Hemlock Decline, Reserve Selection, and Conserving Canada's Largest Remaining Old-Growth Eastern Hemlock Stand at Trent Lakes, Ontario

Author: Quinby, Peter A.

Source: Natural Areas Journal, 45(3) : 226-240

Published By: Natural Areas Association

URL: https://doi.org/10.3375/2162-4399-45.3.10

Conservation Issues

Hemlock Decline, Reserve Selection, and Conserving Canada's Largest Remaining Old-growth Eastern Hemlock Stand at Trent Lakes, Ontario

Peter A. Quinby[1,2]

[1]Ancient Forest Exploration & Research, RR#4, Powassan, ON, Canada P0H1ZO

[2]Corresponding author: pquinby@ancientforest.org

Associate Editor: John N. Williams

ABSTRACT

If current logging trends continue, eastern hemlock (*Tsuga canadensis*)–dominated forests in Ontario will be depleted by ~2075. Possibly the most valuable remnant stand of old-growth eastern hemlock forest in Canada, the Catchacoma Forest, remains unprotected despite efforts to protect this stand since 2019. A government analysis found that the Forest was a common, fully represented landscape element that does not require protected status. This decision was based on a methodology that initially filters potential reserves by focusing exclusively on representation of the combinations of forest vegetation with surficial geological composition ignoring many other significant potential reserve selection attributes including forest stand age, ecological integrity, and species-at-risk. Consideration of these and other common attributes shows that the Catchacoma Forest is an exemplary old-growth forest candidate reserve. Protection of this forest would provide numerous ecological, cultural, educational, and scientific benefits to society at local to international scales since eastern hemlock forests are common throughout the temperate portions of eastern North America. From an economic perspective, the Catchacoma Forest is at least 10× more valuable if left unlogged. The current approach to natural heritage protection in Ontario is likely resulting in the loss of all types of old-growth forests throughout the ~44 million ha of Ontario where the 2006 provincial gap analysis method is applied. Many policies and strategies that apply to the protection of biodiversity and forest carbon in Ontario provide a solid foundation to facilitate increased landscape protection. The most significant missing component required for nature protection implementation in Ontario is political will and associated action.

Index terms: Catchacoma Forest; Ontario; eastern hemlock forests; forest biodiversity protection; natural heritage assessment; primary old-growth forest

INTRODUCTION

Calls for increasing the protection of natural ecosystems at local, regional, and global levels have been accelerating in the last few years (Watson et al. 2018; Brodiea and Watson 2023). Both the 30 × 30 Protection Strategy (e.g., Jetz et al. 2021) set forth by the Federal Government of Canada (ECCC 2024) and Criterion 6.5, required for Forest Stewardship Council (FSC) certification (FSC 2022), specify quantitative protection goals. The federal strategy states that at least 30% of the land cover in Canada should be protected from development activities, including logging, by the year 2030. FSC Criterion 6.5, which requires at least 10% land protection, is the current standard in central Ontario (BMFC 2021), which is 9% greater than the Ontario government protection requirement of 1% (Crins and Kor 2006) but 20% less than the federal 30 × 30 Strategy. FSC Criterion 6.5 states that:

> "The Organization [logging company] shall identify and protect representative sample areas of native ecosystems and/or restore them to more natural conditions. Where representative sample areas do not exist or are insufficient, The Organization shall restore a proportion of the Management Unit to more natural conditions. The size of the areas and the measures taken for their protection or restoration, including within plantations, shall be proportionate to the conservation status and value of the ecosystems at the landscape level, and the scale, intensity and risk of management activities" (Ontario Nature 2017; FSC 2022).

For roughly 30 years, the Ontario government has not kept up with the need for creating new protected areas and reserves in the face of rapid biodiversity decline and climate warming. As stated by the Ontario Protected Areas Working Group (OPAWG 2021), "Ontario has fallen behind other provinces and territories, ranking eighth in terms of area protected or conserved" and "there is no comprehensive provincial policy in place for protected and conserved areas, and there has been no substantive, target-based activity since Lands for Life in the mid '90s." In the past five years, Ontario has added only ~3000 ha, compared to 20 million ha across the rest of Canada (OPAWG 2021). Many nongovernment organizations are working toward the establishment of protected areas for a wide variety of natural landscapes in Ontario in the absence of government leadership through the program *Your Protected Places - A Shared Vision for Ontario* (Ontario Nature 2023).

One of the places that contributes to the *Shared Vision* is the unprotected Catchacoma Forest, which is Canada's largest-known eastern hemlock (*Tsuga canadensis*) old-growth forest landscape located in northern Peterborough County, Ontario (662 ha; Figure 1,

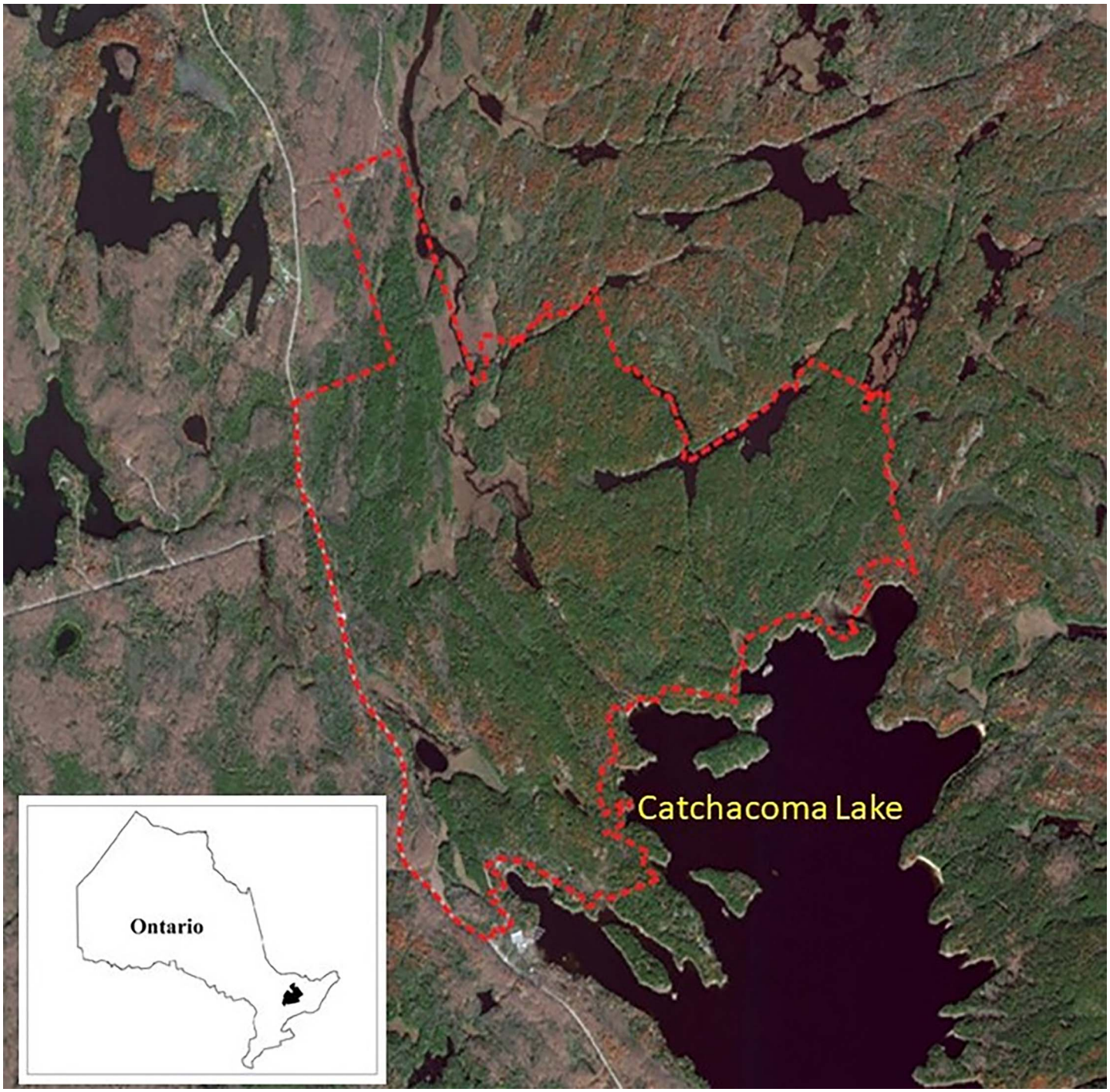

Figure 1.—Location of the Catchacoma old-growth forest, Ontario. See online version of this paper for color image.

Table 1). In response to public pressure since 2019, a recent gap analysis conducted by the Ontario government to assess the natural heritage significance of this landscape identified the Catchacoma Forest as a common, fully represented landscape element that does not require protected status (OMECP 2020). This decision was based on a methodology that initially filters potential reserves by focusing exclusively on representation of the combinations of forest vegetation with surficial geological composition ignoring many other significant potential reserve selection attributes (Crins and Kor 2006). The decision may also be related to the Ontario requirement to protect only 1% or 50 ha of each land-vegetation type compared with 10% protection required by FSC (Ontario Nature 2024), 30% by the federal government (ECCC 2024), and 50% by the Global Safety Net (Dinerstein et al. 2020; Finklestein et al. 2023).

What is not emphasized by the Ontario natural heritage assessment method is that representation has different meanings at different scales and thus may be applied differently by different practitioners simply based on choice of scale. This

Table 1.—Forest stand composition and forest types in 2020 based on forest resource inventory mapping in the Catchacoma Forest, Ontario (BF-balsam fir; CE-white cedar; HE-hemlock; IW-ironwood; MH-sugar maple; MR-red maple; OR-red oak; PO-poplar; PW-white pine; associated numbers are % divided by 10; LIO 2024).

Forest Type	Stand Composition	Development Stage	Age (in 2020)	Size (ha)
Hemlock-Red Maple	HE 9 MR 1	Old growth	177	134
	HE 9 MR 1	Old growth	177	23
	HE 9 MR 1	Old growth	177	20
Hemlock-Red Maple-Mixed	HE 6 MR 2 CE 1 PO 1	Old growth	142	10
	HE 6 MR 2 CE 1 PO 1	Late Mature	131	1
	HE 6 MR 2 CE 1 MH 1	Late Mature	133	31
	HE 6 MR 2 CE 1 MH 1	Late Mature	133	8
	HE 7 MR 1 PW 1 OR 1	Old growth	148	109
	HE 7 MR 1 PW 1 OR 1	Old growth	148	5
Hemlock-Sugar Maple	HE 5 MH 2 MR 2 IW 1	Old growth	142	4
	HE 6 MH 2 PW 1 OR 1	Late Mature	133	10
	HE 4 MH 2 PO 2 PW 1 MR 1	Old growth	153	14
	HE 3 MH 3 OR 2 MR 1 PW 1	Mid Mature	98	42
Hemlock-Maple-Oak	HE 7 MH 2 OR 1	Late Mature	133	8
	HE 7 MH 1 MR 1 OR 1	Old growth	143	13
	HE 7 MH 1 MR 1 OR 1	Old growth	143	10
Hemlock-Mixed	HE 6 MH 1 PW 1 PR 1 OR 1	Late Mature	133	14
Hemlock-Red Oak	HE 6 OR 2 MR 1 PW 1	Old growth	143	149
	HE 6 OR 2 MR 1 PW 1	Old growth	143	23
	HE 6 OR 2 MR 1 PW 1	Old growth	143	5
	HE 4 OR 3 PW 2 MR 1	Old growth	188	17
Hemlock-White Cedar	HE 5 CE 2 BF 1 MH 1 MR 1	Mid Mature	108	11
			Total	**662**

potential subjectivity as well as the dominance of representation over the application of other nature reserve selection attributes can result in inaccurate natural heritage assessments. For example, 14 species-at-risk and their habitat as well as endangered old-growth forests present in the Catchacoma Forest have been ignored by the desk-top (no field data) government analysis of the natural heritage value of this forest (OMECP 2020).

Field data from the Catchacoma Forest (34 random sample plots; Quinby et al. 2021) confirmed that: (1) this forest is dominated by the old-growth forest condition—half the plots were in the early old-growth forest stage and the other half were in the late old-growth forest stage; (2) stand ages varied from 120 to 224 years, with a mean of 176 years based on tree core aging; (3) super-canopy trees were present in half of the plots; (4) the forest was regenerating well with eastern hemlock dominating forest regeneration in three-quarters of the plots; (5) no evidence of logging was observed in 53% of the plots; and (6) woodpecker excavations in snags were observed in almost half the plots. All plots were in the western half of the forest and to date only two cut stumps have been found in the eastern half. The Catchacoma Forest is currently designated for "contingency" logging and could be converted to "allocated" logging if the provincial government allows it.

The Catchacoma Forest should be designated as a protected area as soon as possible since old-growth forests are endangered in central Ontario, natural eastern hemlock forests are extremely rare in Canada, and the Catchacoma Forest is Canada's largest remaining old-growth eastern hemlock forest (there are many other good reasons). The purpose of this article is five-fold: (1) to address the decline of eastern hemlock forests in Ontario, (2) to document the ecological value of the Catchacoma Forest, (3) to conduct a comparative review of the Ontario government's natural heritage assessment methodology (Crins and Kor 2006), (4) to evaluate the government analysis used to determine that the Catchacoma Forest is a redundant landscape element that does not need protection (OMECP 2020), and (5) to discuss policy options for improving natural heritage assessment in Ontario and for protecting the Catchacoma Forest.

Data and Literature Sources

Data used to describe the decline of all forests with eastern hemlock content (10–100%) were obtained from Ontario's Forest Resource Inventory (FRI) digital data bank (LIO 2024). The amount of eastern hemlock–dominated forest (50% +) used for the projected 2030 abundance is based on doubling the amount of decline from 1987 to 2007, which was applied based on the Ontario government's current policy to double logging/tree fiber production by the year 2030 (OMNDMNRF 2021). Data describing known eastern hemlock forests in Canada that included stand size data were obtained from both published and technical (unpublished) reports (Quinby 2019b).

To evaluate the Ontario natural heritage assessment method, reserve selection criteria applied in Canada and Europe were obtained from Beechey (1989), Gotmark and Nilsson (1992), Crins and Kor (2006; Ontario government method), Branquart et al. (2008), OMNR (2010), and Coristine et al. (2018). The resulting 30 attributes that have been used to select protected areas/reserves are discussed in the context of representation, ecological functionality, and utilitarian and administrative

Table 2.—Decline of eastern hemlock forests in Ontario over 20 years (1987–2007) (data from LIO 2024, OMNRF 1987, and OMNRF 2007).

% Hemlock in Stand	1987 FRI Total Area (ha)	2007 FRI Total Area (ha)	% Decline Over 20 Years	Growth or Decline
100	752	295	61	decline
90	1090	780	28	decline
80	3376	1884	44	decline
70	7985	5765	28	decline
60	13,579	12,938	5	decline
50	17,980	15,774	12	decline
40	21,305	21,331	0	even
30	23,400	22,913	2	decline
20	44,502	40,137	10	decline
10	61,138	57,645	6	decline
Total	**195,107**	**179,463**	**8**	**decline**

values. Primary attributes are defined as those used at the first stage of filtering potential reserves into either the rejected group or the retained group. Secondary attributes are defined as those applied only to the potential reserves in the retained group following primary attribute evaluation and/or those considered of minor importance by a given method.

SYNTHESIS

Decline of Eastern Hemlock Forests in Ontario

Forests with an eastern hemlock component in Ontario's Area of the Undertaking (AOU; ~44 million ha) made up ~0.4% (~179,463 ha) of this region in 2007 (Table 2; see also Quinby 2019a). The AOU occupies the region of central Ontario located between Southern Ontario and the Far North, and it is where industrial logging takes place in the province. Further, forests dominated by eastern hemlock (50% + eastern hemlock; ~37,436 ha) in the AOU made up less than 0.09% of the region in 2007. However, this estimate is high since eastern hemlock forests have been and continue to be logged since 2007 (last FRI data availability). Finally, forests with 100% eastern hemlock composition (295 ha) make up ~0.007% of the AOU and may potentially be gone by now due to continued logging since 2007. The overall eastern hemlock forest decline of 8% is roughly half of the 16.4% decline of eastern hemlock–dominated forests.

Using the difference in the amount of eastern hemlock–dominated forest in 1987 and 2007 (Table 2), and the amount predicted for 2030, a trendline was produced to estimate when this forest type could disappear from the central Ontario landscape (Figure 2). The trendline ($R = 0.9777$) indicates that eastern hemlock–dominated forests in central Ontario will be depleted due to current logging trends by ~2075—only about 50 years from now. Similar declines have been documented for other tree species in central Ontario including basswood, American beech, yellow birch, black ash, and white ash (Drever et al. 2010; Quinby 2019a; Quinby et al. 2022).

This precipitous, potentially catastrophic decline of eastern hemlock–dominated forests should be a conservation wake-up call for all who consider this forest type integral to Ontario's current and future natural heritage. These forests are critically endangered and require immediate attention particularly since hemlock woolly adelgid was observed in 2022 only 120 km south of the Catchacoma Forest (Invasive Species Centre 2022) and continues moving northward.

Canada's Remaining Old-growth Eastern Hemlock Forests

A literature search found 26 known eastern hemlock old-growth forest stands in Canada with available size information (Table 3; see also Quinby 2019b) ranging in size from 5 to 662 ha. Of these 26 stands, 17 are in Ontario, 6 are in Quebec and 3 are in Nova Scotia. The 9 largest stands are found in Ontario and the largest of all stands is the Catchacoma Forest (662 ha), located at the north end of Catchacoma Lake in northern Peterborough County (Figure 1, Table 1). Roughly 54% of these stands are protected, not including the Catchacoma Forest.

Reserve Selection Methodology and the Catchacoma Forest Assessment

The application of the Ontario AOU method (Crins and Kor 2006) to the Catchacoma Forest natural heritage assessment (OMECP 2020) is evaluated in this section. In total, 23 additional primary attributes beyond those used by the Ontario AOU method have been used to select reserves in Canada and

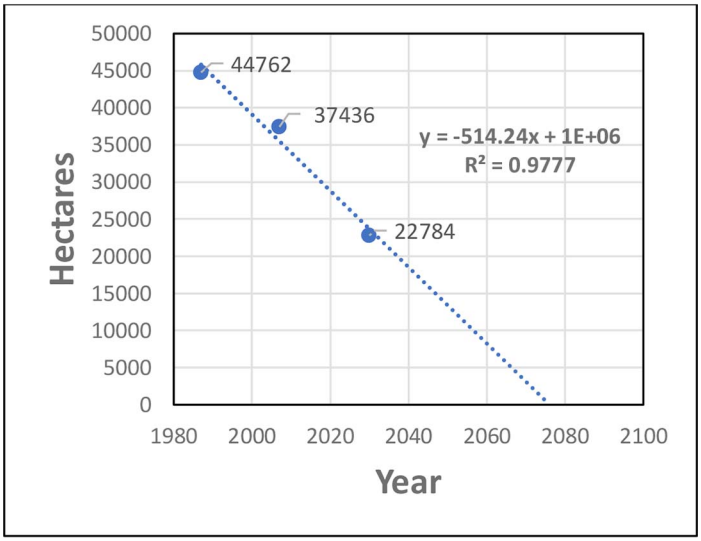

Figure 2.—Decline of eastern hemlock–dominated forest in Ontario's Area of the Undertaking (~44 million ha) from 1987 to ~2075. See online version of this paper for color image.

Table 3.—Known old-growth eastern hemlock forests in Canada with size data (from Quinby 2019b).

Site Name	Province	Area of Old-growth Hemlock (ha)	Protection Status
Catchacoma Lake Old-growth Hemlock Forest	Ontario	662	NO
Clear Lake Conservation Reserve	Ontario	453	YES
North Tea and Cayuga Lakes Old-growth Hemlock Forest	Ontario	406	partial
Raganooter Lake Conservation Reserve	Ontario	311	YES
DeGaulle Lake Old-growth Hemlock Forest	Ontario	305	NO
Gold Lake Old-growth Hemlock Forest	Ontario	285	NO
Lost Dog Lake West Old-growth Forest Cluster	Ontario	192	partial
Algonquin Park (>100 ha; <281 ha; 28 stands)	Ontario	190 (100–280)	YES
High Park	Ontario	160	YES
Booth Lake Eastern Hemlock Old-growth Forest	Quebec	152	unknown
Wesleyville Ravines	Ontario	138	YES
Lost Dog Lake Central Old-growth Hemlock Forest	Ontario	79	partial
Echo Lake Ancient Forest	Quebec	56	YES
Panuke Lake Nature Reserve	Nova Scotia	47	YES
Gagnon Lake Eastern Hemlock Old-growth Forest	Quebec	45	unknown
Devlin Lake Eastern Hemlock Old-growth Forest	Quebec	31	unknown
Sisco Lake Old-growth Hemlock Forest	Ontario	29	partial
Sporting Lake Nature Reserve	Nova Scotia	25	YES
Gillies Grove	Ontario	25	YES
Preston Lake Eastern Hemlock Old-growth Forest	Quebec	20	unknown
Balls Falls Gorge (Twenty Valley)	Ontario	20	YES
Mckeel Woods Eastern Hemlock Old-growth Forest	Quebec	17	unknown
Decew Falls and Gorge	Ontario	11	YES
Durland Lake Old-growth Forest	Nova Scotia	10	YES
Jackson Creek Old-growth Forest	Ontario	5	YES
Hemlock Valley	Ontario	5	YES

Europe (Table 4). Only two attributes were used to evaluate the Catchacoma Forest; at least 28 additional attributes should be applied to evaluating the natural heritage values of this exceptional, nationally significant forested landscape. In addition, compared to all other methods in Table 4, the Ontario AOU method relied far more heavily on secondary attributes for natural heritage assessment. For the Catchacoma Forest analysis, no secondary attributes were considered.

Representation Attributes: Seven selection attributes were identified from the literature (Table 4 – Part 1) that address representation of: *natural terrestrial ecosystems*; *rare, threatened, endangered, and endemic species*; *physiography and geology*; *natural aquatic ecosystems*; *special habitats*; *palaeoecological sites*; and *modified ecosystems with special scientific, research, and/or educational value*. The Ontario AOU method (Crins and Kor 2006) applies representation of *natural terrestrial ecosystems* in combination with representation of *physiography and geology* (land-vegetation type) as the first, primary reserve selection filter. The four primary representation attributes not used by the Ontario AOU method include *natural aquatic ecosystems*; *rare, threatened, endangered, and endemic species*; *special/significant habitats such as old growth*; and *palaeoecological sites* (Table 4 – Part 1).

Secondary criteria activate only for those reserves that have not been rejected at the first stage of selection, even though rejected reserves may have excellent additional (primary and secondary) attributes not utilized by the Ontario AOU method. Three secondary attributes are available for application by the Ontario AOU method and include *rare, threatened, endangered, and endemic species*; *natural aquatic ecosystems*; and *special/significant habitats*. The only unused secondary criterion by the Ontario AOU method is applied by two other methods—Beechey (1989) for Canada and Gotmark and Nilsson (1992) for Sweden. This attribute is *modified ecosystems with special scientific, research, and/or educational value.*

The application of the Ontario AOU method to the Catchacoma Forest (OMECP 2020) utilized only two primary attributes—representation of *natural terrestrial ecosystems* in combination with representation of *physiography and geology* (land-vegetation type). All other potential primary and secondary selection attributes (e.g., stand age, species-at-risk) were excluded in the OMECP (2020) natural heritage analysis for this forest.

Ecological Functionality Attributes: A total of 16 reserve selection attributes that address ecological functionality were identified in the literature (Table 4 – Part 2) including: *habitat, community, and species diversity*; *rarity*; *size*; *integrity*; *human disturbance*; *connectivity*; *fragility*; *replication*; *shape*; *interior habitat*; *potential to persist*; *endangerment*; *significance*; *distribution*; *climate change resilience*; and *old-growth forest continuity*.

None of the attributes in this category are used as primary attributes by the Ontario AOU method; however, four of these attributes are considered secondary attributes by this method including *habitat*; *community and species diversity*; *rarity*; and *connectivity*. None of the other methods reviewed used secondary attributes in this natural heritage category; instead, all 16 of these attributes are applied as primary attributes by all

Table 4.—Reserve selection attributes from Canada and Europe.

Attributes	Southern Ontario (Natural Heritage Manual; OMNR 2010)	Canada (Beechey 1989)	Canada (Coristine et al. 2018)	Europe (Branquart et al. 2008)	Sweden (Gotmark and Nilsson 1992)	Ontario AOU (Crins and Kor 2006)
			Part 1: Representation values			
Total Number of Primary Attributes (P)	17	16	11	9	6	2
Total Number of Secondary Attributes (S)	0	5	0	0	5	7
Representation Values						
Natural Terrestrial Ecosystems	P	P	P	P	P	P
Rare, Threatened, Endangered, Endemic, etc. (genetic and evolutionary conservation)	P	P	P	P	P	S
Physiography and Geology (e.g., habitat conditions)	P	P	P		P	P
Natural Aquatic Ecosystems	P	P	P		S	S
Special Habitats (e.g., hibernacula, calving grounds, denning and feeding sites, etc.)	P	P				S
Palaeoecological Sites (important fossil sites – e.g., pollen banks, to study prehistoric ecological succession and evolutionary change)		P				
Modified Ecosystems with special scientific, research, and/or educational value		S			S	
			Part 2: Ecological functionality values			
Total Number of Primary Attributes (P)	**17**	**16**	**11**	**9**	**6**	**2**
Total Number of Secondary Attributes (S)	**0**	**5**	**0**	**0**	**5**	**7**
Ecological Functionality Values						
Habitat, Community, and Species Diversity	P	P	P	P	P	S
Rarity (relative scarcity of an ecological feature, phenomenon of national importance take priority over those of regional or local interest)	P	P	P	P	P	S
Size (large sites favored over small sites, reduced extirpation potential, better for recolonization, minimize edge effect)	P	P	P	P		
Integrity (incorporate whole viable systems into protected ecological areas thereby minimizing extrinsic biophysical impacts)	P	P	P	P		
Human Disturbance (degree of human disturbance, particularly important when selecting benchmark sites, human disturbance may be disqualifying)		P	P	P		S
Connectivity (migration routes for diverse species)	P		P	P		S
Fragility (the ability of an area to tolerate use)	P	P				
Replication (two or more examples of a phenomena broadens opportunities for protecting the phenomena variation and studying the causative factors)	P	P				
	P					

Table 4.—Continued.

Attributes	Southern Ontario (Natural Heritage Manual; OMNR 2010)	Canada (Beechey 1989)	Canada (Coristine et al. 2018)	Europe (Branquart et al. 2008)	Sweden (Gotmark and Nilsson 1992)	Ontario AOU (Crins and Kor 2006)
Shape (a wide core area is better than a narrow one, a high interior to edge ratio is better than a low one)						
Interior Habitat (habitat more than 100 m from the edge)	P					
Potential to Persist (if land use changes have already occurred or been approved that are deleterious, the site may not be a good choice)	P					
Endangerment (uncommon ecosystems under pressure for conversion to other land uses should receive priority for protection)		P				
Significance (rank areas on the basis of all criteria to determine their overall relative significance, insures that protection efforts are concentrated on the most important sites)		P				
Distribution (accessibility and use may influence the selection of sites)		P				
Climate Change Resilience (protect climate refugia)			P			
Old-growth Forest Continuity (over time, including dead wood)				P	P	
			Part 3: Utilitarian and administrative values			
Total Number of Primary Attributes (P)	17	16	11	9	6	2
Total Number of Secondary Attributes (S)	0	5	0	0	5	7
Utilitarian & Administrative Values						
Significance already Established (presence of one or more provincially significant features)	P					
Potential for Stewardship (potential to be enlarged and/or improved)	P					
Protection in Place (ownership or legal interest provides a secure future)	P					
Scientific Value (importance of the site for study and research, established research enhances the value of a site for future investigations and environmental monitoring)		S			S	
Educational Value (the range of features within a particular site largely determines its potential for educational use)		S			S	
Nature Appreciation (a function of the ecological values being protected)		S			S	
Accessibility (depends on use pressures)		S				

other methods (Table 4 – Part 2). Finally, none of these attributes were applied by the OMECP (2020) natural heritage analysis of the Catchacoma Forest despite the relevance of each attribute to the ecology and conservation of this forest.

Utilitarian and Administrative Attributes: Seven selection attributes that address utilitarian and administrative values were identified in the literature including: *significance already established*, *potential for stewardship*, *protection in place*, *scientific value*, *educational value*, *nature appreciation*, and *accessibility* (Table 4 – Part 3). None of these attributes are included in the Ontario AOU method (Crins and Kor 2006) and none of them were applied by the OMECP (2020) analysis of the Catchacoma Forest. Three of these seven attributes were used as primary selection attributes by other reviewed methods including: *significance established*, *stewardship potential*, and *protection in place*. All seven of these attributes, particularly *science, education, accessibility* and *protection in place*, apply in exemplary fashion to this forest.

When only a few attributes are considered in reserve selection, forests are undervalued increasing the risk of their damage and the loss of benefits to society (e.g., flood control and water provision, forest canopy cooling—up to 20°C, to counter eco-anxiety and obesity) resulting in further biodiversity decline, climate warming, and societal conflict within a positive feedback loop. Destructive natural phenomena are rising globally putting more pressure on society to develop smartly that includes an effective Global Ecological Safety Net (GESN; Dinerstein et al. 2020; Finkelstein et al. 2023).

Ecology and Values of the Catchacoma Forest

The ecology and values of this forest are addressed through consideration of the following functional and structural components using existing literature: integrity; biodiversity; species-at-risk; old-growth forests; other habitats including wetlands, streams, and small lakes; and carbon storage.

Integrity: As part of their field assessment to identify potential road access to the newly created Kawartha Highlands Provincial Park, Stantec (2008) commented extensively on the pristine nature and species-at-risk in the area occupied by the Catchacoma Forest stating that:

1. The "... native [plant] species reflects the original character of the land cover and dominance of natural, high-quality habitats, such as forests, swamps, and marshes in which the native species thrive,"
2. "... much of the northern portion of the study area appeared to have undergone very little recent disturbance,"
3. "... the only significant recent human impacts observed in this area were a few widely scattered hunt camps, two major snowmobile trails and two old roads,"
4. "... immediately to the south of the [road alignment] ... is relatively undisturbed," and
5. "... the extensive natural landscape to the north [of the road alignment] forms what could be considered a relatively intact 'wilderness area.'"

Only two cut stumps were found within the Central and Eastern Portions of the Catchacoma Forest (~50% of the Forest; Quinby et al. 2021; Quinby and Marcus 2024).

Biodiversity: To date, the presence of 656 species that occur in the Catchacoma Forest (Figure 3) including 14 species-at-risk has been documented (Mihevc and Robles Gil 2022). They include: 194 animal species, 349 plant species, 106 fungi (including lichens), and 7 slime molds. Of the 194 animals, there are 15 mammal species, 67 bird species, 9 amphibian species, 7 reptile species, 5 fish species, 74 insect species, 9 arachnid species, 1 millipede species, 1 crustacean species, 5 mollusk species, and 1 leech species. Of the 349 plants, there are 26 tree species; 31 shrub and vine species; 215 flowering herbaceous plant species; 49 grass, rush and sedge species; 7 clubmoss species; and 21 moss and liverwort species. This site biodiversity is indicative of habitat corridors that support natural wildlife populations at all trophic levels. As a result of their provincial-level assessment, O'Brien et al. (2023) found that the Catchacoma Forest is regionally significant for its wildlife connectivity values (Haliburton Land Trust 2024) based on use of remotely sensed data unassociated with digital Ontario FRI mapping that was used for our studies of this forest.

Species-At-Risk: A total of 14 species-at-risk (SAR) are known to occur in the Catchacoma Forest (Mihevc and Robles Gil 2022). Stantec (2008) found that "The cerulean warbler (*Dendroica cerulea*) (threatened) is particularly common on this site, with half a dozen heard calling at various locations along the western half of the route." They also provided an assessment of three reptile SARs that have been found in the Catchacoma Forest landscape as follows.

1. "The access road alternative to Bottle Lake provides appropriate habitat for the Blanding's turtle (*Emydoidea blandingii*), five-lined skink (*Plestiodon fasciatus*), and eastern hog-nosed snake (*Heterodon platirhinos*)."
2. "There are several sites along the route that could provide habitat for Blanding's turtle. A wide, slow river, approximately 1 km east of County Road 507, has ideal shallow, weedy water with basking logs."
3. "Approximately halfway along the route, near Catchacoma Lake, the forest understory becomes more open forming a dry hemlock forest. Two eastern hog-nosed snakes were observed in this community."
4. "Oak barren, with an open canopy and rocky outcrops ... provides habitat for both the eastern hog-nosed snake and the five-lined skink."

The other 10 SARs include the Algonquin wolf (*Canis lupus lycaon*, threatened), black ash (*Fraxinus nigra*, endangered), Canada warbler (*Wilsonia canadensis*, special concern), eastern wood pee-wee (*Contopus virens*, special concern), eastern ribbon snake (*Thamnophis sauritus*, special concern), monarch butterfly (*Danaus plexippus*, special concern), rusty blackbird (*Euphagus carolinus*, threatened), snapping turtle (*Chelydra serpentina*, special concern), wood thrush (*Hylocichla mustelina*, threatened), and pink dimple lichen (*Coenogonium pineti*, S3) (Mihevc and Robles Gil 2022).

Old-growth Forests: More than 80% of the stands in the Catchacoma Forest are in the old-growth condition based on

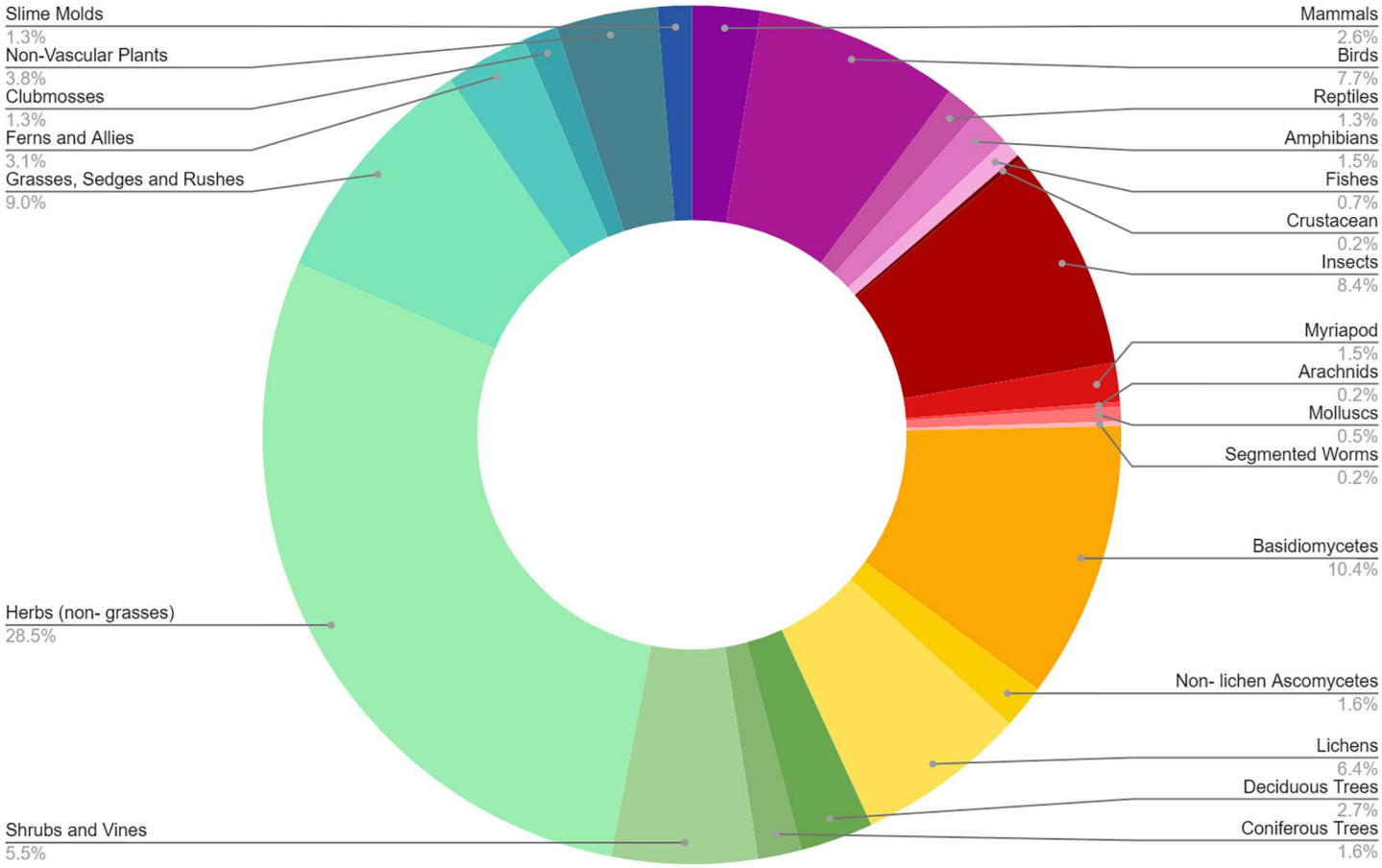

Figure 3.—Known species in the Catchacoma Forest by species group (Mihevc and Robles Gil 2022). See online version of this paper for color image.

Ontario government mapping (Table 1), and field data (Quinby et al. 2021) showed that half of the plots sampled in the Western and Central Portions of this forest were in the early old-growth forest stage (trees 140+ years, minimal dead wood) and the other half were in the late old-growth forest stage (trees 140+ years, high amounts of dead wood). Based on aging of tree cores, mean stand age in the Catchacoma Forest was 176 years and half of the plots contained super-canopy trees (Quinby et al. 2021).

Other Habitats: In addition to upland forest ecosystems, wetlands, stream, and small lake ecosystems are present within this forest (Stantec 2008; Figure 1). Wetland types included treed bogs, treed fens, alder–wintergreen organic thicket swamp, broad-leaved sedge organic shallow marsh, and fowl manna grass organic shallow marsh. Two headwater streams with riffle-pool-run sequencing and in-stream substrates including boulders, gravel, sand, and coarse woody debris drain south into Catchacoma Lake. Water lily–bullhead and lily floating-leaved shallow aquatic communities are well represented in semi-stagnant waters in the widest portions of the streams. A few small, shallow lakes are also found there with pickerel-weed mixed shallow aquatic vegetation, which is well-developed in shallow open waters, mostly along lakeshores.

Carbon Storage: In their provincial-level assessment, O'Brien et al. (2023) found that the Catchacoma Forest is regionally significant for its high carbon storage values. High carbon content in this forest was also documented by Marcus and Quinby (2024a) finding that logged areas in the Western Portion of the Catchacoma Forest stored an estimated 202 t C/ha before logging, which decreased to 82 t C/ha after logging. On average, the aboveground carbon in intact areas (173 t C/ha) was 111% higher than in logged areas (82 t C/ha) of the Catchacoma Forest. The Central Portion of this forest stored a conservatively estimated 128 t C/ha. A comparison of 55 temperate forest stands (old-growth and mature) across NE North America showed that the Western and Central Portions of the Catchacoma Forest fall within the top 15% and 36% of aboveground live carbon for these 55 forest stands, respectively (Marcus and Quinby 2024a).

Reserve Selection Policy

Reserve selection in Ontario is governed by many policies and chief among them is the *Ontario Provincial Parks and Conservation Reserves Act* (PPCRA; Province of Ontario 2006), which states that, "The Lieutenant Governor in Council may make regulations . . . setting apart an area as a provincial park or

conservation reserve" and ". . . protecting provincial resources in provincial parks and conservation reserves, including, but not limited to, flora, fauna, habitats, geological features, cultural features and archaeological features." In addition to the PPCRA, the most relevant policies, written guidance, and strategies related to selecting and creating reserves in Ontario include the *Ontario Protected Areas Planning Manual*, the *Ontario Old-growth Forest Policy*, the *Natural Heritage Reference Manual*, the 2021 *Ontario Protected Areas Recommendations Report*, the *30 × 30 Land Protection Strategy*, the *Global Safety Net*, and *Your Protected Places - A Shared Vision for Ontario*.

Ontario Protected Areas Planning Manual: The *Ontario Protected Areas Planning Manual* (OMNR 2023), first approved in 2009, is required by the PPCRA to guide all aspects of protected areas planning and management in Ontario over a projected 20-year period including (1) to provide policy direction to government staff and partners, (2) to define minimum requirements for preparing new management direction, (3) for examining and adjusting existing management direction, (4) to provide considerations related to implementation, and (5) to assist stakeholders including the public to participate in protected areas planning and management. The *Planning Manual* applies to proposed, recommended, and existing protected areas under the PPCRA and is supported by guidelines, templates, and other tools that provide a non-scientific, procedural, regulatory, and timing roadmap for creating and managing parks and conservation reserves in Ontario.

As evidence of a non-scientific document, no mention of protecting landscapes for old-growth forest values or for carbon storage values is included in the *Planning Manual*. For NGOs involved in identifying and proposing new reserves, the provision for stakeholder involvement is the key component. It states that stakeholder involvement must be open and transparent with easy access to information, clear communication of proposed direction, and provision of the rationale behind government decisions. Through the *Planning Manual*, the government commits to the provision of public involvement in protected area planning and management by:

1. Seeking input from all potential stakeholders including Aboriginal communities and the public on ecological, social, cultural, and economic considerations;
2. Facilitating the exchange of information, discussion of proposals, and development of partnerships with stakeholders;
3. Recording all discussions with and comments received from stakeholders;
4. Explaining how stakeholder input was considered (or not considered) during decision making;
5. Describing how stakeholder input was incorporated into management direction; and
6. Providing the rationale for whether input was incorporated or not.

The *Planning Manual* states that, "Any person can propose an amendment by making a submission to . . . [the government] . . . identifying details of the proposed amendment and explaining the benefits." Following their consideration, the government commits to providing the proponent (stakeholder) with a written notice of decision (accepted, declined, or deferred) including the rationale for the decision. Unfortunately, no rationale was provided by the government for the rejection of the Catchacoma Forest protection proposal as detailed in Marcus and Quinby (2024b).

Despite the availability of this substantial guidance document since 2009 and in the face of increasing severity of biodiversity loss and planet warming, the Province of Ontario increased its protected land by only 0.8% in a decade, from 9.9% in 2010 to 10.7% in 2020 (CPAWS 2021; protection remains at $<$11%). In contrast, Quebec increased their protected terrestrial areas by 8.1% during this time, from 8.6% in 2010 to 16.7% in 2020, showing that expanding natural heritage protection while maintaining the economy is possible.

Old-growth Forest Policy: In 2003 without public or industry consultation, the Ontario government finalized the *Ontario Old-growth Forest Policy* (OMNR 2003a) creating a policy that was less legally binding than the 1995 *Conservation Strategy for Old-growth Red and White Pine* (OMNR 1996) that it replaced (ECO 2004). The following weaknesses of the *Policy* and its formation were identified and addressed by the Environmental Commissioner of Ontario shortly after its release (ECO 2004).

1. Inadequate time was allocated for meaningful public consultation.
2. Ontario forest management plans recommend but do not require development of protection targets for old-growth forests and targeting is not linked to components of the *Policy*. Old-growth targets are to be set at the local level by the forest industry planning teams without adequate technical guidance from government.
3. The *Policy* does not contain requirements to ensure adherence to minimum standards and effectiveness. Currently, only through careful monitoring of individual forest management plans by members of the public will effective old-growth forest monitoring take place.
4. The government communicated old-growth forest conservation requirements through a "FMP Note," which has no legal authority under the *Crown Forest Sustainability Act* (Province of Ontario 1994). This form of communication, which can be revised by the government at any time without public consultation, represents a creeping loss of transparency and an abdication of the spirit of the *Act*. The *Policy* requirements should have been incorporated into the *Forest Management Planning Manual*, which is approved and revised by legislation, to guarantee greater accountability including requirements for public consultation.
5. The government allows old growth in parks and protected areas to count toward targets for old growth in areas where forest harvesting is taking place. This should not be used to permit the area of old growth in forest harvesting areas to decrease below 1995 levels as specified in the *Policy*.

6. The current *Policy* does not include plans and targets to identify and conserve old-growth forests in southern Ontario (~8.2 million ha of land area), where the pressures on vanishing forests are immense and urgent.

To date, The Ontario government has not determined minimum standards for integrity and density/volume for old trees, snags, and logs within old-growth forest types that occur in the province (Issekutz 2020). Their most significant achievement has been the classification of old-growth forest types (by tree composition and site type) and the determination of the age-of-onset for each of these forest types (OMNR 2003b). The only comprehensive old-growth forest standards that address integrity, old tree density, snag density, and log density/volume for Ontario were produced using data from 41 plots within 30 of the oldest and largest old-growth red and eastern white pine forest stands in Temagami, Ontario, ranging in size from 11 to 913 ha (Quinby 1991). Old-growth standards for eastern hemlock forests are addressed in detail by Quinby and Marcus (2024).

In addition, the Ontario reserve selection methodology (Crins and Kor 2006) allows for the continued logging of old-growth forests, as shown by the case of Canada's largest remaining old-growth eastern hemlock forest (see Marcus and Quinby 2024b), which remains unprotected. In addition, this methodology requires that only 1% of the landscape be protected for natural heritage. Until appropriate standards and methods are developed and/or updated for the assessment of old-growth forests in Ontario, these unique, rare, and valuable ecosystems will continue to decline as is the case for Ontario's eastern hemlock–dominated forests that could be eliminated by 2075 (Figure 2).

Natural Heritage Reference Manual: The foundation of the Ontario AOU reserve selection methodology (Crins and Kor 2006) is based on filling gaps in representation of the combinations of forest vegetation with surficial geological composition ignoring many other significant potential reserve selection attributes. However, with respect to endangered old-growth forests, the representation attribute is irrelevant since all rare forest ecosystems containing marketable fiber (older forests) are the most vulnerable of all ecosystem types and forest ages given both their small, fragmented populations and their extremely high wood biomass content, which is highly sought after by logging companies. Given their rarity, vulnerability, and high ecological value to society, some have called for the protection of all remaining old-growth forests (Dinerstein et al. 2020).

Of all the methods described in Table 4, the *Ontario Natural Heritage Reference Manual* (OMNR 2010), applied exclusively in southern Ontario, uses the greatest number of primary reserve selection attributes (17). At the opposite extreme, the Crins and Kor (2006) method applied in central and northern Ontario (AOU) uses the fewest primary reserve selection attributes. So, if the Ontario government has one of the most comprehensive natural heritage assessment methods in the world that it applies in southern Ontario, why is that method not applied in the central and northern portions of the province? This is likely due to the presence of industrial logging throughout central and northern Ontario but not in southern Ontario where forests have been very heavily exploited leaving only 0.07% of original forest remaining (Quinby et al. 2022). Forest conservation in central and northern Ontario would improve significantly if the methods recommended in the *Ontario Natural Heritage Reference Manual* (OMNR 2010) replaced the Crins and Kor (2006) AOU methodology.

Protected Areas Working Group Recommendations: The *Protected Areas Working Group* was appointed by the Ontario government to "identify opportunities to protect and conserve more natural areas" in the province. The report, *A New Approach: Advancing Protected and Conserved Areas in Ontario*, was finalized in 2021, however it was not made available to the public until June of 2023 through a successful Freedom of Information request by the Ontario Wilderness Committee. The report proposes a seven-point strategic framework to facilitate expansion of Ontario's protected areas system (Hasenack 2023) as follows:

1. Critically important are Indigenous-led conservation (e.g., *Indigenous Protected and Conserved Areas*) and nation-to-nation dialogue in keeping with the *United Nations Declaration on the Rights of Indigenous Peoples*.
2. Uphold the national and international goal of protecting 30% of the landscape by 2030, known as the *30 × 30 Target*, and provide associated achievement timelines.
3. Develop a comprehensive *Provincial Protected Areas Strategy* that includes clear objectives, targets, and timelines that is approved by the *Provincial Cabinet*.
4. Facilitate/support a community-driven, collaborative approach to reserve selection and *Strategy* development and implementation.
5. Rapid action is required (1) to conduct a thorough, provincial natural heritage gap analysis, (2) to protect current candidate protected areas, and (3) to improve protections for key natural features such as wetlands, riparian forests, old-growth forests, wildlife corridors, roadless areas, and habitat for species-at-risk.
6. Establish a *Wild Ontario Accelerator Fund* to provide the funding required to develop and implement the *Provincial Protected Areas Strategy*.
7. Public support for this effort is strong—86% of survey respondents support the creation of more parks and protected areas in Ontario.

The Ontario government has yet to implement any of these recommendations; however, the report does provide a comprehensive, high-level strategy that has potential for success but only with significant government involvement.

30 × 30 Strategy, Global Safety Net and Roadless Areas: The *30 × 30 Strategy* includes a target for governments to protect 30% of their lands and waters by 2030 (e.g., ECCC 2024) to maintain biodiversity and carbon storage within natural ecosystems. More than 150 countries including Canada agreed to adopt this target at the United Nations Biodiversity

Conference (COP15) that was held in Montreal, Canada, in December 2022 (Jetz et al. 2021; CBD 2022). Ontario nature protection currently sits at less than 11% requiring 20 million ha of new protected areas to meet the 30% protection goal by 2030.

Another more aggressive strategy is the *Global Safety Net* (GSN), which envisions the motto "think globally, act locally" for nature conservation and stewardship at a planetary scale by expanding terrestrial protected areas globally from 15% (currently) to 50% through action at the grassroots level (Dinerstein et al. 2020; Finkelstein et al. 2023). Analyses indicate that the GSN strategy would reverse further biodiversity loss, prevent CO_2 emissions from land conversion, enhance natural carbon removal, add sites of great biodiversity value, and stabilize climate (Dinerstein et al. 2020). A total of 50 ecoregions and 20 countries contribute disproportionately to achieving proposed GSN protection targets, which include Ontario's northern *Great Lakes-St. Lawrence Forest Region* and *Boreal Forest*.

Recent findings show that Ontario's most unique and valuable contribution to the GSN is the large extent of roadless areas (RAs) and the high carbon storage in terrestrial ecosystems (Finkelstein et al. 2023). With its roadless area (Quinby et al. 2022) and documented high carbon content (O'Brien et al. 2023; Marcus and Quinby 2024a), the Catchacoma Forest located on the southern edge of Ontario's Intact Wilderness (Finkelstein et al. 2023) is exactly what the GSN is calling for. Data from Dinerstein et al. (2020) indicates that the Ontario contribution of currently unprotected intact, roadless areas would be ~74 million ha or about 70% of the provincial land area.

This high amount of targeted protected area is likely due to the disproportionate contribution of Ontario's roadless areas to global terrestrial carbon storage (Finkelstein et al. 2023). If all remaining RAs in Ontario were designated as protected areas, Ontario would achieve ~93% of the *30 × 30 Strategy* target. However, doubling logging production by 2030 per a new Ontario policy (OMNDMNRF 2021) could reduce RAs by as much as 20% to ~14.8 million ha by 2030, potentially resulting in their depletion between 2090 and 2100 (Quinby et al. 2022).

Your Protected Places - A Shared Vision for Ontario: Many nongovernment organizations are working toward the establishment of protected areas for a wide variety of natural landscapes in Ontario in the absence of government leadership through the program *Your Protected Places - A Shared Vision for Ontario* (Ontario Nature 2023). This project allows individuals and organizations to propose candidate protected areas within a loosely defined structure that includes four main reserve categories:

1. Wildlife habitat and unique ecosystems such as old-growth forests, wetlands, and ecological corridors;
2. Forest industry and Indigenous reserves such as "*designated conservation lands*" that are certified by the Forest Stewardship Council and "*Indigenous protected and conserved areas*" such as the *Eagle Lake First Nation's Farabout Peninsula IPCA*;
3. Urban areas and southern Ontario, where most people in the province live, have had historically few opportunities for people to access natural areas and thus reserves and their benefits are in high demand; and
4. Areas of Natural and Scientific Interest (ANSI; unprotected) and existing protected areas: there are over 119,000 ha of provincially significant ANSIs and 2.75 million ha of candidate ANSIs on unceded Crown land in Ontario representing an ideal opportunity for expansion and expanding existing protected areas. This can buffer and connect important core habitats, which helps to maintain biodiversity and ecological integrity such as adding the Catchacoma Forest as an expansion to Kawartha Highlands Provincial Park.

To date, over 200 candidate protected areas totaling to more than 4 million ha, including the Catchacoma Forest, have been proposed by more than 35 NGOs through the project submission internet portal. Requirements for adding a candidate protected area to the *Ontario Protected Areas StoryMap* includes site name and size, site location (including GPS coordinates), and information describing the unique and special conservation values of the candidate site. Additional candidate site submissions are encouraged. When regulatory opportunities emerge, many candidate reserves will be ready for final approval and legislative designation.

CONCLUSION

In less than 50 years, by ~2075, eastern hemlock–dominated forests in Ontario will be depleted if current logging trends continue, which emphasizes the urgency of protecting all remaining old-growth forests of this type. Possibly the most valuable stand of old-growth eastern hemlock forest in Canada, the Catchacoma Forest, remains unprotected despite efforts to protect this stand for several years. The natural heritage assessment of this forest by the Ontario government found that it was a common, fully represented landscape element that does not require protected status. This decision was based on a methodology that initially filters potential reserves by focusing exclusively on representation of the combinations of forest vegetation with surficial geological composition, ignoring many other significant potential reserve selection attributes including forest stand age, ecological integrity, and species-at-risk.

Considering 30 key attributes used for reserve selection derived from the literature, we found that the Catchacoma Forest is an exemplary old-growth forest candidate reserve. However, a few basic features of this forest alone would typically qualify it for protection including its status as Canada's largest-known eastern hemlock old-growth forest, the presence of at least 14 species-at-risk, and a high level of landscape diversity and integrity including forests, wetlands, streams, and lakes undisturbed by humans within a 662 ha area. The government's exclusive focus on two of 30 primary reserve attributes has resulted in ignoring old-growth forests as significant natural heritage features allowing them to be logged. For old-growth

forests that support high tree biomass, the representation attribute is irrelevant since by virtue of their rare, threatened, and endangered status, few of them remain and they are often the first landscape elements to be lost to loggers seeking stands with high fiber content.

By protecting the Catchacoma Forest, the largest of its type in Canada, as a community-based reserve for nonconsumptive use, this reserve would not provide timber for products such as pallets and garden mulch that are currently produced from eastern hemlock trees. However, protection would provide the following benefits (and more) to society at local to international scales since eastern hemlock forests are common throughout the temperate portions of eastern North America:

- Contribute to the Ontario Protected Areas Vision
- Spiritual respite and renewal
- Physiological (e.g., phytoncides) and mental health benefits (e.g., treatment for eco-anxiety) to people who are emersed within the forest
- Provides for the continuation of existing recreational activities with potential for more light trail-based recreational activities
- Both formal and informal education
- Scientific study of landscape baseline conditions including carbon dynamics and biodiversity ecology
- Long-term studies as the best way to truly understand nature (656 species found to date)
- Storage and sequestration of CO_2 as global temperature continues to rise
- Provide habitat for rare, threatened, and endangered species (14 SARs found to date)
- Provide for the most natural conditions possible to support natural evolution (unimpeded by humans)
- To function as a sentinel of biological invasions (e.g., hemlock woolly adelgid) that are on the rise globally
- Adds a separate and contiguous area to Kawartha Highlands Provincial Park making the region more resilient to both climate change and biodiversity loss.

From an economic perspective, the Catchacoma Forest is at least 10× more valuable if left unlogged and logging contingency areas are available to replace the removal of 662 ha from the productive forest. To not protect the Catchacoma Forest from logging is to miss a significant opportunity to address two issues that are extremely important to the public (conservation of biodiversity and carbon), including the positive public relations that could be achieved. In addition, private companies (e.g., Bancroft Minden Forest Company) and regulatory agencies in Ontario (e.g., OMNRF, OMECP) could decrease the amount of protection required by the *30 × 30 Strategy* for their logging region down to ∼207,000 ha if logging was removed and the 662 ha was converted to protected status.

This approach to natural heritage protection in Ontario is also likely resulting in the loss of all types of old-growth forests throughout the ∼44 million ha of Ontario where the provincial AOU gap analysis method is applied. This flaw could be corrected by updating this almost two decades–old gap analysis methodology by requiring assessment of at least 21 additional key natural heritage attributes commonly used for reserve assessment and selection worldwide.

Many policies and strategies at the provincial, federal, and international levels that apply to the protection of biodiversity and forest carbon in Ontario provide a solid foundation to facilitate increased landscape protection. For example, *Your Protected Places - A Shared Vision for Ontario* has accumulated more than 200 candidate protected areas proposed by more than 35 NGOs totaling more than 4 million ha, including the Catchacoma Forest.

In this article, a case has been made for granting protection to the Catchacoma Forest based on multiple data sources. Nevertheless, the final component required for the protection of this forest and in general, for nature protection implementation in Ontario, is the will and action of politicians and environmental management agencies.

ACKNOWLEDGMENTS

Thanks to Ted Elliott for assisting with data analysis. Funding was provided by the Canada Summer Jobs granting program and ECO Canada. Support from the Catchacoma Forest Stewardship Committee, particularly Katie Krelove, is also much appreciated.

Peter Quinby is Chair & Chief Scientist for Ancient Forest Exploration & Research. In addition to managing the NGO, he studies forest landscape conservation including the ecology and protection of primary forests.

LITERATURE CITED

Beechey, T.J. 1989. Guidelines for the Selection of Protected Ecological Areas. Occasional Paper No. 5, Canadian Council on Ecological Areas, Ottawa, ON. <https://ccea-ccae.org>

[BMFC] Bancroft Minden Forest Company. 2021. Forest Management Plan for the Bancroft Minden Forest Management Unit #220, 2021 to 2031. BMFC, Bancroft, ON. <https://nrip.mnr.gov.on.ca/s/published-submission?language=en_US&recordId=a0z3g000000yyFUAAY>

Branquarta, E., K. Verheyenb, and J. Latham. 2008. Selection criteria of protected forest areas in Europe: The theory and the real world. Biological Conservation 141:2795–2806.

Brodiea, J.F., and J.E.M. Watson. 2023. Human responses to climate change will likely determine the fate of biodiversity. PNAS 120(8) e2205512120.

[CBD] Convention on Biological Diversity. 2022. Press release: Nations Adopt Four Goals, 23 Targets for 2030. In Landmark UN Biodiversity Agreement. <https://www.cbd.int/convention/>

Coristine, L.E., A.L. Jacob, R. Schuster, S.P. Otto, N.E. Baron, N.J. Bennett, S.J. Bittick, C. Dey, B. Favaro, A. Ford, et al. 2018. Informing Canada's commitment to biodiversity conservation: A science-based framework to help guide protected areas designation through Target 1 and beyond. FACETS 3:531–562.

[CPAWS] Canadian Parks and Wilderness Society. 2021. The Grades are In: A Report Card on Canada's Progress in Protecting its Land and Ocean. <https://cpaws.org/wp-content/uploads/2021/06/cpaws-reportcard2021-web.pdf>

Crins, W.J., and P.S.G. Kor. 2006. Natural Heritage Gap Analysis Methodologies Used by the Ontario Ministry of Natural Resources,

Version 3.0. Earth Science Report 0602, Ontario Parks, Ontario Ministry of Natural Resources, Peterborough, ON. <https://www.ontario.ca/document/significant-wildlife-habitat-technical-guide/appendix-e-natural-heritage-gap-analysis>

Dinerstein, E., A.R. Joshi, C. Vynne, A.T.L. Lee, F. Pharand-Deschênes, M. França, S. Fernando, T. Birch, K. Burkart, G.P. Asner, and D. Olson. 2020. A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. Science Advances 6:eabb2824.

Drever, C.R., J. Snider, and M.C. Drever. 2010. Rare forest types in northeastern Ontario: A classification and analysis of representation in protected areas. Canadian Journal of Forest Research 40:423–435.

[ECCC] Environment and Climate Change Canada. 2024. Canada and Ontario commit to significant collaboration on shared nature conservation goals. Press release. <https://www.canada.ca/en/environment-climate-change/news/2024/03/canada-and-ontario-commit-to-significant-collaboration-on-shared-nature-conservation-goals.html>

[ECO] Environmental Commissioner of Ontario. 2004. Forest Management Policy for Old Growth. Pp. 99–104 *in* Choosing our Legacy, ECO Annual Report, 2003-04. The Queen's Printer for Ontario, Toronto, ON.

Finkelstein, S.A., C. Doherty, and A.L. Loder. 2023. Safety Net Ontario: Ontario's outsized role in the "Global Safety Net" for climate and biodiversity. FACETS 8:1–17.

[FSC] Forest Stewardship Council. 2022. Study on Criterion 6.5 of FSC Principles and Criteria. Forest Stewardship Standards. <https://ca.fsc.org/ca-en/newsfeed/study-on-criterion-65-of-fsc-principles-and-criteria-underway>

Gotmark, F., and C. Nilsson. 1992. Criteria used for protection of natural areas in Sweden 1909–1986. Conservation Biology 6:220–231.

Haliburton Land Trust. 2024. Forests and Barrens in the Highlands Corridor. Accessed 18 April 2024 from <https://www.highlandscorridor.ca/forests-and-barrens/>

Hasenack, S. 2023. Ontario's Protected Areas Working Group Report: Seven Things You Need to Know. Ontario Nature Blog 20 July 2023. <https://ontarionature.org/protected-areas-working-group-report-blog/>

Invasive Species Centre. 2022. Hemlock Woolly Adelgid CFIA Update. <https://www.invasivespeciescentre.ca/hemlock-woolly-adelgid-cfia-update/>

Issekutz, P.B. 2020. A Critical Evaluation of Old-Growth Forest Definitions in Canada. Department of Earth and Environmental Sciences, Student Report for ENVS 4901, Supervisor Dr. Peter Duinker, Dalhousie University, Halifax, NS.

Jetz, W., J. McGowan, D.S. Rinnan, H.P. Possingham, P. Visconti, B. O'Donnell, and M.C. Londoño-Murcia. 2021. Include biodiversity representation indicators in area-based conservation targets. Nature Ecology and Evolution 6:123–126.

[LIO] Land Information Ontario. 2024. Forest Resource Inventory. <https://www.ontario.ca/page/land-information-ontario>

Marcus, A., and P. Quinby. 2024a. Carbon Storage Reduction and CO2 Produced by Logging in the Catchacoma Old-growth Forest. Research Report No. 43, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_1e7af83ee10c4b2cbd1e7daa68aa3fcc.pdf>

Marcus, A., and P. Quinby. 2024b. Stewardship of Primary Forests: Opportunities to Protect Canada's Largest Eastern Hemlock Old-growth Forest at Catchacoma Lake, Ontario. Research Report No. 47, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_d4df3ef8546f43689640d7e4c45da68f.pdf?index=true>

Mihevc, J., and L. Robles Gil. 2022. Catchacoma Forest Species Inventory: 2022 Field Season. Research Report No. 45, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_d75e42839cce42ee88b82cb4f6598a9c.pdf>

O'Brien, P., J.S. Gunn, A. Clark, J. Gleeson, R. Pither, and J. Bowman. 2023. Integrating carbon stocks and landscape connectivity for nature-based climate solutions. Ecology and Evolution 13:e9725.

[OMECP] Ontario Ministry of Environment, Conservation and Parks. 2020. Catchacoma Forest LV Map: Landform/Vegetation Association Achievement Level. MECP, Peterborough, ON. <https://8e1108ad-02ad-4c2e-b3b4-294c65552fe4.filesusr.com/ugd/1eacbf_faa0672c24104856918a47922217a621.xlsx?dn=Catchacoma_Area_LV_Achievement_clip.xlsx>

[OMNR] Ontario Ministry of Natural Resources. 1996. Conservation Strategy for Old Growth Red Pine and White Pine Forest Ecosystems. *In* Forest Management Planning Manual for Ontario's Crown Forest. Queen's Printer for Ontario, Toronto, ON.

[OMNR] Ontario Ministry of Natural Resources. 2003a. Old-growth Policy for Ontario's Crown Forests. Natural Resources Information Centre, Peterborough, ON. <https://dr6j45jk9xcmk.cloudfront.net/documents/2830/policy-oldgrowth-eng-aoda.pdf>

[OMNR] Ontario Ministry of Natural Resources. 2003b. Old-growth Forest Definitions for Ontario. Queen's Printer for Ontario, Toronto, ON. <https://www.publications.gov.on.ca/old-growth-forest-definitions-for-ontario-009288>

[OMNR] Ontario Ministry of Natural Resources. 2010. Natural Heritage Reference Manual, 2nd Ed. Queen's Printer for Ontario, Ontario Ministry of Natural Resources, Peterborough, ON. <http://www.mnr.gov.on.ca/289522.pdf>

[OMNR] Ontario Ministry of Natural Resources. 2023. Ontario Protected Areas Planning Manual. Queens Printer for Ontario, Peterborough. ON. <https://www.ontario.ca/page/ontarios-protected-areas-planning-manual>

[OMNRF] Ontario Ministry of Natural Resources and Forestry. 1987. Forest Resources Inventory Mapping for FMUs: French-Severn, Northshore, Algoma, Sudbury, Nipissing, Algonquin, Mazinaw Lanark, and Bancroft Minden (Ottawa Valley data unavailable). <https://geohub.lio.gov.on.ca/pages/forest-resources-inventory>

[OMNRF] Ontario Ministry of Natural Resources and Forestry. 2007. Forest Resources Inventory Mapping for FMUs: French-Severn, Northshore, Algoma, Sudbury, Nipissing, Algonquin, Mazinaw Lanark, and Bancroft Minden (Ottawa Valley data unavailable). <https://geohub.lio.gov.on.ca/pages/forest-resources-inventory>

[OMNDMNRF] Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry. 2021. Sustainable Growth: Ontario's Forest Sector Strategy. Accessed 26 October 2021 from <https://www.ontario.ca/page/sustainable-growth-ontarios-forest-sector-strategy>

Ontario Nature. 2017. Protected Areas & Forest Stewardship Council (FSC) Certification in Ontario. Ontario Nature, Boreal Program, Thunder Bay, ON. <https://ontarionature.org/wp-content/uploads/2017/11/16-ProtectedAreas-Booklet-FA-LRSpreads2.pdf>

Ontario Nature. 2023. Your Protected Places: A Shared Vision for Ontario. Ontario Nature, Toronto, ON. <https://storymaps.arcgis.com/stories/41eff1b612824398ac5d80b96db56f21>

Ontario Nature. 2024. Protected Areas in Waiting A Legacy Conservation Opportunity to Contribute to Canada's Biodiversity Commitment. News release. Ontario Nature, Toronto, ON. <https://ontarionature.org/news-release/protected-areas-in-waiting/#:~:text=November%2028%2C%202024%20%E2%80%93%20Ontario%20Nature, Council%20(FSC)%20certified%20forests>

[OPAWG] Ontario Protected Areas Working Group. 2021. A New Approach: Advancing Protected and Conserved Areas in Ontario. Ministry of Environment, Conservation and Parks, Peterborough, ON. <https://ontarionature.org/protected-areas-working-group-report-blog/>

Province of Ontario. 1994 (updated 2021). Crown Forest Sustainability Act. Ontario Legislature, Queen's Park, Toronto, ON.

Province of Ontario. 2006 (updated 2021). Provincial Parks and Conservation Reserves Act. Ontario Legislature, Queen's Park, Toronto, ON.

Quinby, P. 1991. Preliminary Definitions of Old-growth Red and White Pine Forest in Central Ontario. Tall Pines Project, Temagami Wilderness Society & Earthroots, Toronto, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_bbd4b2be63154eb682c5927d800959c8.pdf>

Quinby, P. 2019a. Rare, Threatened and Endangered Forest Ecosystems in Ontario's Temperate Forest Region. Forest Landscape Baselines No. 34, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_de3f60444cbc47d6ababfff04540690c.pdf?index=true>

Quinby, P. 2019b. An Inventory of Documented Old-growth Eastern Hemlock Forests in Canada. Forest Landscape Baselines No. 35, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_46dd96ba2b7f4c9387fb9f8f89812303.pdf>

Quinby, P.A., R.E. Elliott, and F.A. Quinby. 2022. Decline of regional ecological integrity: Loss, distribution and natural heritage value of roadless areas in Ontario, Canada. Environmental Challenges 8:100584.

Quinby, P., and A. Marcus. 2024. Rapid Assessment of Mother Trees to Identify Biodiversity Hotspots, Create a GIS Database, and Document Old-growth Forest Standards: Central Catchacoma Eastern Hemlock Forest. Research Report No. 46, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_11cf63ba53294cd58ce9203825da44db.pdf?index=true>

Quinby, P., T. Martens, and K. Cowcill. 2021. Comparing Stand Ages Using Tree Cores and Forest Resource Inventory Mapping from 1987 and 2007 in the Catchacoma Forest, Northern Peterborough County, Ontario. Preliminary Results Bulletin #10, Ancient Forest Exploration & Research, Powassan, ON. <https://www.ancientforest.org/_files/ugd/1eacbf_7f4126b4a5d347c7a39939060ac5c770.pdf>

Stantec. 2008. Kawartha Highlands Signature Site Park Access Road Study: Final Environmental Study Report. Prepared by Stantec Consulting Ltd. for Ontario Parks, Ministry of Natural Resources, Peterborough, ON.

Watson, J.E.M., T. Evans, O. Venter, B. Williams, A. Tulloch, C. Stewart, I. Thompson, J.C. Ray, K. Murray, A. Salazar, et al. 2018. The exceptional value of intact forest ecosystems. Nature Ecology & Evolution 2:599–610.