

## The scientific value of the largest remaining old-growth red pine forests in North America

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**Abstract** Old growth red pine forests (*Pinus resinosa*) cover less than 1% of their original range in North America and are essential for maintaining biodiversity at stand and landscape scales. Despite this, the largest remaining old-growth red pine forest in the world, the Wolf Lake Forest Reserve, is currently threatened by mining claims in Northern Ontario and has been receiving considerable media and public attention in recent months. We provide a timely review of how large old growth red pine forests maintain biodiversity at several taxonomic levels (with

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a focus on trees and plants) through heterogeneous partitioning of limiting resources such as light and nitrogen, formation of complex habitats through increased accumulation of coarse woody debris, and the maintenance of natural disturbance-driven succession. These processes shape the overstory community, allowing for the regeneration of pines, coexistence of early-mid successional shade intolerant species and cross-ecotonal establishment of late successional tree species in response to regional warming over the past three decades. Using Wolf Lake as a case study, we review legislation and policy complexities around this issue and provide scientific arguments for the preservation of this forest. We invoke recent insights into the ecological role of refugia, the development of criteria for assessing endangered ecosystems, and the challenges of conservation in the face of climate change and disturbance regimes. These forests are ecologically important and provide a scientifically irreplaceable system for assessing baseline ecosystem function, processes and services. As the largest remaining old-growth red pine forest in the world, Wolf Lake Forest Reserve deserves intensive study, monitoring and full protection from future development.

**Keywords** Landscape ecology · Mining exploration · Natural resource policy · Ecological services · Great Lakes-St. Lawrence forest · Forest biodiversity

## Introduction

Only 0.6% of undisturbed red and white pine forest stands remain in their pre-settlement range in North America (Frelich et al. 1995; Ziegler 2010). These mixed conifer-deciduous forests tend to occur across a broad scale ecotone between boreal forests to the north and temperate forests to the south and developed after the retreat of the Laurentian ice sheet beginning around 11,000 years ago. Before European settlement, red pine (*Pinus resinosa*) occupied about 7 million acres of pine forest in Minnesota, Wisconsin, and Michigan, but now only occupies 1 million acres (Noss et al. 1995; Gilmore and Palik 2006). In Canada, the situation is just as dire (Boucher et al. 2009). In Northern Ontario forests are currently facing imminent threat from mining and other industrial developments and the few naturally-occurring red pine stands present in the region are highly fragmented with little interior forest area (Perera and Baldwin 1993).

Throughout North America, red pine is disappearing from the landscape due to heavy timber harvesting, increased fire suppression, and land conversion (Carleton et al. 1996; Gilmore and Palik 2006). With the suppression of forest fires in much of its historical

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range, many red pine stands are having difficulty maintaining their current population numbers (Gilmore and Palik 2006). Such forests in Ontario usually occur on nutrient-poor sites found on the Canadian Shield while logging has selectively reduced the abundance of medium-aged stands (Carleton and Gordon 1992). The largest known intact red pine forest in North America, the Wolf Lake Forest Reserve, is currently threatened by active mining exploration, and risks further development. In this paper, we aim to highlight the history and challenges faced by Wolf Lake Forest Reserve and the ecological value of old-growth red pine forests, both at Wolf Lake and elsewhere.

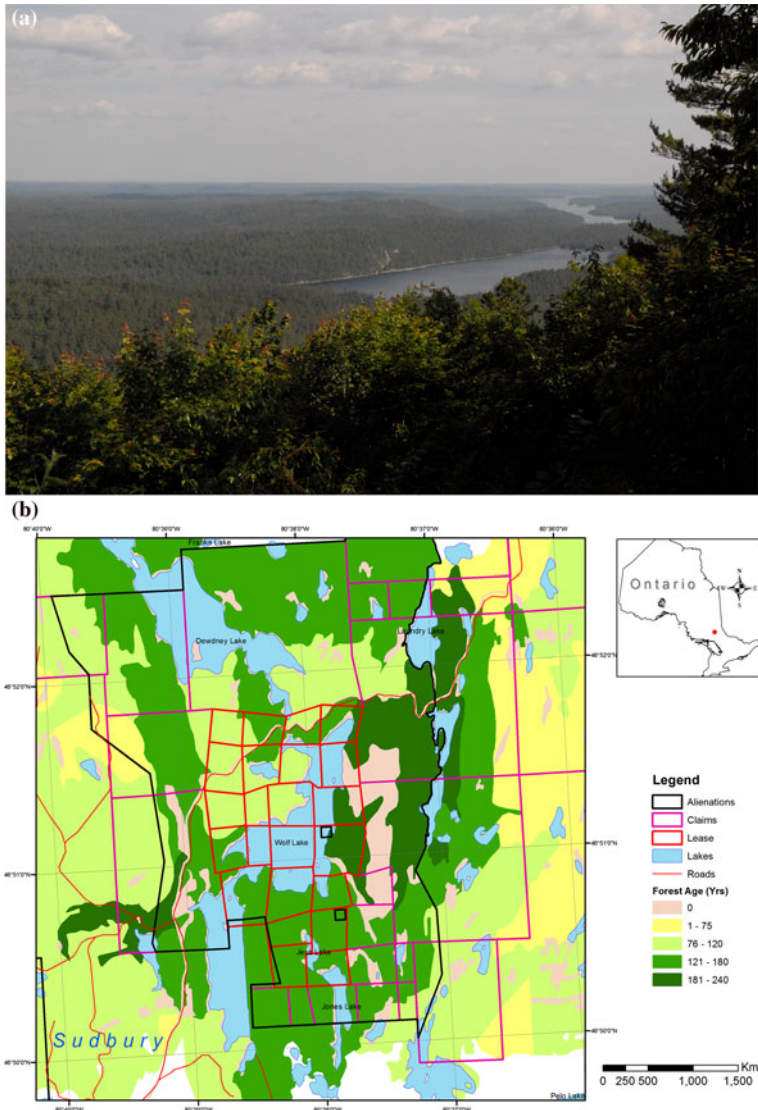
### **Taking a stand: The history and status of Wolf Lake Forest Reserve**

Wolf Lake Forest Reserve is at the center of the largest known intact old-growth red pine dominated forest in North America. Bordered on two sides by Chiniguchi Waterway Provincial Park, the Wolf Lake Forest, “F175”, is a parcel of crown land (Fig. 1a) connected via waterways to the white pine dominated old-growth forests of Temagami, Ontario that have faced similar challenges. Wolf Lake Forest is widely praised for its aesthetic appeal and is a popular camping and canoeing destination.

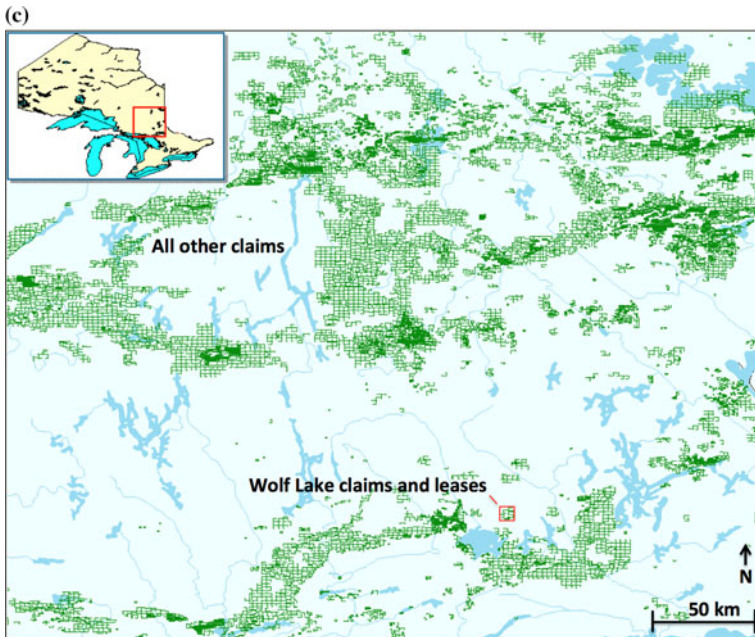
In 1988 and 1989 the region gained international attention when the “Red Squirrel Road blockade” against logging resulted in 344 arrests including that of current Member of Parliament and former Premier of Ontario Bob Rae. In 1998 the Ontario division court found the Ontario government’s logging plans in Temagami illegal in a lawsuit brought about by environmental groups. In 1999, Ontario’s Living Legacy Land Use Strategy designated Wolf Lake and 65 other “forest reserves” to eventually become conservation areas or provincial parks—finally protecting them completely. From mid-2002 to June 2004 the Ontario Prospectors Association and the Partnership for Public Lands, with assistance from government staff, made joint recommendations to disentangle pre-existing mining claims from 55 of the 66 forest reserves; Wolf Lake remains one of the 11 reserves where consensus was not reached. At Wolf Lake, this process is stalled. Active mining exploration claims and leases for potential mineral deposits (Fig. 1c) have been repeatedly renewed by the Ontario Ministry of Northern Development and Mines (OMNDM), delaying its conversion to provincial park status.

The designation of “Forest Reserve”, given to Wolf Lake, is very similar to the designation of “Conservation Reserve”, with the exception that mining activities are allowed to continue in forest reserve areas (OMNR 1999). The primary focus of both types of reserves is to protect natural heritage areas and entire ecosystems that are the foundation of Ontario’s landscape (Provincial Parks and Conservation Reserves Act 2006). Partly due to misleading terminology, controversy now surrounds the land designation in Wolf Lake (The Toronto Star 2012). The provincial Environmental Assessment Act (1990) and federal Canadian Environmental Assessment Act (2012) only cover mining activities on voluntary basis unless certain triggers are met. As a result, while large mining development activities require review, mining exploration is typically not subject to environmental assessment. The principle renewal criteria for mining exploration leases established under the Mining Act (1990) is that exploration and/or development is occurring. By many accounts, such active exploration has nearly ceased in recent years yet the majority of the leases have been renewed by the Minister of Northern Development and Mines (Northern Life 2012).

There are two provincial ministries involved in this conflict: the Ministry of Natural Resources (OMNR), whose mandate is to ensure sustainable management of forests, and the Ministry of Northern Development and Mines (OMNDM), whose mandate is to promote economic development in Ontario’s northern regions. Their stated aims seem to be in



**Fig. 1** **a** Photo of Wolf Lake Forest Reserve 2010; **b** Map of Wolf Lake Forest Reserve with location of mining leases and claims. The area shown under lease is technically referred to as “disposition” by OMNDM that means *transferring to the care or possession of another*. “Alienation” refers to transferring of title to or interest in a property to another (Data Source: LIO, OMNR and CLAIMaps, OMNDM). **c** Map of current mining claims and leases (*green*) in Northeastern Ontario. Wolf Lake is highlighted by the *red square*, representing only 0.0001 % of mining leases and claims in Ontario, expressing plenty of mining interest elsewhere. The connectivity of the lakes through waterways is underestimated here as only very large lakes and rivers are presented (information obtained publicly from Ontario CLAIMaps website: <http://www.geologyontario.mndmf.gov.on.ca/website/claimapsiii/viewer.asp>, figure recreated from Wolf Lake Coalition 2012). (Color figure online)



**Fig. 1** continued

direct conflict here yet a joint statement published recently portrays the two Ministers as team players (Sudbury Star 2012). In most similar cases in Ontario, forest conservation has taken precedence over mining development in ecologically sensitive areas. In this case, the conflict between private interest and the public good remains. Wolf Lake Forest Reserve is held in limbo, neither fully exploited or protected. While there may be short-term economic arguments favoring its development, or aesthetic ones for its conservation (though they are also good economic reasons for protected areas), here we review this conflict and emphasize the ecological basis for conservation of this forest stand.

### Old-Growth and maintaining biodiversity

An understanding of the processes, patterns and structure of pristine and old-growth forests is important for the creation and improvement of forest management guidelines for conservation and production (Spies and Turner 1999; Lindenmayer et al. 2000; Roberts and Gilliam 1995). Features unique to old-growth red pine forests are that they maintain biodiversity at several taxonomic levels compared to young-mid aged stands. The most prominent feature is age, where non-grass herb diversity has been shown to peak at 140 years, and fern and fungi diversity to peak at 180 years (Carleton and Arnup 1993). Age also brings an increase in habitat heterogeneity, where fallen logs in particular correspond to greater plant diversity with amount of woody debris peaking at 140 years (Carleton and Arnup 1993), though data on older stands is needed for better comparisons. Exposed rock outcrops are common in remaining old-growth red pine forests and create heterogeneous forest floor environments and low tree density through red pine spacing and are important drivers of understory plant diversity (Carleton and Gordon 1992; Carleton

**Table 1** List of vertebrate species and their current conservation status that show specific preference for living/establishing within old-growth red pine forests (Bellhouse and Naylor, personal communication. In: Clark and Perera 1995)

Group	Common name	Scientific name	Conservation status	
Amphibians	Two lined salamander	<i>Eurycea bislineata</i>	Least concern	
Reptiles	Wood turtle	<i>Glyptemys insculpta</i>	Endangered	
Birds	Ruffed grouse	<i>Bonasa umbellus</i>	Least concern	
	Long-eared owl	<i>Asio otus</i>	Least concern	
	Northern saw-whet owl	<i>Aegolius acadicus</i>	Least concern	
	Pileated woodpecker	<i>Dryocopus pileatus</i>	Least concern	
	American crow	<i>Corvus brachyrhynchos</i>	Least concern	
	Red breasted nuthatch	<i>Sitta canadensis</i>	Least concern	
	Cape may warbler	<i>Setophaga tigrina</i>	Least concern	
	Black throated green warbler	<i>Setophaga virens</i>	Least concern	
	Pine warbler	<i>Setophaga pinus</i>	Least concern	
	Pine grosbeak	<i>Pinicola enucleator</i>	Least concern	
	Purple finch	<i>Carpodacus purpureus</i>	Least concern	
	Red crossbill	<i>Loxia curvirostra</i>	Least concern	
	Mammals	Little brown bat	<i>Myotis lucifugus</i>	Least concern
		Small-footed bat	<i>Myotis leibii</i>	Least concern
Silver-haired bat		<i>Lasionycteris noctivagans</i>	Least concern	
Eastern pipistrelle		<i>Perimyotis subflavus</i>	Least concern	
Big brown bat		<i>Eptesicus fuscus</i>	Least concern	
Red squirrel		<i>Tamiasciurus hudsonicus</i>	Least concern	
Porcupine		<i>Erethizon dorsatum</i>	Least concern	
Southern red backed vole		<i>Myodes gapperi</i>	Least concern	
Marten		<i>Martes americana</i>	Least concern	
Lynx		<i>Lynx canadensis</i>	Least concern	
Bobcat		<i>Lynx rufus superiorensis</i>	Least concern	

and Arnup 1993). This is compounded by natural self-thinning of pines in older stands providing space for late successional colonizing tree and understory species to establish and persist. These rocky heterogeneous environments therefore may contain greater diversity than secondary recovered red pine forests over homogeneous terrain (Leithead et al. 2012a). Furthermore, many vertebrate species prefer conditions found within old-growth red pine habitats to those in young and medium aged forests (Table 1).

The biotic and abiotic spatial heterogeneity of old-growth red pine forests creates microhabitats with diverse levels of water, light and nutrient availability. Frelich et al. (2003) examined the response of understory vegetation in old-growth red pine forests in Minnesota to nitrogen and light availability and found understory plants form three distinct communities, each preferring different levels of nitrogen and light. This increases alpha-diversity at the stand scale and increases beta-diversity at regional scales. In particular they found shrub species to respond positively to light availability (Frelich et al. 2003), created through treefall gap formation most common in old-growth stands (Frelich 1995).

These ecosystems are often nitrogen limited and inputs of nitrogen to the forest floor, such as leaf litter from deciduous trees, are very important and may influence understory

plant diversity and composition (Carleton and Gordon 1992). Recent findings suggest that deciduous red maples (*Acer rubrum*) are migrating northward through forest canopy gaps. The addition of this southern species to the community may further influence the spatial heterogeneity of resources in these nitrogen limited systems and thus patterns of understory and tree diversity patterns (Leithead et al. 2010).

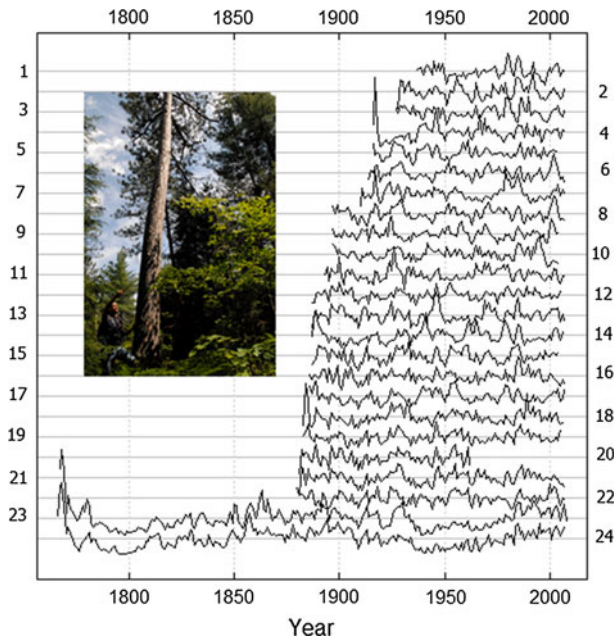
Maintenance of not just old-growth, but also large contiguous areas of old-growth, is important for maintaining alpha-diversity in these red pine forests. Greater area leads to greater habitat heterogeneity, maintains ecosystem processes essential to diversity maintenance such as wildfire (Niklasson and Drakenberg 2001) and increases species richness through species-area relationships. Conserving large areas also allows for preservation of other non-forest habitats such as lakes, bogs and riparian habitats located within red pine forest matrices scattered throughout Northern Ontario and its range that represent an important part of the entire ecosystem (important for species in Table 1).

### Preserving ecological processes

Bowen (1999) argued that “preserving particular *objects* (genes, species, or ecosystems) is not the ultimate goal of conservation. In order to be successful, conservation efforts must preserve the *processes* of life.” Relatively few process-based ecological studies have been done in old-growth red pine forests in North America. Studies to date reveal rather significant and unique biodiversity for boreal North American forests with natural disturbance regimes dominated by low-intensity surface fires (Drobyshev et al. 2008). As a result, old-growth pine forests likely exhibit abundant and unique biodiversity that is sensitive to human impacts (Bergeron and Gagnon 1987; Bergeron and Brisson 1990; Quinby 2000; Frelich et al. 2003).

The Wolf Lake Forest Reserve, located about 50 km northeast of Sudbury, can be considered a model of what the forests surrounding Sudbury in Northern Ontario used to be like. This can both inform future restoration practices as well as serve as an important seed source for natural recovery of those forests. The area surrounding Sudbury is perhaps the world’s most famous case of forest degradation due to mining; the resulting deforestation, pollution and acid rain denuded an entire landscape. Several decades after the abatement of pollution and initiation of a formidable restoration program, the landscape remains marred with low levels of biodiversity and forest structure (Anand et al. 2005; Rayfield et al. 2005). The long-term negative consequences of mining are difficult to predict and mitigate but with careful monitoring and experiments the scientific understanding of environmental degradation and restoration is advancing. Critical in the restoration process is the retention of intact forests as source areas for populations of plants, as well as for small mammals, birds and other taxa that are difficult to actively restore and generally slower to recover (Babin-Fenske and Anand 2011; Chillo and Anand 2012). Due to its proximity, Wolf Lake Forest acts as an ideal reference site for understanding ecological restoration in old-growth pine forest ecosystems from past human-induced damages and acts as an ecologically significant refugia for the region.

Wolf Lake Forest Reserve is within a climatically-defined transition zone (Goldblum and Rigg 2010), making it an ideal site for the study of forest responses to climate change. For example, recent work has revealed declining growth in young and old red pines over the past 10 years despite increasing atmospheric CO<sub>2</sub> (Silva et al. 2010). Although a comprehensive chronology of the old-growth red pine trees on the site has yet to be constructed, recent field investigations have discovered individual red pine trees as old as



**Fig. 2** Standardized tree-ring width series of old-growth red pine trees from Wolf Lake, Ontario (1767–2007). Cross-dating of series was evaluated using COFECHA program (Grissino-Mayer 2001). Series were standardized (i.e., removed age related growth trends) by Spline method using dplR library in R (Bunn 2010). Exp Pop Sig (EPS) of the standardized cross-dated series is 0.814. Series 23 and 24 shows the data from trees over 240 years old

240 years (Fig. 2). The age of some of these stands could allow essential insight into growth responses of red pine populations in response to climate change. Significant increases in temperature over the past few decades in Northern Ontario have been documented (Leithead et al. 2012b) and the impact of this on red pine growth can only be sought through climate-dendrochronological studies for which old trees growing in relatively undisturbed natural stands are needed. This knowledge will be useful not just for ecologists studying these forests, but also for industry and governmental agencies involved with red pine plantations common in Southern Ontario. Additionally, a potential pathway of species migration in response to climate change has been identified with tree species at their northern range limit, such as red maple, establishing at much higher densities in canopy gap clearings than in the shaded understory (Leithead et al. 2010). Forest refugia are essential for long-term resilience of forests to climate change (Keppel et al. 2012). Protected high-quality ecosystems may mitigate the impact of climate change at the species scale (Thomas et al. 2012) and in this case facilitate tree migration.

The large size of the Wolf Lake Reserve increases its value for biological conservation, not simply through the link between size of areas and species diversity, but also because of implications for processes. The small size of many reserves prevents natural disturbance processes from operating within these areas (Niklasson and Drakenberg 2001). For red pine forests, fire appears to be the major disturbance agent (Drobyshev et al. 2008) and maintaining this disturbance factor is important for ensuring natural forest dynamics, diversity of habitats, and biological diversity of the species (Spies et al. 2006). The large majority of the red pine distribution range is in the area of active fire suppression, reducing



their ability to reproduce and migrate. Very small areas, as are commonly protected, typically exist within a matrix of fire suppression and will therefore get their ignition sources almost exclusively from within their own perimeter. As a result, fire frequency will drop below natural levels and active fire management would be required to maintain natural mixed pine stands. Large protected areas have an advantage as more ignitions occur and can spread within their boundaries. Even if the surrounding landscape is under effective fire suppression, a close-to-natural fire regime can be maintained within such large areas through “self” ignitions. “Natural disturbance emulation” is a popular strategy to preserve the healthy and essential processes of managed forests. The intuition is that by mimicking natural disturbances, harvest practices can mitigate the disruption experienced to the ecosystem without requiring a full knowledge of the workings of the ecosystem. In this context, protected areas such as Wolf Lake act as essential ecological baselines in understanding the pattern and process of the natural disturbances we are attempting to emulate (Arcese and Sinclair 1997).

### Assessing endangerment at the ecosystem level

The most powerful legislation that can be currently used to protect the Wolf Lake Forest Reserve from mining activities is the Endangered Species Act (2007). Owing to the lack of comprehensive biodiversity surveys, no endangered species have been documented from this Reserve to date. However, Wolf Lake is within the ranges of several suitable species included in the list of species at risk in Ontario (OMNR 2012), leading to the possibility that comprehensive surveys would reveal their presence. Many vertebrate species including the endangered wood turtle (*Glyptemys insculpta*) show a preference for living in old-growth red pine forests (Bellhouse and Naylor, per. comm. In: Clark and Perera 1995). Numerous rare plant species, including the provincially significant Large Round-leaved Orchid (*Plantanthera orbiculata*) are also found in the Wolf Lake region (Quinby 1996).

Ecologists realize the value of protecting endangered ecosystems as well as species. Legislation on the issue lags, but the government of Ontario is making the first steps towards implementing this view. As part of their recent recommendations, the Endangered Species Act Panel suggested that there needs to be a focus on the ecosystems and functional groupings of endangered species to streamline management (ESA Stakeholder Panel 2012). But an ecosystem perspective has benefits far beyond simple efficiency. Protecting threatened ecosystems helps maintain essential ecological processes and diversity on the landscape scale, with side benefits for countless specialist organisms. Four criteria for endangered ecosystems have been developed recently for presentation to IUCN (Rodríguez et al. 2011); the old-growth red pine forests of Wolf Lake meet three.

Criterion A covers observed or projected short-term decline in distribution or ecological function. It is likely that there has been short-term decline in the functioning of this ecosystem that will continue over the next 50 years throughout its current range, given the impact of past logging on nutrient cycling (Quinby et al. 1996), of climate change on the growth of red pine (Silva et al. 2010), and the ongoing threat of mining. In both Canada and the United States, red pine has been disappearing from the landscape due to heavy timber harvesting, increasing fire suppression, and land conversion (Gilmore and Palik 2006; Carleton et al. 1996). Criterion B states that there should have been a historical decline in distribution or ecological function in the last 500 years. Red pine forests are now estimated to cover only 1.2% of their original pre-settlement range (Quinby 1996; Noss et al. 1995). Criterion C holds that the ecosystem should have a small current distribution and face decline

in distribution or ecological function. Old-growth red pine forests are estimated to occupy only 20,834 ha (208 km<sup>2</sup>) and are found at few sites (Quinby 1996). Wolf Lake covers 1,600 ha and is four times larger than the next largest remnant red pine dominated forest (Fig. 3). Finally, criterion D states that the ecosystem should have a very small current distribution i.e. less than or equal to 100 km<sup>2</sup>. Although old-growth red pine forests are distributed across a greater area than 100 km<sup>2</sup>, none of the remaining old-growth stands, including Wolf Lake (16 km<sup>2</sup>), cover more than this area on their own. Anticipated effects of climate change on these forests may further affect species and ecosystem range sizes, which has yet to be fully studied.

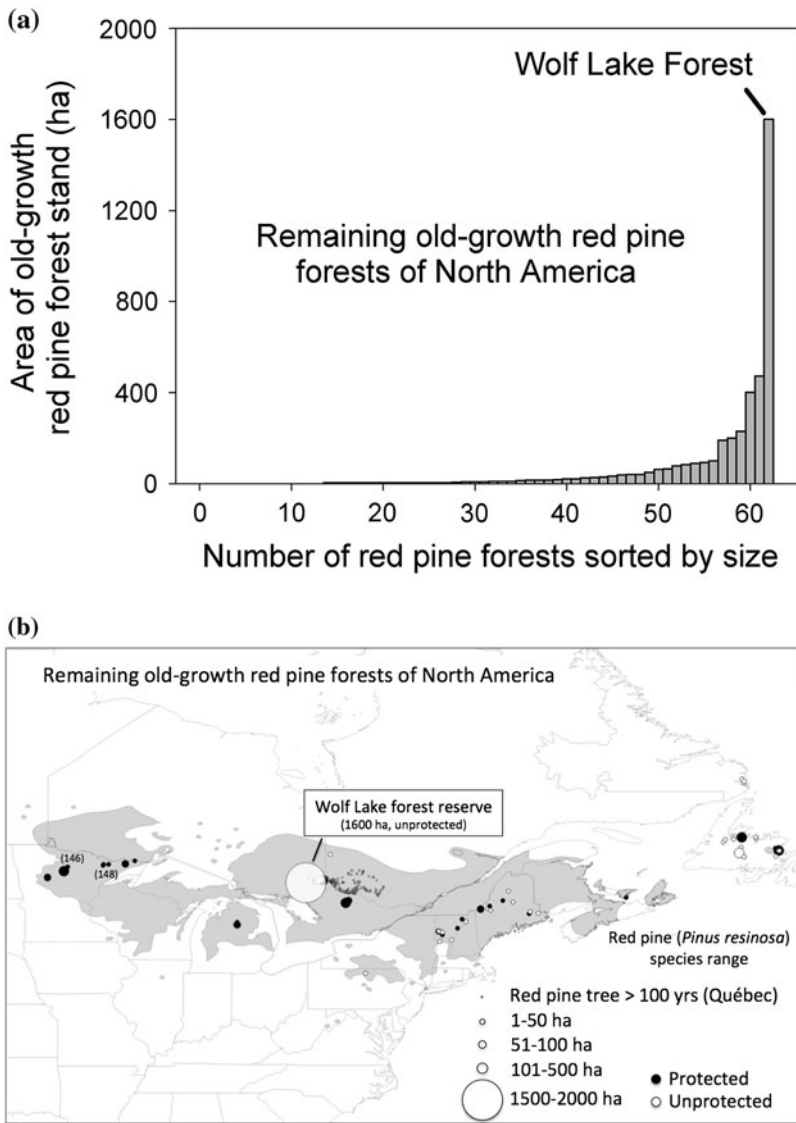
## Final considerations and conclusion

We argue that the myriad processes and mechanisms that influence the preservation or endangerment of old-growth red pine forests should be considered in their assessment, particularly the role that large stands can have in the preservation of an ecosystem (Fig. 4). The maintenance of natural processes and critical ecosystem services, conservation of resources and of wildlife, are interconnected aspects that depend on area and degree of fragmentation in any given ecosystem. Increased habitat area:

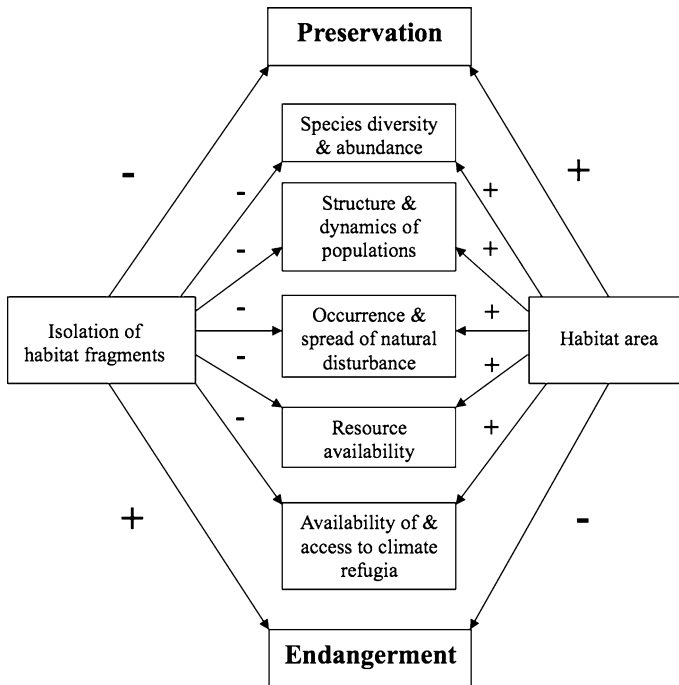
- (i) Increases species diversity, which increases the potential for ecosystems to respond to environmental changes (Reich et al. 2012). It has also been shown to have as large an impact on ecosystem productivity as other landscape features such as resource availability, disturbance, or herbivory (Tilman et al. 2012)
- (ii) Increases the size and structure of populations and the distance of propagule dispersal, reflecting increased persistence (Hanski 1999)
- (iii) Alters the occurrence of natural disturbance, including fire (Parsons and Gosper 2011). Fire has been shown to be more widespread and frequent but less intense in large preserved areas (Drobyshev et al. 2008)
- (iv) Improves the quantity and quality of resources, such as water and nutrient capital, which are enhanced under natural conditions but largely reduced due to erosion, leaching and export of organic and inorganic compounds that follows habitat fragmentation (Dahlgren et al. 2003; Zengshou et al. 2003)
- (v) Increases the availability of and connectivity between potential refugia. Refugia are characteristic of large heterogeneous landscapes and act as isolated shelters for stressed populations during major environmental shifts (e.g. climate change) (Keppel et al. 2012)

There is strong scientific and ecological value in preserving old-growth red pine forests and in particular very large stands, such as the one found at Wolf Lake Forest Reserve. The community has rallied around Wolf Lake, defending its aesthetic and social value in the face of its unconventional appearance. Shallow bedrock means that many of the ancient trees are stunted and the canopy is open; scarcely the majestic, primordial forest evoked by conservationists (Cecile et al. 2013). Conservation decisions often depend on an appeal to emotion which can be justified (Milton 2002). But a broad approach and assessments of all values involved (ecological, cultural and economic) can strengthen our arguments and improve our decisions (Harmon and Putney 2003).

Regulatory acknowledgment of these broad values is possible. The Natural Heritage Act of the province of Québec (which neighbours Ontario) for example, highlights the importance of scientific study in ecosystem preservation. For example, “Ecological



**Fig. 3** **a** Frequency distribution of remaining old-growth red pine forests in Canada and the United States. Wolf Lake represents the largest remaining old-growth red pine stand, 4× larger than the second largest remaining stand. Each bar represents the location of an old-growth red pine stand (the 146 and 148 stands (mean size 9 and 24 ha) were plotted as two single bars representing the mean size of stands at Itasca State Park and Boundary Waters Canoe Area Wilderness, Minnesota. Data accessed from Ancient Forest Brief Progress and Summary Reports, Forest Landscape Baseline No. 14 (Quinby 1996); **b** Spatial distribution of remaining old-growth red pine forests in North America. Red pine range derived from Little (1971). Numbers (146) and (148) refer to the number of stands of mean 9 ha in Itasca State Park and stands of mean 24 ha in Boundary Waters Canoe Area Wilderness of Minnesota. Québec tree data location and ages (>100) provided from Ministère des Ressources Naturelles et de la Faune de Québec. Lac Duparquet ecological reserve, where several seminal scientific studies have been performed in the past decades, is presented as the northern most red pine stand in Québec. Information provided by forest experts from a total of 19 political jurisdictions in Canada and the United States, coinciding with the natural range of red pine forest. Data accessed from Ancient Forest Brief Progress and Summary Reports, Forest Landscape Baseline No. 14 (Quinby 1996)



**Fig. 4** Relationship between habitat area and habitat fragment isolation and preservation or endangerment of old-growth pine ecosystems. Linkages between ecosystem properties depicted in the central boxes do exist but are not shown for the sake of simplicity and to emphasize the role of habitat area and fragmentation in ecosystem preservation

Reserves” aim to (1) conserve the elements constituting biological diversity in their natural state, as integrally as possible and in a permanent manner, in particular by protecting ecosystems and the elements or processes on which their dynamics are based; (2) to set aside land for scientific study or educational purposes; or (3) to safeguard the habitats of threatened or vulnerable species of flora or fauna (Natural Conservation Heritage Act, Province of Québec Natural Heritage Conservation Act 2009). Rare ecosystems are valuable for their own sake and explicit regulatory protection would help conserve these hotspots of biodiversity. As the largest remaining old-growth red pine forest, Wolf Lake Forest Reserve has considerable ecological, social, aesthetic and scientific value. It is uniquely situated to act as an ecological baseline for biodiversity, ecological processes and services and as a long-term monitoring site for landscape-scale restoration and climate change-driven community shifts. The window of opportunity for mineral exploration at Wolf Lake has long since elapsed; the Ministry of Natural Resources and the Ministry of Northern Development and Mining need to work together to complete the transition of Wolf Lake to fully protected provincial park status today.

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