Ecological and Biological Considerations for Sustainable Management of Non-timber Forest Products in Northern Forests

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Abstract.—With a current output of over $241 million per year, non-timber forest products (NTFPs) contribute significantly to the welfare of rural and First Nations communities in Canada. Maple sap products, wild mushrooms, and wild fruits are the most important NTFPs for consumption both in Canada and abroad. However, because of increased access to international markets by entrepreneurs along with a growing international demand for NTFPs, it may be possible to double or triple Canada's NTFP harvest. As well, the development of this industry requires that biological research be conducted to better manage and locate the NTFP resources. To avoid depleting forest biodiversity, future research should also address the domestication of NTFPs.

INTRODUCTION

In recent years, non-timber forest products (NTFPs) have attracted the attention of politicians, entrepreneurs, economic development agencies, and First Nations agencies as a means to improve the quality of life in rural Canada (Brubaker 1999, Davidson-Hunt 1998, De Geus 1995, Higgins 1998, Mohammed 1999). NTFPs encompass a wide variety of products derived from forests, including conifer boughs, wild rice, wild blueberries, maple sap products, wild mushrooms, and wild medicinal herbs. In British Columbia 200 types of NTFPs are recognized and in Ontario 50 types are commercially used (Mohammed 1999), although we surmise that there may be as many as 500 NTFPs in Canada. In the Upper Peninsula of Michigan, Emery (1998) documented residents harvest of various plant parts from more than 132 tree, shrub, and herb species for commercial sale and personal use.

For this paper, we define NTFPs as non-timber products growing in forests and derived from plants or animals in their natural environment. However, we exclude animal products from this discussion because of wildlife regulations that control and/or prohibit the sale of wildlife or their products in many Canadian provinces. Applied broadly, our definition includes logging residues such as branches, stumps, or rotten logs that have been culled during timber harvesting operations. Although we exclude products such as wild ginseng and Christmas trees that have been domesticated for cultivation in agricultural settings, we recognize that they can become important income generators in rural communities.

Although many NTFPs can be harvested successfully in the short term, the long-term sustainability of the NTFP industry depends on a thorough understanding of NTFP biology and ecology for three reasons. First, it is essential to understand how NTFPs grow in order to promote their conservation through sustainable harvesting and cultural techniques. Second, gatherers and entrepreneurs need to understand the biology of NTFPs in order to optimize harvesting

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operations in both the short and long terms. And third, some NTFPs will eventually require domestication; to achieve this, a complete understanding of their genetics, biology, and ecology will be needed to grow a product that is as attractive as the naturally grown product. This understanding can be acquired through traditional knowledge gleaned from multiple generations of experience, through scientific research, or through a combination of these types of knowledge. The objective of this paper is twofold: First, we present an overview of the current NTFP industry in Canada. Second, we discuss the need to understand NTFP biology and ecology.

CANADA'S CURRENT NTFP HARVEST

We conducted an informal survey of the value of NTFP shipments by dealing with known entrepreneurs, local and regional economic development agencies, academics, consultants in the fields of NTFPs, and government agencies. In table 1, we report our findings for 1997 illustrating a total yearly value of approximately $241 million Canadian in NTFP shipments. NTFP outputs make up 0.4 percent of the $58.7 billion Canadian yearly output in forest products from Canada. However, NTFPs play a critical socioeconomic role at the regional levels because they contribute greatly to rural economies through seasonal employment and often allow families to increase their yearly income by $8,000-10,000. Hence we perceive NTFP harvesting as a means to reduce poverty and improve quality of life in rural Canada. At present, maple sap products and wild mushrooms make up the bulk of Canada's NTFP output for national consumption and international export (table 1). In contrast, wild berries, medicinal plants, and other NTFPs play a relatively unimportant economic role at the national level.

Table 1.—*Estimated non-timber forest products in Canada—value of annual shipments for 1997*

Product	Estimated value (in Canadian dollars)
Maple syrup	$120,000,000
Mushrooms	$100,000,000
Berries (*Vaccinium* spp., *Amelanchier* spp.)	$ 20,000,000
Medicinal plants	$ 1,000,000
Ornamentals	$ 500,000
Essential oils	$ 50,000
Total value of shipments	$241,550,000

It is difficult to determine the actual potential of NTFP outputs in Canada. In this discussion we estimate the yearly potential of NTFPs at $1 billion Canadian based on two approaches: 1) the current yield of NTFPs is assumed to be $1.00/ha of productive forest, so we estimate that this figure can easily be increased fourfold to fivefold; 2) there is a high demand for various types of NTFPs by international markets (Norvell 1995) and resource inventories suggest that NTFP harvesting industries could meet those demands (Duchesne 1995, Miron 1994). Our predicted output of NTFPs is comparable to the total value of timber product shipments from Manitoba, Newfoundland, and Saskatchewan for 1997 (table 2).

Table 2.—*Value of shipments from Canada's timber industry by Province for 1997*

Province	Value of shipments (in Canadian dollars)
Newfoundland	$ 603,000,000
Nova Scotia	$ 1,009,000,000
New Brunswick	$ 2,960,000,000
Quebec	$15,102,000,000
Ontario	$12,059,000,000
Manitoba	$ 702,000,000
Saskatchewan	$ 714,000,000
Alberta	$ 3,482,000,000
British Columbia	$22,039,000,000
Total Canada	$58,700,000,000

ECOLOGICAL SUSTAINABILITY AND NTFP HARVEST

The ecological sustainability of the NTFP harvest is a central issue to the long-term availability and management of NTFP on a broad scale. Undoubtedly, the impact of the evolution of harvesting operations from subsistence level use to commercial exploitation will create new pressures on individual species and ecosystems as well as conflicts with other forest users. Indeed, whereas traditional use of NTFPs by First Nations people was restricteded by technological limitations, the large-scale use of the NTFPs through modern means of extraction and transportation can have a great impact on individual species and ecosystem productivity. A good example is the overexploitation of wild ginseng from eastern North American deciduous forests over the past 50 years.

ECOLOGICAL KNOWLEDGE AND NTFP PROFITABILITY

From a pragmatic perspective, it is critical to help harvesters of NTFPs acquire and use verified knowledge that helps them select the more profitable sites, harvest in an efficient and ecologically sound way, and handle the product so that value is mantained. To survive in the NTFP business, entrepreneurs must have this knowledge. A vast body of scientific literature and practical experience teaches NTFP harvesters that plants are not found uniformly through the forests. Their production and abundance varies with a wide range of environmental and internal plant factors such as soil conditions, climate, time of the growing season, history of disturbance, vegetation type, and plant age and condition. As well, it is important to recognize that within forest ecosystems not all NTFP sources are equally desirable. For example, the quality of birch bark varies among trees in a stand and between birch stands as does the pattern of annual ring width of black ash trees, an important factor in selection of trees for baskets (Collins 2000, McPhee 1989). Therefore, knowledge about the biology of NTFPs is critical to predict NTFP abundance and quality in order to profitably harvest and market NTFPs.

At this time, the most successful NTFP harvesting operations are supported by facilitating scientific knowledge. In western Canada, morel harvesters visit recent wildfire sites in search of black morels. Because black morel fruiting takes place early in the spring, harvesters start their harvesting operations in the south of the boreal forest and move northward as the morel season starts. In contrast, we have a poor understanding of the biology of many NTFPs, so it is difficult to predict their location and abundance in natural ecosystems. The future of the NTFP industry depends largely on entrepreneurs to gain the necessary knowledge to locate, harvest, handle, and transport NTFPs as efficiently as possible.

ECOLOGICAL KNOWLEDGE AND THE DOMESTICATION OF NTFPS

In the long run, there will be economic and ecological advantages to the domestication of some NTFPs. Domestication can take different forms depending on product, sites, and economic considerations. For example, blueberry producers in eastern Canada manage natural populations of plants while blueberry producers in Minnesota and elsewhere plant and cultivate desired varieties. Substantial revenues are currently derived from domesticated production of NTFPs in the northern forest. In Ontario, the Christmas tree industry and the ginseng harvest from agricultural lands yield combined revenues of over $55 million Canadian per year (Mohammed 1999). Reasons for domesticating these NTFPs included maximizing harvest, avoiding further depletion of natural stocks, stabilizing supplies, and increasing economic return. The intensive culture of ginseng in former tobacco fields of southern Ontario had the double advantage of providing tobacco farmers with an alternative crop when the tobacco demand fell and helping conserve wild ginseng. However, the success of the domestication of wild ginseng is largely due to our understanding of its ecological requirements for seed stratification, nutrient needs, and shading requirements. One caveat to the domestication of ginseng, and a factor that needs to be considered for other crops, is that field-grown ginseng is inferior to wild ginseng, because of the lower content of active ingredients in the former (Ma *et al*. 1995). Further research showed that ginseng grown under the canopy of a forest stand is of better quality (Beyfuss 1999). Other NTFPs, particularly wild mushrooms, could become domesticated if we understood their ecological requirements. For this we need to increase our understanding of NTFP biology and ecological requirements.

BIOLOGICAL FACTORS CONTROLLING GROWTH AND ABUNDANCE OF NTFPS

Understanding how plants grow and reproduce is central to the biology and ecology of NTFP production. Plant growth information needs for NTFP range from the physiology at the cell and whole plant scales of resolution to the interaction of plants with their environment at the stand and landscape scales. For higher plants of temperate ecosystems, growth takes place in two areas. The apical or primary meristems of the shoot and root are responsible for growth in length and increase their area of occupancy. The activity in shoot apices also determines the differentiation of buds into reproductive and vegetative types; this determines the potential for fruit and seed production. The activity of the cambium, referred to as a secondary meristem, produces growth in diameter through formation of new xylem, phloem, and bark (Gartner 1995, Halle *et al.* 1978, Larson 1994, Lyndon 1998, Romberger 1963, Zimmerman and Brown 1971).

In branches and main stems of plants, apical meristems are located in buds that may be active or dormant for many years, becoming active when the plant is damaged or loses vigor. Collectively these primary buds and adventitious buds that form after the plant is disturbed are referred to as the bud bank (Harper 1977, Zasada *et al.* 1992). Their distribution and potential for development within the plant vary within and among species and with the resources available on the site (Gill 1995, Harper 1977). Their location and growth determine the architecture of the plant and distribution and display of the photosynthetic machinery (Gartner 1995, Halle *et al.* 1978). The lack of attention to the presence, location, and potential for growth of these primary meristems can result in excessive harvest of NTFPs like balsam fir boughs and clubmoss, leading to a stunting and decline in the growth potential of the plant and ultimately the loss of this resource. From an ecological perspective, it is important for harvesters to understand the relationship between harvesting intensity and long-term productivity related to growth potential and dynamics of apical meristems and the foliage, fruits, and seeds that develop from them. The interaction between physical, chemical, and biological environmental factors, genetics, and apical meristems determines the potential for fruit production and development of unique NTFPs. For example, burning blueberry plants stimulates the creation of new buds and substantially increases berry production. Whereas this fact was well-known to many Native American cultures of North America, it is now used to promote blueberry production. However, fire has been replaced by mechanical means: rotary blades are now used to prune the apical buds of blueberry plants.

Activity of the cambium in trees and other woody plants is responsible for the formation of the xylem, phloem, ray cells, and bark. Cambial activity and development of the cells and tissues derived from the cambium are very sensitive to environmental conditions (Larson 1994, Zimmerman and Brown 1971). This sensitivity is the basis for the potential that exists for managing the quantity and quality of some NTFPs. Wood characteristics and growth forms such as width of the annual ring (important in black ash basketry), development of burls (used in making wooden bowls and carvings), and wood patterns (important in development of diamond willow) are all directly determined by the inherent capacity of the cambium to interact with the physical and chemical environment of the air and soil and in some cases with other organisms, particularly insects and diseases. The bark from which we obtain important materials for various utilitarian and decorative purposes, such as birch bark baskets, is a direct product of both the cambium and the cork cambium, the latter derived from activity of the cambium and whose specific function is production of the bark layers.

The bark is the first line of plant defense against many insects and pathogens. Its anatomical structure provides a physical barrier, but perhaps more important the bark is the location of many secondary chemical compounds that provide effective chemical barriers against attack by various organisms (Bryant and Raffe 1995, Prance *et al.* 1993, Shain 1995). These chemicals, also called secondary metabolites, have been and continue to be important NTFPs. Up to 50,000 secondary plant molecules are generated from plants and many are located in the bark. They can be used for medicinal purposes, antifeedants, fungicides, essential oils, food additives, and other purposes. They include, for example, the resin of balsam fir trees, tannins in the bark of hemlock, betulin and papyriferic acid in birch bark, taxol in yew bark, and salicylic acid in willow bark to name but a few. The presence, and absolute and relative amounts of these compounds vary among and within the plant and with plant age and resources available for growth. There is little doubt that new compounds and more uses for those currently identified will be discovered as more research identifies and unlocks their potential.

The cambium produces the xylem or wood through which water and dissolved mineral and organic substances are transported in specialized cells, i.e., vessels and tracheids, from the roots to the leaves. Maple and birch sap, comprised of water and of dissolved sugars that were stored overwinter in the parenchyma cells within the wood and mineral elements, are transported in the xylem and removed from the xylem in the spring when trees are tapped. In addition, secondary metabolites accumulate within the ray cells in the wood of trees as they grow older. The tannins of oak wood are critical to the wine industry because they provide chemicals that affect the taste and quality of wine.

Understanding the biology of mushrooms, Canada's second most important NTFP, is equally critical. From an NTFP perspective, there are two types of fungi: those that feed on dead material, also known as saprophytic fungi, and fungi that form symbiotic associations with plants, generally called mycorrhizal fungi. For example, the mass-produced Agaricus, shiitake, and oyster mushrooms are saprophytic species that have been domesticated. In contrast, symbiotic fungi are difficult to cultivate. In nature, the roots of all trees are infected by fungi. With a few exceptions, these root-infecting fungi form symbiotic associations with trees—fungi exchange sugars for nutrients and water with the tree roots. Unfortunately, the most valuable wild mushroom species such as the chanterelles, the boletes, and the pine mushroom are symbiotic species and their domestication has not been achieved. However, cultivation of Lactaria species has recently been reported through the co-incubation of both fungi and a host plant under controlled conditions (Godbout and Fortin 1990).

DISTURBANCE AND MANAGEMENT OF NTFPS

It is important to understand the effects of all types of disturbance on NTFPs. NTFPs fall into four broad categories—materials for spiritual use, medicinal use, ornamental use, and technology (e.g., Marles *et al.* 2000, Turner 1998). Disturbance can be considered in several general classes for each of these categories. In our brief discussion, we list three classes, realizing that others may categorize NTFP disturbance differently.

1. Constant adjustment of forest ecosystems to the variation in climatic patterns and the various types of disturbance related to this variability. They occur at all scales of resolution and each has the potential to affect NTFP quantity and quality. Frosts and insects can affect individual buds and flowers; herbivory, disease, and wind affect parts of or entire plants; wind, fire, and insects affect entire stands and landscapes. The severe damage to sugar maple trees and forests and the effect on syrup production in the northeastern U.S., Ontario, and Quebec is one recent example of the impacts of more extreme forms of natural disturbance on NTFPs. These disturbances must be expected and bring a significant level of uncertainty to the availability of NTFPs at both temporal and spatial scales. Impacts of human activities on the physical and chemical variables considered under the general heading of "global" or "climate" change may add more uncertainty to NTFP availability.

   It is not surprising that the life cycles of many NTFPs are associated with natural forest disturbance. Small fruit-bearing species such as raspberry, mulberry, Saskatoon berry, and pin cherry are early colonizers after disturbance and they disappear as time since last disturbance increases. Many of these species survive in mature forest stands as seeds buried in the soil. The passage of fire activates the seeds and, without competition, these species thrive in open sunlight. However, as ecosystems mature and plant growth creates competition for light and nutrients, the seed-bearing species are displaced from ecosystems. Native cultures of North America were aware of the importance of fire disturbance for the production of small fruits. Succession in ecosystems brings other types of NTFPs as new species are introduced. For example, shade-tolerant species such as wild ginseng and *Lycopodium* develop best in the understory of older forests. Likewise, fungal species also undergo succession as forest stands age after disturbance. Early species after fire in jack pine ecosystems are often the commercial black morel (*Morchella conica*) for a very short period of time (Duchesne and Weber 1993). Black morels are then replaced by other species as the ecosystem matures.

An important aspect of climate and NTFP production is the annual variation in phenology and the effect on timing of collection and the quality of NTFP. Emery (1998), for example, has developed an annual calendar showing the "normal" times of collection/ harvest of many products in the forests of northern Michigan. This analysis clearly shows how various species differ seasonally in their development and how gatherers who collect multiple species time their activities to plant development. For those gatherers who pick along a climatic gradient, e.g., mushroom harvesters who start in warm climates and progress to colder climates, an understanding of effects of temperature and other climate variables is a critical factor in planning.

2. Human disturbances not directed specifically at NTFPs. Forest harvesting, land development, mining, and other human activities that directly affect the land are common, and all have the potential to alter the availability of NTFPs. The effects may be of short duration or, in the case of conversion of forest land, NTFPs may be eliminated. Several points should be considered regarding the effect of these disturbances on NTFPs. First, where it is possible, gatherers of NTFPs should be directed to areas where disturbances are planned that will severely impact important NTFP species. For example, in areas where there is a balsam bough market, and a timber sale is planned that will severely damage a balsam fir understory, bough pickers should be allowed to harvest this material before it is destroyed. Second, many disturbances—forest harvesting is a primary example—result in an increase in production of NTFPs, such as fruits and berries. Where it is possible, these areas should be identified and gathering for personal and commercial use should be encouraged.

3. Human disturbances specifically related to NTFPs. These disturbances occur as a direct result of harvesting NTFPs or from efforts to manage the availability of NTFPs. Other papers in this proceedings describe some of the techniques used by Native Americans to manage the productivity of berries, roots, and other materials essential to their lives. These include the use of fire, harvest techniques, planting, and various levels of cultivation. Even today there are efforts to reduce annual periodicity of some NTFPs, increase production, and reduce natural variation not only by using similar approaches but also by using "modern" technology not available in the past. The other aspect of this category of disturbances is the effect of harvesting on the future availability of the target NTFP or another NTFP that may be available from the same plant. For example, the harvest of birch bark and birch sap may be possible during the life of an individual tree. What needs to be considered about the effects of the harvest of one on the availability and quality of the other? The same can be said of activities that affect entire stands such as burning or mechanical treatment to increase berry or fruit production. How do these treatments affect the potential availability of other NTFPs from the same land base?

CONCLUSIONS

Although NTFPs contribute less than 0.5 percent of Canada's forest output, they often represent a lifeline to rural economies. Because of sharp increases in the global demand for NTFPs, their exploitation is becoming more and more attractive for the economic development of rural communities. As Canadians become more aware of the NTFP potential, there is a need to augment our knowledge base to create a sustainable industry.

Two general types of knowledge are available about NTFPs. First, historic or traditional knowledge has been gleaned and "field tested" by countless generations of Native American and other harvesters and consumers of NTFPs. Often this information far exceeds the scientific knowledge available for a particular product (Richards 1997). The second type is scientific knowledge gained through the study of the natural history of plants and hypothesis testing using designed experiments.

Traditional knowledge and scientific knowledge both have important roles to play in the sustainable production of NTFPs. When traditional knowledge is not available, basic principles of plant reproduction and growth should provide a guide for developing practices for sustainable use of the NTFP resource. Scientific knowledge can also be used to explain the biological basis for the success of well-tested traditional methods of NTFP harvest and utilization.

Disturbance is a key concept for understanding temporal and spatial variation in NTFP quantity and quality. Disturbance should be viewed as occurring at different scales of resolution ranging from the individual bud to landscapes. Natural disturbances are a normal part of forests and they create a significant level of uncertainty in both short- and long-term production and availability of NTFPs. To some extent, the effect of natural disturbance can be managed, but not yet to the degree that uncertainty can be greatly reduced or predicted. Human activities that occur generally in the forest affect the availability of NTFPs and create conflicts among products. There are many opportunities to coordinate major disturbance activities, such as forest harvesting, with NTFP gathering, but these are not fully recognized and taken advantage of at this time. The harvest of NTFPs can affect both the sustainability of the product being harvested and other products from the same plant. Management activities that target one particular NTFP will impact other resources.

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