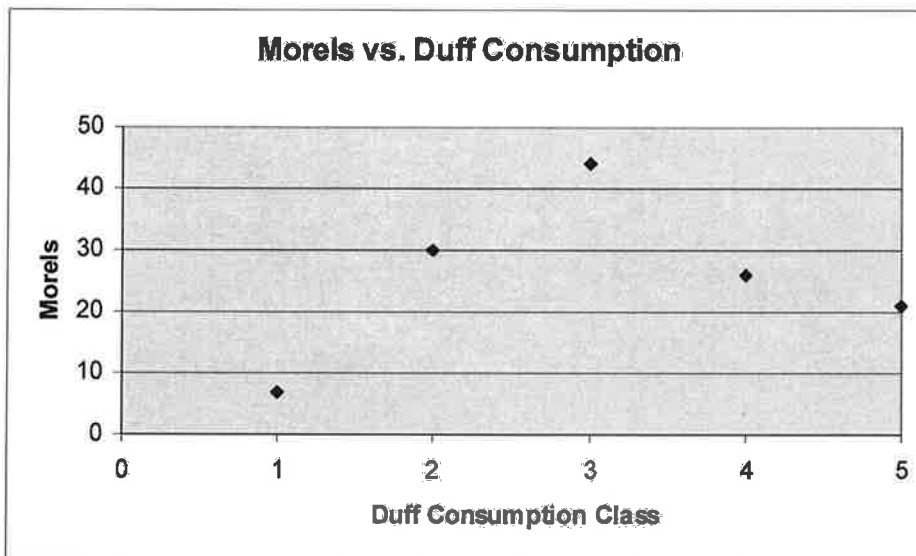


Figure I – Morel Production vs. Duff Consumption Class

Table V – Morel Production per Plot

Production Plot Type	Systematic Random	Systematic	Gold Creek Systematic
Average	37.84314	18.1875	5.727273
Standard Deviation.	33.57521	40.36722	4.314879
Standard Error	0.819454	1.123154	0.367206

Appendix III – Picker Survey Data

Section 1 – General Information

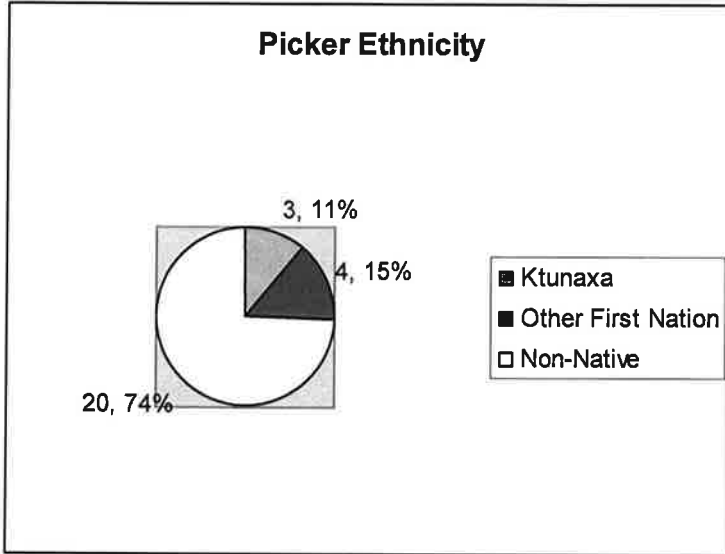


Figure 2: Picker Ethnicity

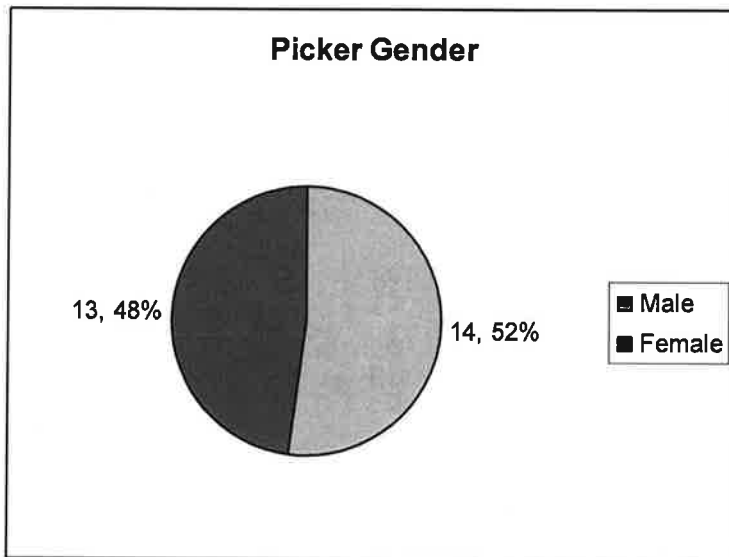


Figure 3: Picker Gender

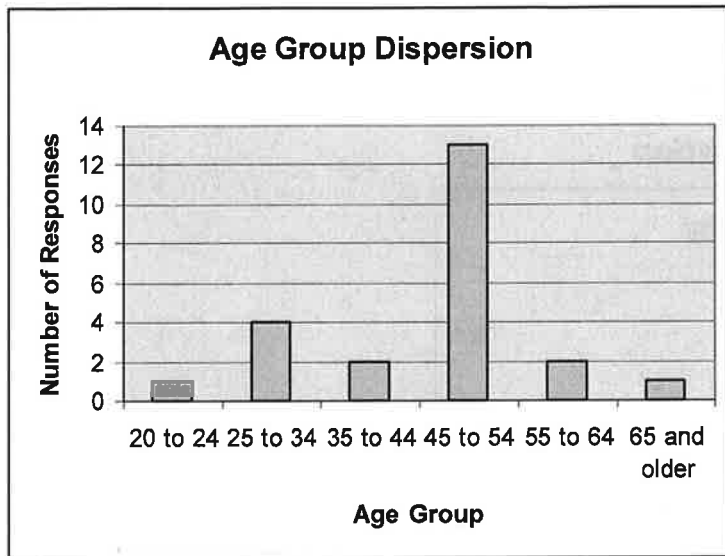


Figure 4: Age Group Dispersion

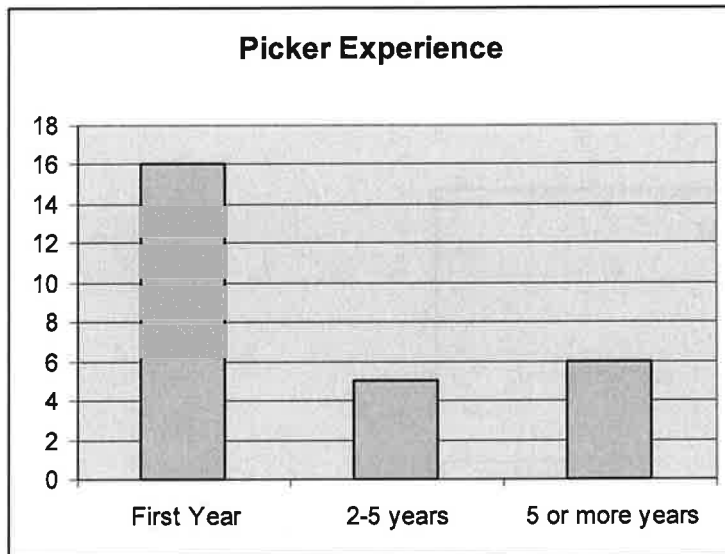


Figure 5: Picker Experience

Section II - Socio-economic

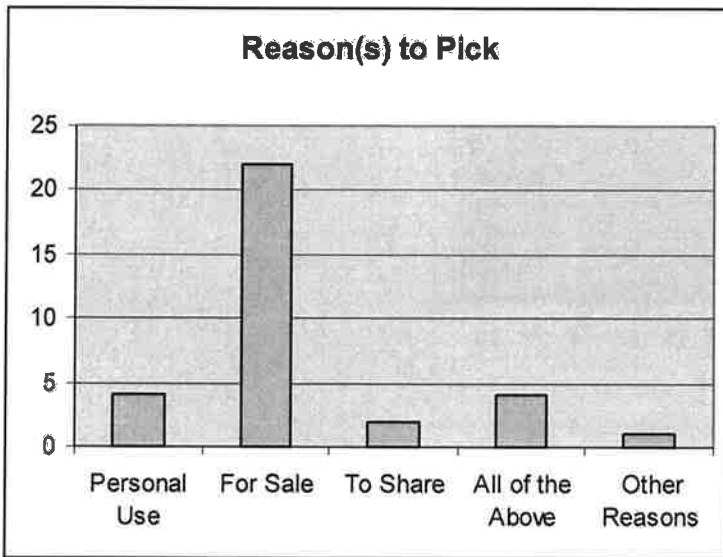


Figure 6: Reason(s) to Pick

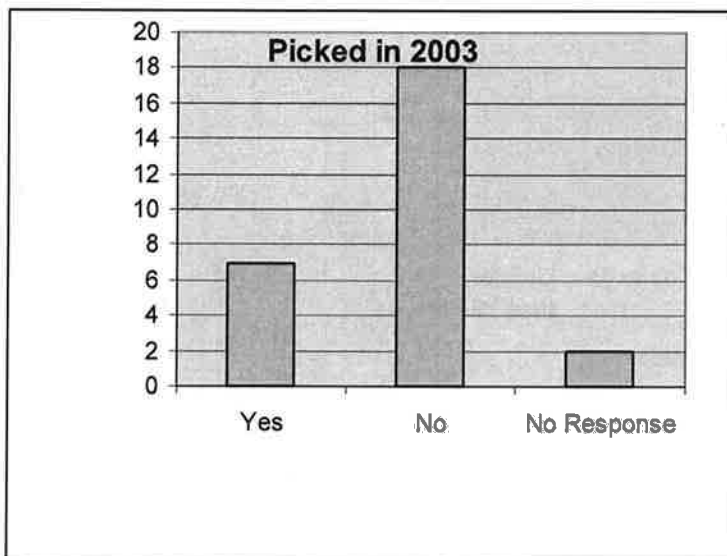


Figure 7: Pickers who picked in 2003

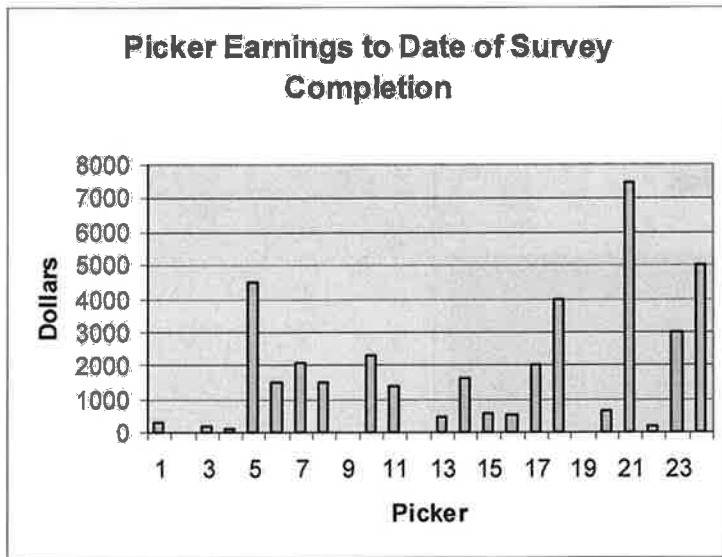


Figure 8: Picker Earnings

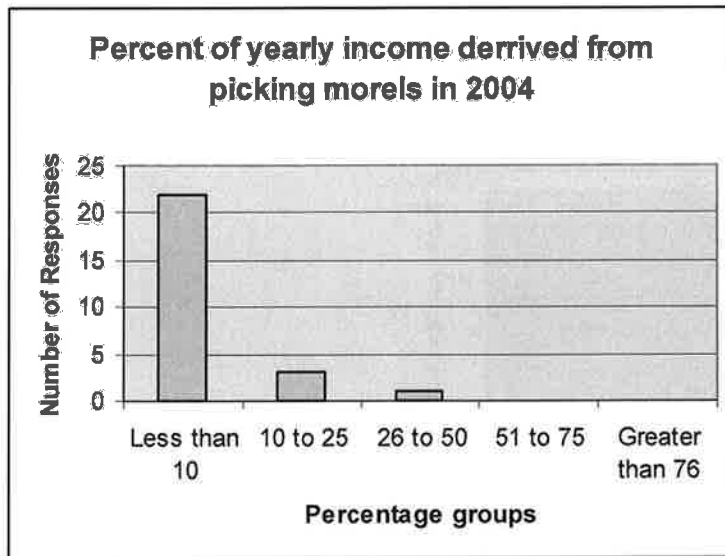


Figure 9: Percentage of yearly income derived from picking morels in 2004

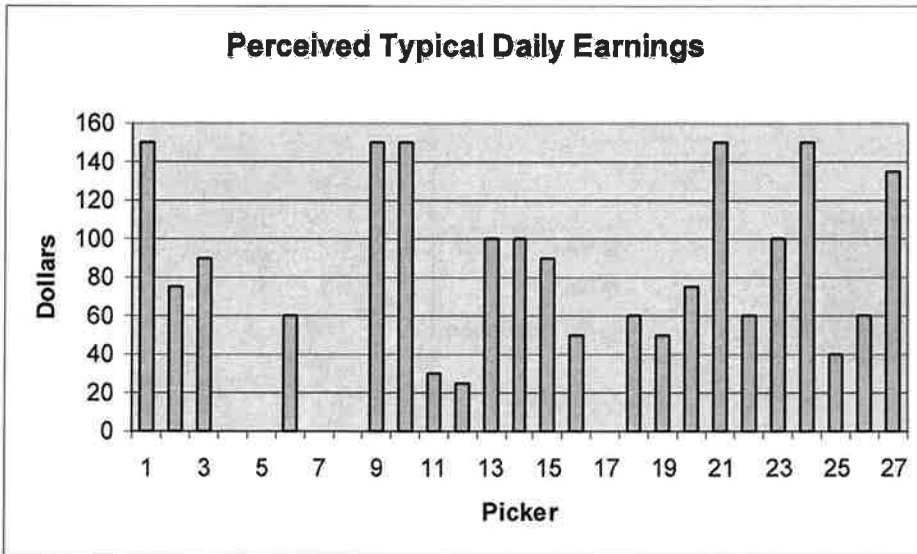


Figure 10: Perceived Typical Daily Earnings

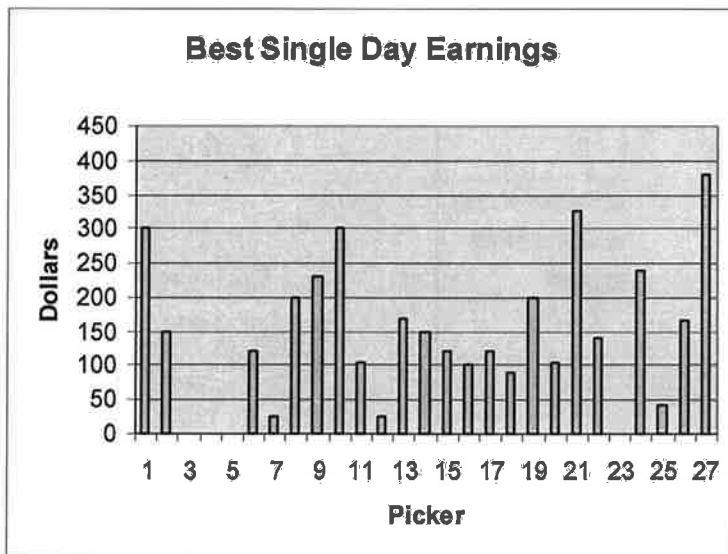


Figure 11: Best Single Days Earnings

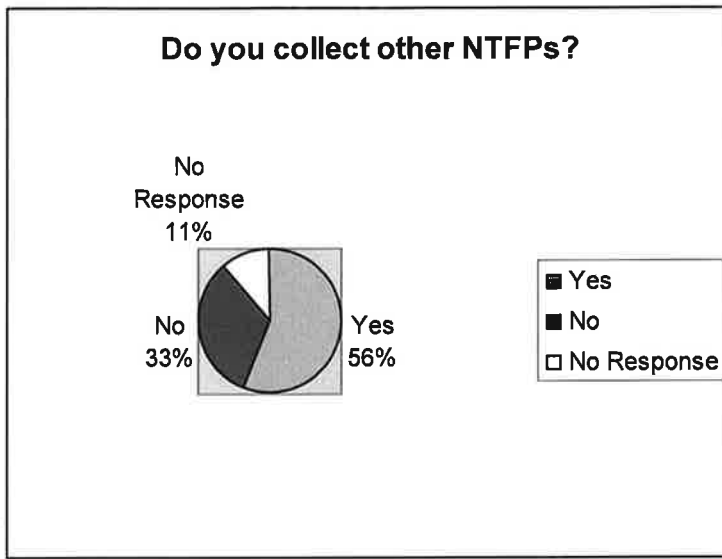


Figure 12: Do you collect other NTFPs?

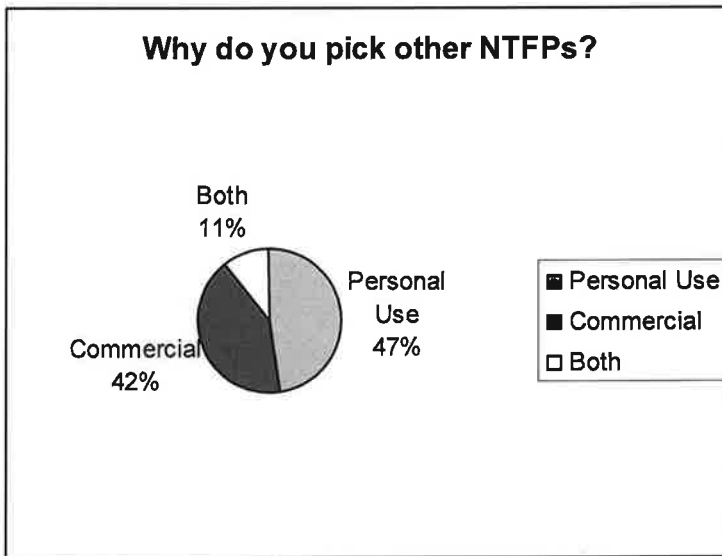


Figure 13: Why do you pick other NTFPs?

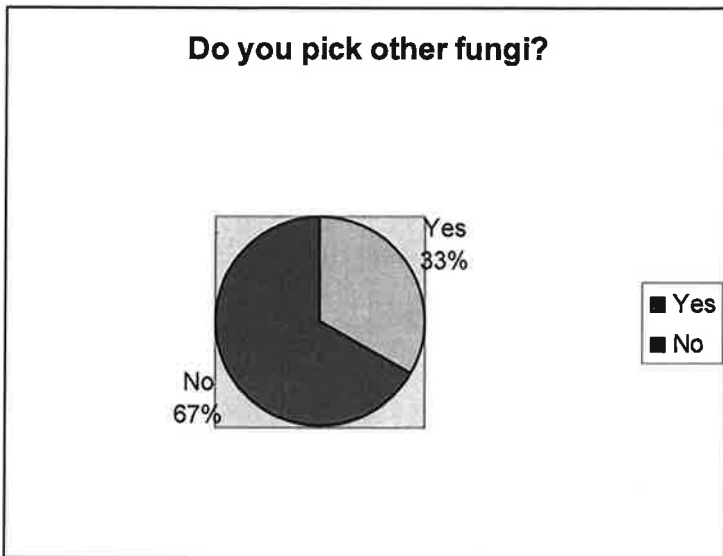


Figure 14: Do you pick other fungi?

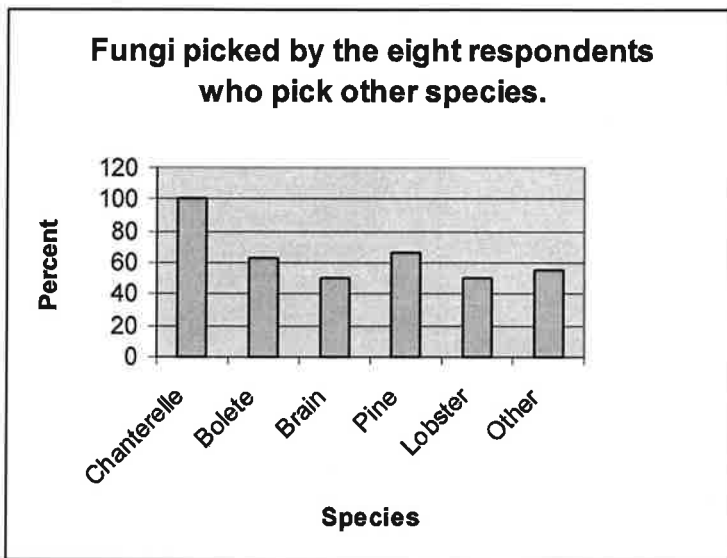


Figure 15: What other fungi do you pick?

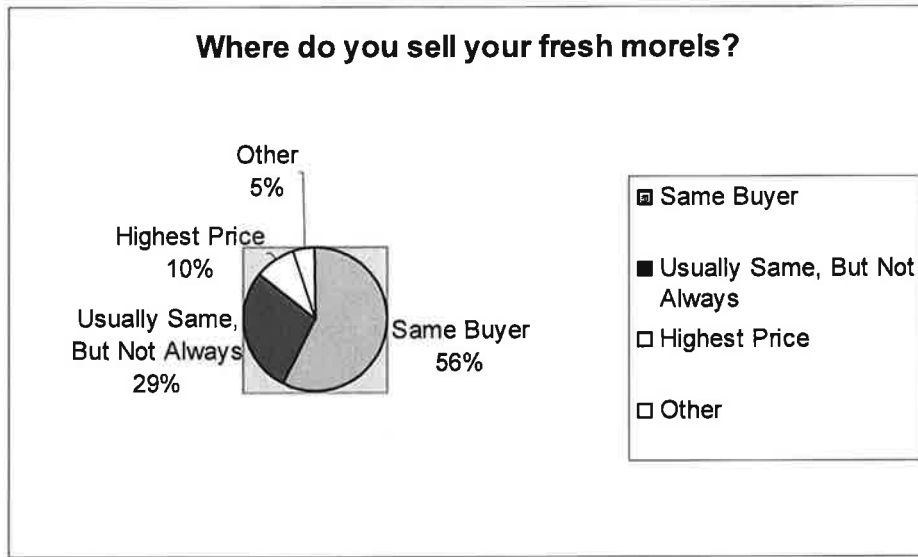


Figure 16: Who do you sell your fresh morels to?

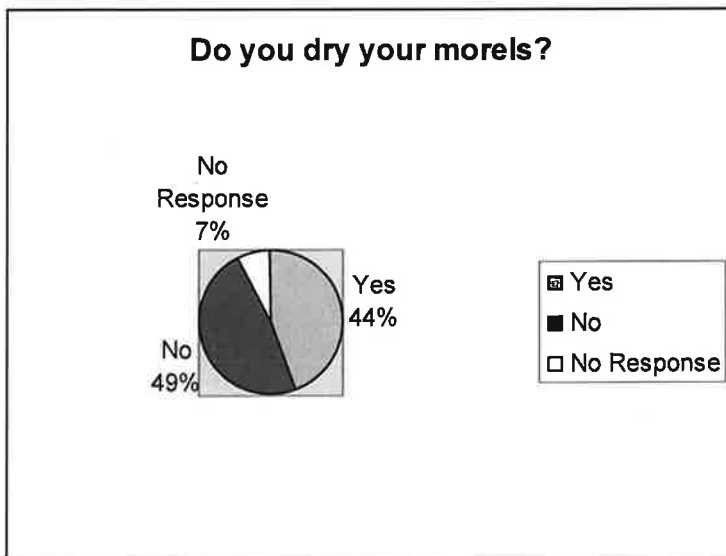


Figure 17: Do you dry your morels?

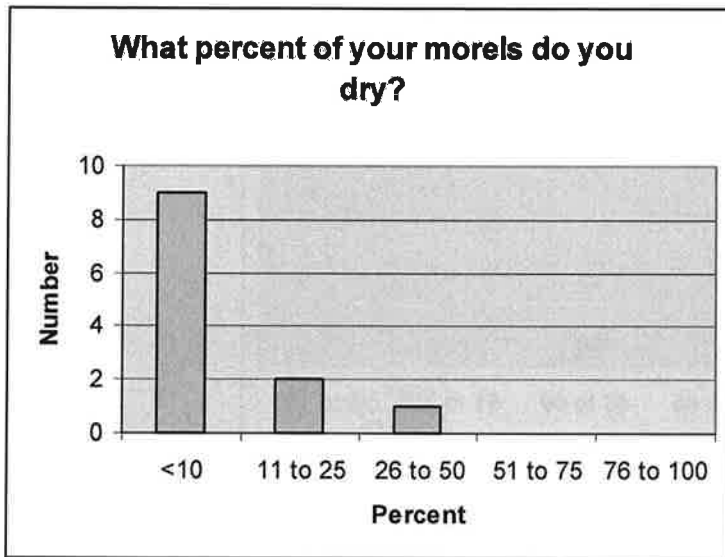


Figure 18: Percentage of Morels Dried

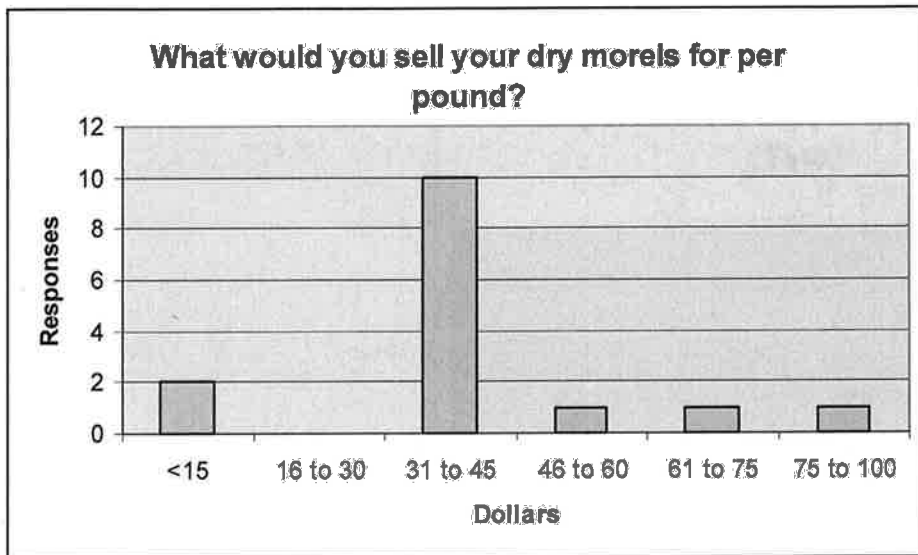


Figure 19: Acceptable Price for Dry Morels per pound

Section III – Ecological Information

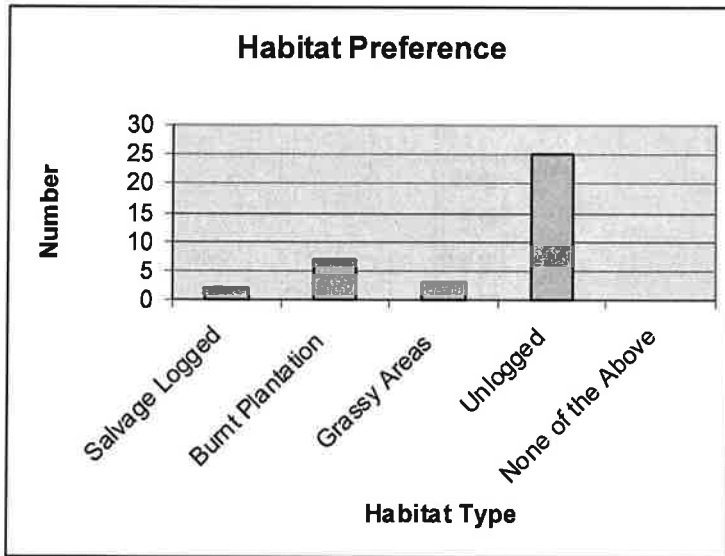


Figure 20: Habitat Preference

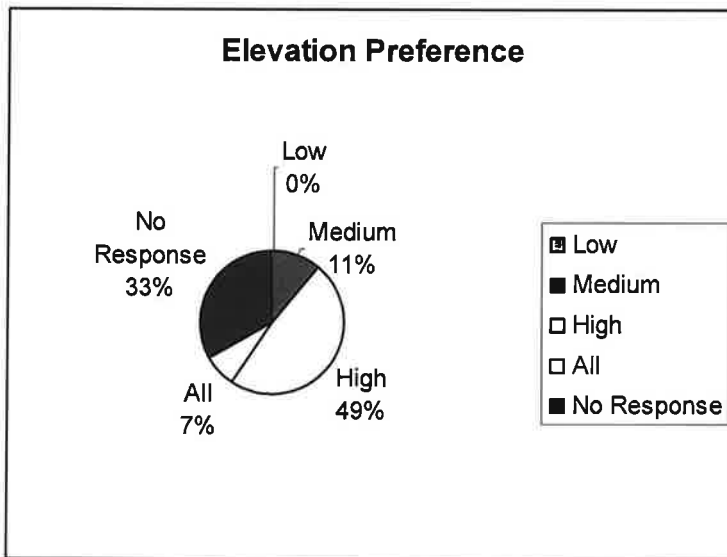


Figure 21: Elevation Preference

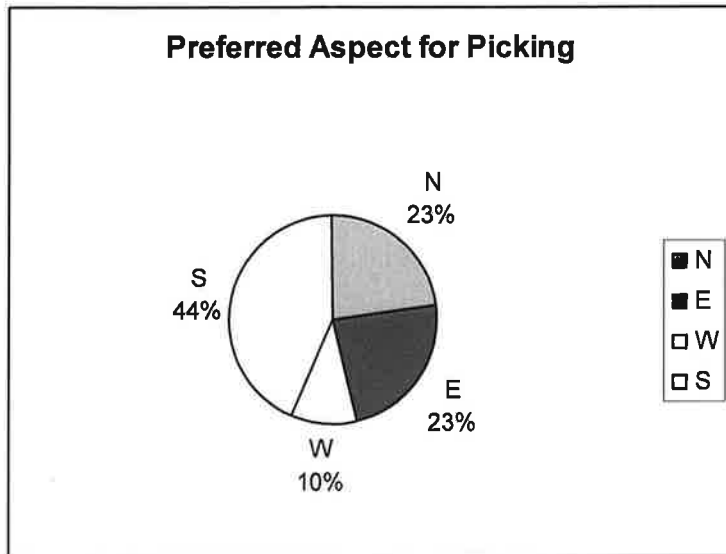


Figure 22: Preferred Aspect for Picking

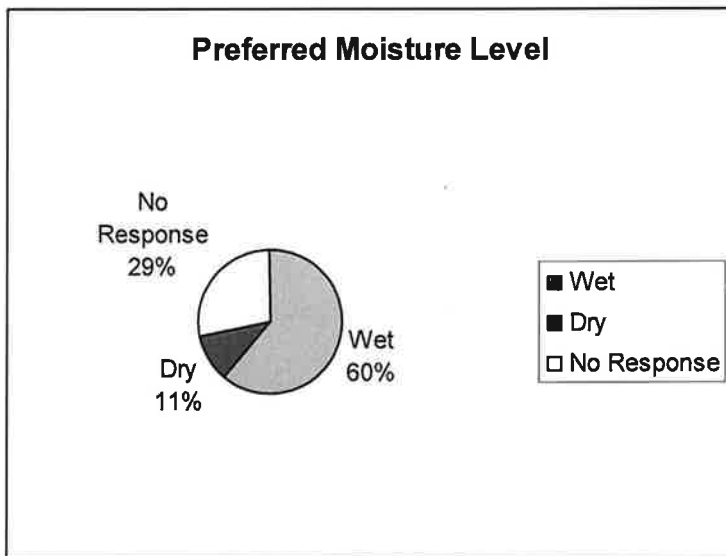


Figure 23: Preferred Moisture Level

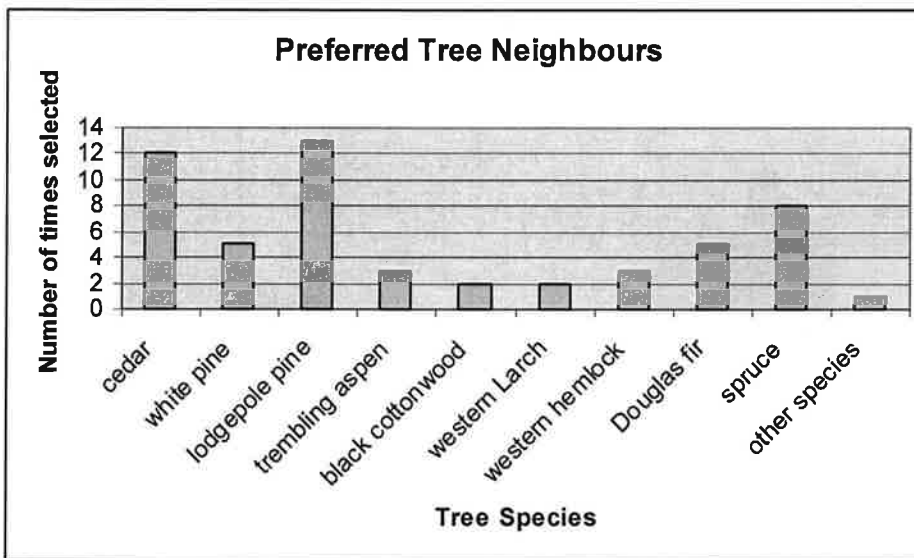


Figure 24: Preferred Neighbouring Trees

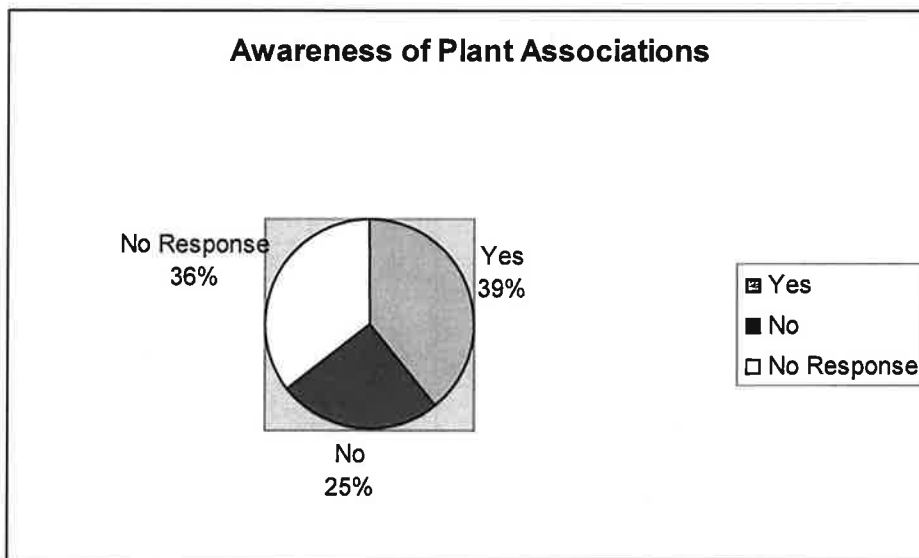


Figure 25: Awareness of Plant Associations

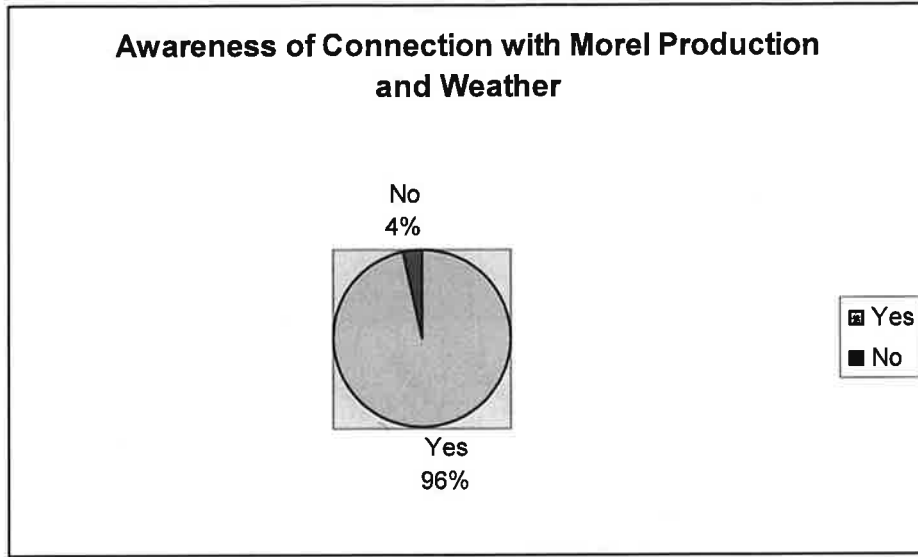


Figure 26: Awareness of Connection with Morel Production and Weather

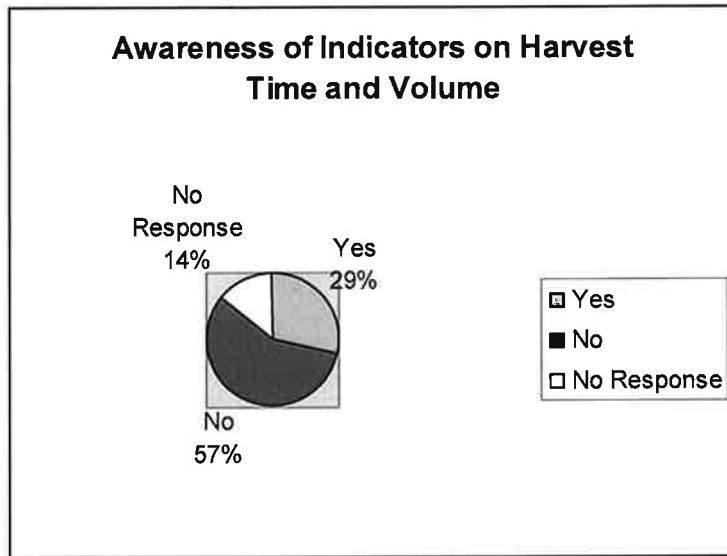


Figure 27: Awareness of Indicators on Harvest Time and Volume



Figure 28: Are peripheral areas of fires more productive?

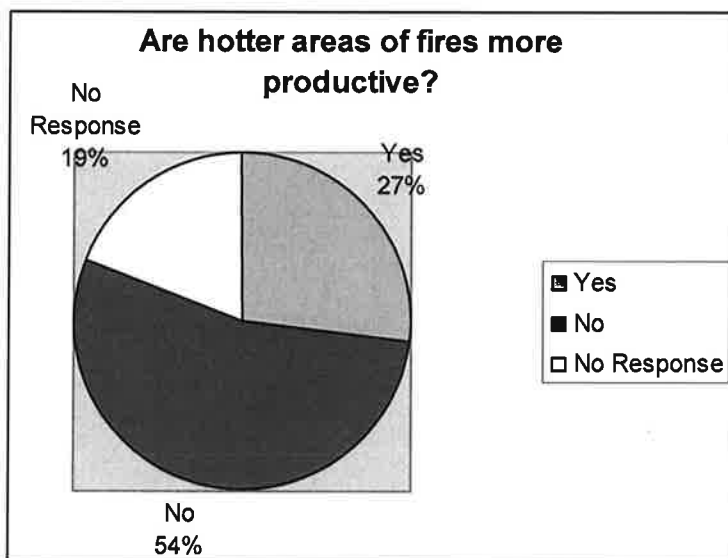


Figure 29: Are hotter areas of fires more productive?

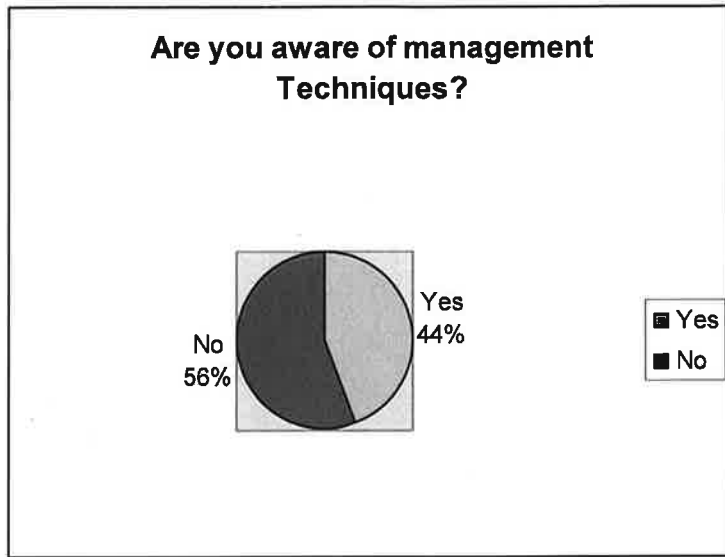


Figure 30: Are you aware of Management Techniques?

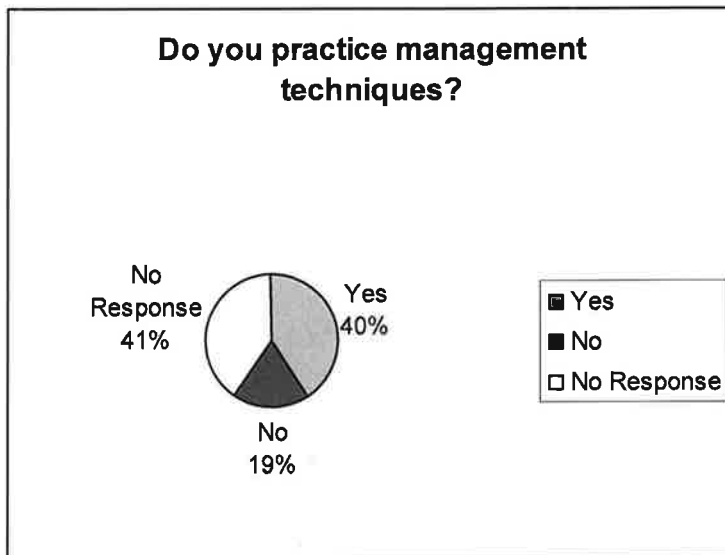


Figure 31: Do you practice management techniques?

Section IV - Production System

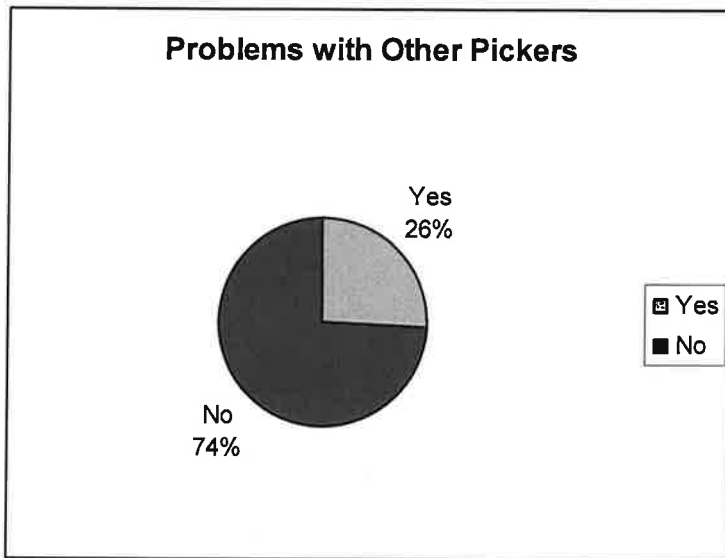


Figure 32: Have you experienced problems with other pickers?

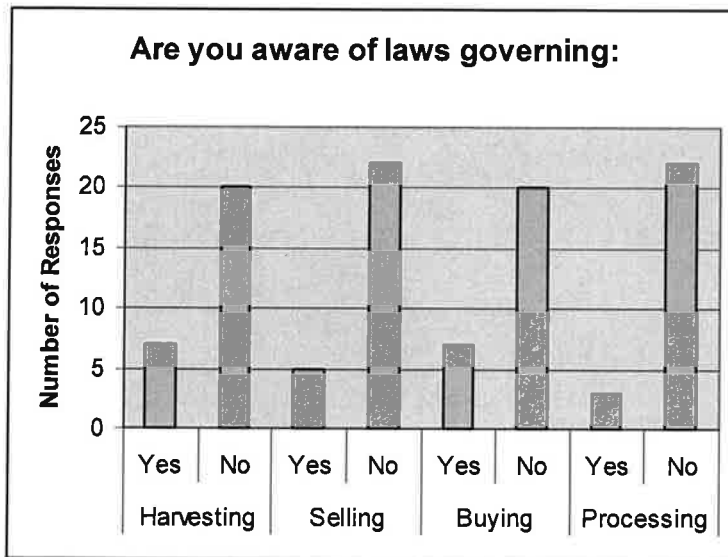


Figure 33: Awareness of Laws Governing Industry

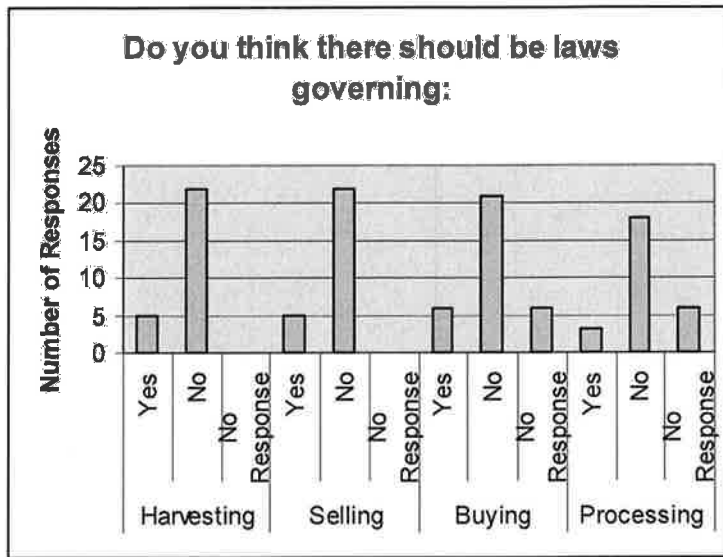


Figure 34: Support for New Legislation

Appendix IV – Maps^[SH2]

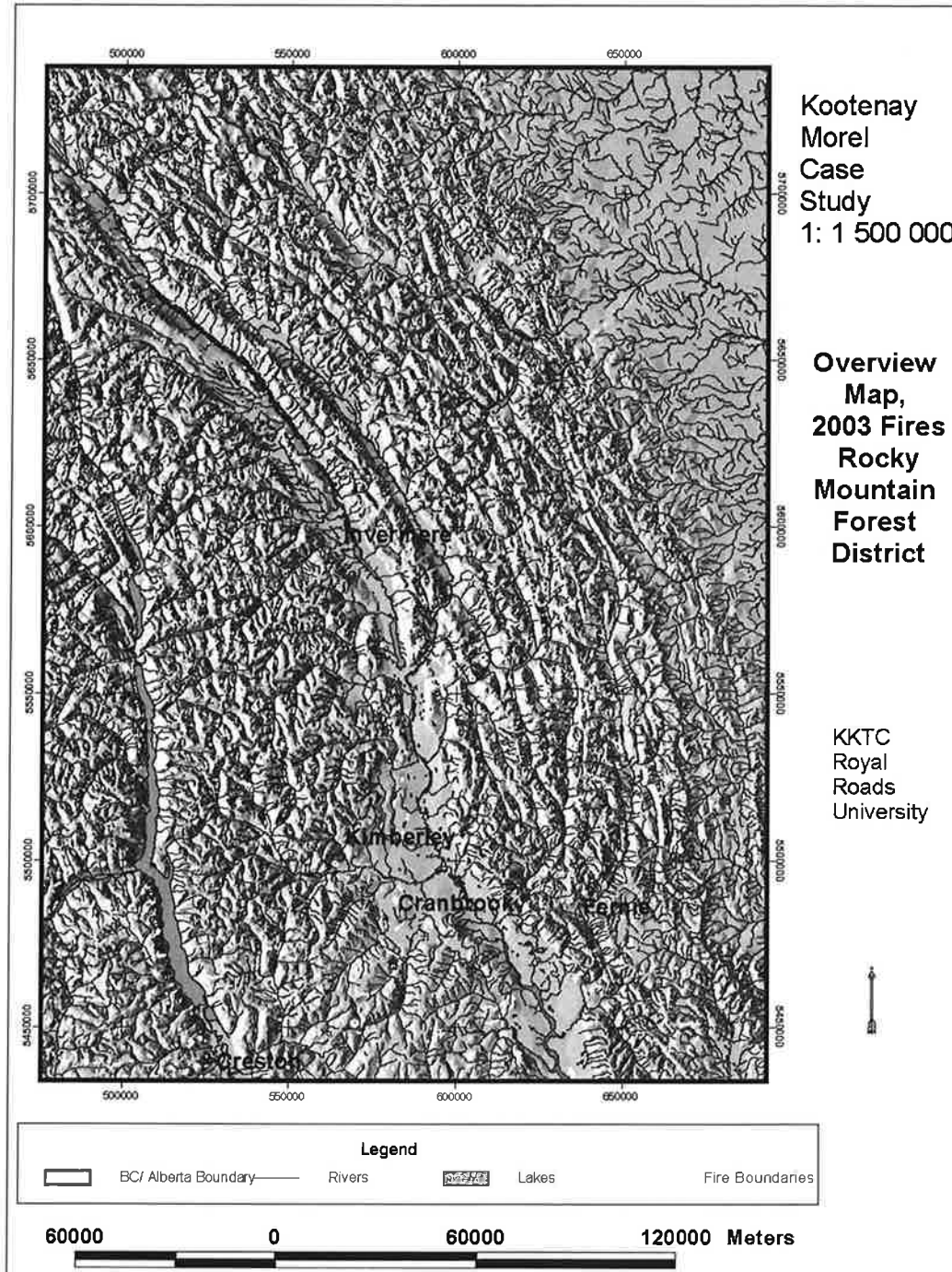


Figure 35: Locator Map

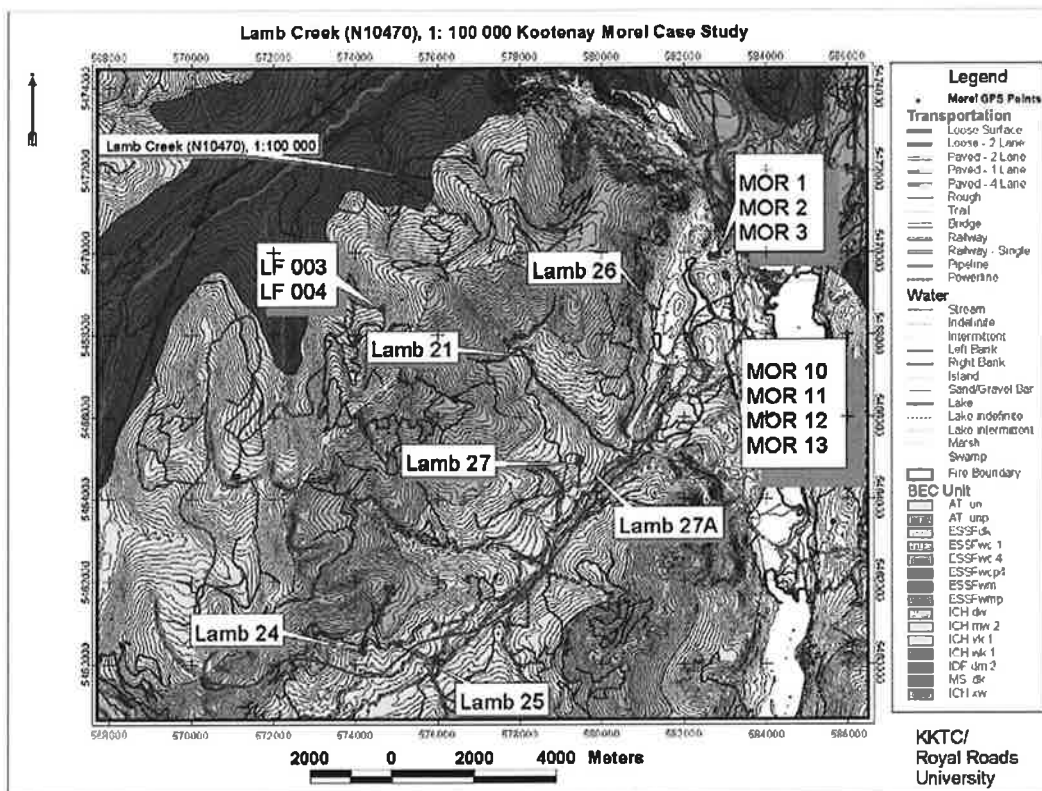


Figure 36: Lamb Creek Fire Map

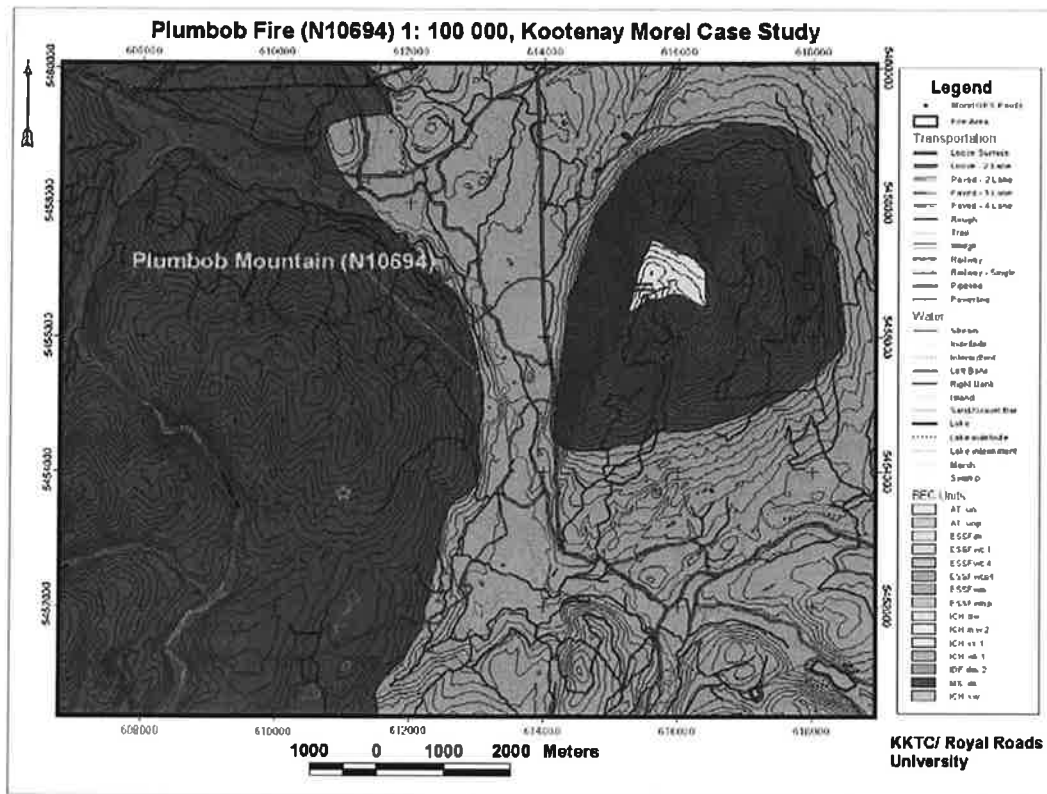
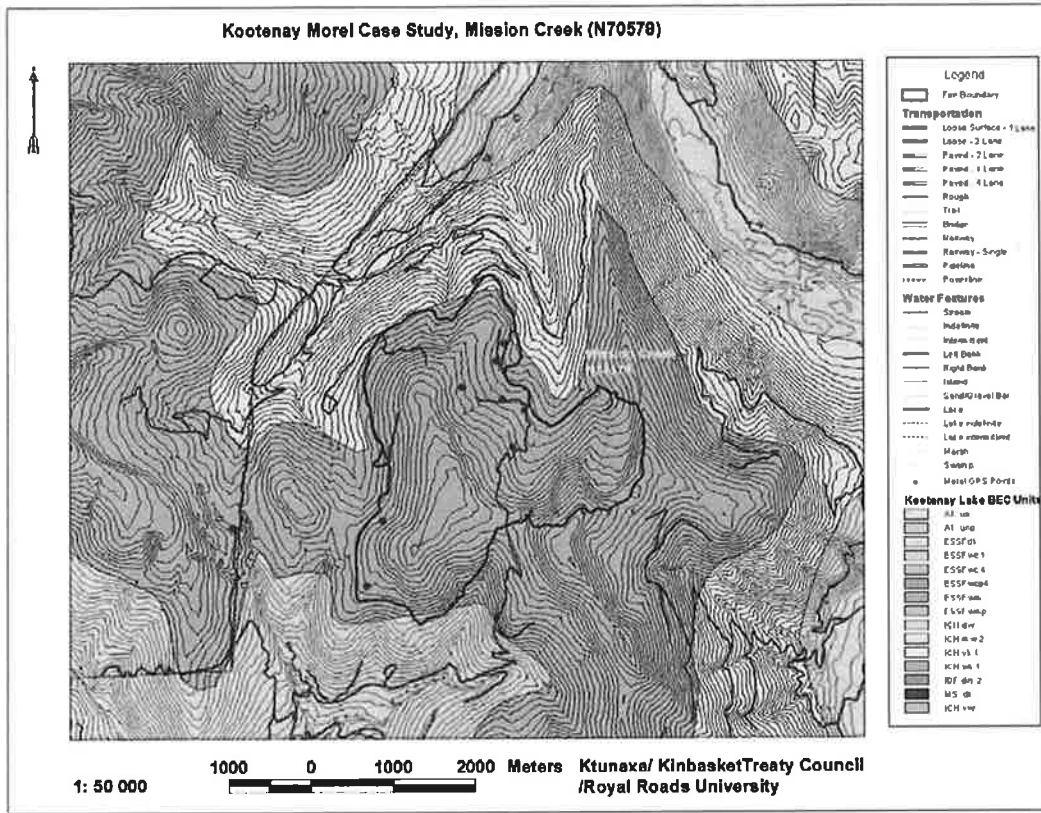


Figure 37: Plumbob Fire (GPS Points Missing)

Fig



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Figure 38: Mission Creek Fire

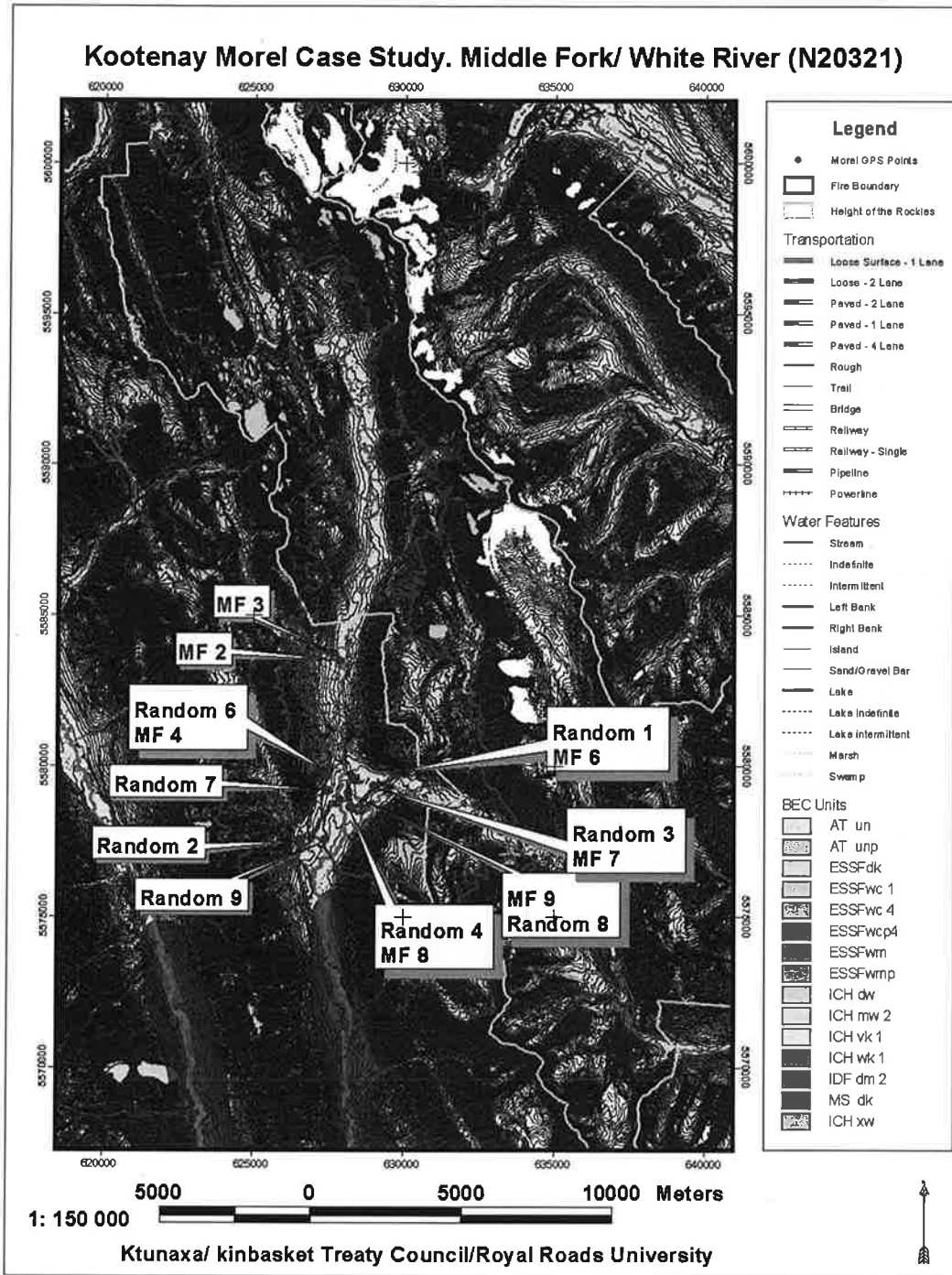


Figure 39: White River Middlefork Fire

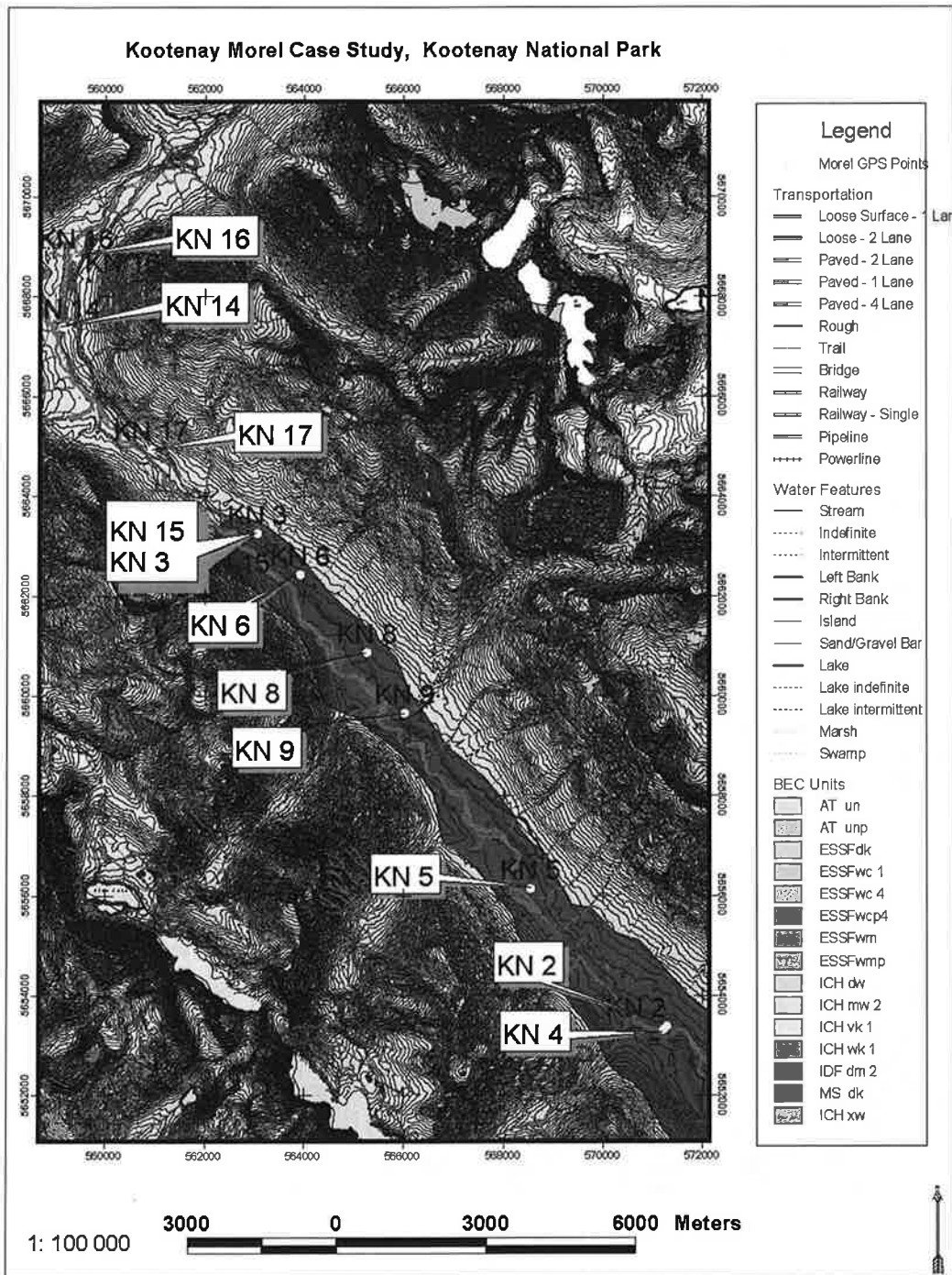


Figure 40: Tokumm/Verrendrye Fire Map 1

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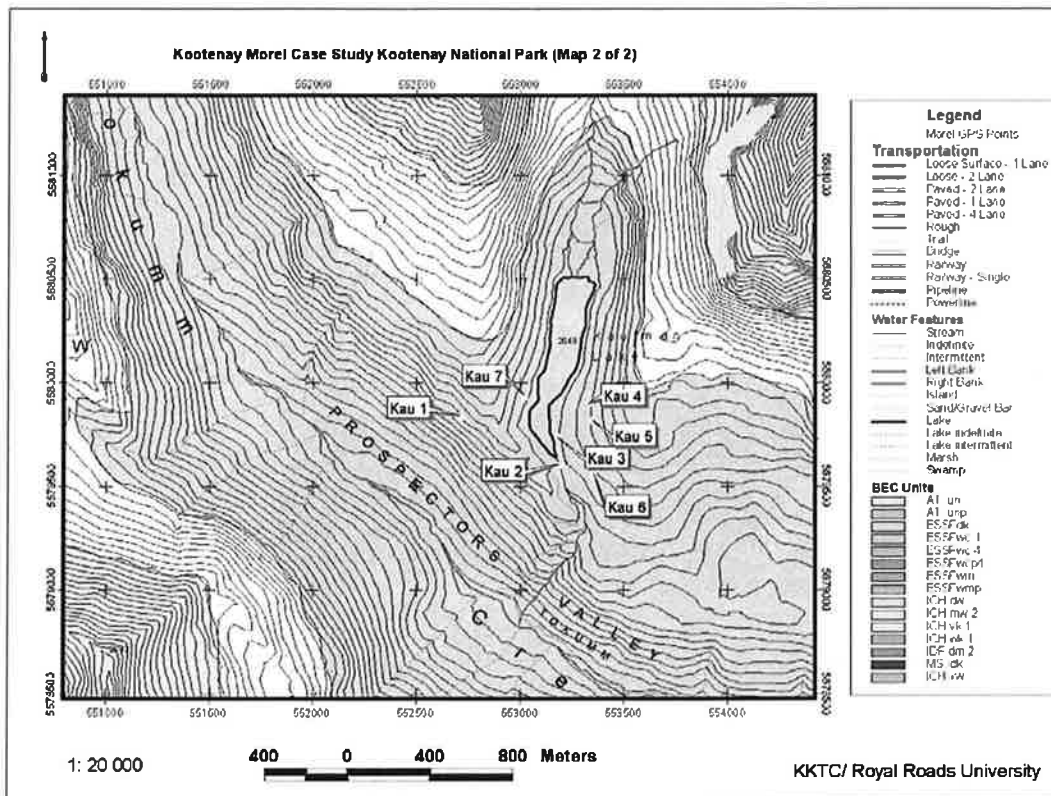


Figure 41: Tokumm/Verrendrye Fire Map 2

Appendix V – Photos



Figure 42: Morels (*M. elata* group)



Figure 43: Mass fruiting Morels (*M. elata* group) in Middlefork Fire



Figure 44: Measuring nearest neighbours



Figure 45: A giant in the *M. Elata* Group



Figure 44: Unproductive Area with Glaciolacustrine Soil

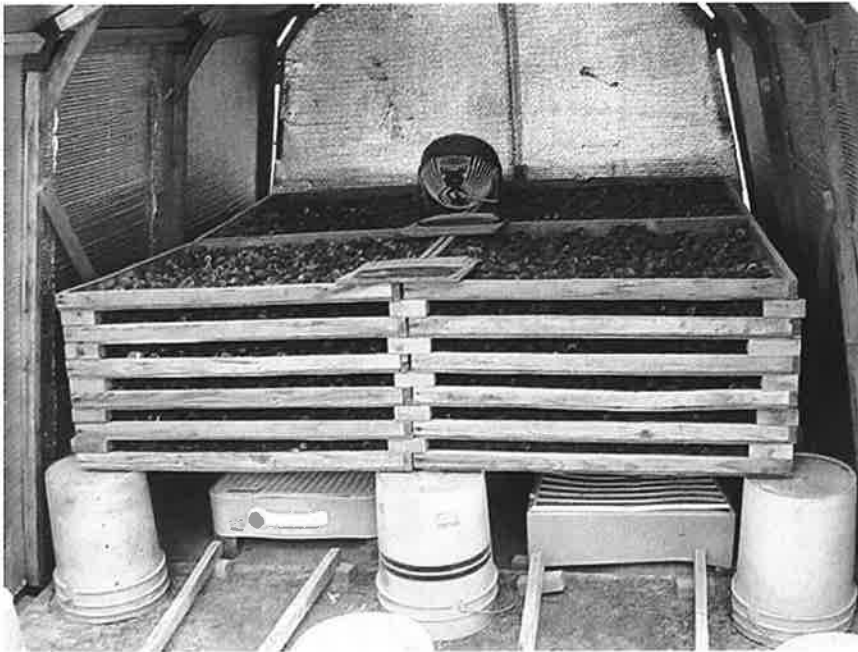


Figure 45: Morel Dryer in Lamb Creek



Figure 46: Morel (*M. elata*) in heavily burnt duff



Figure 47: Isabella Keefer in Morel Habitat in Mountain Pine Beetle Block Gold Creek

[SH3]

