GENUS-LEVEL APPROACH TO *TAXUS* SPECIES.

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I. Background information on the taxa

1. BIOLOGICAL DATA

1.1. Scientific and common names, Genus *Taxus*

Classification of species in the genus *Taxus* is characterised alternately as notoriously difficult or controversial. Species have been described as discouragingly similar. Depending on the taxonomic authority consulted, the genus contains anywhere from one species with numerous varieties (Pilger, 1903) to twenty-four species and 55 varieties (Spjut, R.W. 1999).

The classification adopted by CITES is that of Farjon, (2001). This treatment recognizes 10 species and 3 infraspecific taxa within the genus. Five *Taxus* species with distributions in Asia, the Philippines and Indonesia are listed in CITES Appendix II, including infraspecific taxa. An additional five species with European and North American distribution are recognized. These species are not listed in CITES appendices. (See Annex: Taxus spp. as per (Farjon, 2001) Nomenclature, Distribution, and IUCN Redlist Status).

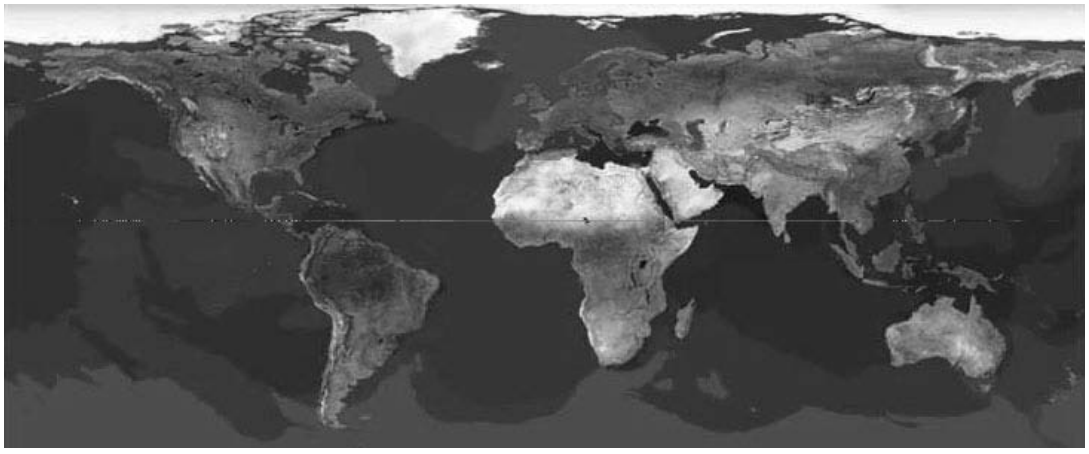
1.2. Genus Distribution

Species of the genus are largely confined to the mid-latitudes of the northern hemisphere, with some intrusion to tropical highlands. Northernmost occurrence is in Norway, southernmost below the equa-

tor in the Southern Celebes (Indonesia). Generally, most species are found in the understorey or subdominant canopy level of moist temperate or tropical mountain forests (Earle, 2008). Elevations range from near sea level in northern stations to 3000 m in tropical forests (de Laubenfels, 1988

The genus range includes, in Europe: Britain to northern Iran. In Asia: Russia, Korea, Japan, China, Taiwan, Himal, India, Burma, Vietnam, Philippines. In North America: southeast Alaska to California, southeast Canada to northeast USA, Florida, Mexico, Guatemala, El Salvador (Earle, 2008).

The five Asian *Taxus* spp. occur from lowland to montane zones in cool climates with moderate to high, evenly distributed precipitation (Farjon 2001). The North American species (in western North America; *T. brevifolia*, in northeast North America; *T. canadensis*, in Florida; *T. floridana*, in Mexico and central America; *T. globosa*) are scattered trees of the understorey of conifer and broadleaf forests (Farrar, 1995, Harlow et. al. 2001), and along riverbanks and ravines (Earle, 2008).



Global Distribution, Genus *Taxus* (Earle, 2008).

1.3. Biological characteristics

1.3.1. *Summary of general biological and life history characteristics*

Non-resinous, evergreen gymnosperms (Pinophyta). Most yew species dioecious; *T. canadensis* (Canada yew) predominantly (not exclusively) monoecious (Farrar, 1995). Lateral branches well developed, similar to leading shoots (Hils, 1993).

Slow-growing plants, form varies from excurrent, upright and arborescent to decurrent, procumbent and shrubby. Excurrent forms often develop a decurrent shrub form following disruption of central stem

development. Multi-stemmed and shrub forms often found within populations of predominantly arborescent species. Decurrent form can be sustained through frequent browsing or shearing. Many species are reported as extremely slow-growing and long lived, taking 100 years or more to attain any appreciable size (CITES, 2004).

Seeds solitary, rate of seed spread and seedling vigour reported as low for *T. baccata*. Species reported as slow-to-establish under natural conditions and in cultivation. Propagation slow (generally two years required for natural germination of seed, two to three months required for artificial propagation of rooted cuttings). Cultivation in plantations considered difficult, with individual plants slow to establish (Dirr, 1998). Establishment of plantations is reported for most species. *T. canadensis* (Canada yew) observed to reproduce vegetatively through layering (rooting of lateral reproductive branches through contact with soil surface). Connections between vegetatively reproduced plants persist for several years (Pinto & Herr, 2005).

Height of yew species varies. *T. wallichiana* (Himalayan yew) reported to reach 20 (30) m with dbh to 1 (1.5) m (NguyÔn *et al*. 2004) *T. brevifolia* (Pacific yew) height to 20 m (Farrar, 1995). Open-grown *T. baccata* (English yew) reaches height 12 to 25 m, (Krüssman 1983). *T. floridana* (Florida yew) to 5 m at maturity (Vance and Rudolf, 1974). Canada yew (*T. canadensis*) a sprawling multi-stemmed shrub rarely exceeding 2 m (Farrar, 1995).

Species generally long-lived, frequently 250 to 500 years old. Individual *T. baccata* (English yew) trees in the past were frequently reported to achieve ages as high as 3,000 years, although these figures may have been based on estimates of multiple, fused close-growing trunks individually averaging not more than 250 years old. Individual specimens planted in country churchyards are reported to have achieved ages of 1,000+ years (Vance and Rudolf, 1974).

Numerous yew cultivars exist, often showing distinct morphological variance in growth form, habit and needle form and colour (Krüssman, 1983). In horticultural use, *Taxus* spp. are noted for tolerance of close shearing. They are often displayed in shaped or sculpted forms (topiary). In particular, an extensive list of cultivars of the hybrid *T. x media* (*T. cuspidata* x *T. baccata*) has been developed for horticulture, one of which (T. x media 'Hicksii') produces strongly vertical stems particularly suited to mechanical harvest of foliage, frequently cultivated in plantations.

1.3.2. *Habitat types*:

Species in general favour moist, forested habitats, are tolerant to highly tolerant of shade. Plants are found in the understorey or canopy of moist temperate or tropical mountain forests, elevation ran-

ging from near sea level in northern stations to 3000 m in tropical forests (de Laubenfels, 1988) ranging over 60° of latitude and a wide temperature and precipitation range.

In cultivation, Taxus spp. noted as requiring fertile soils, ample moisture and excellent drainage (Dirr, 1998).

1.3.3. *Role of the genus in its ecosystem*

Understorey trees or shrubs. Fruit-like arils are eaten by birds. Birds, bears (*Ursus* spp.) and other small mammals consume the seeds. North American species are browsed by moose (*Alces alces andersoni*) and deer (*Odocoileus virginianus*) (Pinto and Herr, 2005).

1.4. Population:

1.4.1. *Global Population size:*

Population distribution (most species) is broad, but nowhere continuous. North American species tend to occur as isolated individuals or in discontinuous populations. Asian *Taxus* spp. generally occur as scattered individuals under the canopy of other trees rather than as a dominant species.

Current information on the size and status of Asian *Taxus* spp. populations is largely unavailable. Field surveys and other supporting data referenced prior to listing of Asian species at CITES CoP13 suggested populations of *Taxus* in Asia were in decline. It is reported that all species of Taxus in China have been reduced due to over-exploitation for their medicinal properties (CITES, 2004).

Overall geographic range of the five Asian species is reported not to have changed significantly over recent history, but localized land conversion and deforestation are likely affecting the species in China, Indonesia, and the Philippines. It is suggested that the life history of Taxus in general, and intense harvest pressure is likely to affect future regeneration of these species, which may reduce their geographical distribution (CITES, 2004).

The European species *Taxus baccata* (English yew) has an extensive distribution and corresponding large population. The species is also extremely common in urban and pari-urban landscapes within and outside of its natural range. Its IUCN status is Least Concern (IUCN, 2007).

T. brevifolia (Pacific yew) is a small tree found in the understorey of primarily coastal or interior western redcedar – western hemlock forests of western North America. It is widely distributed in these areas but generally of moderate to low abundance, and is most abundant in the southern interior (Harlow *et. al*. 2001). It is broadly distributed

from California to Alaska in appropriate habitats. The species has been considered at risk (lowest category of threat) as a result of destructive bark harvesting.

T. canadensis (Canada yew) is distributed throughout eastern Canada and the northeast United States. In Canada, the species occurs from southeast Manitoba, through central and southern Ontario and Quebec, and Atlantic Canada (Prince Edward Island, Nova Scotia, New Brunswick and Newfoundland). Its relative abundance and high taxane content make it highly attractive for commercial-scale biomass harvesting (Smith and Cameron, 2001).

The populations of the North American species T. globosa and T. floridana are geographically restricted.

1.4.2. *Current global population trends:*
___increasing _X_decreasing ___stable ___unknown

1.5. Conservation status

1.5.1. *Global conservation status* (according to IUCN Red List):

___Critically endangered
___Endangered
_X_Vulnerable
___Near Threatened
_X_Least concern
_X_Data deficient

Species	IUCN Status (Red List Category & Criteria) ver 2.3 (1994) assessed 1998
Taxus chinensis (Pilg.) Rehder	Lower Risk Least Concern (LR/lc)
Taxus cuspidata Sieb. & Zucc.	LR/lc
Taxus fuana Nan Li & R.R.Mill	Vulnerable (VU D2)
Taxus sumatrana (Miq.) de Laub.	LR/lc
Taxus wallichiana Zucc.	Data Deficient (DD)
Taxus baccata L.	LR/lc
Taxus brevifolia Nutt	Lower Risk Near Threatened (LR/nt)
Taxus canadensis Marsh.	LR/lc
Taxus floridana Nuttall ex Chapman	Critically Endangered CR B1+2c
Taxus globosa Schlectendahl	LR/nt

1.5.2. *Conservation status or species in the genus* Taxus

Three *Taxus* species native to China (*T. chinensis, T. cuspidata*, and *T. fuana*) are reported listed under the National First Category Protection, which prohibits the collection of Taxus spp. without the authorization of the National Forest Bureau. Forestry policy and regu-

lations under the Native Flora Protection Act of the People's Republic of China outline the rules regarding native flora protection and management (CITES, 2004).

All native species of Taxus in China are listed Class I, which prohibits the collection of yew without the authorization of the Chinese Government. *T. wallichiana* is listed as endangered in the China Plant Red Data Book – Rare and Endangered Plants. All native species of Taxus in China are included in The Manual of the Monitored and Administered Species of Wild Fauna and Flora for Import and Export of the People's Republic of China (CITES, 2004).

Among North American *Taxus* species, *T. floridana* is listed critically endangered and is registered on the endangered plant list of the State of Florida. *T. globosa* is considered a plant of least concern, near threatened (IUCN, 2007). Both species are under pressure as a result of restricted geographical distribution and habitat loss.

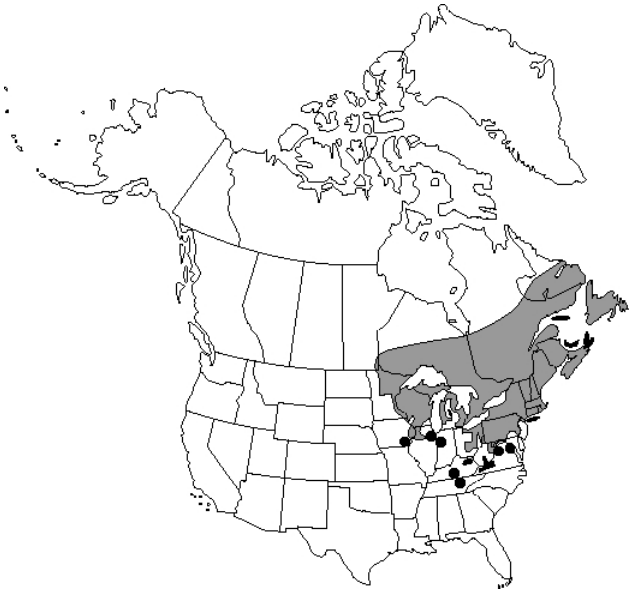
In 2002, the Scientific Authority of the United States of America consulted with range countries on a proposal to include all species of *Taxus* in CITES Appendix II. The study determined that the bulk of the trade was in Asian species of Taxus, and that listing these species in Appendix II would help regulate trade and prevent unsustainable and destructive harvest of these species for the international pharmaceutical industry. Based on trade and information on species status obtained from range countries and a review of the genus, European Taxus baccata and North American species (*T. brevifolia, T. canadensis , T. globosa, T. floridana*) were eliminated from further investigation (CITES 2004).

T. wallichiana, was listed in Appendix II of CITES in 1994. In 2004, the remaining four species of Taxus with Asian distribution were listed in Appendix II.

1.5.3. *Main threats within the case study countries*

___No Threats
_X Habitat Loss/Degradation (human induced)
___Invasive alien species (directly affecting the species)
_X_Harvesting [hunting/gathering]
___Accidental mortality (e.g. Bycatch)
___Persecution (e.g. Pest control)
___Pollution (affecting habitat and/or species)
___Other_____
___Unknown

2. SPECIES MANAGEMENT (EXAMPLE): *T. CANADENSIS*



Distribution of Taxus canadensis (eFloras, 2008).

Explanation:
Management information here presented is specific to the non-CITES listed species *T. canadensis* (Canada yew, also referred to as "ground hemlock"). In Canada, T. canadensis has not historically been considered a forest species having commercial value. As a result, it rarely appears in forest resource inventories, silvicultural manuals or prescriptive harvesting guidelines. However, the distribution and ecology of the species have been studied in detail (e.g. Scoggan, 1978; Soper & Heimburger, 1982) as has the species' ecological profile in forest site classification (e.g. Meades & Moores, 1989). *T. canadensis* is cited as a moderate indicator plant for fresh to moist and organic soils associated with seepage zones (Ringius and Sims, 1998).

Identification of *T. canadensis* as a commercially viable source of harvestable biomass has resulted in development of harvesting guidelines and principles with a specific objective of ensuring that sustainable (i.e. non-detrimental) harvesting methods are employed by commercial harvesters.

Acknowledging that specific biological factors, growth rates and harvest responses vary from one *Taxus* species to another (as they do within geographically diverse populations of *T. canadensis*), it is probable that the general theory regarding sustainable harvest of leaf and twig biomass of *T. canadensis* can inform determination of non-detri-

mental harvest and trade procedures for similar *Taxus* species. Harvest of bark of *Taxus* spp. (e.g. in the past, for *T. brevifolia*) is by definition destructive. E.g. for *T. wallichiana*, it is reported 7272 kg of bark are required to produce one kilogramme of paclitaxel, requiring 10 000 kg of bark or approximately 3000 trees (PC17 Inf.10). Sustainable harvest of *Taxus* spp. for bark is appears problematic and, based on available information, is not recommended.

2.1. Management measures

2.1.1. *General*

Interest in *T. canadensis* biomass as a novel non-timber forest product, and as an alternative source of income for rural communities in Canada, arose in the latter part of the 1990's along with awareness by multinational pharmaceutical companies that wild populations of *T. canadensis* in eastern Canada and the north-eastern United States represented a relatively abundant and untapped source of *Taxus* biomass with relatively high taxane content. This interest lead, initially, to excessive and biologically unsustainable harvesting practices (Canada Yew Association, 2008).

While much of the population of *T. canadensis* within its natural range is remote and inaccessible, early experience suggested unlimited harvesting in the accessible parts of its range could result in localized commercial extinction (Cameron and Smith, 2004).

2.1.2. *Purpose of the management plan in place*

In response to increasing harvesting pressures, and in order to establish a sustainable *T. canadensis* industry in Canada, an ad hoc Working Group comprising Canadian Federal and Provincial forestry officials, private sector growers, harvesters and paclitaxel producers together established a set of voluntary harvesting guidelines and a list of principles and corresponding criteria and indicators, aimed at ensuring sustainable biomass harvesting. Harvesting guidelines were developed based on field trials and research carried out by the Canadian Forest Service and the Prince Edward Island Department of Agriculture and Forestry (Smith and Glen, 2000).

2.1.3. *General elements of the management plan*

The harvesting guidelines and principles developed by the Working Group were intended to address adherence to applicable Canadian provincial and federal legislation, regulations, and international treaties; conservation of biodiversity, soil and water on harvest sites; monitoring and tracking to ensure that harvesting meets sustainability gui-

delines; and access to information by harvesters and landowners regarding the sustainable harvest of *Taxus* biomass.

Several revisions to the guidelines occurred over time, reflecting increased knowledge and familiarity with *T. canadensis*. In early versions of harvest guidelines, removal of more than three years of annual growth was deemed acceptable, provided the amount harvested did not exceed a certain portion of the total green biomass of individual branches. The rationale for the initial guidelines was that removal of up to 4 or 5 years of growth was 'biologically' acceptable provided that the same plants were not re-harvested for period of time equal to, or slightly longer than the number of years of growth extensions removed (Smith and Glen, 2000).

Measurements from subsequent research and harvest trials suggested that plant recovery (regrowth) following removal of 5 or more years of growth was adversely impacted, and that plants would require a period of time significantly longer than 5-6 years to recover before a repeat harvest could be undertaken. Guidelines reflecting results from field harvesting trials, discussions among harvesters and harvest contractors, and general observations of responses to harvesting in Quebec and Atlantic Canada were therefore revised to advocate harvest of significantly shorter stem sections with a removal limit of 3 years of annual growth (Canada Yew Association, 2008).

Current harvest guidelines (Canada Yew Association, 2008) are applied on Crown (publicly owned) lands in two Canadian provinces (as legislation in Prince Edward Island, as part of an pilot study in New Brunswick), and are accepted as an alternative method on private lands in the province of Quebec, which has developed its own harvesting guidelines. Policies specifying harvesting guidelines have not yet been determined in other Canadian jurisdictions within the range of *T. canadensis.*

A management system for *T.canadensis* in eastern Canada has been considered. An integrated program of this type should incorporate protocols for protecting the resource (conservation and sustainable harvesting) with methods of not only sustaining the industry, but for helping it to grow such as through establishing a domestication program. Verifying that any and all harvesting is done sustainably by an independent third-party will be an integral part of managing the resource (NRCan and P.E.I. Dept. Ag., 2002).

(i) *Taxus canadensis* Harvesting Guidelines (Canada Yew Association, 2008)

I. *Timing of Harvest*

Harvesting can be undertaken throughout the year, but a number of factors will affect quality of material harvested, costs of

harvesting, and how plants will respond after harvesting.
Taxane yields are generally higher in dormant shoots than in those that are actively growing. If a purchase arrangement is based on taxane content in biomass, then the recommended time to harvest is likely to be from late August to March and April, times at which the plants are dormant.

II. *Selection of Plants for Harvest*
Harvest should be limited to branches from plants (stems) in excess of 1 metre in height. This limit to harvestable plant size is recommended to ensure harvested plants possess a minimum required vigour prior to harvest. (Adopting the minimum size guideline increases the likelihood that heavily browsed or recently harvested plants will be excluded from harvest).

III. *Quantity of Biomass to Harvest*
a) Limit harvest to the terminal shoot and the two or three most vigorous lateral shoots located closest to the top of the plant.
b) Remove up to, but not more than, three years of growth (i.e. the three most current seasonal growth extensions). On a moderately 'vigorous' branch and plant, current-year growth will measure approximately 7 to 10 cm. Harvesting three years of growth will typically yield a stem or branch with total length of 20 to 25 cm but the cut length can range from 15 to 40 cm depending on plant vigour. For this reason, an age- rather than length-based criterion is recommended.
c) *T. canadensis* shoot surfaces typically remain green for up to three years. Cuts should be limited to sections with green surfaces. Do not make cuts into brown woody stems below (older than) the third year growth extension.
d) Harvested sites should not be re-harvested for a minimum of 4 years (i.e. the number of annual growth extensions growth removed +1).

Additional Notes: Following pruning, new buds (and the shoots that are produced from these buds) will develop adjacent to the cut surface. On plants that are heavily pruned, e.g., in cases where 4 to 6 years or more of growth is removed, the new shoots will take longer to develop than where only 3 years growth is removed. Although large numbers of new shoots may develop on heavily pruned plants, these shoots typically are 'weak' and grow slowly. Measurements from research plots indicate that where more than three years of growth is harvested, new or replacement growth will be greatly reduced (Cameron and Smith, 2009).

IV. *How to Harvest*

a) Use secateurs (hand pruners). Do not break or tear branches.
b) Regardless of how much growth is removed up to the maximum of 3 years of growth extension, make cuts immediately above (distal to) lateral branches. This practice encourages lateral branches below the cut to rapidly extend and 'replace' the removed shoot. As new shoots originate from the tissue located at nodes, regrowth will be rapid, and more vigorous than regrowth from an internode.
c) Leave Every Fifth Stem Unpruned. (In previous harvest guidelines, it was recommended to leave at least one stem in every 'clump' intact. This method remains valid. However, identifying individual clumps can be very difficult in locations where *T. canadensis* is particularly dense. Leaving at least 1 in 5 stems unharvested is practicable and accomplishes the same goal).
d) Do Not repeat harvesting on a site for a minimum of 4 years (= number of years of growth removed +1).

(ii) *Taxus canadensis* Harvesting Principles (Canada Yew Association, 2008)

a) Harvesting of *T. canadensis* will follow all applicable provincial and federal legislation, and international treaties.
b) Harvesting of *T. canadensis* will not diminish the viability of natural populations and will conserve the quality and quantity of *T. canadensis* biomass through the use of appropriate harvesting practices. On-site impacts associated with the harvesting of *T. canadensis* will be minimized.
c) Harvesting practices must ensure the conservation of biodiversity, soil, water and other ecosystem attributes of harvested areas.
d) Handling and transport of the resource will be done in such a way as to maintain the quality of harvested biomass.
e) Monitoring and tracking shall be conducted to ensure that harvesting adheres to sustainability guidelines acceptable to the Association. Auditing will be an integral component of the system. Although independent third party auditing is normally required, an equivalent internal system (e.g. provincial) can be acceptable provided said system is demonstrated to provide the level of objectivity and accuracy necessary to evaluate adherence to all of the principles, criteria and indicators within these guidelines.
f) Harvesters and landowners must have access to information regarding the sustainable harvest of *T. canadensis*. Harvesters

must be trained and supervised sufficiently to ensure adherence to the guidelines.

g) Economic and social benefits from harvesting and processing Canada yew will be fairly distributed and focused on the long-term well being of forest workers, landowners, and local communities while respecting the rights of individuals/ agencies to conduct business.

h) Exemptions from sustainable harvesting practices may be appropriate where land-use conversions will result in the permanent elimination of a population(s) from a given site.

2.1.4. *Restoration or alleviation measures*

Assuming harvest guidelines and principles are followed, restoration or alleviation measures are not required.

2.2. Monitoring system

2.2.1. *Methods used to monitor harvest*

In Canadian jurisdictions, independent third party auditing is not legislated, but is required by the harvesting principles of the Canada Yew Association. An equivalent internal system is acceptable, provided the system is demonstrated to provide the level of objectivity and accuracy necessary to evaluate adherence to all of the principles, criteria and indicators within these guidelines.

2.2.2. Confidence in the use of monitoring

Specific to *T. canadensis* harvesting, the development of a trade association that includes, and facilitates communication among the majority of involved stakeholders, including harvesters and processors, has contributed greatly to confidence in, and adherence to, monitoring procedures.

In eastern Canada, the number of commercial-scale harvesting companies is small, a condition which greatly facilitates monitoring of operations. In 2005, the largest *T. canadensis* harvesting company (Chatham Biotec Ltd.) reported its operations ensured full chain-of-custody control and monitoring of harvested biomass through the use of a "closed loop" tracking system. In this approach, all harvest sites were registered, pre-inspected, mapped and identified using GPS and aerial photographs. During all harvest operations, specially marked and numbered collection bags were issued to harvesters, allowing repeated inspection and verification of adherence to harvesting guidelines by individual harvesters. Marked collection bags were then tracked from harvest sites to the biomass process site using electronic

and paper-based auditing systems. Third-party auditors (Smartwood) were present during some harvest operations (Chatham Biotec, 2005).

2.3. Legal framework and law enforcement: Provide details of national and international legislation relating to the conservation of the species.

The conservation and management of wild species is multi-jurisdictional in Canada, falling under the authority of various provincial, territorial, and federal acts and legislation related to wildlife management. Canada's provinces and territories hold responsibility for management and inventory of natural resources within their respective jurisdictions.

Commercial-scale *T. canadensis* harvesting has influenced Provincial policies regarding collection on Crown (publicly owned) land to varying degrees in four Provinces; (Prince Edward Island, New Brunswick, Quebec and Ontario). Specific regulation of *T. canadensis* harvest varies by jurisdiction.

Examples:

In the Province of Prince Edward Island, adherence to CYA harvesting guidelines and Principles is a legal requirement under the Province's Wildlife Conservation Act. To harvest legally on Crown land, harvesters must obtain a harvesting license from Provincial Ministry of Agriculture and Forestry. To be granted a licence, applicants must successfully complete a government-approved harvester education program. Persons who wish to act as buyers of *T. canadensis* biomass from licensed harvesters must apply for and hold a buyer's license also issued by the provincial government. The license requires buyers to pass a government-approved T. canadensis buyer education program. Buyers must provide the names and addresses of all persons operating buying stations on their behalf and must also provide the location of warehouses, shops or other buildings in which biomass will be stored.

Licensed *T. canadensis* buyers are required to maintain detailed records regarding acquisition of biomass from licensed harvesters, including: the identity and registration of the harvester; the precise position and location in latitude and longitude of the harvest site; the weight of biomass acquired specified as green or dry weight, and; the price paid per unit weight (pound or kilogram) of biomass. The buyer must provide a duplicate copy of this record to the licensed harvester. In the case of harvest on privately owned land, the harvester must have written permission to harvest from the land owner. Transport of biomass requires identification of location, date of harvest and identification of harvester to be clearly displayed on the biomass container. Import and export of *T. canadensis* biomass from the province is res-

tricted to holders of a valid buyer's license (Prince Edward Island, 2006).

In harvesting on private lands in the Province of Quebec, *T. canadensis* is treated in a fashion similar to other forest products. Legislation which covers trade with other provinces and other countries requires that biomass can be sold to processors only by a government marketing board. The marketing board acts as a broker, buying biomass from the harvester and selling it to the processor. All harvested biomass must be sold to the marketing boards who maintain internal auditing procedures (Canada Yew Association, 2005).

The Province of Ontario currently has a voluntary system in place for managing the commercial harvest of *T. canadensis*. Companies requesting the right to harvest on Crown land submit a business plan to the Provincial Ministry of Natural Resources. This plan must meet specific requirements in order for the company to receive a "Letter of Support" from the Ministry. There currently appears to be general compliance with the Ministry's voluntary management system for *T. canadensis* on public land and existing sustainable harvesting guidelines (Ontario Ministry of Natural Resources, 2007).

3. GENUS *TAXUS* UTILIZATION AND TRADE

3.1. **Type of use** (origin) **and destinations** (purposes) (e.g. commercial, medicinal, subsistence hunting, sport hunting, trophies, pet, food)

Biomass (leaves, twig, bark and roots) of all *Taxus* species contains a unique class of diterpenoid alkaloids that are the source of a chemotherapeutic drug Taxol, which is used to treat a range of human cancers. Since the 1990s, a phenomenal demand by pharmaceutical companies for paclitaxel and other taxane compounds extracted from *Taxus* spp. world-wide has subjected all yew populations to severe harvest pressure, to the point that some are currently threatened or endangered. Recent field surveys and other supporting data suggest most populations of *Taxus* spp. are in decline (CITES, 2004).

Beginning in the early 1990's, the bulk of paclitaxel produced globally has been marketed under the name Taxol, a registered trade name held by Bristol Myers Squib. (It is the process by which a paclitaxel-based drug is produced or its formulation which is held under patent, rather than the compound itself). After 2001 additional companies began marketing generic formulations of paclitaxel, thereby increasing the demand for biomass. Subsequently, patents for other processes, including generic and semi-synthesized compounds have also been registered (Nikolakakisa *et. al*. 2003).

Approximately 30,000 kg of *Taxus* biomass is required to produce 1 kg of refined paclitaxel. An estimated 400 kg per year of paclitaxel products are marketed annually in North America and Europe, with global amounts estimated at 800 -1000 kg (Smith and Cameron, 2001). World sales of Paclitaxel in 2003 were estimated at $4.2 billion US, and were expected to grow to $13 billion US by 2008 (CITES, 2004). Bioxel Pharma Inc., a Canadian Laboratory producing active pharmaceutical product projected annual sales of $90 million US in 2004.

Taxus biomass in trade is sometimes exported as dried needles and twigs, or often in a crude liquid or powdered extracts of varying concentrations. Form and appearance of the chemical derivative in varies depending on the state of refinement. Chemical derivatives can be differentiated from finished pharmaceutical product. Chemical extracts of *Taxus* spp. in trade vary in appearance from a tar-like substance (sometimes referred to as "brown liquor") shipped in drums to a light brown powder. Pure paclitaxel is a whitish or yellowish, crystalline material.

Indigenous people are known to have used yew species in utensils and medicines (Hartzell 1991). North American indigenous people used yew for implements, including bows, dip-net and drum frames, as well as for medicines (Alaback et al, 1994). In Europe and Asia the wood of the tree was prized for bows and is still valued for fine musical instruments, cabinets, and utensils (Vance and Rudolf, 1974; Hartzell, 1991). The bark of *T. wallichiana* (Himalayan yew) is used for preparing beverages and medicines (Purohit, *et al.* 2001).

Several Taxus spp., in particular *T. baccata, T. cuspidata* and hybrids have, for more than 100 years, been used extensively in horticulture in North America and Europe. Horticultural material is almost exclusively derived through artificial propagation (Krüssman, 1983).

As chemical derivatives rather than plant biomass are the *Taxus* commodity most often traded, the CITES Appendix II annotation specifically designates all parts and derivatives except seeds, pollen and finished pharmaceutical products.

It is possible to fully synthesise Taxol. However, its molecular structure is complex and its synthesis costly. As a result, harvest of wild or plantation-grown biomass remains more economically attractive to pharmaceutical companies than does full synthesis (Guo *et al*., 2006). Most range countries report efforts to propagate and develop, at varying scales of production, plantations as a source of biomass. Growth and establishment of *Taxus* spp. individuals is slow, suggesting wild harvest of Taxus biomass will continue to represent the main source of material in the short to mid-term (CITES, 2004).

3.2. Harvest:

3.2.1. *Harvesting regime* (extractive versus non extractive harvesting, demographic segment harvested, harvesting effort, harvesting method)

Historically, two approaches to harvesting have been followed for Taxus spp; harvest of bark and harvest of leaf and twig biomass.

Bark from the species *T. brevifolia* (Pacific yew) was the first identified source of paclitaxel. Early clinical studies of Taxol production by the pharmaceutical company Bristol Myers Squib created high demand for bark of the species. The harvest approach was by definition destructive; it required large amounts of bark biomass (i.e. bark from an estimated 52 000 to 78 000 yew trees annually during the early 1990's). Approximately 10,000 kg of Pacific yew bark was required to make 1 kg of Taxol, with the bark of at least six trees required for a single treatment dose. In January 1993, Bristol Myers Squib announced significant progress with alternative approaches and alternative Taxus species, and that the company no longer required large quantities of *T. brevifolia* bark (USDA Forest Service, 1993).

Taxanes were found to occur in the stem bark, roots and needles of other yew species (Witherup et al., 1990) including *T. wallichiana* (Himalayan yew) (WCMC, 2002). Discovery that leaves and twigs of most *Taxus* spp. contained appreciable levels of taxanes created an alternate harvesting approach that had potential to support repeatable and sustainable harvesting. The harvest method is essentially that of pruning or shearing (as with a hedge or a topiary display). For example, the Italian pharmaceutical company Indena (among the world's largest producers of taxane-derived pharmaceuticals) undertakes large-scale production of semi-synthetic paclitaxel using *T. baccata* trees cultivated in plantations in northern Italy (Megget, 2007).

3.2.2. *Harvest management/ control* (quotas, seasons, permits, etc.)

These are specific to individual jurisdictions, and are not considered here.

3.3. Legal and illegal trade levels:

Large paclitaxel production facilities exist worldwide, including facilities in India, China, North America and Europe. Taxanes are a global commodity and the distribution of *Taxus* spp. biomass and chemical derivatives for use in pharmaceutical production occurs on a worldwide basis. The import and export of biomass of one or another *Taxus* species is largely a function of supply and cost.

Demand for Taxol in North America and Europe in 2002 was estimated at 300-400 kg/year, requiring 12,000,000 kg of *Taxus* biomass.

Global demand for Taxol is growing and estimated at 800-1000 kg worldwide by 2012 (Cameron and Smith, 2002).

Although *T. wallichiana* has been listed in CITES Appendix II since 1995, there remains little information available regarding current rates of harvest and trade. It is reported this results from a combination of factors, including: varying interpretations and confusion regarding the taxonomy of *T. wallichiana* and other *Taxus* species; generally low levels of CITES implementation for medicinal plant species; exclusion of chemical derivatives (extracts) from CITES trade controls from 2000-2005; and difficulty in visually identifying the main products in trade (leaves, bark, extract), including with regard to discriminating between parts and derivatives from *T. wallichiana* and those from other *Taxus* species (CITES, 2008).

CITES documents indicate it is difficult to quantify the level and extent of illegal trade in *Taxus* spp., but that unlawful activities undoubtedly occur. In China, attempts have been made to export *Taxus* species by misdeclaration, including illegal export of native *Taxus* species alleged to be processed material originally from North America (CITES, 2004).

It is similarly difficult to quantify the level and extent of illegal harvest of *T. canadensis* elsewhere. In Canada, *T. canadensis* is not specifically regulated as a threatened or endangered species, under domestic law or by CITES. Specific cases of destructive over-harvesting are known to have occurred.

II. Non-detriment finding procedure (NDFs)

1. IS THE METHODOLOGY USED BASED ON THE IUCN CHECKLIST FOR NDFS?

__yes _X_no

Discussion:

It is not the purpose of this general case study to describe a specific non-detrimental finding procedure. However, the sustainable harvesting guidelines developed for *T. canadensis* as discussed in Section 2 address factors that would require consideration in developing an NDF. These emphasize the level of harvest intensity that can reasonably be employed if full regeneration of the harvested population is intended.

With respect to non-detriment determination and the guidelines and principles presented for sustainable harvest of *T. canadensis*:

1. Harvest limits suggested in the guidelines are applied directly to individual plant stems, rather than indirectly to (e.g.) volume of biomass per unit of harvested land area. Specific growth responses will vary among *Taxus* spp., but linkage of sustainable harvest intensity to a physiologically-based rate of annual stem growth is a transferable method for informing non-detriment determination. In addition to biological advantages, use of plant-specific measurements in harvest guidelines can serve to reduce regulatory burdens associated with enforcing area- or volume-based harvest controls.
2. Non-detrimental harvesting and economics are directly linked. Preliminary harvest trials in Canada indicate that limiting *T. canadensis* harvest to 3 years of annual growth results in economic advantages for harvesters (Stewart Cameron, Canadian Forest Service, personal communication). This is because large-diameter branches (i.e. sections older than 3 years) contain appreciably less taxane by volume than do leaves and small twigs (likely the case for other *Taxus* spp. as well). Overly aggressive harvesting of biomass increases the weight and volume of material transported from a harvest site, without greatly contributing to the taxane content of the material harvested. Limiting harvest to 3 years of growth extension reduces handling and transport costs while increasing the quality by volume of the product. The quality of the product expressed as the amount of taxanes per tonne of biomass is also maximized.

   Additionally, overly aggressive biomass harvesting eliminates a site's potential for re-harvest for an extended period of time. As a result, harvesters are obliged to seek ever more distant sites with resulting increases in travel, transport and operating costs. By limiting harvest to three years of growth per stem, harvested sites can be revisited after four years (three years of growth replacement growth plus one year to ensure full recovery from harvest). Carefully planned, a four-year harvesting cycle would allow harvesters to operate commercially and sustainably on a fixed landbase.

3. Artificial Propagation of *Taxus* spp.:
   As an alternative response to increasing demand for biomass, domestication programs have begun in Canada and elsewhere, with the objective of using rooting cuttings from selected high-yield clones in field crop production (Smith and Cameron, 2002). *T. canadensis* stems are reported to be moderately amenable to roo-

ting, but slow to do so. Certain clones cannot yet be rooted effectively (Webster *et. al*., 2005). Given the demonstrated potential for cropping of *T. baccata, T. canadensis*, *T. wallichiana* and of *T. x media* cultivars in plantations, this area of research represents an important additional approach to sustainable harvest and management of all *Taxus* spp.

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