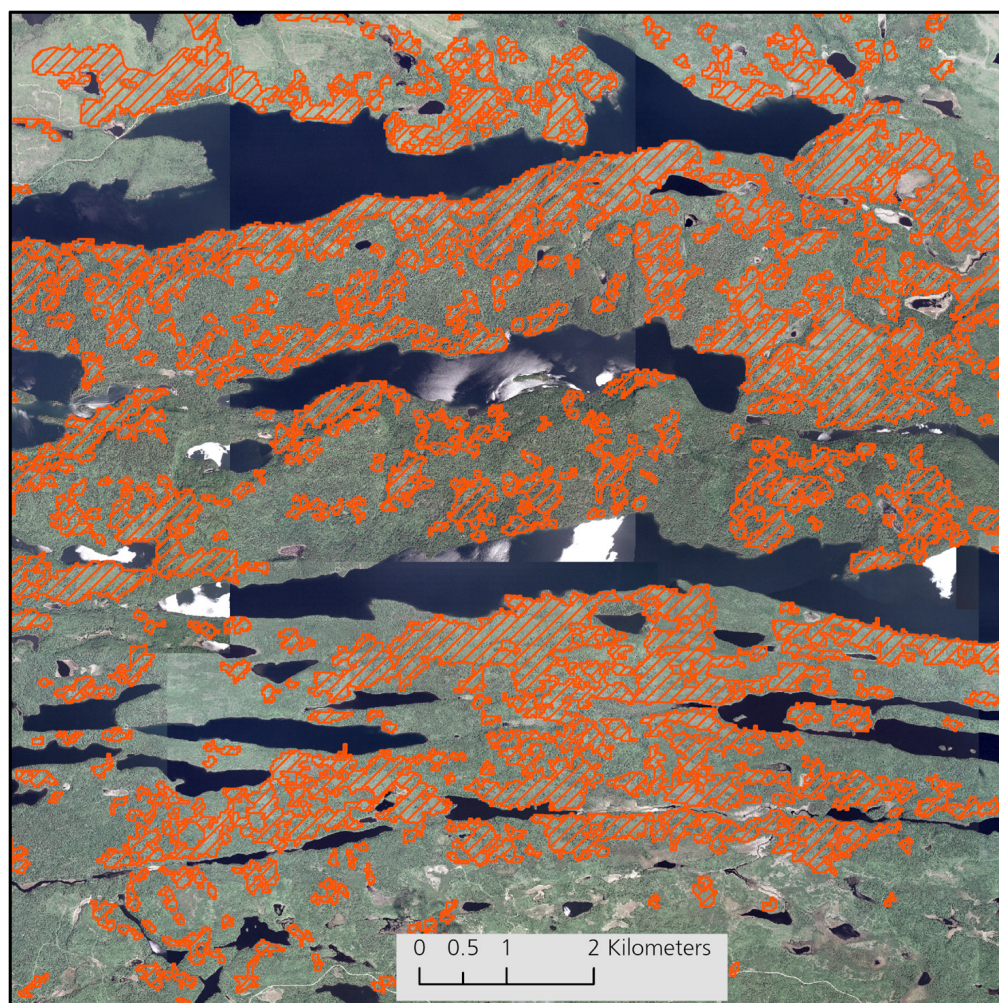




# Landsat-based Monitoring of Landscape Dynamics at Grand Portage National Monument

## *1995–2018*

Natural Resource Data Series NPS/GLKN/NRDS—2022/1353



**ON THE COVER**

Photo of the Boundary Waters Canoe Area showing a portion of the extent of a wind event that occurred in 1999. Image from WorldView satellite.

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## *1995–2018*

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Alan A. Kirschbaum

National Park Service  
Great Lakes Inventory and Monitoring Network  
2800 Lakeshore Drive East  
Ashland, Wisconsin 54806

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Fort Collins, Colorado

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## Abstract

Landscape disturbances such as forest harvest, blowdowns, fire, and development activities create patches on the landscape that modify the structure and function of ecosystems and watersheds. Understanding the timing, location, size, and intensity of these disturbances can assist resource managers when making decisions regarding management options. In an effort to provide information regarding these metrics, the Great Lakes Inventory and Monitoring Network implemented a long-term monitoring project to quantify landscape dynamics inside and surrounding Grand Portage National Monument using an automated satellite-based change detection program called LandTrendr (Landsat-based detection of trends in disturbance and recovery). The analysis area encompassed three watersheds totaling over 83,000 hectares and spanned the years 1995–2018. Inside the park, the only disturbance detected was due to a defoliation event that totaled 60 ha. Lands adjacent the park experienced far greater levels of disturbance, with forest pathogen (defoliation) affecting 7.6% of the land, followed closely by forest harvest and blowdown at 7.4% and 6.3%, respectively. The blowdown occurred in the summer of 1999, the defoliation event occurred the following year (2000), and the forest harvest disturbances were relatively stable throughout the analysis period. Lastly, disturbances by beaver were observed across the analysis area and analysis time period, indicating their prevalence across time and space. Long-term monitoring of this analysis area will contribute to our understanding of how these disturbances may affect ecological processes inside the park.



# Introduction

We report on disturbances for Grand Portage National Monument (GRPO) and the surrounding area using change detection methodology described in the Great Lakes Inventory and Monitoring Network (GLKN) Landscape Dynamics monitoring protocol (Kennedy et al. 2010a). Here we summarize disturbances that occurred between 1995 and 2018 (23 years).

## Methods

### Study Area

The analysis was conducted inside and adjacent to Grand Portage National Monument (GRPO), extending into Ontario, Canada (Figure 1). In total 83,389 ha of land was monitored, of which 277 ha was land inside GRPO. Included in the analysis area are two U.S. watersheds as defined by level 10 delineations of the National Hydrography Dataset's Hydrologic Unit Code (HUC) ([nhd.usgs.gov](https://nhd.usgs.gov)) and one watershed in Canada as defined by the quaternary level of the Ontario watershed delineation ([ontario.ca/page/land-information-ontario](https://ontario.ca/page/land-information-ontario)) (Figure 2). Landcover within the analysis area was dominated by forest, as classified in the U.S. by the 2006 National Land Cover Database (NLCD) (Fry et al. 2011) and in Canada by the Canada-wide Earth Observation for Sustainable Development of Forests (EOSD) (Wulder et al. 2003) (Figures 3 and 4).



**Figure 1.** Analysis area for monitoring landscape dynamics in the greater Grand Portage National Monument ecosystem. Red outline indicates park extent and black outline indicates area monitored outside the park.

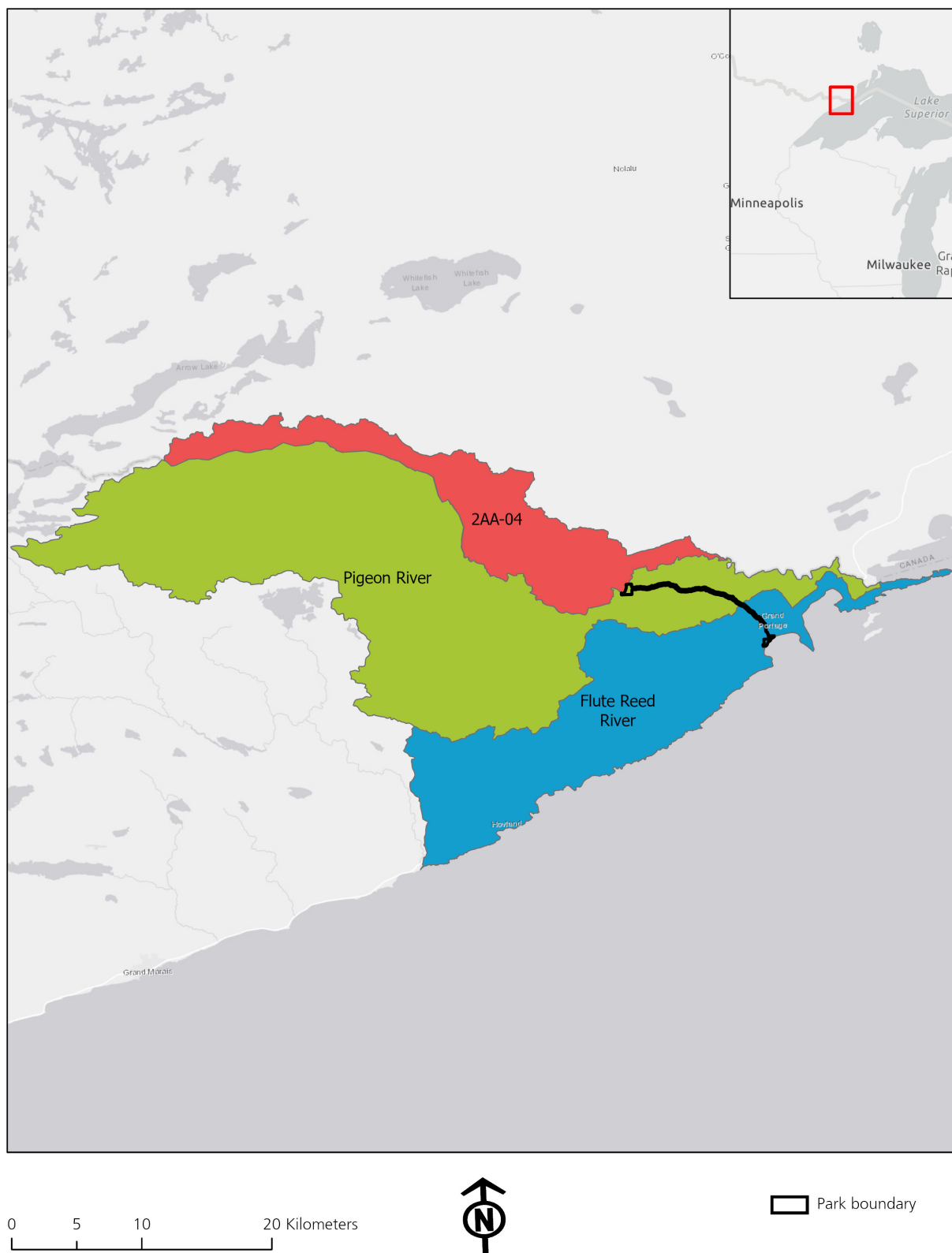


**Figure 2.** Labeled watersheds (three solid colors) included in this analysis, as defined by level 10 Hydrologic Unit Codes (HUCs) in the U.S. and level 4 watersheds in Ontario.

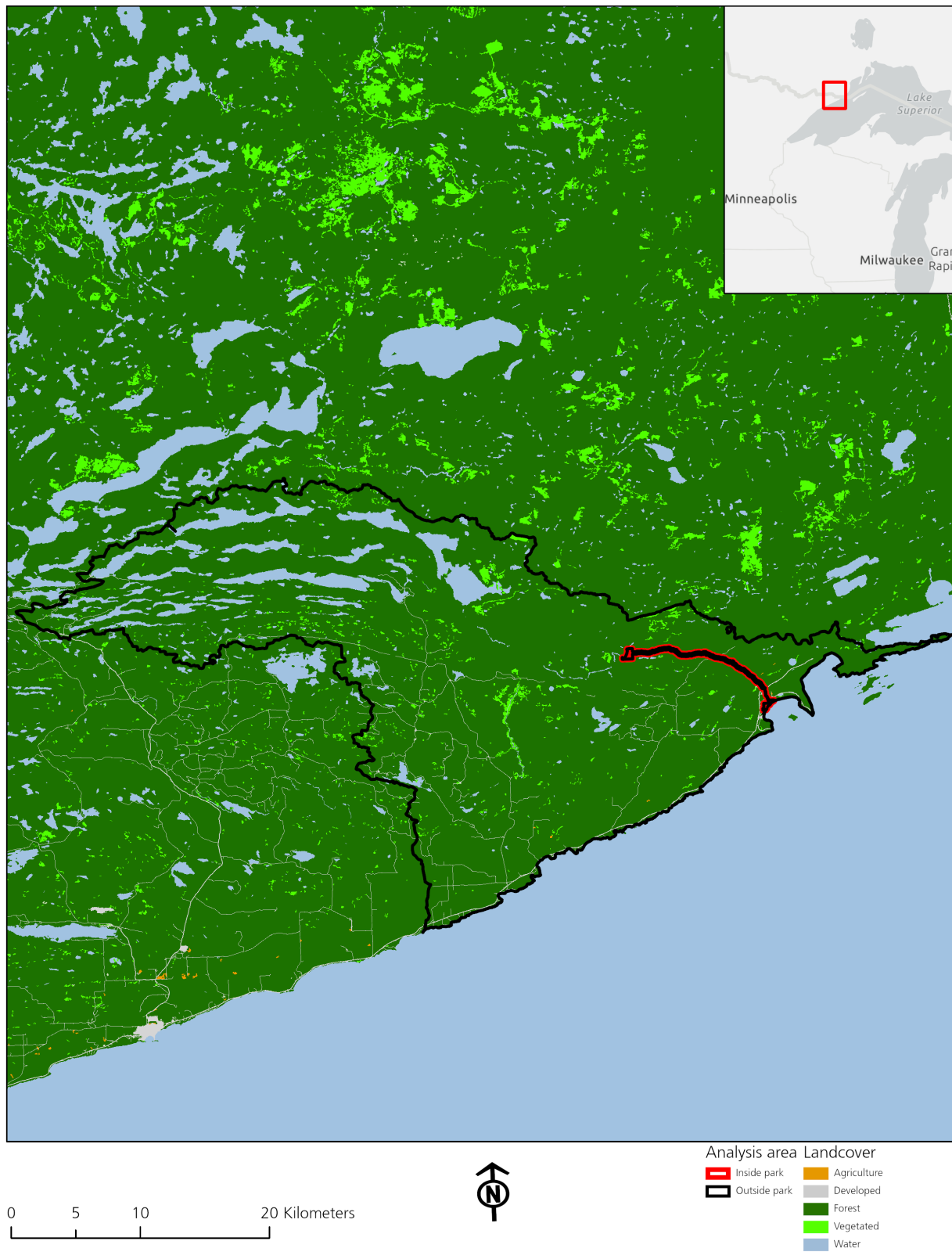


**Figure 3.** Aggregated vegetation classes in the analysis area as mapped by the National Land Cover Database (U.S.) and Earth Observation for Sustainable Development of Forests (Ontario).

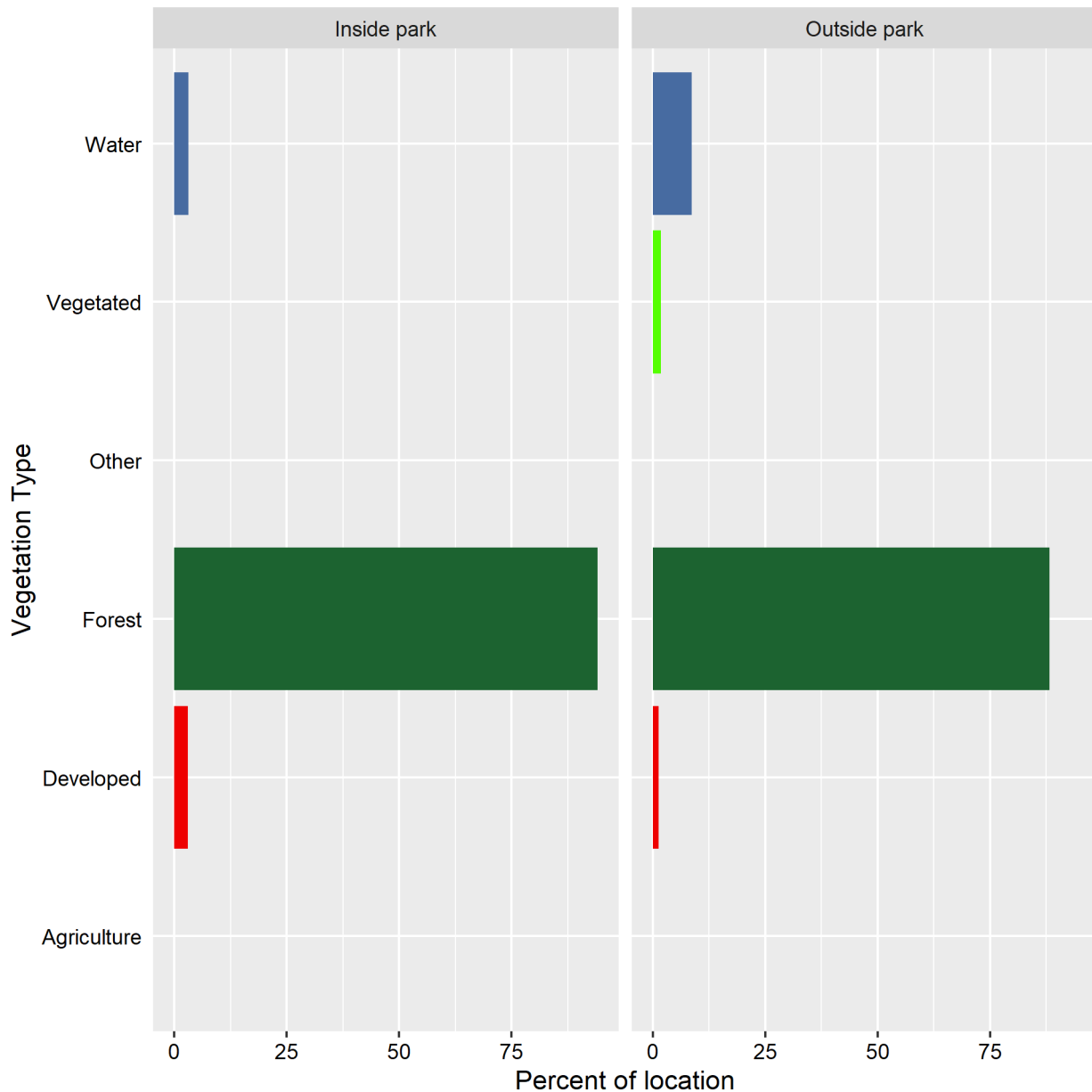


**Figure 4.** Percent of each aggregated vegetation classes in the analysis area as mapped by the National Land Cover Database (U.S.) and Earth Observation for Sustainable Development of Forests (Ontario).

### **Ownership**

Two sources of land ownership exist in the analysis area. In the U.S. portion, we used the State of Minnesota ownership data ([https://www.mngeo.state.mn.us/chouse/land\\_own\\_general.html](https://www.mngeo.state.mn.us/chouse/land_own_general.html)), and in Ontario, we used ownership data obtained from Ontario Land Information Office (LIO; [www.ontario.ca/page/land-information-ontario](http://www.ontario.ca/page/land-information-ontario)). Within the analysis area, the largest proportion of lands were federal (35%) followed by state-owned lands (22%) (Figure 5, Table 1). Crown land is typically federally owned, although most of the land is commonly leased to private industrial companies for timber management and wood extraction.

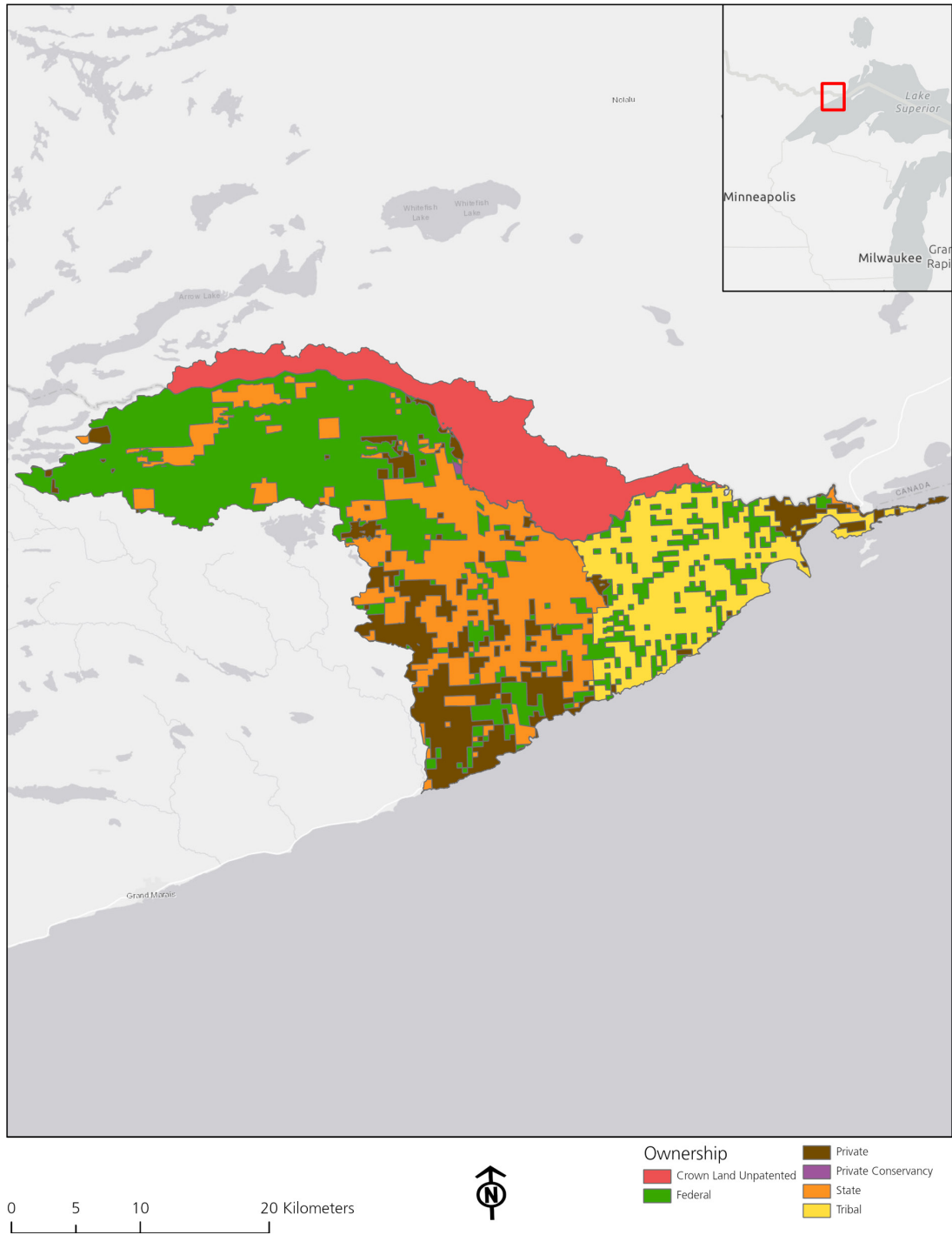


**Figure 5.** Land ownership within the analysis area. Ownership data for U.S. from the State of Minnesota and in Canada from the Ontario Land Information Office.

**Table 1.** Land ownership within the analysis area (in hectares) and proportion of each type in the analysis area. Data from State of Minnesota and Ontario Land Information Office ownership datasets.

| Ownership           | Area (ha) | Proportion of Study |
|---------------------|-----------|---------------------|
|                     |           | Area (%)            |
| Crown               | 14,297    | 16                  |
| Federal             | 31,597    | 35                  |
| State               | 20,095    | 22                  |
| Tribal              | 13,092    | 14                  |
| Private Conservancy | 42        | <1                  |
| Private             | 12,105    | 13                  |

## Disturbance Detection Methodology

We used a set of processing and analysis steps collectively known as LandTrendr (Kennedy et al. 2010a, 2010b, 2012). Using statistical fitting algorithms, LandTrendr works on a per pixel (30-m resolution) basis to describe a time series of spectral reflectance values, capturing the shape of the time series curve, while smoothing undesired random noise, such as phenological condition or sun angle at the time of image acquisition. LandTrendr identifies periods of spectral stability (no change) and instability (change). For this analysis we only report on changes where and when they occurred.

To minimize effects of phenological variation we selected Landsat images between July and September of each year (1984–2018). Atmospheric correction, cloud and cloud shadow masking, and segmentation (disturbance detection) was performed using LandTrendr algorithms implemented through Google Earth Engine (Kennedy et al. 2018). Although Landsat has multiple reflectance bands, LandTrendr can only be run on one band or index for disturbance detection. We chose to use an ensemble composite index (ENC), which incorporates the average of the six highest ranked disturbance indices in Cohen et al. (2018). This index balances the omission and commission error rates and allows the detection of short abrupt changes as well as more subtle disturbances.

## Patch Definition

To delineate patches, adjacent pixels experiencing disturbances in the same year were assumed to have experienced the same event and were grouped together using an 8-neighbor adjacency rule. Patches with 10 or fewer pixels (ca. 1 ha, 2.5 ac) were removed from the dataset to avoid small, often unverifiable disturbance events. This size was small enough to capture most forest harvests in addition to other disturbance agents such as beavers, some development activities, and blowdowns.

## Interpreter-based Validation and Attribution of Change Agents

We validated every (census) disturbance polygon that was generated by LandTrendr to remove commission errors (false positives) and at the same time determine the change agent. If a polygon spanned boundaries (watershed, ownership), we attributed the polygon with the majority of the polygon represented. Validation of possible disturbances followed details given in Kirschbaum and Gafvert (2010) and are briefly summarized here.

After disturbance polygons were created by LandTrendr, the next step was to validate whether a change occurred in the polygon and to document the agent of change (Table 2). Although we can confidently distinguish up to ten change agents during the validation process, for this report we have grouped these ten into six for ease of reporting (Table 3). If we are confident a disturbance did occur, but are unable to attribute a change agent, we use a disturbance agent of “unknown.” To determine whether changes had occurred we used high resolution ( $\leq 1$  m) imagery (air photo and satellite). Much of the imagery used for the U.S. portion was from the National Agriculture Imagery Program (NAIP), with a pixel resolution of 1 m. When validating disturbances in Canada where NAIP imagery was not available, we relied on satellite imagery from various satellites such as WorldView-1, WorldView-2, Quickbird, and GeoEye-1, with pixel resolutions ranging from 0.3 m to 1 m. Contextual information such as forest type, ownership, and drainage patterns were important for determining the disturbance agent and land cover classes. Finally, we also viewed the entire Landsat image stack for each prospective disturbance and a graph of the reflectance values through time (1985–2018) of said disturbance.

In a GIS environment, using high-resolution imagery, ancillary datasets, and the Landsat imagery itself, we validated a total of 6,362 LandTrendr-delineated disturbance polygons, removing all false positive (commission) polygons from the summary analysis. Since the analysis area contains a significant amount of water, disturbance area was computed as percentage of land area, excluding bodies of water as classified by the 2006 National Land Cover Database (Fry et al. 2011) and Earth Observation for Sustainable Development of Forests (EOSD) (Wulder et al. 2003).

Our validation workflow corroborates what has been shown in past studies (Cohen et al. 2010, Antonova et al. 2011) that on-screen validation of polygons with the aid of high spatial resolution imagery, in addition to high temporal resolution (yearly) Landsat imagery and Landsat reflectance values, is as good as any ancillary or ground-based validation method. The most obvious disturbances, such as forest clearcuts (forest harvest) and development, are the two main disturbances that can be field validated. However, they are also the disturbances most easily validated with high resolution imagery and/or Landsat imagery. More subtle or older disturbances are largely not possible to validate in the field due to logistical constraints (too remote to access) or because the evidence (e.g., insect/disease, low level forest harvests) has been masked by time (Cohen et al. 2010, Antonova et al. 2011).

**Table 2.** Disturbance agents identified during manual validation in a GIS environment and how interpreters identify each.

| <b>Disturbance Agent</b>     | <b>Description and Means of Identification</b>                                                                                                                                                              |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Agriculture                  | Conversion of a non-agricultural land use/land cover type (e.g., forest, wetland) to an agricultural land use (row crops, pasture, hay).                                                                    |
| Beaver                       | Landscape changes caused by beaver dams. Identified by flooding (i.e., presence of water) of wooded wetlands and the subsequent killing of trees.                                                           |
| Blowdown                     | The uprooting and tipping over of trees by wind. Blown down trees are evident in high resolution airphotos and are usually oriented in the direction of the wind event.                                     |
| Development                  | Permanent conversion of vegetated surface to non-vegetated surface such as mines, paved roads, parking lots, buildings, and houses.                                                                         |
| Fire                         | Detection is limited to instances where there is mortality in the overstory. Thus, areas in which fires only burn the understory are not delineated.                                                        |
| Forest harvest (light)       | Most easily identified by the proximal presence of pervious roads and very linear features outlining the extent of the disturbance. This category of forest harvest has 60%–90% of the overstory remaining. |
| Forest harvest (moderate)    | Same contextual information as forest harvest (light), but this harvest category has 30%–59% of the overstory remaining.                                                                                    |
| Forest harvest (heavy)       | Same contextual information as forest harvest (light), but this harvest category has 0%–29% of the overstory remaining.                                                                                     |
| Insect/disease (defoliation) | Disturbances in the overstory due to insects or diseases that result in tree defoliation.                                                                                                                   |
| Insect/disease (mortality)   | Disturbances in the overstory due to insects or diseases that result in tree mortality.                                                                                                                     |
| Unknown                      | This category is used when the interpreter is unable to determine the causal agent.                                                                                                                         |

**Table 3.** Simplified disturbance agent groupings used in this report with the agents present in each group.

| <b>Disturbance Agent Grouping</b> | <b>Disturbance Agents Present in Group</b>           |
|-----------------------------------|------------------------------------------------------|
| Development                       | Agriculture, development                             |
| Beaver                            | Beaver                                               |
| Blowdown                          | Blowdown                                             |
| Fire                              | Fire                                                 |
| Forest harvest                    | Forest harvest categories light, moderate, and heavy |
| Forest pathogen                   | Insect/disease defoliation and mortality             |
| Unknown                           | Unknown                                              |

# Results

## Disturbance Agent Summaries

### *Maps of disturbances*

Maps below show the location of disturbances in the analysis area by disturbance agent (Figure 6) and by year (Figure 7). Because the patches of some disturbance agents are small, the polygons for beaver, fire, and development are exaggerated. The defoliation event in 1999 and 2000 was caused by forest tent caterpillar and was well documented by the Forest Health Monitoring Division of the Ontario Ministry of Natural Resources (Figure 6). This outbreak was a defoliation event and to our knowledge did not cause any tree mortality. In 1999, the analysis area experienced a very large blowdown event, mainly in the Boundary Waters Canoe Area of the Superior National Forest (Figures 6 and 7). Forest harvest was the most widespread and ubiquitous change agent, found nearly everywhere outside the park (Figure 7). Inside the park, there was only one type of disturbance and it was due to the defoliation event (Figure 6).

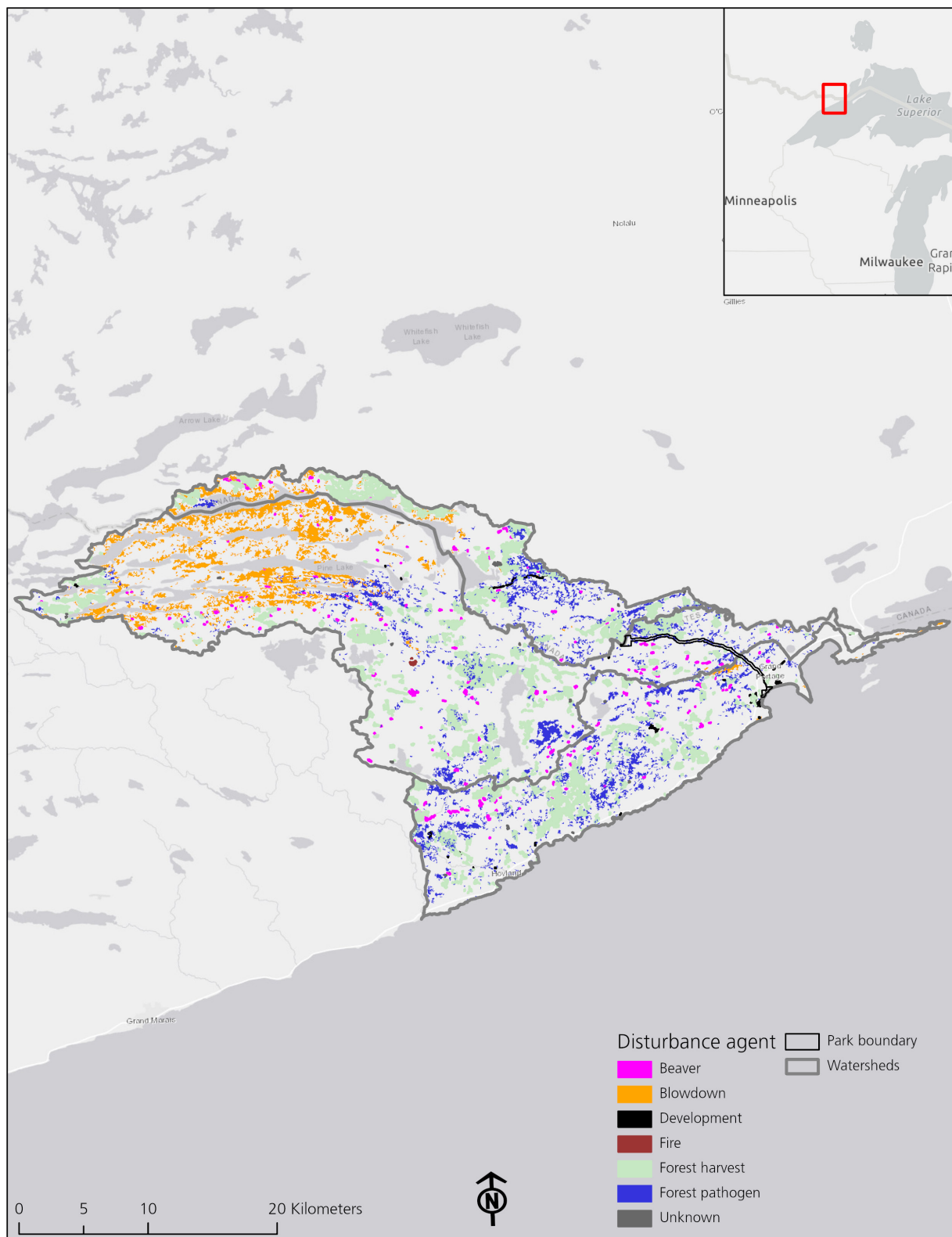


**Figure 6.** Spatial extent of disturbances (1995–2018), by disturbance agent, with watershed boundaries overlaid.

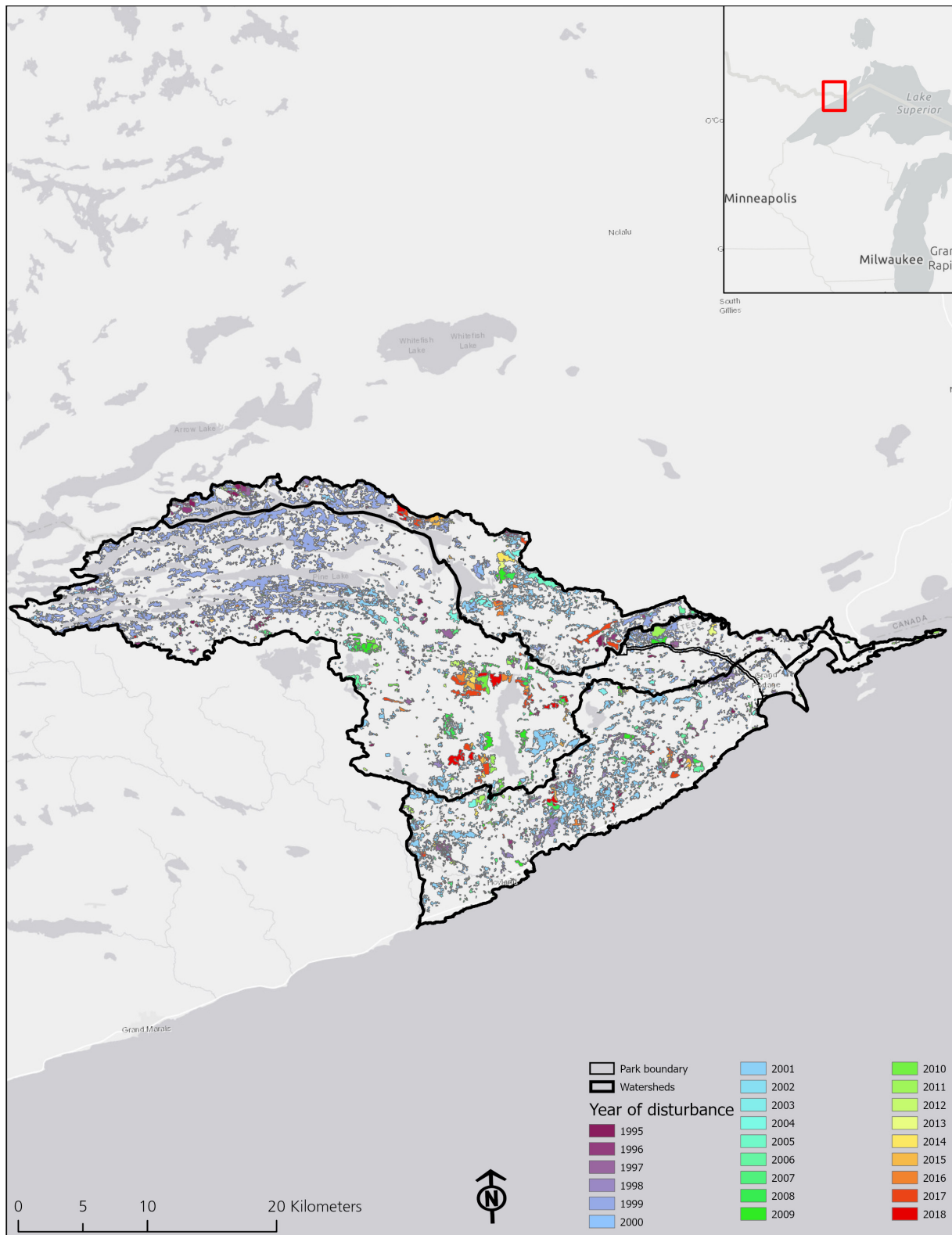


**Figure 7.** Disturbance patch locations, identified by year of onset, with watershed boundaries overlaid.

### ***Inside vs. outside the park***

Inside the park boundary, defoliation, totaling 60 ha, was the only disturbance detected over the time period (Table 4 and Figure 8). As mentioned earlier, no additional tree mortality resulting from the defoliation event was detected. Although 60 ha seems like a small amount of land, it is just over 21% of the park land area (Table 4).

Outside the park, disturbance due to forest pathogen (defoliation) in 2001 affected the largest amount of land, with a total of just over 7% of land affected (Table 4 and Figure 8). The second largest disturbance agent outside the park was forest harvest. Land disturbed as a result of forest harvest totaled just over 6,000 ha, or 7% of land outside the park (Table 4). Except for one year (1999), forest harvest disturbance rates held quite steady (Figure 9). The next most prevalent agent of change was a large blowdown event in the Boundary Waters Canoe Area (Superior National Forest) and Quetico Provincial Park that occurred in the summer of 1999. This event disturbed a total of nearly 5,000 ha during the analysis time period (Table 4 and Figure 8). Lastly, disturbance due to beaver activity was present each year of the analysis period, although the overall percent of land disturbed was low (0.42%, 352 ha, total land disturbed) (Table 4 and Figure 8).

**Table 4.** Total area (hectares) and proportion (%) of land affected by each disturbance agent during the analysis period 1995–2018, inside and outside the boundaries of Grand Portage National Monument.

| <b>Disturbance Agent</b> | <b>Inside Park</b> |                       | <b>Outside Park</b> |                       |
|--------------------------|--------------------|-----------------------|---------------------|-----------------------|
|                          | <b>Area (ha)</b>   | <b>Proportion (%)</b> | <b>Area (ha)</b>    | <b>Proportion (%)</b> |
| Beaver                   | 0                  | 0                     | 352.44              | 0.42                  |
| Blowdown                 | 0                  | 0                     | 5244.63             | 6.31                  |
| Development              | 0                  | 0                     | 57.37               | 0.07                  |
| Fire                     | 0                  | 0                     | 11.25               | 0.01                  |
| Forest harvest           | 0                  | 0                     | 6152.08             | 7.4                   |
| Forest pathogen          | 60.58              | 21.87                 | 6331.64             | 7.62                  |
| Unknown                  | 0                  | 0                     | 39.09               | 0.05                  |

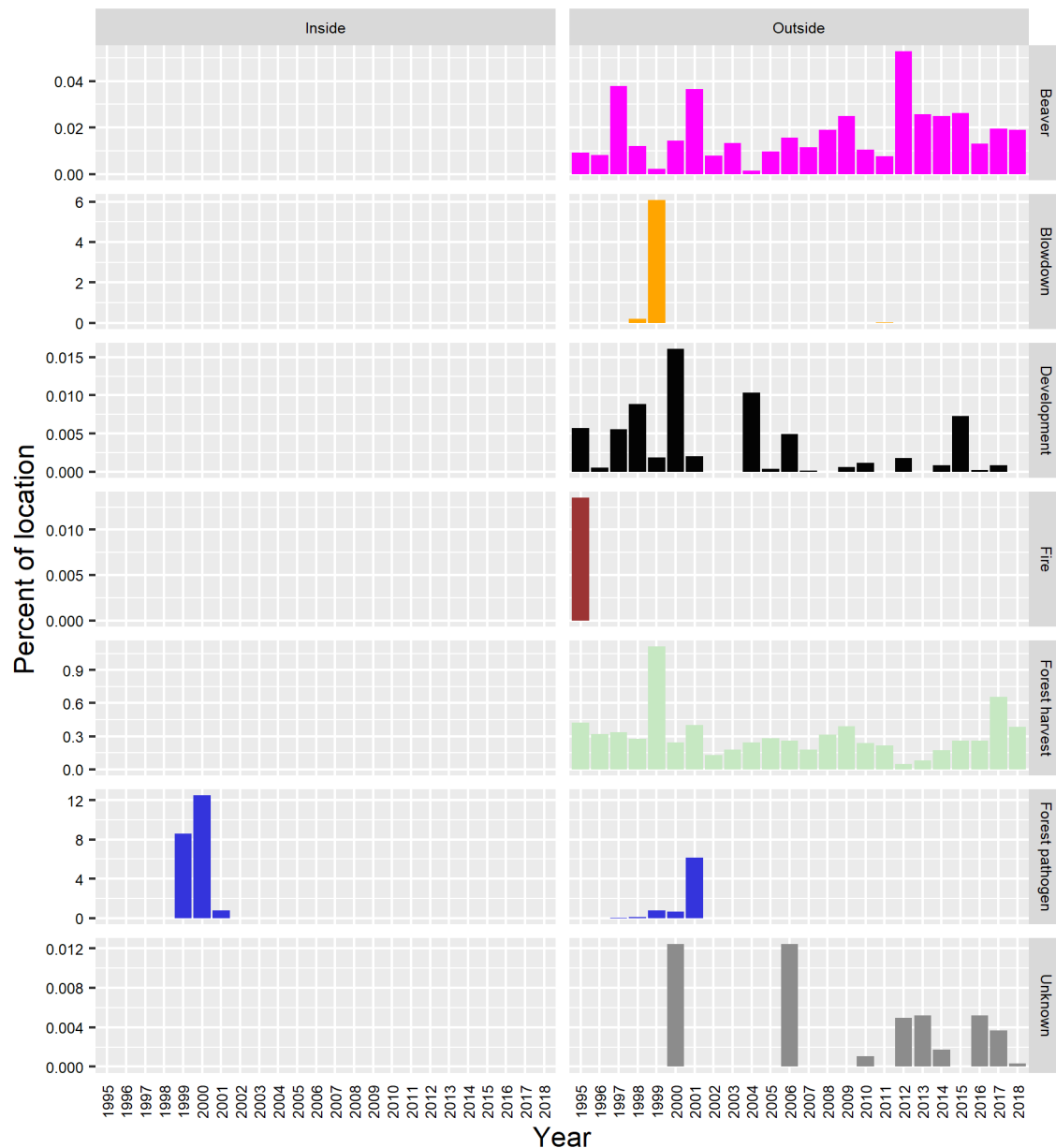


**Figure 8.** Percent of land disturbed inside and outside Grand Portage National Monument, by disturbance agent and year. Note: Y axis scale varies by disturbance agent.

### ***Watershed***

The analysis area encompassed three watersheds, one in Ontario and two in Minnesota (see Figure 2). Of these, the Ontario watershed (2AA-04) had the highest disturbance rates, at 31% of the land disturbed during the analysis period (Figure 9 and Table 5). Forest harvest was the major disturbance agent present in the watershed, with nearly 15% of the land affected (Table 5). Disturbances due to forest pathogen and blowdown were the other two major agents of change in the Ontario watershed.

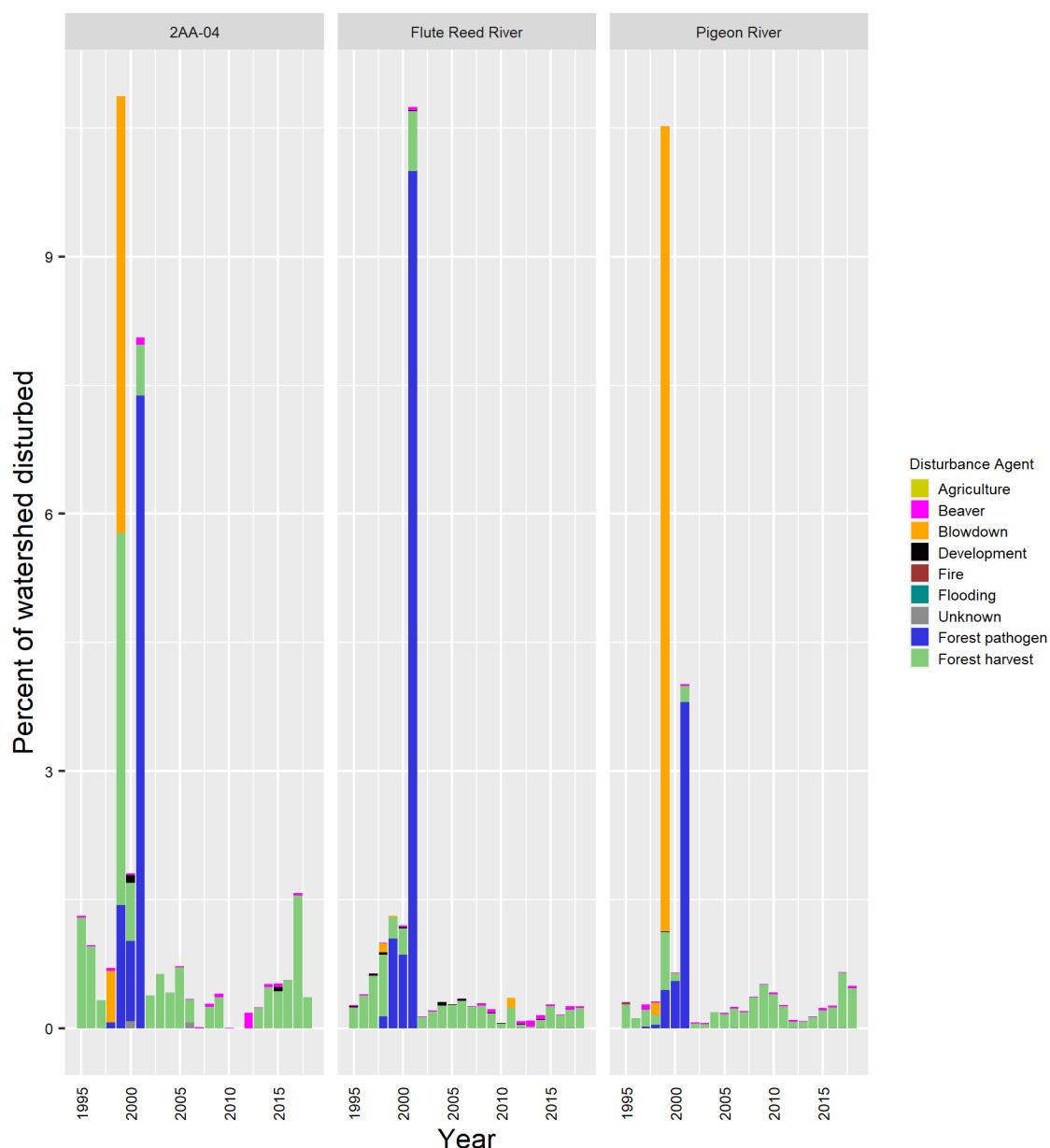


**Figure 9.** Percent of land disturbed within each watershed, by disturbance agent and year.

The watershed with the second highest disturbance rate was the Pigeon River watershed, which spans the analysis area from east to west. Blowdown was the largest agent of change in this watershed, with over 4,000 ha (9.54%) disturbed during the analysis period (Figure 9 and Table 5). The remaining change agents of note within the Pigeon River watershed were forest harvest and forest pathogen, with disturbance rates of 5.8% and 4.8%, respectively (Table 5). The Flute Reed River watershed, located along the Lake Superior shoreline of the analysis area, had the lowest rates of disturbance. A

total of 19% of the land was disturbed, with forest pathogen accounting for 12% (Table 5). The next largest disturbance agent was forest harvest, with just over 6% affected (Table 5).

**Table 5.** Area (ha) and proportion (%) of watershed disturbed, by disturbance agent during the analysis period (1995–2018).

| Disturbance Agent | 2AA-04    |                | Flute Reed River |                | Pigeon River |                |
|-------------------|-----------|----------------|------------------|----------------|--------------|----------------|
|                   | Area (ha) | Proportion (%) | Area (ha)        | Proportion (%) | Area (ha)    | Proportion (%) |
| Beaver            | 70.99     | 0.56           | 112.29           | 0.47           | 169.16       | 0.36           |
| Blowdown          | 719.28    | 5.70           | 52.97            | 0.22           | 4472.38      | 9.54           |
| Development       | 17.52     | 0.14           | 36.88            | 0.15           | 2.97         | 0.01           |
| Fire              | 0.00      | 0.00           | 0.00             | 0.00           | 11.25        | 0.02           |
| Forest harvest    | 1870.18   | 14.82          | 1528.04          | 6.39           | 2753.86      | 5.87           |
| Forest pathogen   | 1238.64   | 9.82           | 2876.77          | 12.04          | 2276.81      | 4.85           |
| Unknown           | 20.05     | 0.16           | 5.51             | 0.02           | 13.54        | 0.03           |

### **Ownership**

The ownership category experiencing the greatest percent of land disturbed was Crown Land Unpatented, with 21% of this land ownership being disturbed during the analysis period (Table 6 and Figure 10). The next two ownership types experiencing the most changes were State and Federal at approximately 16% each (Table 6). Among the ownerships, disturbances due to beaver activity were the most consistent, present in most years and in all but the “Private Conservancy” ownership type (Figure 10). Forest harvest was also common across ownership types and most prevalent on Crown lands (Figure 11).

**Table 6.** Total proportion of land disturbed by ownership type during the analysis period 1995–2018.

| Ownership             | Percent Land Disturbed    |                           |
|-----------------------|---------------------------|---------------------------|
|                       | Excluding forest pathogen | Including forest pathogen |
| Crown Land Unpatented | 21.45                     | 31.47                     |
| Federal               | 16.26                     | 23.70                     |
| Private               | 6.73                      | 13.50                     |
| Private Conservancy   | 0                         | 4.30                      |
| State                 | 16.36                     | 21.21                     |
| Tribal                | 6.09                      | 17.02                     |

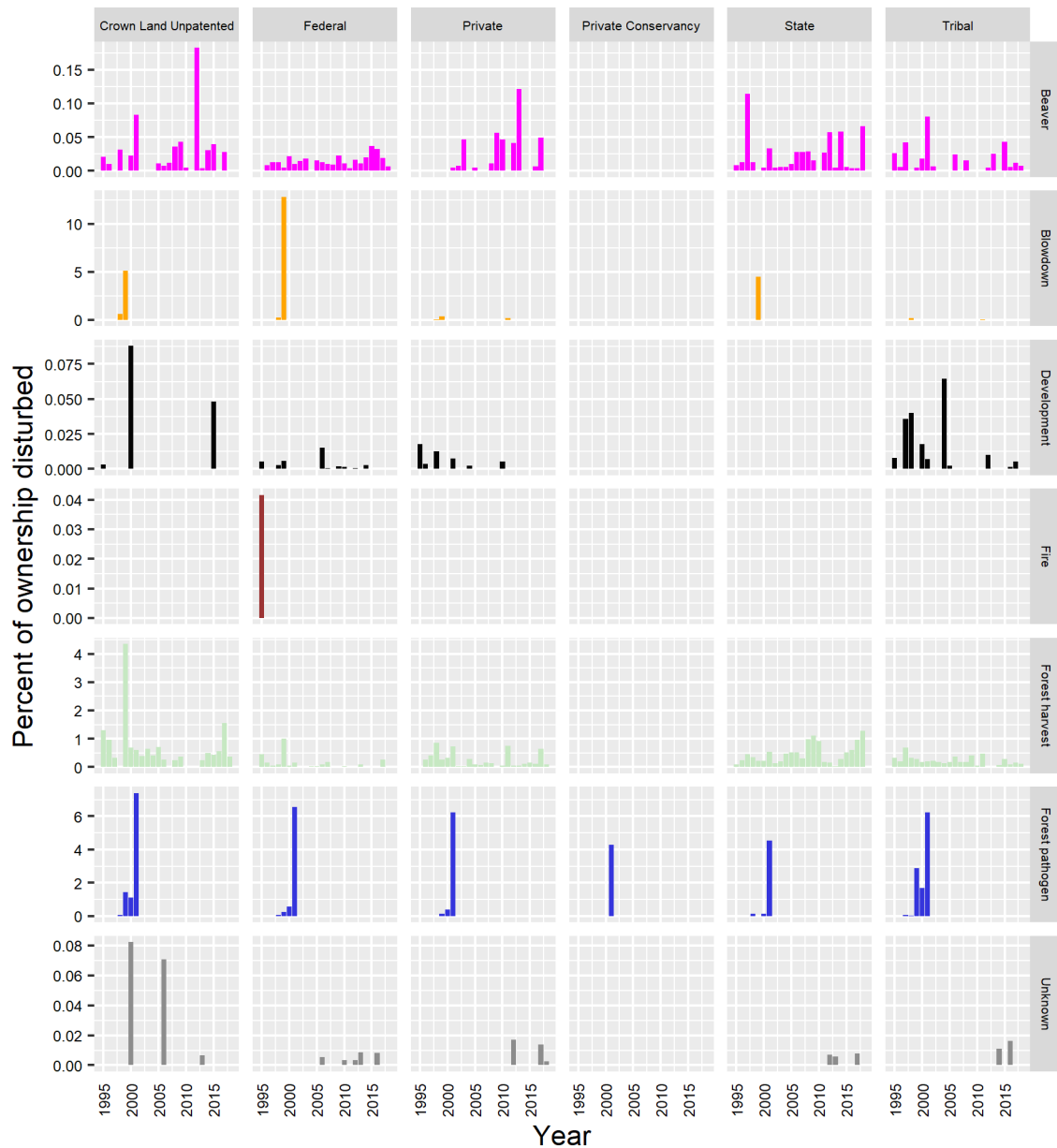


**Figure 10.** Percent of land disturbed within each ownership category, by disturbance agent and year, 1995–2018. Note: Y axis scale varies by disturbance agent.

### **Patch size**

Not surprisingly, overall patch size is much larger outside the park (Figure 11). Outside the park, forest harvest disturbances were characterized by larger patches, with some over 100 ha in size (Figure 11). There were also larger disturbances due to blowdown and forest pathogen (defoliation). The majority of disturbances due to beaver and development were much smaller, mostly around 1 ha or less (Figure 11). Inside the park, the only disturbance detected was forest pathogen and those patches were all less than 10 ha in size (Figure 11).

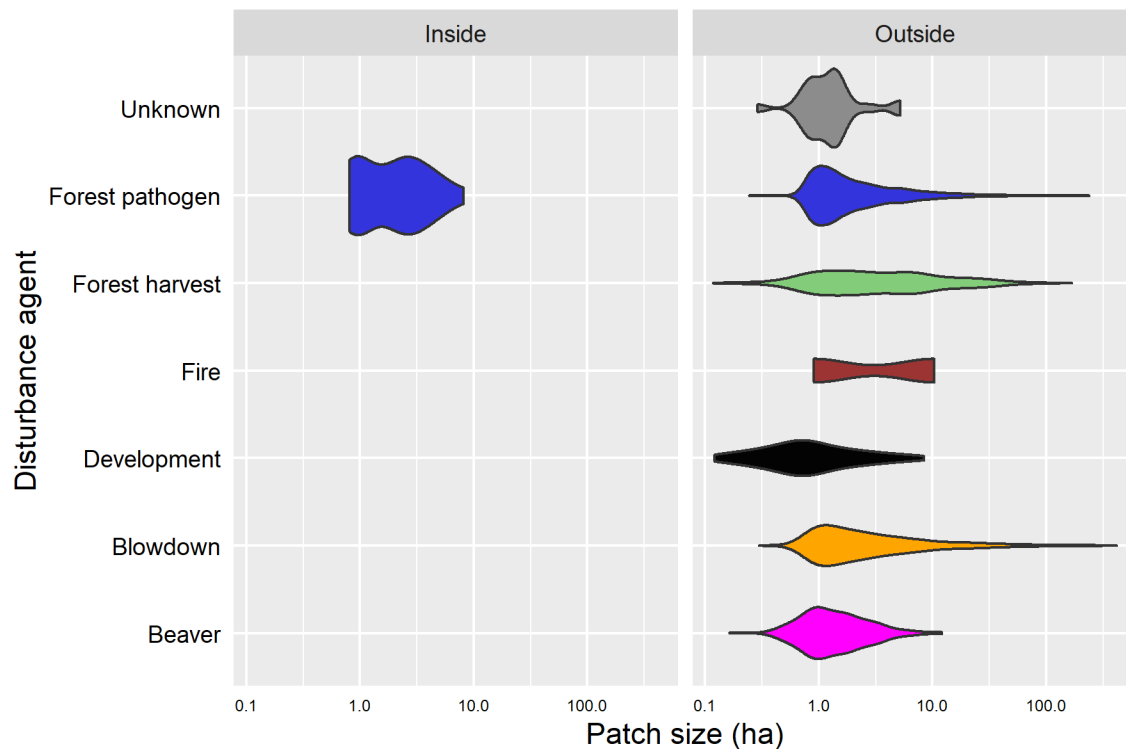


**Figure 11.** Violin plot displaying the patch size distribution of disturbances by disturbance agent inside and outside the park. The height of the violin indicates larger numbers of patches at a given size and the ends of the violin indicate the minimum and maximum patch size. Note: X axis is on log10 scale.

### ***Comparison among GLKN parks***

Compared to other parks monitored as part of this protocol, GRPO has low rates of disturbance inside the park (Figure 12). However, outside the park, GRPO has the highest rates of disturbance due to beaver and blowdown than any of the GLKN parks (Figure 12). It also has the lowest rates of development across GLKN parks. Overall, the disturbance regime for GRPO and its surroundings are similar to Voyageurs National Park (VOYA) and Isle Royale National Park (ISRO).

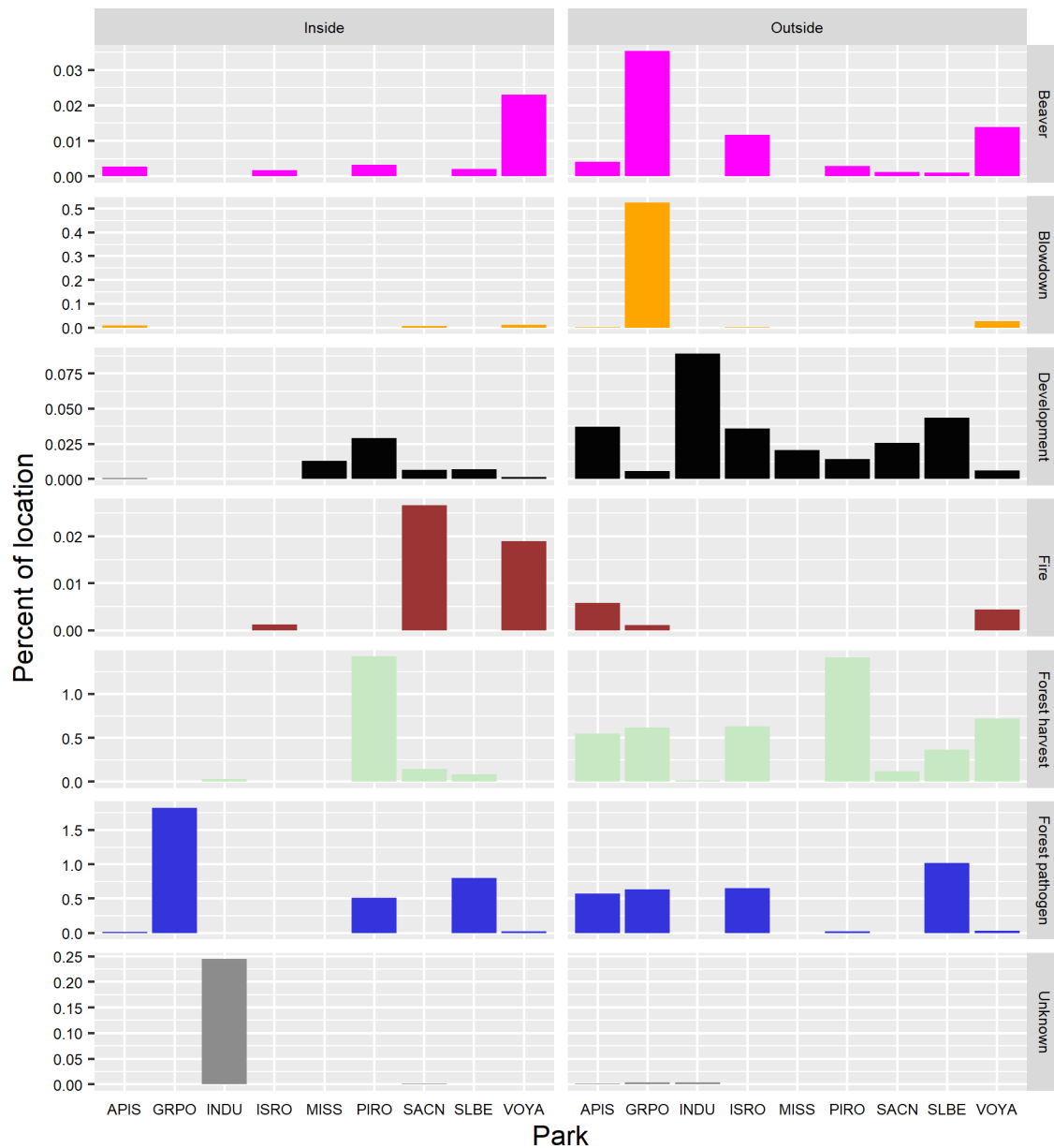


**Figure 12.** Yearly average percent of land disturbed inside and outside parks, by disturbance agent. Note: Y axis scale varies by disturbance agent. APIS=Apostle Islands National Lakeshore, GRPO=Grand Portage National Monument, INDU=Indiana Dunes National Park, ISRO=Isle Royale National Park, MISS=Mississippi National River and Recreation Area, PIRO=Pictured Rocks National Lakeshore, SACN=St. Croix National Scenic Riverway, SLBE=Sleeping Bear Dunes National Lakeshore, and VOYA=Voyageurs National Park.

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## Appendix A. Annual Disturbance Summary, 1995–2018.

Area disturbed by disturbance agent during each year of the analysis period (Tables A1a–A1c).

**Table A1a.** Area (in ha) disturbed inside and outside Grand Portage National Monument, 1995–2002.

| Disturbance Agent | Area Disturbed (ha) Inside/Outside Park Boundary |       |       |       |         |       |         |       |
|-------------------|--------------------------------------------------|-------|-------|-------|---------|-------|---------|-------|
|                   | 1995                                             | 1996  | 1997  | 1998  | 1999    | 2000  | 2001    | 2002  |
| Beaver            | 0/8                                              | 0/7   | 0/32  | 0/10  | 0/2     | 0/12  | 0/30    | 0/7   |
| Blowdown          | 0/0                                              | 0/0   | 0/0   | 0/168 | 0/5,051 | 0/0   | 0/0     | 0/0   |
| Development       | 0/5                                              | 0/0   | 0/5   | 0/7   | 0/2     | 0/13  | 0/2     | 0/0   |
| Fire              | 0/11                                             | 0/0   | 0/0   | 0/0   | 0/0     | 0/0   | 0/0     | 0/0   |
| Forest Harvest    | 0/349                                            | 0/266 | 0/277 | 0/227 | 0/927   | 0/202 | 0/332   | 0/105 |
| Forest Pathogen   | 0/0                                              | 0/0   | 0/11  | 0/59  | 0/615   | 0/546 | 0/5,101 | 0/0   |
| Unknown           | 0/0                                              | 0/0   | 0/0   | 0/0   | 0/0     | 0/10  | 0/0     | 0/0   |

**Table A1b.** Area (in ha) disturbed inside and outside Grand Portage National Monument, 2003–2010.

| Disturbance Agent | Area Disturbed (ha) Inside/Outside Park Boundary |       |       |       |       |       |       |       |
|-------------------|--------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
|                   | 2003                                             | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  |
| Beaver            | 0/11                                             | 0/1   | 0/8   | 0/13  | 0/10  | 0/16  | 0/21  | 0/9   |
| Blowdown          | 0/0                                              | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   |
| Development       | 0/0                                              | 0/9   | 0/0   | 0/4   | 0/0   | 0/0   | 0/0   | 0/1   |
| Fire              | 0/0                                              | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   |
| Forest Harvest    | 0/149                                            | 0/204 | 0/233 | 0/216 | 0/149 | 0/263 | 0/325 | 0/200 |
| Forest Pathogen   | 0/0                                              | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   | 0/0   |
| Unknown           | 0/0                                              | 0/0   | 0/0   | 0/10  | 0/0   | 0/0   | 0/0   | 0/1   |

**Table A1c.** Area (in ha) disturbed inside and outside Grand Portage National Monument, 2001–2018.

| <b>Disturbance Agent</b> | <b>Area Disturbed (ha) Inside/Outside Park Boundary</b> |             |             |             |             |             |             |             |
|--------------------------|---------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                          | <b>2011</b>                                             | <b>2012</b> | <b>2013</b> | <b>2014</b> | <b>2015</b> | <b>2016</b> | <b>2017</b> | <b>2018</b> |
| Beaver                   | 0/6                                                     | 0/44        | 0/21        | 0/21        | 0/22        | 0/11        | 0/16        | 0/16        |
| Blowdown                 | 0/26                                                    | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         |
| Development              | 0/0                                                     | 0/1         | 0/0         | 0/1         | 0/6         | 0/0         | 0/1         | 0/0         |
| Fire                     | 0/0                                                     | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         |
| Forest Harvest           | 0/180                                                   | 0/41        | 0/67        | 0/143       | 0/214       | 0/216       | 0/547       | 0/322       |
| Forest Pathogen          | 0/0                                                     | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         | 0/0         |
| Unknown                  | 0/0                                                     | 0/4         | 0/4         | 0/1         | 0/0         | 0/4         | 0/3         | 0/0         |

## Appendix B. Fields Available in the Full Landscape Disturbance Dataset.

During validation, we fill out numerous fields that are not necessarily reflected in the data summary report series. Table B1 identifies additional fields filled in during the validation process and a brief description of each. The more-detailed dataset is available upon request.

**Table B1.** Fields, and their descriptions, used to describe a disturbance during the validation process, but which are not reported on in this summary.

| Field                                           | Description                                                                                                                                                                                                                                                                        |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Year                                            | Year of disturbance onset                                                                                                                                                                                                                                                          |
| Percent of polygon affected                     | Percent of polygon affected by any disturbance                                                                                                                                                                                                                                     |
| Disturbance agent 1                             | A polygon could be comprised of multiple disturbance agents. We use this field to identify the first (and maybe only) disturbance agent.                                                                                                                                           |
| Percent of polygon in disturbance agent 1       | Percent of disturbed (affected) area due to disturbance agent one.                                                                                                                                                                                                                 |
| Percent cover remaining for disturbance agent 1 | If the disturbance agent is forest harvest, this field is filled in. We estimate the percent cover (in 10% increments) of overstory remaining after the disturbance for disturbance agent one.                                                                                     |
| Disturbance agent 2                             | If multiple disturbance agents are present in the polygon, we identify the second disturbance agent.                                                                                                                                                                               |
| Percent of polygon in disturbance agent 2       | Percent of disturbed (affected) area due to disturbance agent two.                                                                                                                                                                                                                 |
| Percent cover remaining for disturbance agent 2 | If the disturbance agent is forest harvest, this field is filled in. We estimate the percent cover (in 10% increments) of overstory remaining after the disturbance for disturbance agent two.                                                                                     |
| Disturbance agent 3                             | If multiple disturbance agents are present in the polygon, we identify the third disturbance agent.                                                                                                                                                                                |
| Percent of polygon in disturbance agent 3       | Percent of disturbed (affected) area due to disturbance agent three.                                                                                                                                                                                                               |
| Percent cover remaining for disturbance agent 3 | If the disturbance agent is forest harvest, this field is filled in. We estimate the percent cover (in 10% increments) of overstory remaining after the disturbance for disturbance agent three.                                                                                   |
| Start class 1                                   | The starting land cover/land use class of the disturbed area. We allow up to three unique starting classes for each disturbed polygon. Class options are forest closed, forest semi-closed, forest open, shrub, herbaceous, pervious, impervious/vegetated, impervious, and water. |
| Start class 1 percent                           | Percent of the disturbed (affected) area in starting class one.                                                                                                                                                                                                                    |
| Start class 2                                   | If multiple classes were disturbed, we identify the second class.                                                                                                                                                                                                                  |
| Start class 2 percent                           | Percent of the disturbed (affected) area in starting class two (if needed).                                                                                                                                                                                                        |

| <b>Field</b>          | <b>Description</b>                                                                                                                                                                                                             |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Start class 3         | Same as start class 2                                                                                                                                                                                                          |
| Start class 3 percent | Same as start class 2 percent                                                                                                                                                                                                  |
| End class 1           | The ending land cover/land use class of the disturbed area. This should reflect the immediate result of the disturbance and not the future condition of the area. Class options are the same as in the starting class options. |
| End class 1 percent   | Percent of the disturbed (affected) area in ending class one.                                                                                                                                                                  |
| End class 2           | Same as end class 1                                                                                                                                                                                                            |
| End class 2 percent   | Same as end class 1 percent                                                                                                                                                                                                    |
| End class 3           | Same as end class 1                                                                                                                                                                                                            |
| End class 3 percent   | Same as end class 1 percent                                                                                                                                                                                                    |
| Owner type            | During validation we add ownership data from the best available source. Owner type is a higher-level ownership classification such as federal, county, state, and private.                                                     |
| Owner name            | Owner name is a more detailed level of ownership such as National Park Service, Bayfield County, or Wisconsin Department of Natural Resources.                                                                                 |
| Watershed identifier  | During validation we add the unique 12-digit watershed identifier, referred to as the Hydrologic Unit Code 12 (HUC12) from the USGS database.                                                                                  |

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1201 Oakridge Drive, Suite 150  
Fort Collins, CO 80525