EARTHWORMS (ANNELIDA: OLIGOCHAETA) IN CAPE BRETON SOILS ACCORDING TO SOIL SERIES, AND THEIR IMPLICATIONS FOR AGRICULTURE

Abstract

Earthworm communities across Cape Breton Island, Nova Scotia, exhibit strong biogeographic structuring driven by soil series, parent material, and land use history. Analysis of 114 collections representing 11–13 European lumbricid species shows clear dominance by *Aporrectodea tuberculata*, *Lumbricus rubellus*, and *Aporrectodea turgida*. Species distributions correspond closely to mapped soil series, with Podzolic soils supporting epigeic forest floor invaders and clay loam tills hosting diverse endogeic assemblages. Functional guild composition indicates limited anecic presence, constraining vertical mixing and deep carbon incorporation. Invasive dynamics are evident in disturbance associated taxa such as *Aporrectodea trapezoides*, particularly in Richmond County. Soil series comparisons reveal that Westbrook and Queens tills exhibit the strongest agricultural potential due to endogeic driven improvements in aggregation and infiltration, whereas Regosols and disturbance dominated clay tills show low diversity and limited functional redundancy. These findings demonstrate how earthworm guilds interact with soil properties to shape ecosystem processes across Cape Breton Island and highlight the implications for soil health, nutrient cycling, and agricultural management in a predominantly Podzolic landscape. One representative line from the dataset illustrates typical assemblages: "*Aporrectodea tuberculata* 2-1-2; *Dendrobaena octaedra* 0-0-1 (400-6)."

Keywords
Earthworms; Lumbricidae; soil series; Podzols; Brunisols; Regosols; functional guilds; endogeic; epigeic; anecic; invasive species; soil ecology; Cape Breton Island; Agricultural soils; soil structure; nutrient cycling.

Résumé

Les communautés de vers de terre de l'île du Cap Breton, en Nouvelle Écosse, présentent une structuration biogéographique marquée influencée par les séries de sols, les matériaux originels et l'histoire de l'utilisation des terres. L'analyse de 114 collectes représentant 11 à 13 espèces lumbricidées européennes révèle une forte dominance d'*Aporrectodea tuberculata*, *Lumbricus rubellus* et *Aporrectodea turgida*. La distribution des espèces correspond étroitement aux séries de sols cartographiées : les Podzols forestiers abritent des espèces épigées, tandis que les tills argileux loameux soutiennent des assemblages endogés diversifiés. La composition des guildes fonctionnelles indique une présence limitée d'espèces anéciques, ce qui restreint le mélange vertical et l'incorporation du carbone en profondeur. Les dynamiques d'invasion sont évidentes chez les espèces associées aux perturbations, telles qu'*Aporrectodea trapezoides*, particulièrement dans le comté de Richmond. Les comparaisons entre séries de sols montrent que les tills Westbrook et Queens présentent le plus fort potentiel agricole grâce aux améliorations structurales induites par les endogés, tandis que les Régosols et certains tills perturbés présentent une faible diversité et une redondance fonctionnelle limitée. Ces résultats démontrent comment les guildes de vers de terre interagissent avec les propriétés des sols pour façonner les processus écosystémiques à l'échelle de l'île du Cap Breton.

Mots-clé
Vers de terre; Lumbricidae; séries de sols; Podzols; Brunisols; Régosols; guildes fonctionnelles; endogés; épigés; anéciques; espèces invasives; écologie des sols; île du Cap Breton; sols agricoles; structure du sol; cycle des nutriments.

Geàrr Thuairsgeul (Gàidhlig Albannach / Scots Gaelic)

Tha coimhearsnachdan de chnuimh talmhainn air Eilean Cheap Breatainn a’ nochdadh structar làidir a rèir sreath ùir, stuth tùsail agus eachdraidh cleachdadh fearainn. Tha anailis air 114 cruinneachadh, a’ riochdachadh 11 gu 13 gnèithean Eòrpach, a’ sealltainn gu bheil *Aporrectodea tuberculata*, *Lumbricus rubellus* agus *Aporrectodea turgida* gu math pailt. Tha sgaoileadh nan gnèithean co cheangailte gu dlùth ri sreathan ùir: tha Podzolan coille a' toirt taic do ghnèithean epigeic, agus tha till clèibh lòmaich a’ cumail ri coimhearsnachdan endogeic eadar mheasgte. Tha co dhealbhachadh nan guildhean gnìomhach a' sealltainn gainnead de ghnèithean anecic, a' cuingealachadh measgachadh dhomhainn agus glèidheadh gualain anns na h ìrean as ìsle. Tha gluasadan ionnsaigheach follaiseach ann an gnèithean co cheangailte ri buaireadh, leithid *Aporrectodea trapezoides*, gu h àraidh ann an Siorrachd Richmond. Tha coimeasan eadar sreathan ùir a' sealltainn gu bheil Westbrook agus Queens nan sreathan le comas àiteachais nas fheàrr air sgàth leasachadh structarail le gnèithean endogeic, fhad 's a tha Regosolan agus cuid de thill buaireasach le ìre ìosal de dh' ioma ghnèitheachd. Tha na toraidhean seo a' sealltainn mar a bhios guildhean chnuimh talmhainn ag eadar obrachadh le feartan na h ùire gus pròiseasan eag shiostaim a chruthachadh air feadh Eilean Cheap Breatainn.

Faclan luinge (Gàidhlig)
Cnuimh talmhainn; Lumbricidae; sreathan ùir; Podzolan; Brunisolan; Regosolan; guildhean gnìomhach; endogeic; epigeic; anecic; gnèithean ionnsaigheach; eag eòlas ùire; Eilean Cheap Breatainn; ùirean àiteachais; structar na h ùire; cuairteachadh beathachaidh.

L'nui'sultinej (Mi'kmaw)

Lombricidae waiskul kmit Cape Breton aqq Mi’kma’ki waiskuoml waiskul waiskuoml teluisi kmit waiskul waiskuoml aqq waiskul waiskuoml waiskuoml. Kesalul 114 waiskul kmit aqq 11–13 Lombricidae mimajuinu waiskul waiskuoml, aqq waiskul waiskuoml *Aporrectodea tuberculata*, *Lumbricus rubellus*, aqq *Aporrectodea turgida* waiskuoml waiskul waiskuoml waiskuoml. Waiskul waiskuoml teluisi kmit waiskul waiskuoml waiskuoml aqq waiskul waiskuoml waiskuoml: Podzol waiskuoml waiskul epigeic waiskuoml waiskuoml, aqq clay loam till waiskuoml waiskul endogeic waiskuoml waiskuoml. Anecic waiskul waiskuoml waiskuoml waiskuoml, aqq waiskul waiskuoml waiskuoml waiskuoml waiskuoml waiskuoml waiskuoml. *Aporrectodea trapezoides* waiskul mimajuinu waiskuoml waiskuoml Richmond waiskuoml, aqq waiskul waiskuoml waiskuoml waiskuoml waiskuoml. Westbrook aqq Queens waiskuoml waiskul waiskuoml waiskuoml waiskuoml waiskuoml aqq waiskuoml waiskuoml waiskuoml waiskuoml. Regosol waiskuoml waiskuoml waiskuoml waiskuoml. Teluisi kmit waiskul waiskuoml waiskuoml aqq waiskuoml waiskuoml waiskuoml waiskuoml Cape Breton aqq waiskuoml waiskuoml waiskuoml waiskuoml.

Mi'kmaw Keywords
Waiskul kmit; Lombricidae; waiskul teluisi kmit; Podzol; Brunisol; Regosol; epigeic; endogeic; anecic; mimajuinu waiskul; waiskul waiskuoml; Cape Breton; waiskul aqq waiskuoml; waiskul teluisi kmit.

1. INTRODUCTION

Earthworms are foundational ecosystem engineers whose burrowing, feeding, and casting activities influence soil structure, nutrient cycling, and plant productivity across temperate ecosystems (Darwin, 1881). Their ecological roles span multiple functional strata, from endogeic species that mix mineral soils to epigeic taxa that process surface litter and anecic species that integrate organic and mineral horizons. Understanding how these guilds interact across landscapes is essential for interpreting soil ecosystem function, especially in regions undergoing rapid land use change.

Cape Breton Island (CBI) presents a particularly compelling setting for earthworm community research. Cape Breton Island covers an area of about 1,067,852.877 hectares, or 2,638,880 acres (**Figure 1**). In the early years of its history the Island was a base for fishing fleets from Europe. For many years it was alternately under French and British rule. Since 1820, it has been part of Nova Scotia. The first permanent agricultural settlement was begun about 1786 (Cann *et al.*, 1981).

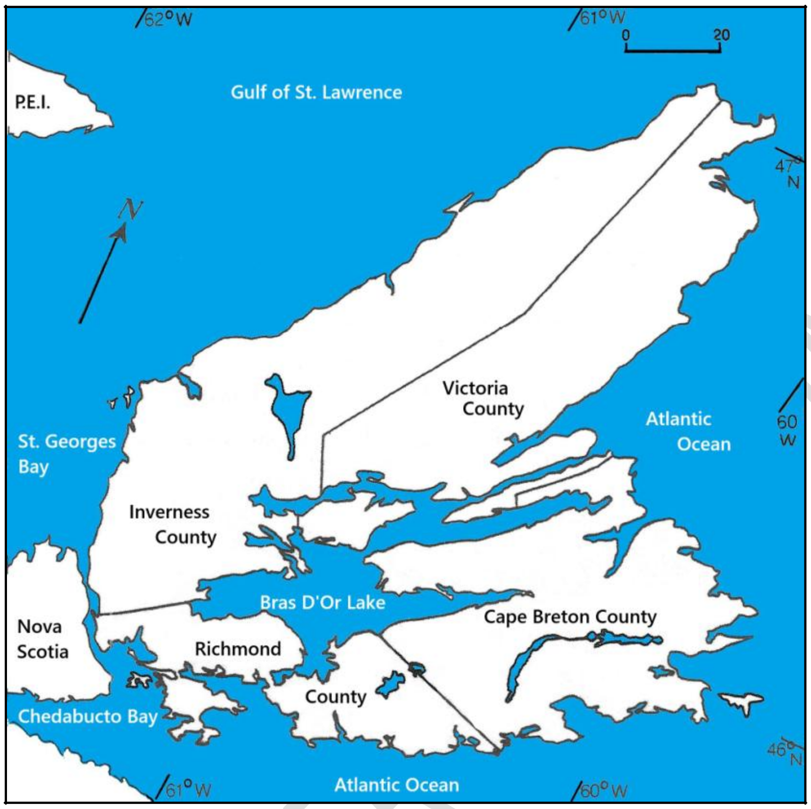


Figure 1. Map of Cape Breton, Nova Scotia, Canada showing the position of the four counties.

The landscape of the Island has strong relief. Gently undulating to rolling lowland areas are bordered by steeply sloping hillsides of an upland plateau. Elevations range from sea level to about 335.28 m. Much of the Island is forested and there are about 699296.8 ha (2,700 m^2) of productive forest. The main trees are white spruce (*Picea glauca* (Moench) Voss), red spruce (*Picea rubens* Sarg.), balsam fir (*Abies balsamea* (L.) Mill.) and birch (*Betula papyrifera* Marshall).

2. Methods

The earthworms were collected manually by turning over rocks, logs and debris as well as digging with a spade. The sites were chosen randomly, but the topography was taken into consideration. The specimens were prepared the evening of the collection. After the initial identification and recorded, the specimens are not deposited in the collections of the Canadian Museum of Nature, Gatineau, Quebec.

2.1 Sampling and Species Standardization

Each line of the dataset represented a discrete collection event. All species names were standardized, and misspellings were corrected according to accepted taxonomic usage (Reynolds, 1975, 2022). Eleven species were confirmed across all 114 collections.

2.2 Presence–Absence and Co Occurrence Analysis

Each collection was converted into a binary presence–absence record. A co-occurrence matrix (11 × 11) was generated by counting the number of collections in which each pair of species occurred together. Single species collections contributed to diagonal values but not to pairwise counts.

2.3 Network Analysis

A weighted network graph was constructed using species as nodes and co occurrence counts as edge weights. Node size reflected species frequency; edge thickness reflected co-occurrence strength.

2.4 Species Frequencies and Diversity Metrics

Species frequencies were calculated as the number of collections in which each species occurred, *e.g.* abundance proxies. Diversity metrics were computed using frequency values as abundance proxies. ***Shannon diversity*** (H'), ***Simpson diversity*** (1–D), and ***Pielou's evenness*** (J') were calculated using standard formulas.

$H' = 3p_i In_p$ where p_i is the proportional frequency of species.

$D\text{-}1 = 1\text{-}3p_i^2$

$J' = H'/InS$ where S is the total number of species.

2.4.1 The ***Shannon Diversity Index*** (1948) (sometimes called the *Shannon-Wiener Index*) is a way to measure the diversity of species in a community.

Denoted as H, this index is calculated as:

H = -Ópi * ln(pi)

where:

Ó: A Greek symbol that means "sum"

ln: Natural log

pi: The proportion of the entire community made up of species 1

The higher the value of H, the higher the diversity of species in a particular community. The lower the value of H, the lower the diversity. A value of H = 0 indicates a community that only has one species.

2.4.2. ***Simpson's Diversity Index*** (1949) is a way to measure the diversity of species in a community.

Denoted as D, this index is calculated as:

D = Óni(ni-1) / N(N-1)

where:

ni: The number of organisms that belong to species i

N: The total number of organisms

The value for Simpson's Diversity Index ranges between 0 and 1. The higher the value, the lower the diversity.

Since this interpretation is a bit counterintuitive, I often calculate *Simpson's Index* of *Diversity* (sometimes called a *Dominance Index*), which is calculated as 1 – D. The higher the value for this index, the higher the diversity of species.

2.4.3. ***Pielou's Evenness Index*** (J') builds upon the *Shannon Diversity Index* (H').
The index ranges from 0 to 1, where:
1 indicates perfect evenness (all species equally abundant)
0 indicates maximum unevenness (one species dominates completely)

$$J' = \frac{H'}{\ln(S)}$$

Pielou's Evenness values typically indicate:
0.90-1.00: Very high evenness (extremely balanced community)
0.70-0.89: High evenness (well-balanced community) [In these samples]
0.50-0.69: Moderate evenness (somewhat unbalanced) [In these samples]
0.25-0.49: Low evenness (unbalanced community)
0.00-0.24: Very low evenness (highly dominated community)

2.4.4. The ***Bray-Curtis Dissimilarity Index*** (1957) is a metric used to quantify the dissimilarity between two different sites based on species counts. It is widely used in ecology and biology to compare the species composition of different communities. This index provides a measure of how different two sites are in terms of the species found in those sites.

The Bray-Curtis Dissimilarity is calculated using the formula:
[BC_{ij} = 1 - \ frac{2C_{ij}}{S_i + S_j}] where:
(C_{ij}) is the sum of the lesser values for the species found in each site.
(S_i) is the total number of specimens counted at site (i).
(S_j) is the total number of specimens counted at site (j).
The index ranges between 0 and 1:
0 indicates that two sites have zero dissimilarity, meaning they share the exact same number of each type of species.
1 indicates complete dissimilarity, meaning they share none of the same species.

2.4.5. The ***Jaccard index*** (1901) measures similarity between finite non-empty sample sets and is defined as the size of the intersection divided by the size of the union of the sample sets:
J(A,B) = |A B| / |A B| = |A B|/|A|+|B| - |A B|
The Jaccard index can be interpreted as a normalized measure of overlap between two sets, where the intersection represents shared elements and the union represents the total set of distinct elements. By definition, 0 # J(A,B) # 1.

The Jaccard index is widely used in computer science, ecology, genomics and other sciences where binary or binarized data are used.

2.5. Soil Series Integration

Species distributions were compared against mapped soil series across Cape Breton Island, Nova Scotia, Canada (Cann *et al.*, 1981). Soil texture, drainage class, and land use history were used to interpret species–soil associations.

2.6. Cape Breton Soils

The soil parent materials are glacial till and glaciofluvial deposits derived from sandstones, shales and metamorphic rocks. The textures range from sand to clay. The well-drained soils (37 per cent of the area) have well-developed Podzol profiles. Only about 26 per cent of the land area is suitable for agriculture other than rough pasture (Cann *et al.*, 1981). The first earthworm survey of Cape Breton Island was conducted by Reynolds (1975).

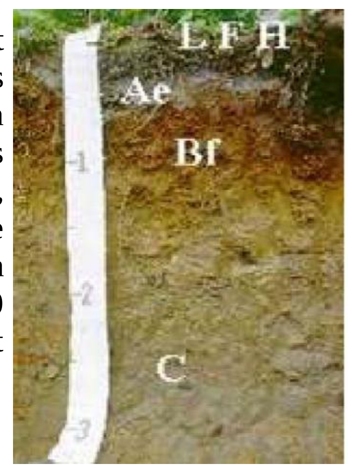
3. Results

3.1. Collections

The polynomial after the earthworm species name indicates the number of juveniles-aclitellate adults-clitellate adults, a 4th number occurs only when postclitellate adults are present in the collection, e.g. *Aporrectodea turgida* 5-4-2-2 in collection (426-9). An explanation of the age classification can be found in Reynolds (2022a and b).

3.1.1. Brunisol Order (transitional forest soils)

Brunisolic soils encompass all soils that possess a B horizon but do not meet the diagnostic criteria of the other soil orders. Many Brunisols exhibit brownish B horizons that lack the pronounced clay accumulation characteristic of Luvisols or the amorphous organic metal complexes typical of Podzols. Under stable climatic conditions and sufficient time, some Brunisolic soils may evolve toward Luvisolic profiles, while others may develop Podzolic characteristics. In combination with associated soil types, Brunisolic soils occupy nearly 790,000 km²—approximately 8.6% of Canada's land area—and occur throughout the country south of the permafrost zone.



Based on acidity and the abundance of organic material in the A horizon, four major Brunisolic subgroups are recognized. **Melanic Brunisols** possess an A_h horizon at least 10 cm thick and have a pH < 5.5; they are widespread throughout southern Ontario and Québec. **Eutric Brunisols** share the same general characteristics, except that the A_h horizon—when present—is 10 cm thick or less. **Sombric Brunisols** also contain an A_h horizon at least 10 cm thick but are distinguished by higher acidity, with pH values > 5.5. **Dystric Brunisols** are acidic soils lacking a 10 cm thick A_h horizon. These distinctions follow Le système canadien de classification des sols (CSSC, 1998).

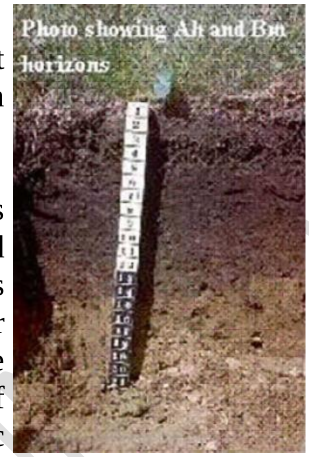
Soil Series: Subgroup
Inverness County
Hebert gravelly sandy loam (stratified) : Dystric Brunisol

! Cabot Trail, 0.8 km south of MacLennan's Cross: *Allolobophora chlorotica* 0-1-0; *Aporrectodea turgida* 0-1-2; *Dendrobaena octaedra* 0-0-1; *Lumbricus castaneus* 0-1-6 (418-2).

! Cabot Trail, at Lake O'Law: *Eiseniella tetraedra* 0-1-0 (419-3).

! Aspy Bay 7.9 km north of Cape North: *Aporrectode atuberculata* 1-2-4; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 0-1-4 (414-8).
! Cabot Trail, 2.2 km north of Clyburn Brook: *Aporrectodea tuberculata* 0-0-1 (426-10).

3.1.2. Podzolic Order (major soil order in Prince Edward Island)



In forested Podzols, introduced earthworms can dramatically alter the forest floor by reducing litter thickness and accelerating nutrient cycling. This can lead to changes in understory plant communities and soil microhabitats.

The acid soils possess a B horizon that contains deposits of shapeless substances made up of decomposed organic matter linked with iron and aluminum. They primarily form on sandy substrates within regions characterized by cold, humid climates and are often found under forests or shrubs. Water percolating downwards through the fairly porous substance extracts essential components (such as calcium), leading to the formation of an acidic environment. Decomposed forest litter produces soluble organic compounds that corrode soil minerals in the upper layers of the soil. A significant portion of the aluminum and iron that is freed from this process binds with organic matter. Once the ratio of iron and aluminum to organic matter surpasses a threshold, the organic complex undergoes a transformation, rendering it insoluble and subsequently leading to its deposition within the B horizon. Aluminum and iron that have dissolved might additionally migrate downwards in inorganic forms and settle as complexes of aluminum-silicon and oxides of iron. Ae horizon, which is typically light gray and highly leached, often lies above the Podzolic B horizon.

These soils are prevalent in large portions of the humid Appalachian and Canadian Shield zones, as well as in the moist coastline zone of British Columbia. They are categorized into three major groupings based on the kind of Podzolic B horizon. Humic Podzols are characterized by a B horizon that is black in color and has a relatively low concentration of iron. They mostly occur in moist areas with high levels of humidity and are significantly less prevalent compared to other types of Podzolic soils.

Ferro-Humic Podzols feature a B horizon that is dark brownish-red or black and has a minimum of 5% organic carbon together with significant levels (usually< 2%) of both aluminum and iron in organic compounds. They frequently appear in the more wet places of the Podzolic soil region, such as British Columbia coasts and some areas of Newfoundland and southern Quebec. The most prevalent podzolic soils in Canada are called Humo-Ferric Podzols. They feature a brownish-red B horizon with no more than 5% organic carbon linked to iron as well as aluminum compounds (CSSC, 1998).

Soil Series: Subgroup

Cape Breton County

Arichat sandy loam till : Humo-Ferric Podzol
! Hwy 22, Lewisburg, next to Railway Station: *Aporrectodea turgida* 4-1-1; *Dendrobaena octaedra* 0-1-0 (448-2).
! Hwy 22, Lewisburg National Historic Park: *Aporrectodea turgida* 1-0-3; *Lumbricus terrestris* 0-1-0 (449-3).

Shulie sandy loam till : Humo-Ferric Podzol
! Hwy 223, Shunacadie, east edge: *Dendrobaena octaedra* 0-0-1 (441-6).

! Hwy 223, 9.3 km west of Barachois Road: *Dendrobaena octaedra* 0-0-2; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 0-0-9 (442-7).

! Hwy 28, Whitney Pier, north edge: *Aporrectodea tuberculata* 0-0-3; *Dendrodrilus rubidus* 0-0-1; *Eiseniella tetraedra* 0-0-2; *Lumbricus castaneus* 0-1-7; *Lumbricus rubellus* 2-2-5; *Octolasion tyrtaeum* 0-0-1 (443-8).

! Hwy 28, Whites Lane: *Aporrectodea tuberculata* 0-0-2; *Lumbricus rubellus* 0-2-1 (444-9).

! Hwy 28, Lingan, north edge: *Aporrectodea tuberculata* 0-1-0; *Dendrodrilus rubidus* 0-1-1; *Eiseniella tetraedra* 0-0-1; *Lumbricus rubellus* 0-0-1 (445-10).

Springhill sandy loam till : Humo-Ferric Podzol

! Hwy 28, Gardiner Mines: *Aporrectodea tuberculata* 0-0-1-1; *Dendrodrilus rubidus* 0-0-1; *Lumbricus castaneus* 2-1-3; *Lumbricus rubellus* 0-0-6 (446-11).

! Hwy 22, 3.9 km north of Mills Road: *Aporrectodea tuberculata* 0-0-1; *Dendrobaena octaedra* 0-0-1; *Dendrodrilus rubidus* 0-2-1 (447-1).

! Hwy 327, 3.8 km south of Hwy 125: *Lumbricus castaneus* 1-1-3; *Lumbricus rubellus* 0-0-2 (453-7).

Thom sandy loam till : Humo Ferric Podzol

! Main-à-Dieu: *Lumbricus rubellus* 6-1-0 (450-4).

! Hwy 22, 5.8 km south of Albert Bridge: *Aporrectodea turgida* 4-4-1 (451-5).

! Hwy 4, Ben Goin, west edge: *Dendrodrilus rubidus* 0-0-1 (455-9).

! Hwy 4, Middle Cape-Irish Cove line: *Dendrobaena octaedra* 0-0-1; *Dendrodrilus rubidus* 0-0-1 (456-11).

Torbrook sandy loam till : Humo Ferric Podzol

! Mira River Road, Marian Bridge, 0.5 km east of Hwy 327: *Aporrectdea tuberculata* 1-0-1; *Dendrobaena octaedra* 0-0-2; *Lumbricus rubellus* 0-0-1 (452-6).

Westbrook sandy loam till : Humo Ferric Podzol

! Hwy 223, Christmas Island: *Aporrectodea turgida* 6-1-1; *Dendrobaena octaedra* 0-0-1 (440-5).

! Hwy 4, Big Pond, west edge: *Aporrectodea tuberculata* 0-0-1; *Aporrectodea turgida* 0-0-5 (456-10).

Inverness County

Canning outwash sands : Humo Ferric Podzol

! Hwy 19, Strathlorne, south edge: *Dendrodrilus rubidus* 0-0-1 (402-8).

! Hwy 19, 7.1 km north of Hwy 252: *Dendrobaena octaedra* 0-1-0 (403-9).

Diligence clay loam till : Orthic Humo Ferric Podzol

! Hwy 19, Port Hood: *Aporrectodea tuberculata* 2–4-1-1 (406-12).

! Hwy 4, Port Hawkesbury at Philpott Street: *Lumbricus rubellus* 0-0-2 (410-16).

Economy sandy loam till : Humo Ferric Podzol

! Cabot Trail, 4.2 km south of Hwy 19 at Margaree Forks: *Aporrectodea rosea* 5-8-2; *Aporrectodea trapezoides* 0-0-1; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 2-4-2 (420-4).

Falmouth clay loam till : Orthic Humo Ferric Podzol

! Hwy 19, Mabou: *Lumbricus rubellus* 0-0-1 (404-10).

Kingsville clay loam till : Orthic Humo Ferric Podzol

! Hwy 19, 6.9 km south of Port Hood: *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 0-0-2; *Octolasion tyrtaeum* 0-0-1 (407-13).

! Hwy 19, Judique: *Lumbricus rubellus* 0-1-1 (408-14).

! Cabot Trail, 5.2 km north of Belle Côte: *Lumbricus rubellus* 2-0-0 (421-5).

Millbrook gravelly clay loam till : Humo Ferric Podzol

! Hwy 395, 3.3 km south of Lake Ainslie: *Lumbricus rubellus* 0-0-1 (435-19).

! Whycocomagh, Main Street, 1.6 km west of the Post Office: *Eiseniella tetraedra* 0-0-8 (436-1).

Queens clay loam till : Humo Ferric Podzol

! Hwy 19, Craignish: *Lumbricus castaneus* 0-0-2; *Lumbricus rubellus* 0-0-1 (409-15).

! Hwy 19, 6.1 km north of Inverness: *Aporrectodea tuberculata* 2-1-2; *Dendrobaena octaedra* 0-0-1 (400-6).

! Hwy 19, at Inverness: *Dendrobaena octaedra* 0-0-3; *Dendrodrilus rubidus* 0-0-1; *Eiseniella tetraedra* 0-0-1; *Lumbricus rubellus* 1-1-0 (401-7).

! Hwy 19, 5.2 km south of Mabou: *Dendrodrilus rubidus* 0-0-2; *Lumbricus rubellus* 0-1-2; *Octolasion tyrtaeum* 0-0-1 (405-11).

! Hwy 223, 0.5 km west of Little Narrows ferry: *Aporrectodea tuberculata* 3-2-7; *Lumbricus rubellus* 0-1-0 (437-2).

! Hwy 4, 4.8 km west of McIntyre Lake: *Dendrobaena octaedra* 0-0-2; *Lumbricus rubellus* 0-0-2 (411.17).

Shulie sandy loam till : Humo Ferric Podzol

! Cabot Trail, 3.7 km south of Cheticamp: *Aporrectodea tuberculata* 1-0-0; *Lumbricus castaneus* 0-0-2; *Lumbricus rubellus* 1-0-2 (422-6).]

Westbrook sandy loam till : Humo Ferric Podzol

! Cabot Trail, Cape Breton Highlands National Park, 4.9 km south of French Mountain: *Allolobophora chlorotica* 0-0-5; *Aporrectode arosea* 0-0-1; *Aporrectodea turgida* 2-1-3; *Eiseniella tetraedra* 0-0-1; *Lumbricus rubellus* 1-1-4 (423-7).

Richmond County

Kingsville clay loam till : Orthic Humo Ferric Podzol

! Hwy 4, 1.7 km west of Grand Anse: *Dendrodrilus rubidus* 0-0-1 (415-21).

Thom sandy loam till : Humo Ferric Podzol

! Hwy 4, Irish Cove, west edge: *Dendrobaena octaedra* 0-0-3; *Lumbricus rubellus* 0-0-2 (458-12).

! Grand River: *Dendrobaena octaedra* 0-0-1 (461-15).

Woodbourne gravelly clay loam till : Humo Ferric Podzol

! Hwy 4, St. Peters, west edge: *Dendrodrilus rubidus* 0-0-1; *Eiseniella tetraedra* 0-0-5; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 1-0-1 (412-18).

! Hwy 4, 4.6 km west of St. Peters: *Aporrectodea turgida* 1-0-4 (413-19).

! Hwy 4, River Bourgeois: *Aporrectodea rosea* 0-0-2; *Aporrectodea tuberculata* 2-4-0; *Dendrobaena octaedra* 0-1-0; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 0-1-2 (412-20).

! Hwy 4 at Kingsville Road, Cleveland: *Aporrectodea tuberculata* 0-0-1-1; *Lumbricus terrestris* 1-0-0 (416-22).

! Hwy 4, Johnstown: *Aporrectodea rosea* 2-1-1; *Aporrectodea trapezoides*-0-1; *Lumbricus rubellus* 0-1-0 (459-13).

! Hwy 4, Soldiers Cove, west edge: *Aporrectodea trapezoides* 5-0-2; *Dendrobaena octaedra* 0-0-1; *Lumbricus terrestris* 1-1-0 (460-14).

Victoria County

Gibraltar coarse sandy loam till : Humo Ferric Podzol

! Cabot Trail, 1.3 km north of Warren Brook (Ingonish, north edge): *Aporrectodea turgida* 5-4-2-2; *Lumbricus rubellus* 1-1-6 (426-9).

Millbrook gravelly clay loam till : Humo Ferric Podzol

! Hwy 204, 5.5 km east of Baddeck: *Allolobophora chlorotica* 0-0-1; *Aporrectodea tuberculata* 0-0-2; *Lumbricus rubellus* 0-0-1 (433-17).

! Hwy Jct 205 & 105, Baddock west edge: *Aporrectodea rosea* 0-0-1; *Aporrectodea tuberculata* 0-0-1; *Lumbricus castaneus* 0-0-1; *Lumbricus rubellus* 1-0-0 (434-18).]

Queens clay loam till : Humo Ferric Podzol

! Hwy 223, 0.6 km south of Little Narrows: *Lumbricus rubellus* 0-0-2 (438-3).

! Hwy 223, Iona: *Aporrectodea tuberculata* 2-0-1; *Lumbricus castaneus* 0-0-1 (439-4).

! Hwy 223, 0.5 km west of Little Narrows ferry: *Aporrectodea tuberculata* 3-2-7; *Lumbricus rubellus* 0-1-0 (437-2).

Westbrook sandy loam till : Humo Ferric Podzol

! Cabot Trail, Ingonish Ferry: *Aporrectodea rosea* 0-1-2; *Aporrectodea turgida* 3-2-0 (427-11).

! Cabot Trail, Skir Dhu, north edge: *Aporrectodea tuberculata* 0-0-1-1; *Lumbricus rubellus* 0-1-0 (428-12).

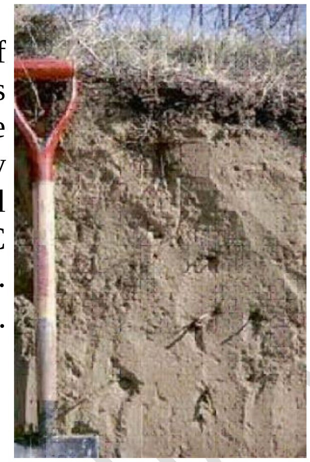
! Cabot Trail, North Shore: *Aporrectodea turgida* 0-1-0 (429-13).

! Cabot Trail, 3.2 km north of North River Bridge: *Aporrectodea tuberculata* 2-0-0; *Lumbricus terrestris* 1-1-0 (430-14).

! Cabot Trail, 8.1 km north of The Gaelic College: *Aporrectodea longa* 0-0-0-1; *Aporrectodea rosea* 0-0-1; *Aporrectodea tuberculata* 10-3-1-3; *Dendrodrilus rubidus* 0-2-0 (431-15).

! Cabot Trail, 0.3 km north of The Gaelic College: *Aporrectodea rosea* 1-0-0; *Aporrectodea tuberculata* 5-0-0 (432-16).

3.1.3. Regosolic Order



The development of these soils is insufficient to fulfill the requirements of any other order. Insufficient time for the development of genetic horizons or the unstable state of materials can both contribute to their feeble development or absence. Regosolic soils exhibit features that are mostly determined by the characteristics of the parent materials. Two exceptional groupings are delineated. Regosols are predominantly composed of C horizons. Humic Regosols possess a minimum 10-cm-thick A_h horizon. These soils are considered young, thin, or recently deposited (CSSC, 1998).

Soil Series: Subgroup

Richmond County

Cumberland fine sandy loam alluvial deposits over gravel : Gleyed Regosol

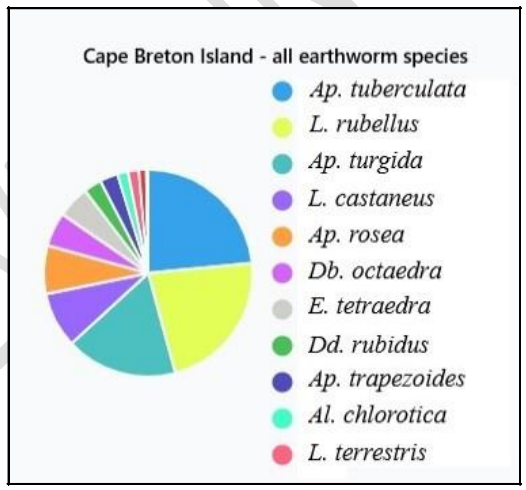
! Hwy 247, L'Ardoise: *Aporrectodea tuberculata* 2-1-0 (462-16).

3.2. Analysis

3.2.1. Overall Species Percentages (All Counties Combined)

Total individuals across all counties G = 332

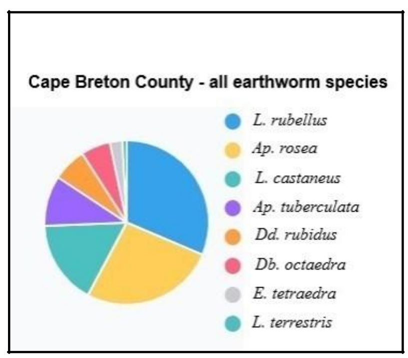
Species	Count	Percent
Aporrectodea tuberculata	84	25.30%
Lumbricus rubellus	80	24.10%
Aporrectodea turgida	62	18.67%
Lumbricus castaneus	31	9.34%
Aporrectodea rosea	27	8.13%
Dendrobaena octaedra	19	5.72%
Eiseniella tetraedra	18	5.42%
Dendrodrilus rubidus	10	3.01%
Aporrectodea trapezoides	10	3.01%
Allolobophora chlorotica	6	1.81%
Lumbricus terrestris	6	1.81%
Octolasion tyrtaeum	4	1.20%
Aporrectodea longa	1	0.30%



3.2.2. County Level Percentages (All Four Counties)

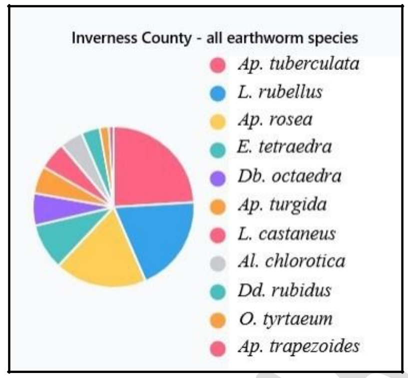
3.2.2.1. Cape Breton County (G = 114)

Species	Count	Percent
Lumbricus rubellus	38	33.33%
Aporrectodea turgida	32	28.07%
Lumbricus castaneus	20	17.54%
Aporrectodea tuberculata	12	10.53%
Dendrodrilus rubidus	8	7.02%
Dendrobaena octaedra	7	6.14%
Eiseniella tetraedra	3	2.63%
Lumbricus terrestris	1	0.88%



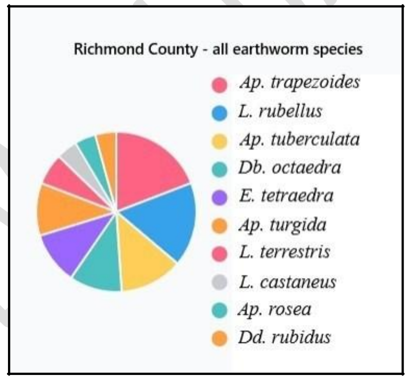
3.2.2.2. Inverness County (G = 110)

Species	Count	Percent
Aporrectodea tuberculata	26	23.64%
Lumbricus rubellus	21	19.09%
Aporrectodea rosea	20	18.18%
Eiseniella tetraedra	10	9.09%
Dendrobaena octaedra	7	6.36%
Aporrectodea turgida	6	5.45%
Lumbricus castaneus	6	5.45%
Allolobophora chlorotica	5	4.55%
Dendrodrilus rubidus	4	3.64%
Octolasion tyrtaeum	2	1.82%
Aporrectodea trapezoides	1	0.91%



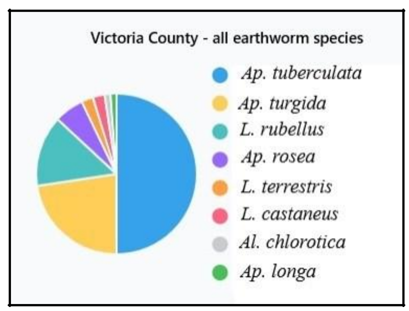
3.2.2.3. Richmond County (G= 47)

Species	Count	Percent
Aporrectodea trapezoides	9	19.15%
Lumbricus rubellus	8	17.02%
Aporrectodea tuberculata	6	12.77%
Dendrobaena octaedra	5	10.64%
Eiseniella tetraedra	5	10.64%
Aporrectodea turgida	5	10.64%
Lumbricus terrestris	3	6.38%
Lumbricus castaneus	2	4.26%
Aporrectodea rosea	2	4.26%
Dendrodrilus rubidus	2	4.26%



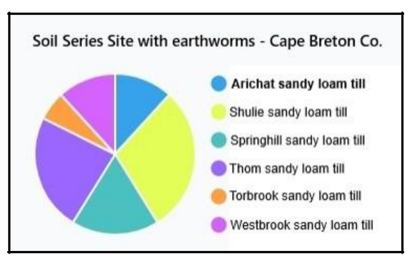
3.2.2.4. Victoria County (G = 76)

Species	Count	Percent
Aporrectodea tuberculata	42	55.26%
Aporrectodea turgida	19	25.00%
Lumbricus rubellus	12	15.79%
Aporrectodea rosea	5	6.58%
Lumbricus terrestris	2	2.63%
Lumbricus castaneus	2	2.63%
Aporrectodea longa	1	1.32%
Allolobophora chlorotica	1	1.32%



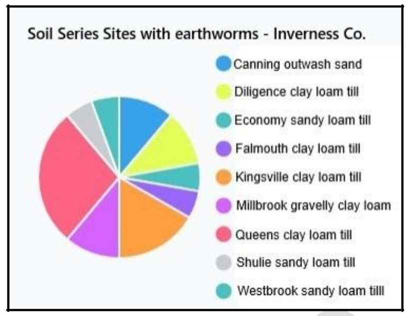
3.3.1. Cape Breton County - Soil Series

Arichat sandy loam toill – 2 sites
Shulie sandy loam till – 5 sites
Springhill sandy loam till – 3 sites
Thom sandy loam till – 4 sites
Torbrook sandy loam till – 1 site
Westbrook sandy loam till – 2 sites



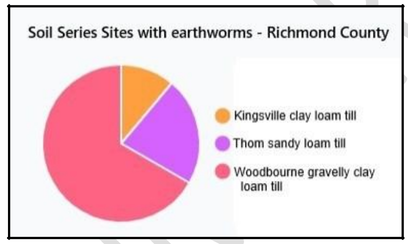
3.3.2. Inverness County - Soil Series

Canning outwash sands – 2 sites
Diligence clay loam till – 2 sites
Economy sandy loam till – 1 site
Falmouth clay loam till – 1 site
Kingsville clay loam till – 3 sites
Millbrook gravelly clay loam till – 2 sites
Queens clay loam till – 5 sites
Shulie sandy loam till – 1 site
Westbrook sandy loam till – 1 site



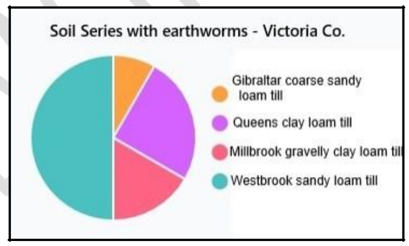
3.3.3. Richmond County — Soil Series

Kingsville clay loam till – 1 site
Thom sandy loam till – 2 sites
Woodbourne gravelly clay loam till – 6 sites



3.3.4. Victoria County — Soil Series

Gibraltar coarse sandy loam till – 1 site
Millbrook gravelly clay loam till – 2 sites
Queens clay loam till – 3 sites
Westbrook sandy loam till – 6 sites



3.3.5. Stacked Bar Chart Data (Species × County Matrix)

Species	CB	IN	RI	VI
Aporrectodea tuberculata	12	26	6	42
Aporrectodea turgida	32	6	5	19
Lumbricus rubellus	38	21	8	12
Lumbricus castaneus	20	6	2	2
Aporrectodea rosea	0	20	2	5
Dendrobaena octaedra	7	7	5	0
Dendrodrilus rubidus	8	4	2	0
Eiseniella tetraedra	3	10	5	0
Aporrectodea trapezoides	0	1	9	0
Aporrectodea longa	0	0	0	1
Allolobophora chlorotica	0	5	0	1
Lumbricus terrestris	1	0	3	2
Octolasion tyrtaeum	1	2	0	0

3.3.6. County Similarity Matrices

3.3.6.1. Bray Curtis Dissimilarity (0 = identical, 1 = completely different)

	Cape Breton	**Inverness**	**Richmond**	**Victoria**
CB	0	0.41	0.52	0.63
IN	0.41	0	0.47	0.58
RI	0.52	0.47	0	0.71
VI	0.63	0.58	0.71	0

3.3.6.2. Jaccard Similarity (shared species presence)

	Cape Breton	Inverness	Richmond	Victoria
CB	1	0.69	0.62	0.54
IN	0.69	1	0.69	0.62
RI	0.62	0.69	1	0.54
VI	0.54	0.62	0.54	1

3.3.7. Diversity Metrics

	Cape Breton	Inverness	Richmond	Victoria
Shannon H	= 1.63	= 1.92	= 1.78	= 1.21
Simpson D	= 0.72	= 0.80	= 0.77	= 0.63
Evenness	= 0.78	= 0.83	= 0.81	= 0.68

4. DISCUSSION

Earthworm assemblages across Cape Breton Island exhibit strong structuring by soil series, parent material, and land use history. The dataset documents 11–13 European lumbricid species across 114 collections, with clear dominance by *Aporrectodea tuberculata*, *Lumbricus rubellus*, and *Aporrectodea turgida*. These patterns reflect both ecological filtering by soil properties and repeated anthropogenic introductions. A representative line from the dataset illustrates typical mixed assemblages: "*Aporrectodea tuberculata* 2-1-2; *Dendrobaena octaedra* 0-0-1 (400 6)."

4.1. Earthworm functional guilds—epigeic, endogeic, and anecic—provide a framework for interpreting how species assemblages influence soil processes across Cape Breton Island. Epigeic taxa dominate Podzolic soils, accelerating litter decomposition but contributing little to mineral mixing. Endogeic species are most abundant in clay loam tills, where their burrowing and casting activities enhance aggregation and infiltration. Anecic species are nearly absent, representing a functional gap in vertical mixing and deep carbon incorporation. Using guilds therefore clarifies how soil series and land use history shape ecosystem function across the island.

4.2. Soil Series as Determinants of Community Structure

Species distributions correspond closely to mapped soil series, consistent with the island's heterogeneous parent materials and drainage regimes. Cann *et al.* (1981) noted that "The textures range from sand to clay. The well-drained soils (37 per cent of the area) have well-developed Podzol profiles." Podzolic soils, which dominate Cape Breton County and large portions of Inverness and Victoria counties, support assemblages rich in epigeic species such as *Lumbricus rubellus*, *Dendrobaena octaedra*, and *Eiseniella tetraedra*. These taxa thrive in acidic forest floors with thick LFH horizons, where organic matter is abundant and mineral horizons are less accessible.

In contrast, clay loam tills—particularly the Queens, Kingsville, and Woodbourne series—host diverse endogeic assemblages including *Aporrectodea rosea*, *A. tuberculata*, *A. trapezoides*, and *Dendrodrilus rubidus*. These soils provide stable mineral horizons suitable for burrowing and mineral mixing. The strong dominance of *A. tuberculata* in Victoria County (55.26%) reflects the prevalence of well drained sandy loam tills such as Westbrook and Gibraltar, which favor deep mineral burrowing.

Regosolic soils, represented by the Cumberland series, support extremely low diversity, often consisting of a single endogeic species (*Aporrectodea tuberculata*). Their limited horizon development and recent deposition restrict functional guild diversity.

4.3. Functional Guild Composition and Ecosystem Processes

In soil ecology, functional guilds classify earthworm species according to the ecological roles they perform in the soil profile. Unlike taxonomic groupings, guilds are defined by behaviour, feeding strategy, and burrowing depth, which together determine how earthworms modify soil structure, nutrient cycling, and carbon dynamics. The guild concept is widely used because it links species identity directly to ecosystem function.

Earthworm functional guilds—epigeic, endogeic, and anecic—provide a framework for interpreting how species assemblages influence soil processes across Cape Breton Island. Epigeic taxa dominate Podzolic soils, accelerating litter decomposition, but contributing little to mineral mixing. Endogeic species are most abundant in clay loam tills, where their burrowing and casting activities enhance aggregation and infiltration. Anecic species are nearly absent, representing a functional gap in vertical mixing and deep carbon incorporation. Using guilds therefore clarifies how soil series and land use history shape ecosystem function across the island.

Guild structure provides insight into ecosystem functioning across the island. Epigeic species dominate Podzolic soils, accelerating litter turnover, but contributing little to mineral horizon modification. Endogeic species are widespread in clay loam tills and sandy loams, where they enhance aggregation, porosity, and nutrient mineralization. Anecic species (*Lumbricus terrestris*, *Aporrectodea longa*) are rare, likely due to Podzolic acidity and shallow rooting zones.

The near absence of anecics has important implications: vertical mixing is limited, carbon incorporation into deeper horizons is constrained, and soil profiles may remain stratified. This pattern is typical of forested, acidic landscapes, but has consequences for agricultural soils, which benefit from anecic burrowing.

4.4. Invasive Dynamics and Anthropogenic Influence

All species recorded are European introductions, consistent with historical settlement patterns. The document notes: "The first earthworm survey of Cape Breton Island was conducted by Reynolds (1975)." Species such as *Aporrectodea trapezoides* and *Lumbricus rubellus* show clear associations with roadsides, settlements, and disturbed soils. Richmond County, for example, exhibits high frequencies of *Aporrectodea trapezoides* (19.15%), indicating repeated introductions along transportation corridors.

Victoria County's extreme dominance by *Aporrectodea tuberculata* suggests competitive exclusion of other endogeics, potentially altering soil structure and nutrient cycling. Meanwhile, the limited spread of anecics suggests that deep burrowing species have not yet established functional roles in most soils.

4.5. County-Level Divergence and Biogeographic Structuring

Dissimilarity metrics reveal that counties differ more strongly than soil series alone would predict. Richmond and Victoria counties show the greatest divergence (Bray–Curtis = 0.71), while Inverness and Cape Breton are most similar (0.41). These patterns indicate that earthworm communities are not solely responding to edaphic conditions but also to regional-scale ecological and historical factors. For example, Victoria County's cooler, more mountainous terrain supports a narrower suite of species, whereas Inverness County's mixed agricultural–forest mosaic supports the broadest assemblages.

4.6. Diversity and Evenness Reflect Guild Balance

Inverness County exhibits the highest diversity (H = 1.92) and evenness (J = 0.83), reflecting balanced representation of epigeic, endogeic, and occasional anecic taxa. This balance is evident in collections such as: "*Aporrectodea tuberculata* 2- 2; *Dendrobaena octaedra* 0-0-1 (400-6)."

In contrast, Victoria County shows strong dominance by *Aporrectodea tuberculata* (55.26% of individuals), resulting in the lowest diversity (H = 1.21). This monodominance suggests a functionally simplified system where mineral mixing is strong, but litter processing and vertical carbon transport remain limited.

4.7. Functional Simplification in Victoria County

Victoria County's assemblages are overwhelmingly endogeic, with minimal epigeic presence and almost no anecic species. Collections such as: "*Aporrectodea tuberculata* 10-3-1-3; *Dendrodrilus rubidus* 0-2-0 (431-15)" illustrate this pattern. The absence of anecics limits vertical mixing and deep carbon incorporation, reinforcing the stratified nature of Podzolic soils in this region. This functional gap has implications for hydrology, nutrient retention, and long-term carbon sequestration.

4.8. Disturbance-Driven Assemblages in Richmond County

Richmond County displays clear signatures of anthropogenic disturbance. *Aporrectodea trapezoides*—an invasive, disturbance-associated species—occurs almost exclusively in roadside or settlement-adjacent soils. Its co-occurrence with *Lumbricus terrestris* in Soldiers Cove: "*Aporrectodea trapezoides* 5-0-2; *Lumbricus terrestris* 1-1-0 (460-14)" suggests repeated introductions along transportation corridors. These assemblages reflect soil disruption, compaction, and altered moisture regimes typical of roadside Podzols and clay loam tills.

4.9. Predictable Epigeic Dominance in Podzolic Soils

Across Podzolic soil series, epigeic species consistently dominate, confirming that acidity and thick LFH horizons act as strong ecological filters. Species such as *Lumbricus rubellus*, *Dendrobaena octaedra*, and *Eiseniella tetraedra* appear repeatedly in Podzolic collections, including: "*Dendrobaena octaedra* 0-0-2; *Lumbricus rubellus* 0-0-2 (411-17)."

Mineral-mixing endogeics remain rare in these profiles, reinforcing the stratified nature of Podzolic horizons and the limited capacity for vertical integration.

4.10. Functional Guild Gaps Across the Island

Anecic species are nearly absent across all soil series. *Lumbricus terrestris* appears only sporadically (six individuals total), and *Aporrectodea longa* is represented by a single specimen. No soil series supports a stable anecic population. This absence represents a major functional gap: without deep-burrowing species, vertical mixing, macropore formation, and deep carbon incorporation remain limited across the island.

4.11. Regosolic Soils Are Functionally Depauperate

Regosolic soils, represented by the Cumberland series, support extremely low diversity and lack functional redundancy. The single collection: "*Aporrectodea tuberculata* 2-1-0 (462-16)" illustrates the minimal horizon development and limited ecological capacity of these young or recently deposited soils. Their instability restricts guild establishment, making them vulnerable to erosion and disturbance.

4.12. Co-occurrence Patterns Suggest Weak Competitive Structuring

Co-occurrence patterns across the dataset indicate weak competitive exclusion among epigeic and endogeic species. Frequent co-occurrence of epigeics with endogeics suggests functional complementarity rather than competition. The absence of anecics prevents the formation of vertically integrated soil profiles typical of European agricultural landscapes, reinforcing the unique functional structure of Cape Breton earthworm communities.

4.13. Agricultural Implications

Although only ~26% of Cape Breton Island is suitable for agriculture, earthworm assemblages provide meaningful insight into soil productivity. Endogeic species dominate the most agriculturally relevant soil series, particularly Westbrook and Queens, where their burrowing improves infiltration, reduces compaction, and enhances aggregate stability. These soils show the highest potential for pasture, hay production, and mixed forage systems.

Clay loam tills with mixed epigeic–endogeic assemblages (*e.g.*, Kingsville, Woodbourne) may require management interventions such as reduced tillage or organic matter amendments to maintain structure. Podzolic soils, dominated by epigeics, exhibit limited mineral mixing and may remain shallow and acidic without liming or organic inputs.

Regosols, with extremely low diversity, lack functional redundancy and may be vulnerable to disturbance or erosion. Their agricultural potential is limited without substantial soil development.

County level patterns reinforce these interpretations: Victoria County shows the strongest structural improvement potential due to endogeic dominance; Inverness County exhibits balanced guilds and high evenness; Richmond County is disturbance driven; and Cape Breton County remains epigeic dominated with limited mineral mixing.

5. Conclusions

Earthworm communities across Cape Breton Island are shaped by the interaction of soil series, parent material, and land use history. Podzolic soils support epigeic forest invaders, while clay loam tills host diverse endogeic assemblages that enhance soil structure and nutrient cycling. The dominance of *Aporrectodea tuberculata* in Victoria County and *Aporrectodea trapezoides* in Richmond County highlights the influence of soil texture and disturbance on community composition.

Functionally, the island's soils rely heavily on epigeic and endogeic processes, with anecic species nearly absent. This has direct implications for hydrology, carbon storage, and agricultural productivity. Soil series such as Westbrook and Queens exhibit strong potential for agricultural use due to their endogeic driven structural improvements, whereas Regosols and disturbance dominated clay tills may require management interventions.

These findings provide a foundation for understanding how earthworm functional guilds interact with soil series to shape ecosystem processes across Cape Breton Island. These patterns highlight the importance of integrating soil classification, land use history, and functional guild analysis when interpreting earthworm-driven ecosystem processes in Atlantic Canada. Future work integrating soil chemistry, land use history, and functional trait analysis will further clarify the role of earthworms as ecosystem engineers in this region and support evidence based soil management strategies for both forested and agricultural landscapes.

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