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# The impacts of anthropogenic disturbance on plant species richness in the freshwater lakes of Algonquin Provincial Park

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## Abstract

**This study quantified the impact of human activity on aquatic and shoreline plant species richness. We hypothesized that human activity at the shoreline would negatively impact plant species richness and that the extent of the impact would depend on the intensity of human activity. To test this, we sampled 11 lakes in Algonquin Provincial Park, of which five permitted motorboat access, and five permitted canoe access and prohibited motorboat access. The remaining lake, which had no designated access point for boats and was only accessible to researchers, acted as a control. To assess the impact of anthropogenic disturbance at each lake, we measured plant species richness in three 10 m by 2 m plots: a first plot at the access point, assumed to be the site of highest disturbance; a second at the site of intermediate disturbance, 30 m down shore from the access point; and a third at the site of lowest disturbance, 60 m down shore from the access point. We found a significant negative relationship between the level of disturbance and plant species richness, both in the motorboat-accessible and canoe access-only lakes. The control lake exhibited no correlation between disturbance level and plant species richness. However, there was no significant difference between motorboat-accessible and canoe access-only lakes in the relationship between disturbance level and plant species richness. Overall, this study highlights the consequences of anthropogenic disturbance on freshwater aquatic and shoreline plant communities, and provides a framework for future management and rehabilitation strategies.**

**Keywords:** Disturbance; Species richness; Macrophytes; Freshwater lakes; Boat access; Algonquin Provincial Park

## Introduction

Assessing and quantifying the impact of anthropogenic disturbance on the environment has increasingly become a priority, owing to population growth and to the prevalence of intensive resource-acquisition operations. These are accompanied by increases in environmental disturbances related to land use practices such as agriculture, urban expansion, and resource exploitation. The impacts of these activities are apparent in a variety of landscapes, including terrestrial and aquatic areas in both urban and rural environments (Urban et al. 2006). Studies that focus on anthropogenic disturbance and its connection to species diversity provide a basis for sustainable ecosystem management and conservation efforts (Kershaw and Mallik 2013).

The relationship between disturbance and species diversity in terrestrial environments is well-documented. To a lesser extent, this relationship has also been investigated in aquatic environments (Freckman and Virginia 1997; Hobbs and Huenneke 1992). As species diversity is often a measure of ecosystem health (Mormul et al. 2010), it is important to study the relationship between disturbance and diversity in freshwater ecosystems (Schmera et al. 2011). Especially as the global population continues to grow, the protection of global freshwater stores is becoming a pressing concern. Moreover, only 0.009% of the world's water exists in the form of freshwater lakes (Bureau of Reclamation 2016). Over 9% of Canada's total area consists of freshwater lakes (Natural Resources Canada 2016), making it an ideal location for studies of the relationship between disturbance and diversity in freshwater ecosystems.

While many studies of anthropogenic impacts on freshwater lakes focus on areas with high population densities (Baart et al. 2010; DeCatanzaro and Chow-Fraser 2010; Akasaka et al 2010), it is possible that human activity

also impacts lake communities in more pristine areas. Algonquin Provincial Park, located in Northern Ontario, contains over 1,500 freshwater lakes (The Friends of Algonquin Park 2013a). It is one of the largest parks in Canada, spanning an area of 7,653 $km^2$ (The Friends of Algonquin Park 2013b), and is a popular tourist destination for recreational activities such as boating, camping, and swimming. It is important, however, to note that there are strictly enforced boating permits and horsepower limits in each lake (The Friends of Algonquin Park 2013c). Boating, camping, and swimming either partially or completely utilize shoreline areas that are home to many different species, including macrophytes and terrestrial plants. These plants are important components of the lake ecosystem, as they provide habitats and breeding grounds for fish and invertebrates, and are an essential food source for many species (Short and Wyllie-Echeverria 1996; Mormul et al. 2010; Alahuta et al. 2013). For instance, Bryan et al. (1992), who examined developed shorelines (those with high levels of human activity) and undeveloped (those which humans do not frequent) shorelines in northwestern Iowa, found that fish populations were highest in undeveloped areas where macrophyte abundance and species richness were greatest. In addition to sustaining biological organisms, macrophytes and shoreline plants are integral components of erosion prevention and the maintenance of shoreline structure and stability (Short and Wyllie-Echeverria 1996; Eriksson et al. 2004; Mormul et al. 2010). Macrophytes and shoreline plants are also quickly and strongly impacted by changes to the local environment, making their diversity a good measure of lake health (Alahuta et al. 2001; Engelhardt and Ritchie 2001; Eriksson et al. 2004). In a review of sea grass diversity, Short and Wyllie-Echeverria (1996) found that boating activities resulted in a reduction of both aquatic and terrestrial plant cover, likely due to damage from propellers and boat hulls. Additionally, Eriksson et al. (2004) showed that in the Baltic Sea, motorboat activity has negatively affected other types of aquatic vegetation. These physical disturbances change plant community structure, negatively affecting the overall health of the aquatic ecosystem (Eriksson et al. 2004; Schmera et al. 2013). Further, certain macrophyte species do not recover quickly from these effects, which may have long-term community impacts (Short and Wyllie-Echeverria 1996; Eriksson et al. 2004).

We therefore sought to determine whether the level of human activity affects the plant species richness in relatively pristine bodies of freshwater. More specifically, we investigated how the relationship between disturbance level and macrophyte species richness differs between motorboat-accessible and canoe access-only lakes. If anthropogenic disturbance, caused by boating and canoeing, negatively affects plant structure, plant species richness will decrease (Barry et al. 2004). We predicted that the disturbance caused by these activities would negatively impact plant species richness along the shoreline. Moreover, we predicted that due to a higher intensity of physical disturbance on the shoreline, there would more shoreline damage, and therefore a stronger negative impact on plant species richness, in motorboat-accessible lakes than in canoe access-only lakes.

# Methods

In the month of August, 2013, we selected 11 lakes in Algonquin Provincial Park in which to study the effect of anthropogenic disturbance on plant species richness. Of these lakes, five were motorboat-accessible (Lake Opeongo, Canoe Lake, Whitefish Lake, Lake of Two Rivers, and Rock Lake), and five were canoe access-only (Pog Lake, Lake Sasajewun, Coon Lake, Mew Lake and Cannisbay Lake). The remaining lake (Kathlyn Lake), which permitted neither canoe nor motorboat access, served as a control. All lakes were located along the Highway 60 corridor running through the southern end of the park (**Figure 1**). The lakes chosen as motorboat-accessible were those that permitted both motorboats and canoes, while those chosen as canoe access-only lakes were those that permitted only canoes. The control lake did not have any designated access point for motorboating, canoeing, or swimming, and could only be accessed by researchers from the Wildlife Research Station.

At each of the lakes, we sampled three sites along a disturbance gradient. The first site sampled was the area we assumed to have the highest level of anthropogenic disturbance, typically an access point such as a boat launch or a swim beach. The next three sites were located away from the area of highest disturbance, at 30 m and 60 m down shore from the first site, respectively. We assumed that the 30 m site represented an area of intermediate disturbance, and that the 60 m site represented an area of low disturbance. At each of the three sample sites, we used a 60 m measuring tape to identify a 10 m by 2 m plot, using flags and flagging tape to mark the site. The longer, 10 m sides of the plot ran along the length of the shore, while the 2 m sides included 1 m along the water and 1 m along the terrestrial shoreline. In each plot, we measured plant species richness by enumerating the different species present. Pictures and samples taken of each specimen found were brought back to the laboratory to ensure the proper species identification. (At this stage, we made use of Newmaster 1997; Peterson and McKenny 1968; Bouchard and Neron 1999; and Petrides 1972). Plant species were also categorized into the following groups: emerged macrophytes; submerged macrophytes; floating-leaved macrophytes; shrubs; sedges; herbs; grasses; ferns; bryophytes; and trees.

We tested our prediction using a two-step approach. First, we used a linear regression analysis to determine individually the relationships between disturbance level and species richness in each lake. To determine whether a difference existed between motorboat-accessible and canoe access-only lakes, we compared the slopes obtained from the linear regression analysis using a two-sample t-test. In all tests, an alpha of 0.05 was used to determine significance.

# Results and discussion

### *Anthopogenic disturbance and plant species richness:*

We found a significant negative relationship between plant species richness and disturbance level in both motorboat-accessible and canoe access-only lakes (**Figure 2**). A slope not significantly different from zero was calculated for the control lake, indicating a constant level of richness along the control lake's shoreline (**Figure 3***)*. These findings support the hypothesis that anthropogenic disturbance along the shoreline negatively impacts the local plant community. Other studies have found a similar relationship between richness and disturbance (Odum 1985; Quinn et al. 2011). Miserendino et. al (2011) examined a variety of landscapes that varied in their level of human activity. They found that urbanized areas had the poorest water quality and lowest littoral, riparian, and macroinvertebrate taxa richness compared to less disturbed sites.

### *Motorboat-accessible vs. canoe access-only lakes:*

Short and Wyllie-Echeverria (1996) demonstrated that human disturbance in lake systems is most often caused by boating activities. Damage from propellers, the dragging of boat hulls, the use of anchors, and increased shade cover from docks affects shoreline habitats (Short and Wyllie-Echeverria 1996; Eriksson et al. 2004). Eriksson et al. (2004) also found that wave action produced by boats had a negative impact on shoreline plants, affecting floating macrophytes most severely. We had consequently also predicted that motorboat-accessible lakes would exhibit greater amounts of physical damage to the shoreline areas, and would therefore exhibit greater losses in plant species richness than canoe access-only lakes.

However, results from a two-sample t-test yielded no significant difference in the richness-disturbance relationship between motorboat-accessible and canoe access-only lakes ($t = -0.07$, $df = 8$, $p = 0.47$, **Figure 3**). The lack of comparatively stronger negative impacts in motorboat-accessible lakes may be influenced by the fact that the study was completed in a park that not only limits the accepted horsepower in each lake, but also strictly enforces boating permits (The Friends of Algonquin Park 2013c). Additionally, Blakely and Didham (2010) found that ecosystem size and the effect of anthropogenic disturbance are inversely correlated, meaning that larger areas will be impacted less by anthropogenic disturbance than smaller ones. Because motorboat-accessible lakes are often larger than canoe access-only lakes in Algonquin Provincial Park, lake size could be a confounding variable affecting the lack of difference between the lake types in this study (Reed-Anderson et al. 2000). Nevertheless, the fact that our results show no significant difference in the richness-disturbance relationship between motorboat-accessible and canoe access-only lakes may indicate that current lake health management is effective.

### *Species diversity:*

Our study found shrubs and herbs only at the sites of lowest disturbance in both the motorboat-accessible and canoe access-only lakes (**Figure 4**). As shoreline areas are often cleared for human use, this lack of larger land vegetation was expected. In addition, floating-leaved and emerged macrophytes were not found in any high disturbance sites in motorboat-accessible lakes, yet they were found at all three sites (the areas assumed to exhibit the highest disturbance, intermediate disturbance, and the lowest disturbance) in canoe access-only lakes. Submerged macrophytes, however, were found at every location, including the sites of highest disturbance in motorboat-accessible lakes (**Figure 4**). In support of our findings, studies (Radomski and Goeman 2001; Elias and Meyer 2003) which examined lakes in Minnesota and Wisconsin found that developed shorelines had less overall vegetative cover than underdeveloped shorelines. Specifically, these studies noted a lack of floating and emergent macrophytes (Radomski and Goeman 2001; Elias and Meyer 2003) along developed shorelines.

A decrease in water quality associated with increased disturbance may account for the decline in macrophytes observed at the sites of highest disturbance. Although this investigation did not examine water quality, a study completed by Alahuhta et al. (2013) showed that floating-leaved macrophyte species are heavily affected by changes in water quality (including changes to Secchi disc transparency, levels of chlorophyll-a, total phosphorus, total nitrogen, conductivity, and turbidity). Therefore, it is likely that floating-leaved macrophyte species are not found in high disturbance sites due to the increased sedimentation caused by motorboat activity (Alahuta et al. 2013). This same relationship between floating-leaved species and water quality has also been documented in other studies (Short and Wyllie-Echeverria 1996; McNair and Chow-Fraser 2003), and is consistent with the observations of the present study. Additionally, floating-leaved and emerged macrophytes are located closer to the surface, making them more susceptible to physical damage by boats (Sass et al. 2010). As such, they undergo the most drastic decline in richness in areas of high human impact (Sass et al. 2010). Combined with our observations, this suggests that floating-leaved and emerged macrophytes are more strongly affected by anthropogenic disturbances than other macrophyte groups. This reduction in macrophyte biomass through increased anthropohenic disturbance is concerning, as macrophytes are integral to the aquatic ecosystem, providing habitats, breeding grounds, and protection from shoreline erosion (Short and Wyllie-Echeverria 1996; Mormul et al. 2010; Alahuta et al. 2013).

### *Implications for future research:*

Eriksson et al. (2004) found that boats of all varieties, from small pleasure crafts to larger ferry boats, have a similar negative impact on the aquatic environment. They also showed that the resultant effects can manifest in many different ways and in water bodies of various shapes and sizes (Eriksson et al. 2004). Accordingly, the current study is applicable to larger, more developed lakes, and provides a framework for further research. The results of the present study are open to two interpretive possibilities. On one hand, it could be argued that canoeing and motorboating similarly affect shoreline macrophytes in Algonquin Provincial Park. Given the predicted level of disturbance, this conclusion would be surprising. On the other hand, our study may also suggest that the effects of this disturbance are highly localized. At the areas of lowest disturbance, disturbed lakes exhibited 54% of the diversity of the undisturbed control lake. At areas of high disturbance, disturbed lakes exhibited only 11% of the diversity. Thus, by limiting the amount and distribution of access points to each lake, it is to some extent possible to mitigate the negative effects of human activity on shoreline plant species richness, both in motorboat-accessible and canoe access-only lakes. A commitment to mitigating human impact is stated in Algonquin Provincial Park's own regulations, and contributes to the park's stated aim to "leave no trace" (The Friends of Algonquin Park 2014). This attempts to ensure, for instance, that the park's wildlife, an integral component of the wetlands ecosystem (Semlitsch and Bodie 1998), and whose sightings are a major contributor to the park's appeal, is minimally affected by human activities.

This study did not account for any invasive species or for the age of the vegetation. A study conducted by Quinn et al. (2011) showed that highly disturbed sites in Australian rivers were more likely than undisturbed, more established sites, to be invaded by foreign species. Another study, conducted by Connell and Slayter (1977), concluded that a site hosting a greater number of juvenile than adult plants may be less established, and may therefore indicate a more recent disturbance. Future studies could investigate these observations in greater detail, and could examine age-distribution among the different macrophytes in the freshwater lakes of Algonquin Provincial Park, as well as the presence of invasive species along these disturbance gradients.

As the impacts of anthropogenic disturbance are becoming increasingly apparent, it is necessary to develop better management and sustainability practices. Furthermore, in order to aid in the recovery of natural systems following anthropogenic perturbations, it is imperative that post-disturbance changes in ecosystem structure are adequately understood. Our study highlights the impacts of human disturbance in a well-monitored provincial park, suggesting that even greater negative impacts may be occurring in more developed and less well-monitored areas. We can deepen our understanding of these impacts through further research, potentially providing insights that could subsequently be used to reduce our global ecological footprint.

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# Tables and Figures


Figure 1. Google Map of the Highway 60 corridor in Algonquin Provincial Park, detailing the lakes chosen for inclusion in this study. Of the lakes chosen, 5 were motorboat-accessible (Canoe Lake, Lake Opeongo, Lake of Two Rivers, Rock Lake, and Whitefish Lake), and 5 were canoe access-only (Canisbay Lake, Coon Lake, Lake Sasajewun [Sas], Mew Lake, and Pog Lake). The remaining lake (Kathlyn Lake [Kath]), which had no designated access point for boats of any sort, and which was accessible only to researchers, served as a control.

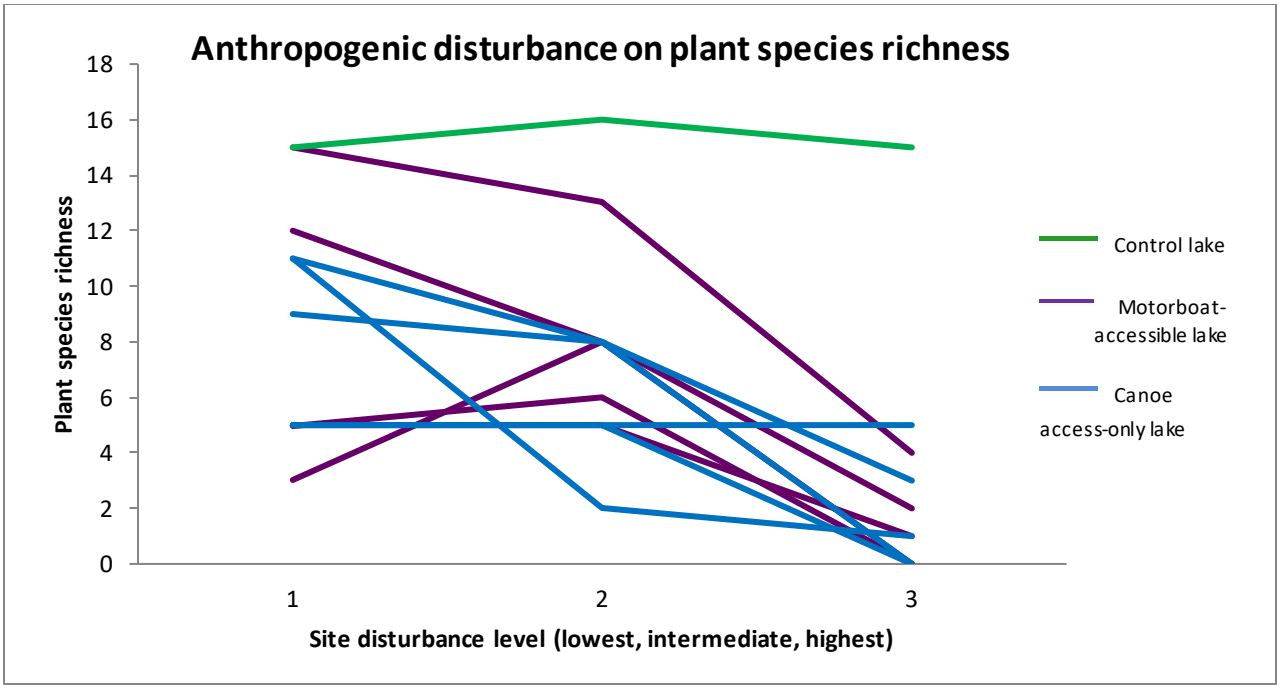


Figure 2. Graph of the effects of anthropogenic disturbance on plant species richness. After linear regression analysis, 95% confidence intervals were obtained for the slopes of the motorboat-accessible (-3.30 ± 2.07) and canoe access-only (-3.20 ± 1.78) lakes. As neither of these confidence intervals contain the null value, zero, there is a significant negative correlation between the level of disturbance and plant species richness. For the control lake, the slope was zero, indicating that there was no significant correlation between the level of disturbance and plant species richness.

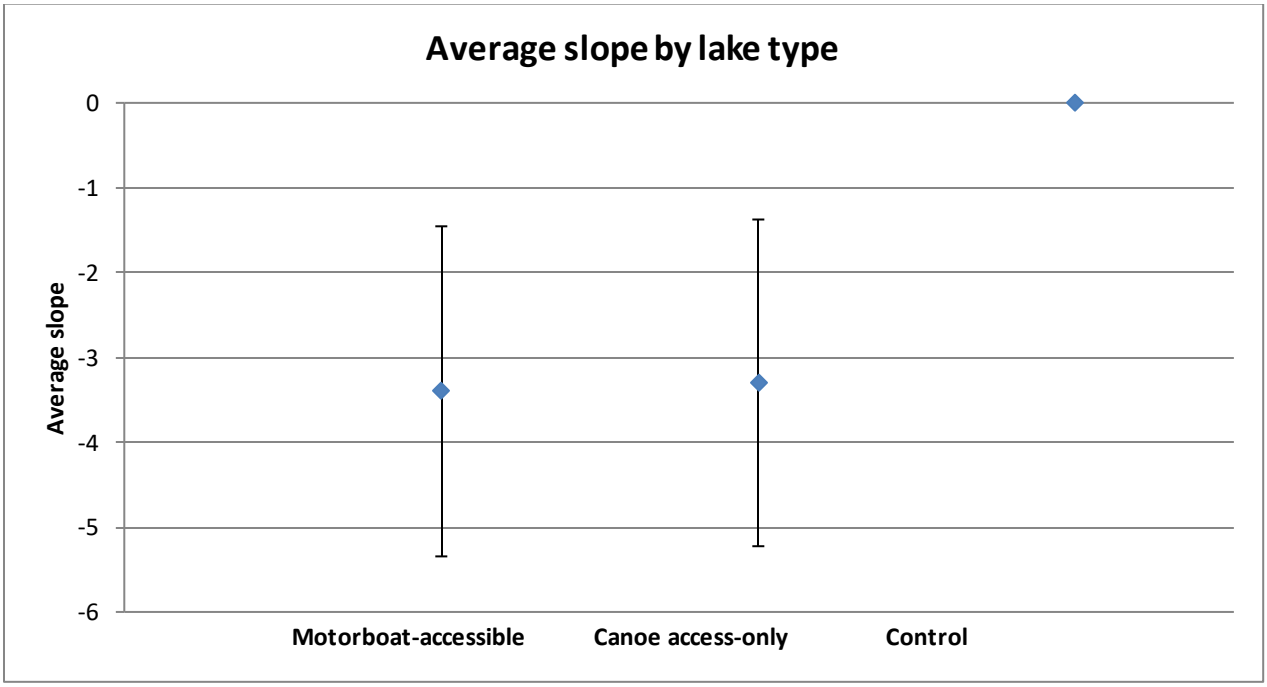


Figure 3. Plot of average slopes calculated for motorboat-accessible lakes, canoe access-only lakes, and the control lake. Error bars indicate a 95% confidence interval. The majority of the slopes are negative for both motorboat-accessible and canoe access-only lakes, indicating a negative correlation between the level of disturbance and plant species richness. For the control lake, the slope is zero, indicating that there was no significant correlation between the level of disturbance and plant species richness.

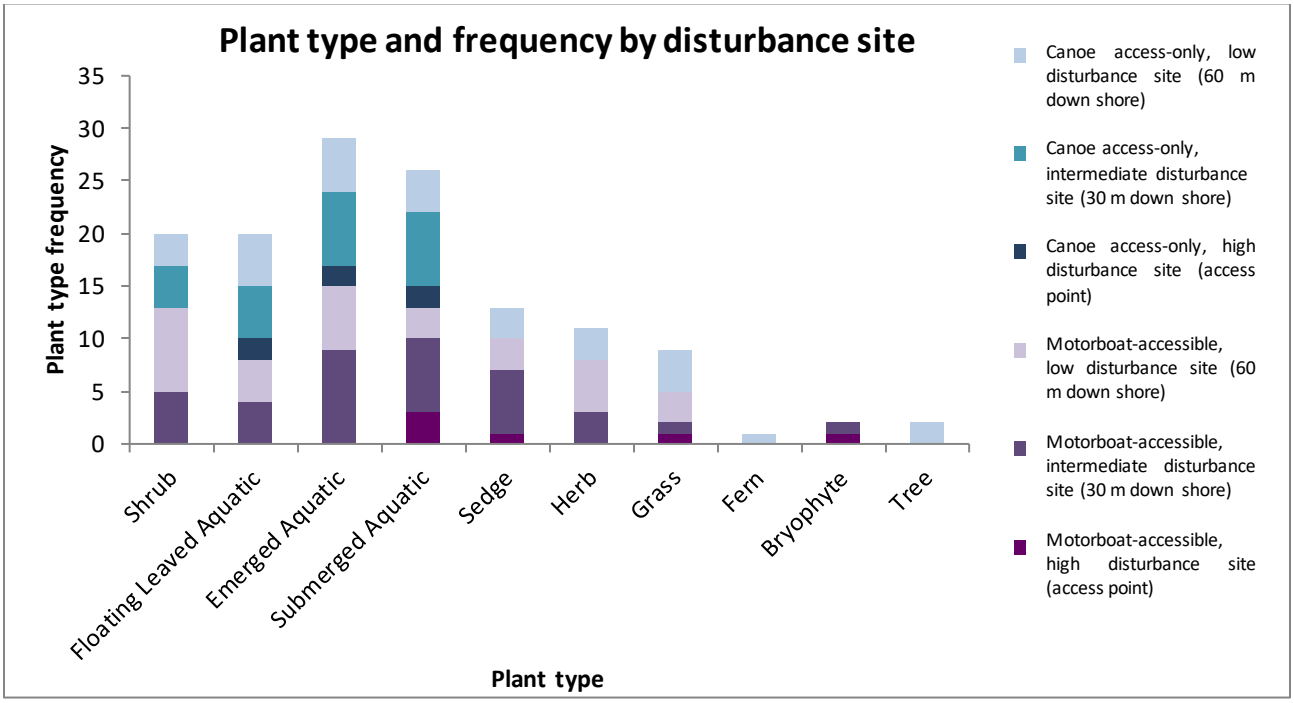


Figure 4. Graph of plant categories observed at each disturbance site in motorboat-accessible and canoe access-only lakes.