Methods draft:

Our project aimed to understand and quantify the relationship between sequential disturbances in the boreal forest and the forest’s ability to store carbon. Our first step in attaining this goal was estimating carbon stored in Newfoundland’s National Parks’ boreal forests. We used the relationships between carbon measured in the field and aerial surveyed and remote sensed environmental data at sampled sites to estimate carbon in areas we didn’t sample. Our next step examined the relationship between sequential disturbances and carbon storage through a spatially explicit mathematical model of forest clearing events, moose herbivory, and carbon storage in a dynamic boreal forest system. The mathematical models were parameterized using in-field, aerial surveyed and remote sensed data as well.

Site selection:

We measured carbon at 92 sites throughout Gros Morne and Terra Nova National Parks in the summers of 2022 and 2023 (Figure and/or table #). Sites in 2022 were selected to include areas of mature forest and forest affected by dominant disturbance mechanisms (i.e. insect defoliation, forest fires, wind blowdown, and recreational logging) in each park. Sites in 2023 were also chosen to include mature and disturbed forests and to ensure the sites sampled across both years represented the moose densities and environmental variables found throughout each park. We accomplished the latter by comparing histograms of moose densities and environmental variables from sites sampled in 2022 to the histograms of the variables from the entirety of each respective park (Supplementary #). Luckily, the only range of an environmental variable not covered in 2022 sampling was elevations above 200 m. Therefore, several 2023 sites in each park had elevations above 200 m. We also considered accessibility of sites by roads and trails. Based on these criteria, we selected and sampled from 40 sites in 2022 and 52 sites in 2023 (Table #).

Sampling:

Each site consisted of four subplots in which we measured the above and below ground carbon. The first subplot was always in the southwest corner of the site, with the second subplot 10 m east of the southwest corner, the third subplot 5 m east and 5 m north of the southwest corner, and the fourth subplot 10 m north of the southwest corner (Figure #). We chose the specific location of the southwest corner so that all subplots fell within the type of forest of interest (mature or disturbed), or if many locations met that requirement, we placed a random point within a bounding polygon of the area of interest using QGIS (cite). Additionally, each subplot was at least 30 m from where the mature forest becomes a disturbed area or vice versa, when possible. Subplots consisted of one 3 m x 3 m large quadrat (B) with a 0.5 m x 0.5 m small quadrat in each corner (C & D), and in 2022 one 1 m x 5 m transect (A), which doubled to two parallel 1 m x 5 m transects in 2023. We laid out the quadrats and transects according to Figure #.

In each 1 m x 5 m transect, we measured the height (meters; using a meter stick) and recorded the species of all live trees and woody shrubs taller than 30 cm. Then, for trees and woody shrubs between 30 cm and three meters tall, we measured the basal diameter (centimetres; using callipers) and orthogonal diameters (centimetres; using a measuring tape). And for trees taller than three meters, we measured the diameter at breast height (centimetres; using DBH tape).

In each 3 m x 3 m large quadrat, we measured the length (centimeters; using a measuring tape) and orthogonal diameters (centimeters; using callipers) of dead trees with a diameter of at least 10 cm. Our measurements did not include parts of a dead tree that tapered to less than 10 cm or exited the large quadrat. We also recorded whether the dead tree was softwood or hardwood, the class of deadwood (table #), and whether it was standing, fallen or a stump.

In all four 0.5 m x 0.5 m small quadrats of each subplot, we measured the height (centimeters; using a measuring tape), basal diameter (centimeters; using callipers), and orthogonal diameters (centimeters; using callipers), and recorded the species of each tree or woody shrub under 30 cm tall. We also recorded the percent cover of forbs, grasses, ferns, brambles (annual vegetation with thorns), lichens, mosses, bare dirt, bare rock, leaf litter, and needles. Total percent cover could exceed 100%. In the two furthest west small quadrats of each subplot, we took two soil samples. One sample was taken from the southwest corner of the quadrat, and one was taken from the northwest corner. We sampled the soil using a brass cylinder (15 cm long and 2 cm in diameter) malleted into the ground and pulled out to retrieve a soil core. We removed the soil from the cylinder by pushing with the end of the mallet. An abrupt change in colour and texture characterized the boundary between organic and inorganic soil. But, if we didn’t reach inorganic soil with one core, we repeated the process until we found the boundary. We recorded the depth of the organic soil layer (centimetres; using a measuring tape) from the cores and stored the organic soil layer in a plastic bag labelled with park, site number and quadrat number. We returned the inorganic soil to the hole we took the sample from. From the area within the southwest small quadrats, we gathered all dead vegetation small enough to fit in the large freezer bags. The freezer bags stored the litter, and we labelled the bags with park, site number and quadrat numbers. Soil and litter samples froze in our deep freeze until processing could begin.

Sample processing:

We needed the dry weight and percent carbon of the leaf litter and soil samples to calculate the carbon. First, we dried each soil and leaf litter sample in a 60˚ c oven until they reached a constant weight (dry weight), indicating all water had evaporated. Once the samples dried, we combined them by subplot (Appendix #) and proceeded to grind the 2022 soil and leaf litter samples and 2023 soil samples. The 2023 leaf litter was not ground. A blender\* ground the 2022 soil and leaf litter, and then, to speed up the process, a bead mill ground the 2023 soil samples. We sent the ground samples to Guelph University for \*\*what is the technique called\*\*, to determine percent carbon. Instead of grinding and sending away the 2023 leaf litter samples, we used the percent carbon results for each combination of park and disturbance type (Table #) from 2022 leaf litter as the average percent carbon in 2023. We then calculated the amount of carbon in each soil and leaf litter sample by multiplying dry weight by percent carbon (eq #?).

\*\* a few samples were burned so we made the soil content equal to the median soil content of mature forests in Gros Morne in 2023

Allometric equations:

We used allometric equations to convert in-field measurements of live vegetation and deadwood into biomass (table #), which we then converted to carbon. Rachael Moran created the list of allometric equations from published articles (cite Rachael's manuscript). The resulting biomass (grams) was halved to give carbon content (grams). We then summed carbon by subplot. However, because each transect in 2022 was 5 m2, each pair of transects in 2023 was 10 m2, and each small quadrat was 0.25 m2, we first had to sum by transect and small quadrat and convert the summed carbon values to carbon per 9 m2. The large quadrats were already 9 m2. Finally, we could find the total carbon in each subplot. \*\* likely averaged then extrapolated to 25 m2.\*\*

Environmental variables:

I collected aerial surveyed and remote sensed environmental data that may affect carbon storage or mediate the effect of disturbance on carbon storage. I searched Earthdata () for datasets with a spatial window that included the national parks in Newfoundland, a similar spatial resolution (~ 25 – 30 m), and a relevant temporal window. The latter depended on the environmental variable of concern. Why? The resulting suite of environmental datasets is outlined in table #. We reprojected all datasets to EPSG: 26921 – NAD83/UTM zone 21N, resampled to 30 m georeferenced units using nearest neighbour resampling because dominant species was categorical, and aligned to the same georeferenced extent that encompassed both parks and all sampling sites. This was done using warp() in QGIS (). We also create two subsets of each dataset, one clipped to each national park, using clip to mask ().

Extracting environmental data at each site:

Correlation:

GzLM:

Model validation:

Predict: