

# The Influence of the Characteristics of Geomorphological Deposits on Terrestrial Plant Species Richness in the Low Flow Channel Downstream from an Inversion-Type Reservoir



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## Abstract

The article analyzes the influence of the characteristics (including grain size) of geomorphological deposits formed in the low flow channel downstream from a dam on the Matawin River (5770km<sup>2</sup>) in Quebec. Since its construction in 1930, this dam has inverted the natural flow regime, with maximum flows occurring in winter and minimum flows in springtime, during snowmelt. A plant survey carried out in 2003 revealed that terrestrial plant species have become more abundant (46.2%) than obligate wetland (28.4%) and facultative-wetland (25.4%) species in the low flow channel of the river downstream from the dam. Terrestrial species are more abundant on sandy deposits than on boulder deposits. They develop preferentially on stabilized geomorphological sandy and boulder deposits that were rarely flooded and are no longer reworked by stream current, and they are completely absent from annually flooded geomorphological deposits. The study suggests that, to stop the expansion of terrestrial species at the expense of wetland obligate species (a process called channel terrestrialization) downstream from the Matawin dam, high flows (> 400m<sup>3</sup>/s) must be released each year in order to flood all geomorphological deposits accumulated in the low flow channel downstream from this dam.

**Keywords:** Terrestrial species; Obligate wetland species; Facultative-wetland species; Grain size of sediments; Geomorphological deposits; Inversion of the natural flow regime; dam

## Introduction

Over 45,000 large dams (height > 15m) have been built around the world [1] since the 19<sup>th</sup> century. These structures have altered the natural hydrologic regimes of rivers to various extents, as well as their morphological evolution and ecosystems. (e.g., [2-6]). In Quebec, over 500 large dams have been built, and three types of regulated hydrological regimes are observed downstream from these dams (e.g., [7,8]). The first of these (natural-type regulated regime) is characterized by the occurrence of maximum flows in the spring during snowmelt, and minimum flows in winter or summer. This type of regulated hydrological regime differs from hydrological regimes in natural rivers in that it shows a slight increase in flows in winter and a slight decrease in flows in springtime. This regime accounts for about 40% of all dams. The second type of regulated hydrological regime (homogenization-type regulated regime), which accounts for about 20% of large dams, is characterized by flows that remain nearly constant year round. Finally, the third type of regulated regime (inversion-type regulated regime), which accounts for roughly 40% of large dams, is characterized by the occurrence of maximum flows in winter

and minimum flows in the spring during snowmelt. The annual cycle of streamflow is thus inverted compared to that observed in natural rivers.

Of these three regulated hydrological regimes, the last one, the inversion-type hydrologic regime, leads to a very large decrease in flows downstream from dams in spring and summer (growing season). Reduced flows downstream from dams leads to reduced channel width and/or depth (e.g., [4,9-16]). This channel contraction results from the gradual invasion of dried up low flow channels by vegetation consisting mainly of terrestrial plant species at the expense of obligate wetland species [17]. While flows are undoubtedly the main cause of this channel terrestrialization phenomenon, the morphological and sedimentological characteristics of the deposits also exert considerable influence on the spatial and temporal variability of low flow channel colonization by terrestrial species [12,18-20]. However, while there is an abundant literature focusing on the impacts of dams on vegetation (e.g., [3,6,12,21]), very few studies as of yet have looked at the influence of the morphological and

sedimentological characteristics of deposits in low flow channels on the species richness in these channels (e.g., [18,19,22-24]). Assani et al. [22] found a relationship between species richness and the morphological evolution of deposits in a gravelly channel downstream from a reservoir in Belgium. Like the other studies, this study did not look specifically at the terrestrialization phenomenon, that is how the morpho-sedimentological characteristics of geomorphological deposits might influence the spatial distribution of terrestrial plant species in the low flow channel of a stream subjected to a significant decrease in streamflow after construction of a dam.

In Quebec, as part of a project aimed at analyzing the influence of abiotic factors (flows and habitat) on the terrestrialization of low-flow channels downstream from inversion-type dams, Assani et al. [25] demonstrated that, downstream from the Matawin dam, which is characterized by an inversion of the annual hydrological cycle, the abundance of terrestrial species on sand bars of similar type is strongly influenced by flow variations. Thus, during the growing season (April to September) when water levels are relatively high, the number of terrestrial species decreases on these bars due to the relatively extensive period during which these sites are under water. Dubeau et al. [26], for their part, showed that the duration of immersion of islets in springtime downstream from the Matawin dam strongly influences the number of terrestrial species on these islets. Thus, when islets

remain under water for long periods in springtime, as was the case in 2008 (La Niña year), the number of terrestrial species decreases markedly to be replaced by obligate wetland species. On some islets, terrestrial species disappeared completely after the 2008 spring freshet only to reappear after the major drought that occurred in 2010 (El niño year). However, these two studies did not investigated at the long-term effects of this hydrologic inversion phenomenon on the terrestrial plant species richness (terrestrialization phenomenon) in the low flow channel of the Matawin River downstream from the Taureau reservoir and the impacts associated with variations in the morphological and grain-size characteristics of the sites (deposits). Given the above, the goals of the present study are twofold:

a) To see whether 60 years after construction of the Matawin dam in 1930, terrestrial plant species have become more abundant than obligate wetland species and facultative-wetland species in the low flow channel downstream from the dam as a result of the inversion of the natural hydrological cycle of flow (reduced flows and curtailing of the spring freshet during the growing season).

b) To see whether terrestrial plant species develop preferentially in some geomorphological deposits (sites) depending on their grain size and geomorphological evolution in the low flow channel downstream from the Taureau reservoir.

## Methodology

### Description of the Taureau reservoir

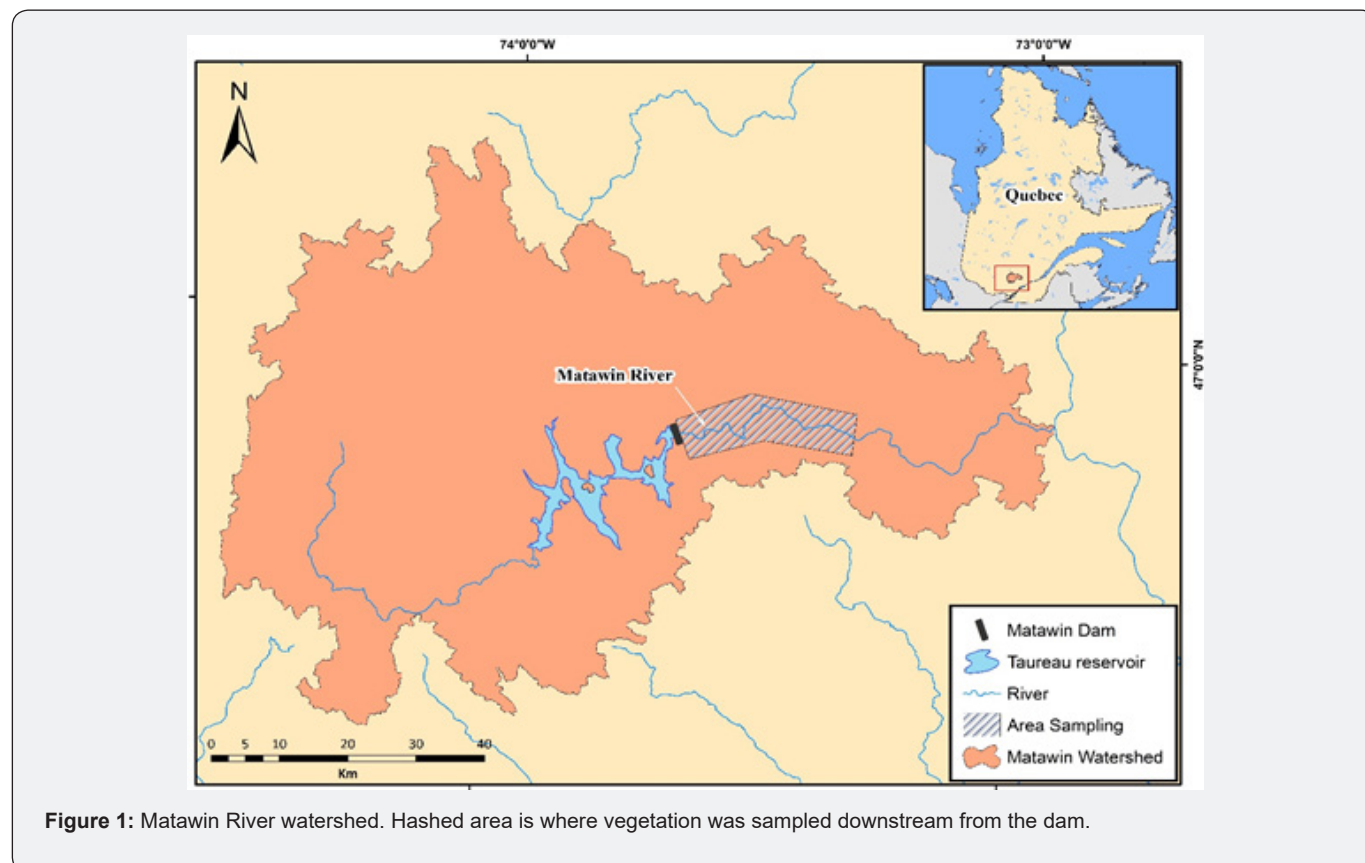


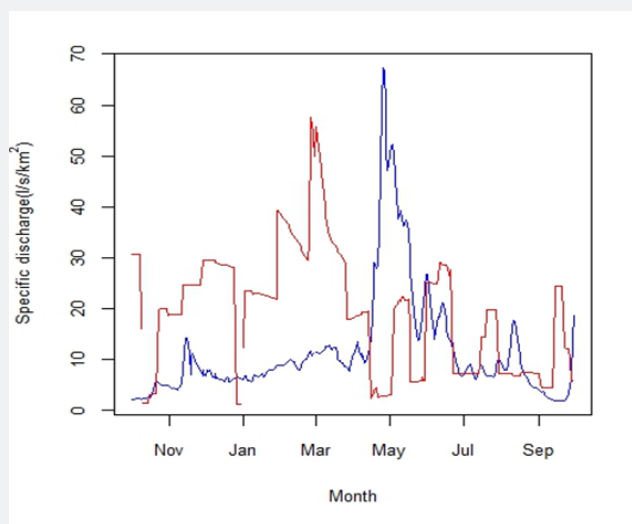
Figure 1: Matawin River watershed. Hashed area is where vegetation was sampled downstream from the dam.

The Matawin River, which is the main tributary of the Saint-Maurice River, drains a 5770-km<sup>2</sup> watershed, flowing entirely over the Canadian Shield along regularly alternating boulder, rocky, and sandy reaches (Figure 1). Due to their relatively strong slope, flow velocities are greater in boulder and rocky reaches than in sandy reaches. Climate in the region is of continental-subpolar type, with total annual precipitation on the order of 1000mm (more than half falls as snow mainly from December to March) and a mean annual temperature of 4°C. All of the watershed is located within the northern temperate vegetation zone, immediately south of the boreal zone, and lies for the most part in the Balsam Fir-Yellow Birch bioclimatic domain.

In 1930, the Shawinigan Power Company built a dam which impounded the Taureau reservoir. The Matawin dam is the gravity dam [27] which, at 720m in length and 26m in height, drains a 4070-km<sup>2</sup> area and has a total impoundment capacity of roughly 946,000,000m<sup>3</sup> [27]. It was built primarily to supply water in

winter to hydroelectric power plants built.

Downstream along the Saint-Maurice River. In Quebec, because of the continental cold temperate climate, precipitation falls as snow in winter. For larger watersheds (> 1000km<sup>2</sup>), rivers generally start to freeze over in late December and thawing occurs in late April. To produce hydropower, numerous reservoirs have been built which store water derived from snowmelt in springtime and rainfall in summer, this water being released in winter to supply the hydroelectric power plants. This flow management mode, which has not changed since the dam was built despite the ownership change in 1962, has resulted in a complete inversion of the annual flow regime downstream from the dam in which, contrary to natural rivers, maximum flows occur in winter and minimum flows occur in springtime, during snowmelt (Figure 2). Several studies have provided a detailed description of this inversion phenomenon in Quebec [8,27-30].



**Figure 2:** Comparison of specific discharge upstream (blue curve) and downstream (red curve) from the dam in 2003. The figure highlights the inversion of the natural cycle of flow downstream from the dam: maximum flows occur in winter and minimum flows, in springtime (complete disappearance of spring freshets) and summer (growing season).

Streamflow in the Matawin River has been measured continuously on a daily basis since 1930 at the Saint-Michel-des-Saints station, located upstream from the dam, and at a station located immediately downstream from it. The dam does not affect streamflow upstream from it [28].

### Description of the characteristics of morphological deposits

In light of field observations obtained since the summer of 2002, four types of deposits (are arranged from low to high inundation frequency) were identified on the Matawin River below and 40 km downstream from the Taureau reservoir based on grain size and stability:

a) Stabilized bank deposits: these sandy (S1) or boulder (B1) deposits were not affected by erosion by the river. No trace of erosion (fresh grooves) on these deposits or adjacent banks

is visible in the field. In addition, they no longer undergo annual flooding during the growing season due to curtailing of the spring freshet downstream from the reservoir. The presence of plant debris and litter reflects the lack of any sediment reworking by current. Field observations show that these deposits are only flooded in very wet years when relatively large flows are released (flows > 400m<sup>3</sup>/s), downstream from the dam. Only five times over the period from 1931 to 2010 did flows reach or exceed such levels.

b) Deposits linked with slowing current: these sandy (S2) or boulder (B2) deposits are formed along curves or abruptly widening reaches. A sharp decrease in current velocity accounts for this type of deposit, which form bars and, as a result of their topographic position, are more frequently flooded during the growing season, although in very dry years they remain above water. These sites are flooded when flows released downstream

from the dam are between 200m<sup>3</sup>/s and 400m<sup>3</sup>/s. Such flows occurred on average every two to three years during the growing season (April to September) over the period from 1931 to 2010.

c) Confluence deposits: these deposits are formed at the confluence of tributaries (S3). Sandy sediments carried by tributaries accumulate in the Matawin River low flow channel as a result of the inversion of the hydrological regime by the Taureau reservoir. During snowmelt, water levels in the Matawin River decrease dramatically downstream from the reservoir due to water storage. This reduces the capacity of the river to transport and remove sediments brought in by tributaries. Unlike the former two types of deposits, confluence deposits are flooded annually by tributary inputs during the spring freshet. These sites are flooded by flows < 200m<sup>3</sup>/s that occur every year.

d) Residual deposits: these comprise very coarse boulders that cannot be displaced (B3), and they were formed by hydrodynamic conditions different from those currently observed. These deposits are flooded when flows exceed 400m<sup>3</sup>/s.

### Sediment and plant sampling

Sediment and plant sampling was conducted from May to

**Table 1:** Geomorphological characterization of analyzed boulder (B) and sandy (S) deposits downstream from the dam as a function of the intensity of the frequency of their flooding during the growing season (April to September).

Code	Type of Geomorphological Deposit	Intensity of Frequency of Annual Flooding
B1	Stabilized bank deposits	Rare (Q> 400m <sup>3</sup> /s)
B2	Deposits linked with slowing current (bars)	High (annual flooding) (Q< 200m <sup>3</sup> /s)
B3	Residual deposits	Moderate (200m <sup>3</sup> /s<Q< 400m <sup>3</sup> /s)
S1	Stabilized bank deposits	Moderate (200< Q< 400m <sup>3</sup> /s)
S2	Deposits linked with slowing current (bars)	High (annual flooding) (Q< 200m <sup>3</sup> /s)
S3	Confluence deposits	High (annual flooding) (Q< 200m <sup>3</sup> /s)

As far as vegetation is concerned, a species inventory (presence only) was carried out at random on each deposit on fifty 1m x 1m quadrats. The surface area of some deposits limited the number of quadrats. It is important to note that prior sampling carried out at three sites with different surface areas revealed that 50 quadrats were more than sufficient for a proper inventory of all species present in each site. This number also allowed for a thorough sampling, likely as a result of the limited number of species at each site (< 70). Plant species were identified *in situ*. However, when *in situ* identification was not possible, specimens were collected and identified in the laboratory with the help of recognized experts on southern Quebec plant taxonomy. The Laurentian flora nomenclature [33] was used to identify plant species. Once identified, species were divided into ecological groups based on the southern Quebec plant classification scheme proposed by the Ministère du Développement durable, de l'Environnement et des Parcs [34]. In this classification, species are subdivided into three ecological groups, namely:

September 2003 (growing season). For each type of deposit, three sites were sampled over a distance of 40km downstream from the dam (Figure 1). The characteristics of the four types of deposits are summarized in Table 1. For sediment samples, roughly 300g of sediments were collected in three different sites from the first 50cm (same soil horizon) of each sandy deposit, taking care to remove roots and other organic material. The sites were selected at random, but at a sufficient distance from one another. These samples were then sent to the laboratory where they were dried for two days in a 105°C oven. After drying, grain-size analysis of 200g of each sample was carried out by sieving to constrain the relative proportions of sand, silt and clay. For boulder deposits, the "largest constituent" method was used, which consists in measuring the intermediate axis of the largest boulders in order to estimate the average grain size of that deposit (e.g., [31,32]). In the present case, the intermediate axis (b-axis) was measured on the 30 largest pebbles. The choice of 30 pebbles is based on the fact that prior sampling revealed that the average values of intermediate axes obtained for 30 and 50 pebbles from a deposit were not statistically different at the 5% level. This comparison was made using the Kruskal-Wallis method and the Student t test.

a) Obligate wetland species (OBL): these are species that only grow in wetlands (e.g., *Carex aquatilis*, *Carex versica*, *Equisetum fluviatile*, *Hypericum boreal*, *Juncus brevicaudatus*, *Glyceria strita*, *Potentilla palustris*, etc.).

b) Facultative-wetland species (SWS): these are species that preferentially grow in wetlands, but can also occur in terrestrial settings (e.g., *Hypericum Canadensis*, *Mentha Canadensis*, *Poa palustris*, *Juncus tenuis*, *Roripa islandica*, etc.).

c) Terrestrial species (TERR): these species that can adapt to wetlands form the third category consisting of terrestrial species with broad ecological amplitude. Their number is unknown (e.g., *Aralia nudicaulis*, *Betula alleghanensis*, *Fragaria Americana*, *Agrotis scabra*, *Panicum boreal*, *Viola septentrionalis*, etc.).

The list of all species collected at the various sites is shown in Appendix 1.

**Quantitative analysis**

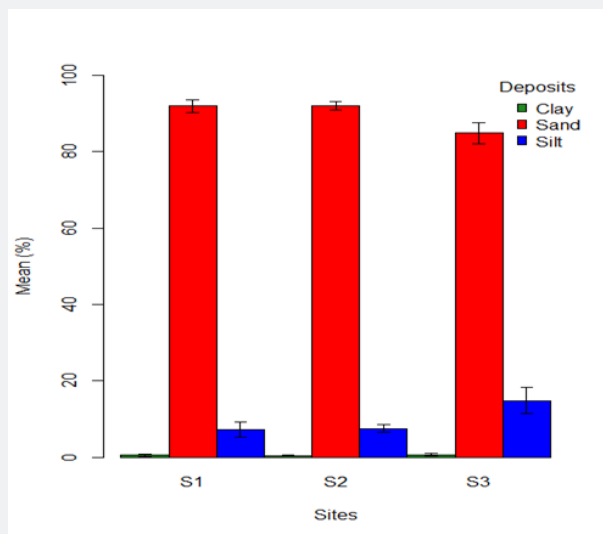
To analyze grain size and plant species richness data, the following quantitative methods were used:

- a) Analysis of variance using a single classification criterion (ANOVA) to compare relative proportions of sand, silt, and clay at sandy sites [35]. Each type of grain-size distribution was analyzed separately. The same method was used to compare the mean diameter (intermediate axis) of boulder deposits.
- b) The classic chi-square method to compare the species richness in the three ecological groups of plants as a function of the nature and grain size of the deposits.
- c) The classic Jaccard index to compare the degree of floristic resemblance between two sites (e.g., Dagnélie 1987).

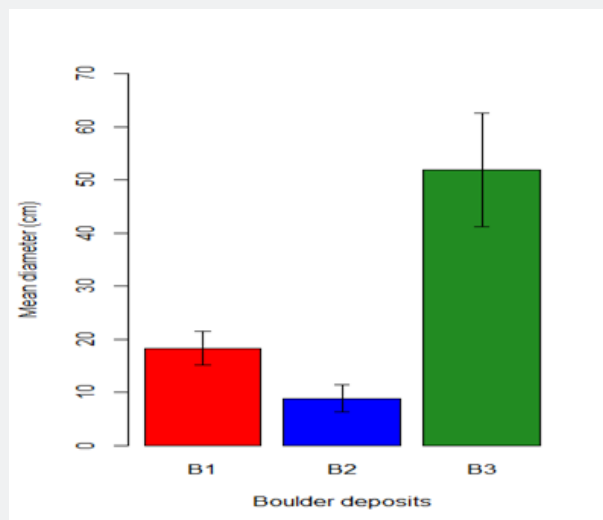
The Jaccard index is an association coefficient that constrains the similarity between two individuals for binary absence/presence data.

**Results**

The proportions of sand, silt, and clay in the three types of sandy deposits are shown in Figure 3, from which it may be seen that the proportions of sand in S1 and S2 deposits are higher than in S3 deposits, while this latter type contains more silt than the other two. The proportion of clay is very small and similar for all three types of deposits. For boulder deposits (Figure 4), the B3 type is made up of larger constituents than the other two types, B1 and B2. Of the three types of boulder deposits, B2 comprises the smallest constituents.



**Figure 3:** Comparison of clay, sand, and silt percentages in three types of sandy deposits downstream from the Taureau reservoir. B) Comparison of the mean diameter (average of 30 largest boulders) of three types of boulder deposits downstream from Taureau reservoir. For each type of deposit, 90 boulders were measured (three sites).



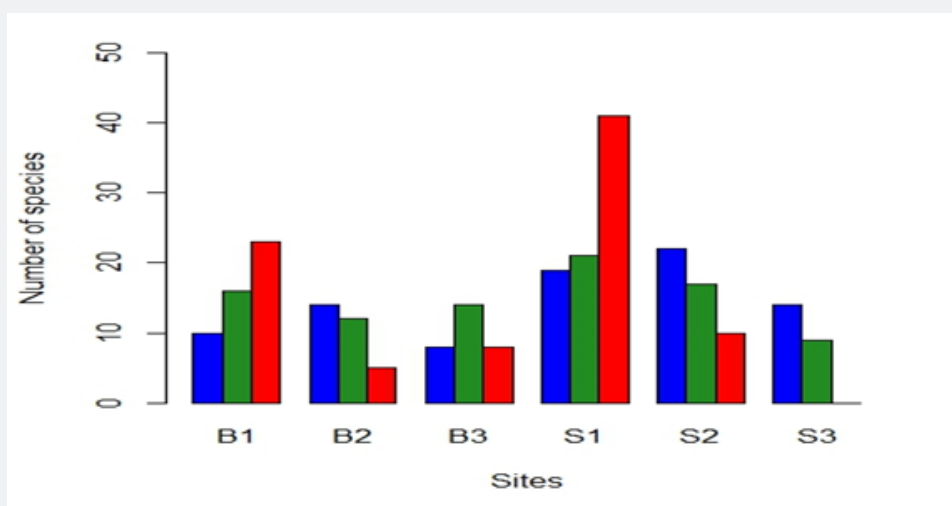
**Figure 4:** Comparison of the mean diameter (average of 30 largest boulders) of three types of boulder deposits downstream from Taureau reservoir. For each type of deposit, 90 boulders were measured (three sites).



In the summer of 2003, 134 plant species were inventoried in total on the six types of geomorphological deposits sampled downstream from the dam. These 134 species included 38 (28.4%) obligate wetland species, 34 (25.4%) facultative-wetland species, and 62 (46.2%) terrestrial species. The majority of plant species found on geomorphological deposits formed in the Matawin River low flow channel downstream from the dam are terrestrial. Of these 134 species, 105 (31 obligate wetlands species, 28 facultative-wetlands species, and 46 terrestrial species) were present on the three types of sandy deposits, and 80 species (23 obligate wetlands species, 25 facultative-wetlands species, and 32 terrestrial species) were observed on the three types of boulder deposits. Hence, the number of ecological terrestrial species was larger than the numbers observed in the other two ecological groups on both types of deposits.

Analysis of the relationship between geomorphological deposit types and the number of plant species in three ecological groups

using the chi-square method revealed a statistically significant correlation at the 5% level (Khi-square score: 40.65; ddl: 16) between the two groups of variables (Table 2 and Figure 5). It is therefore possible to conclude with certainty that terrestrial species grow preferentially on stabilized bank deposits (B1 and S1). This preference is also observed on sandy deposits (Khi-square score: 27.35; ddl: 7). However, no terrestrial species was found on the S3 sandy deposit. If only boulder deposits are considered, however, this preference disappears. Thus, unlike for sandy deposits, the chi-square method suggested no significant difference between the three types of boulder deposits and the three groups of plant species (Khi-square score: 11.02; ddl: 7). It is important to note that no statistically significant relationship was found between distance to the dam and plant species richness (including terrestrial species). Hence, there is no longitudinal variation in the number of terrestrial species downstream from the Taureau reservoir.



**Figure 5:** Comparison of abundance (total number) of species in the three ecological groups found on boulder (B1, B2, and B3) and sandy (S1, S2, and S3) deposits downstream from Taureau reservoir. Blue bars: obligate wetland species; green bars: facultative-wetland species; red bars: terrestrial species.

**Table 2:** Comparison of species richness in three ecological groups collected on different types of deposits in 2003.

Deposit Types	Total	Obligate Wetland Species	Facultative-Wetland Species	Terrestrial Species
B1	49	10	16	23
B2	31	14	12	5
B3	30	8	14	8
S1	81	19	21	41
S2	49	22	17	10
S3	23	14	9	0

Finally, regarding the floristic similarity of the different geomorphological deposits, Table 3 shows that the mean value of Jaccard indices is less than 30%. In other words, two different deposits have fewer than 30% species in common. More than half

the species are specific to one type of deposit and no species was observed at all sites. The lowest Jaccard index value derived was between B1 and S3 deposits, and the highest value was between B2 and S2 deposits.

## Discussion

As far as the long-term effects of the inversion of the natural hydrological cycle downstream from the Taureau reservoir are concerned, a comparison of the species richness in three ecological groups revealed that the number of terrestrial species is higher (more than half of the species tallied in 2003) than the number of species in the other two ecological groups (obligate wetland and facultative-wetland species), despite the fact that the low flow channel is normally a wet setting and therefore not very hospitable to terrestrial species. It is the hydrologic inversion phenomenon that accounts for this presence of terrestrial species

in much larger numbers than wetland and facultative-wetland species. This inversion results in the disappearance of the spring freshet and the maintenance of unusually low flows during the growing season (April to September). Moreover, in dry years, periods with no flow downstream from the dam are frequently observed which can sometimes last more than 100 consecutive days. As a result, a large portion of the low flow channel remains dry during the whole growing season, which, over time, promotes the gradual invasion of the channel by terrestrial plants (Figure 6), resulting in the gradual terrestrialization of the Matawin River channel downstream from the Taureau reservoir.



**Figure 6:** Exposure of the dry low flow channel of the Matawin River downstream from the dam in June 2003 favouring the invasion of terrestrial species. This drying of the channel is due to water storage in the reservoir resulting in intermittent flow downstream from the dam.

However, in the low flow channel, these terrestrial species appear to grow preferentially on some sites (deposits), and three factors – the grain size of geomorphological deposits, their morphological evolution, and the frequency of flooding of these deposits during the year – are interpreted to influence the nature of these preferred sites. As far as grain size is concerned, the relative proportion of species that are terrestrial is higher on sandy deposits (55%) than on boulder deposits (45%). The presence of fines promotes plant colonization on sandy deposits and the area of available habitat is much larger [22-24]. As far as the morphological evolution of the deposits is concerned, stabilized sandy and boulder deposits show larger numbers of terrestrial plant species than the other types of deposits; the lower likelihood of sediment erosion or accumulation on these deposits allows plant establishment and persistence. Finally,

as far as the frequency of flooding of the deposits is concerned, terrestrial plants are absent from annually flooded sites, such as confluence deposit sites which are flooded annually by tributaries, even though the Matawin dam curtails the spring freshet. This annual flooding prevents terrestrial plants from colonizing these sites [25].

Jaccard index values derived between the different types of deposits were generally very low (<30%), indicating that species tend to colonize only one type of deposits. These low Jaccard index values also suggest that the geomorphological nature of the deposit has a much greater influence on the presence of a species at a given site than the grain size of the deposit. This could likely be due to the heterogeneous nature of the components of these deposits. This heterogeneity could influence seed sprouting and the establishment of seedlings on these deposits.

## Conclusion

With a view to limit terrestrialization (invasion by terrestrial species) of the Matawin River channel downstream from the dam, flow releases high enough to flood the whole channel ( $> 400\text{m}^3/\text{s}$ ) should be carried out every year to prevent the gradual invasion of terrestrial plants at the expense of obligate wetland species. This suggestion is based on observations of plants on islets downstream from the dam from 2006 to 2011. During the 2008 growing season (April to September), there were many days

when relatively large flows ( $> 100\text{m}^3/\text{s}$ ) were released [36], such that islets remained submerged during this high flow period. This prolonged immersion led to the near disappearance of terrestrial species on the islets the following year [26]. This clearly shows that the duration of immersion of sites significantly affects the number of terrestrial species. It follows that the suppression of spring flooding should promote the expansion of islets on the low-flow channel of the Matawin River downstream from the dam. Reestablishing spring flood flows could therefore limit this expansion.

## Appendix

Annex: List of species.

Obligate Wetland Species								
	Name of Species	B1	B2	B3	S1	S2	S3	TNS
Present on 6 deposits								0
Present on 5 deposits	<i>Carex aquatilis l</i>	x	x	x	x	x		4
	<i>Lycopus americanus</i>		x	x	x	x	x	
	<i>Polygonum hydropiper</i>		x	x	x	x	x	
	<i>Sium suave</i>	x	x	x		x	x	
Present on 4 deposits	<i>Carex versicaria</i>	x			x	x	x	5
	<i>Equisetum fluviatile</i>	x	x		x	x		
	<i>Hypericum virginicum</i>		x		x	x	x	
	<i>Lycopus uniflorus</i>	x			x	x	x	
	<i>Véronica scutellata</i>		x		x	x	x	
Present on 3 deposits	<i>Hypericum boreal</i>		x		x	x		5
	<i>Iris versicolor</i>	x			x	x		
	<i>Lysimachia terrestris</i>		x		x		x	
	<i>Mimulus ringens</i>				x	x	x	
	<i>Viola pallens</i>	x		x		x		
Present on 2 deposits	<i>Chelone glabra</i>		x		x			8
	<i>Glyceria borealis</i>		x	x				
	<i>Glyceria (canadense) canadensis</i>					x	x	
	<i>Juncus brevicaudatus</i>		x				x	
	<i>Myrica gale</i>	x	x					
	<i>Sagittaria latifolia</i>					x	x	
	<i>Scirpus actrocintus</i>				x	x		
	<i>Scirpus cyperinus</i>				x	x		
Present on 1 deposits	<i>Acer saccharinum</i>	x						16
	<i>Eleocharis acicularis</i>				x			
	<i>Eleocharis smallii</i>					x		
	<i>Eriocaulon septangulare</i>						x	
	<i>Glyceria ferna(n)ldii</i>			x				
	<i>Glyceria grandis</i>			x				
	<i>Glyceria septentrionalis</i>				x			
	<i>Glyceria striata</i>				x			
	<i>Polygonum sagittatum</i>						x	
	<i>Potentilla palustris</i>					x		



Present on 1 deposits	<i>Rhamnus alnifolia(us)</i>	x							16
	<i>Scirpus rubrot(c)inctus</i>						x		
	<i>Scirpus sp.</i>						x		
	<i>Scutellaria epilobifolia</i>						x		
	<i>Scutellaria lateriflora</i>		x						
	<i>Torreyochloa pallida</i>				x				
<b>Semi-Wetland Species</b>									
Present on 6 deposits	<i>Ranunculus reptans</i>	x	x	x	x	x	x	x	1
Present on 5 deposits	<i>Aster puniceus</i>		x	x	x	x	x	x	6
	<i>Carex crinita</i>		x	x	x	x	x		
	<i>Eupatorium maculatum</i>	x	x	x	x	x			
	<i>Gal(l)ium pal(l)ustre L.</i>		x	x	x	x	x		
	<i>Hypericum canadense</i>	x	x	x	x	x			
	<i>Thalictrum pubescens</i>	x	x	x	x	x			
Present on 4 deposits	<i>Juncus filiformis</i>	x	x		x	x			1
Present on 3 deposits	<i>Acer rubrum</i>		x	x				x	9
	<i>Agrotis alba L.</i>		x		x			x	
	<i>Alnus rugosa</i>	x			x	x			
	<i>Aster umbellatus</i>	x		x	x				
	<i>Calamagrotis canadensis(e)</i>				x	x	x		
	<i>Carex scoparia</i>		x	x	x				
	<i>Poa palustris</i>	x		x		x			
	<i>Salix discolor</i>	x		x		x			
	<i>Salix rigida</i>	x				x	x		
Present on 2 deposits	<i>Cornus stolonifera</i>	x			x				5
	<i>Mentha Canadensis</i>				x	x			
	<i>Onoclea sensibilis</i>				x		x		
	<i>Salix bebbiana sp.</i>	x			x				
	<i>Scirpus a(n)trovirens</i>	x					x		
Present on 1 deposits	<i>Impatiens capensis</i>				x				12
	<i>Juncus tenuis</i>				x				
	<i>Larix laricina</i>	x							
	<i>Lythrum salicaria</i>						x		
	<i>Muhlenbergia glomerata</i>			x					
	<i>Osmunda cinnamomea</i>	x							
	<i>Osmunda regalis</i>			x					
	<i>Populus balsamifera</i>	x							
	<i>Populus deltoides</i>				x				
	<i>Roripa islandica</i>		x						
	<i>Salix lucida</i>					x			
	<i>Viburnum cassinoides</i>				x				
<b>Terrestrial Species</b>									
Present on 6 settings									0

Present on 5 deposits	<i>Solidago graminifolia</i>	x	x	x	x	x		2
	<i>Spirea latifolia</i>	x	x	x	x	x		
Present on 4 deposits								0
Present on 3 depositis	<i>Anaphalis margaritaceae</i>	x			x	x		2
	<i>Fragaria americana</i>	x			x	x		
Present on 2 depositis	<i>Acer pensylvanicum</i>	x			x			15
	<i>Agrotis scabra</i>				x	x		
	<i>Apocynum androseamifolium</i>	x			x			
	<i>Aster cordifolius</i>			x	x			
	<i>Betula papyrifera</i>	x			x			
	<i>Corylus cornuta</i>	x			x			
	<i>Diervilla lonicera</i>	x			x			
	<i>Erigeron strigosus</i>	x				x		
	<i>Hieracium aurantiacum</i>	x			x			
	<i>Panicum boreal</i>			x	x			
	<i>Pinus divaricata</i>	x			x			
	<i>Populus tremuloides</i>	x			x			
	<i>Rubus idaeus</i>	x			x			
	<i>Vaccinum myrtilloides</i>	x			x			
	<i>Viola septentrionalis</i>		x		x			
Present on 1 deposit	<i>Abies balsamifera</i>	x						41
	<i>Acer spicatum</i>				x			
	<i>Achillea millefolium</i>				x			
	<i>Amélanchier wiegandii</i>				x			
	<i>Amélanchier sp.</i>				x			
	<i>Anemone canadense</i>					x		
	<i>Aralia nudicaulis</i>				x			
	<i>Aster acuminatus</i>		x					
	<i>Aster macrophyllus</i>				x			
	<i>Aster novie-belgii</i>			x				
	<i>Athyrium filix-femina</i>				x			
	<i>Betula alleghanensis</i>				x			
	<i>Carex convulata</i>			x				
	<i>Carex communis</i>				x			
	<i>Clematis virginiana</i>			x				
	<i>Cornus alternifolia</i>	x						
	<i>Épilobium angustifolium</i>	x						
	<i>Habenaria fimbriata</i>				x			
	<i>Linnaea borealis</i>	x						
	<i>Maianthemum canadense</i>				x			
<i>Oxalis stricta</i>					x			
<i>Phleum pratense</i>		x						
<i>Picea glauca</i>	x							
<i>Pinus resinosa</i>	x							

Present on 1 deposit	<i>Pinus strobes</i>			x				41
	<i>Plantago major</i>					x		
	<i>Polygonum cilinode</i>				x			
	<i>Polygonum convulvus</i>				x			
	<i>Potentilla norvegica</i>	x						
	<i>Prunus pensylvanica</i>	x						
	<i>Pteridium aquilinum</i>				x			
	<i>Pyrola elliptica</i>				x			
	<i>Salix humilis</i>				x			
	<i>Solidago canadense</i>					x		
	<i>Solidago macrophylla</i>				x			
	<i>Solidago puberla</i>				x			
	<i>Solidago rugosa</i>				x			
	<i>Sorbus americana</i>				x			
	<i>Steptopus roseus</i>				x			
<i>Taraxacum officinale</i>				x				
<i>Vicia cracca</i>				x				

X = presence; TNS = Total number of species.

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