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Spatial, Geographical, Climatic, and Edaphic Influences on Moss Community Structure: A Case Study from Qinhuangdao, China

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Abstract: In the realms of ecology and biogeography, the interaction between biodiversity and environmental factors is a critical area of research. This intersection highlights how biological communities, especially among groups like bryophytes, are influenced and shaped by their surrounding environmental conditions. This study presents a pioneering investigation into the diversity and community structure of mosses in Qinhuangdao, Hubei Province, China, a region marked by its diverse topography and climate. Employing extensive field surveys across 30 plots, we gathered and analyzed the relationship between moss species distribution and environmental variables, including topographical, climatic, and soil factors. Utilizing a range of analytical techniques, such as cluster analysis, canonical correspondence analysis (CCA), and partial least squares path modeling (PLS-PM), we characterized the intricate relationships between moss biodiversity and environmental gradients. The research has documented 84 species distributed among 36 genera and 13 families. Solar radiation has a great impact on moss diversity. There were significant differences between Form. *Entodon compressus* and Form. *Plagiobryum demissum*. Climate has a great impact on the community structure of mosses. Geographical factors were also identified as key secondary influences, affecting moss community structures both directly and indirectly by creating suitable microenvironments and influencing climate and soil properties. Additionally, the study highlights the indirect impact of spatial factors on these environmental variables, which in turn shape the structure of biological communities. The findings indicate that the annual temperature range is a key factor influencing the distribution and formation of moss community structures. The findings provide new insights into the ecological adaptation of mosses in diverse environmental settings and lay a crucial foundation for biodiversity conservation and ecosystem management in the Qinhuangdao area.

Keywords: moss; richness; community; climate; Qinhuangdao

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1. Introduction

Biodiversity, serving as a fundamental pillar for the functionality and stability of Earth's ecosystems, showcases the diversity and complexity of life's unique evolutionary journey on the planet [1]. At the intersection of ecology and biogeography, the interplay between biodiversity and the environment has always been a focal point of research, revealing how biological communities adapt to, influence, and are shaped by their surrounding environments [2].

Bryophytes play a crucial role in Earth's ecosystems, enriching plant diversity and significantly impacting the hydrological and carbon cycles [3]. As one of the oldest terrestrial plants, bryophytes demonstrate unique survival strategies in adapting to land environments. Unlike other embryophytes, their characteristics include small size and reliance on ectohydric (external water conduction) rather than internal water-conducting cells [4]. Their high dependence on moisture and specialized physiological structures enable them to thrive in extreme conditions, resulting in their distribution across various ecosystems globally [5].

Topographical features such as mountain ranges, valleys, and various types of landforms not only directly influence the ecological niches and resources available to bryophytes but also indirectly shape their growth and distribution by affecting environmental conditions like light intensity, moisture retention, and soil characteristics [6]. For instance, the shading effect of mountains and the moist conditions of valleys can create microenvironments conducive to the growth of mosses [7]. Additionally, the slope and orientation of different terrains determine the extent and duration of sunlight exposure for bryophytes, thereby affecting their photosynthetic efficiency and growth patterns [8,9].

Climate factors, particularly temperature and humidity, have been proven to be key determinants affecting the diversity and distribution of bryophytes [10,11]. Climatic variables such as temperature and humidity directly influence physiological processes in mosses, such as photosynthesis, water absorption, and nutrient exchange, thereby determining their survival and reproductive capabilities [12]. For instance, fluctuations in temperature can affect the metabolic activities and seasonal growth patterns of moss plants, while changes in humidity can impact their water-use efficiency and drought adaptability [13].

Soil, as a dynamic and complex medium, provides more than just a physical substrate for mosses [14]. It plays a pivotal role in determining the availability of nutrients and water, factors that are crucial for the metabolic activities and physiological well-being of these non-vascular plants [15,16]. The intricate interplay between soil properties and moss physiology is evident in the varied responses of these plants to different soil types. For example, the nutrient-rich, well-draining qualities of certain soils can enhance moss growth, whereas compact, nutrient-poor soils may limit their spread [17,18].

Furthermore, the soil pH significantly influences moss species distributions, with certain species exhibiting a preference for either acidic or alkaline conditions [19]. This preference is often linked to the mosses' tolerance to metal ions and other soil-borne chemicals, which vary with pH. Additionally, soil moisture—a variable heavily influenced by both intrinsic soil properties and external climatic factors—is a critical determinant of moss survival and distribution, given these plants' limited water-retention mechanisms [20].

Taken together, studies into mosses, with their unique ecological adaptations, provide insights into the complexity of terrestrial ecosystems. We focus on understanding their unique ecological adaptations and the impact of external environmental factors like topography, climate, and soil conditions. This approach aims to unravel the complex interdependencies within these ecosystems. We delineate three primary research objectives: (1) How does moss diversity vary across community form? (2) Which specific ecological mechanisms are instrumental in determining the moss community? (3) What are the key environmental variables that are instrumental to shaping the moss communities in this region?

2. Materials and Methods

2.1. Study Area

Qinhuangdao City is located in the northeastern part of Hebei Province, China. Its geographical coordinates range from 39°24′ to 40°37′ North latitude and 118°33′ to 119°51′ East longitude, with a total area of 7812.4 square kilometers. Geographically, Qinhuangdao is bordered by the Yan Mountains to the north and faces the Bohai Sea to the south. In terms of climate, Qinhuangdao has a warm–temperate, semi–humid continental monsoon climate with ample moisture [20]. The average annual precipitation is 736.3 mm, mainly concentrated from June to August. The average annual temperature is 10.1 °C, with the average temperature in January being around −5 °C and in July being 24.5 °C. The region typically has an average frost-free period of about 176 days and an annual sunshine duration of 2796 h [21]. The plant growing period usually ranges between 130 and 190 days [22]. The soil types in Qinhuangdao are diverse, including brown, sandy, and saline soils, all of which are suitable for the growth and propagation of a variety of plants.

2.2. Sampling and Identification

From June to September 2023, a detailed field survey of mosses was conducted in the Qinhuangdao area. Our survey covered diverse environments in Qinhuangdao, which included substrate habitats near coastal rivers and lakes, as well as forest and mountain ecosystems like Lianfeng, Zushan, and Tianma Mountains, spanning 30 sampling sites in total. We used three quadrats at each site, resulting in a total of ninety quadrats, to conduct a thorough survey of soil moss species. In the mountain ecosystems, we selected 6 sites (18 quadrats); in the forest ecosystems, we chose 20 sites (60 quadrats); and along the riverbanks, we established 4 sites (12 quadrats). These sampling locations effectively represent the climatic and geographical diversity of Qinhuangdao and provide ideal settings for our study.

At each site, the species of mosses on the soil substrate were investigated to research the relationship between bryophyte diversity and environment in Qinhuangdao. A sampling frame measuring 0.5 m by 0.5 m, segmented into 100 individual grids, was employed for meticulous sample collection and analysis. This method enabled precise counting and recording of the coverage of moss species. Additionally, key information such as geographical coordinates, altitude, and vegetation type of each site was meticulously recorded. All the moss specimens collected on site were air-dried and identified at the Hebei Environmental Engineering College. All specimens collected during this survey have been preserved in the Ecology Department of Hebei Environmental Engineering College and are available for subsequent research and reference.

2.3. Environmental Data

The study used an environmental plot matrix to investigate the key factors influencing biodiversity, species distribution, and community structure. Bio-climatic indicators from bio1 to bio19, as well as solar radiation, wind speed, and water vapor pressure, were obtained from the WorldClim Database [23]. Variables representing annual mean growing degree days (GDD) above a 0 °C threshold were selected [24], along with site water balance (SWB) [25]. These data were extracted from the CHELSA climate layers (resolution of 1 km). Data on potential evapotranspiration (PET) and aridity index were acquired from the CGIAR-CSI repository [26].

To clarify the relationship between soil properties and moss cover, our approach integrated detailed field observations. Simultaneously, vital soil attributes, such as nitrogen content, carbon levels, pH, soil moisture, sand content, and bulk density, were acquired from the OpenLandMap Database [27]. All soil data were characterized by a high spatial resolution of 0.5 km, providing a detailed foundation for our analysis. We downloaded the topographic wetness index (TWI) and compound topographic index (CTI) to use as geographical factors in the study (resolution of 90 m). These soil properties were systematically recorded alongside moss diversity data within each 0.5 × 0.5 m quadrat, enabling us to directly compare the distribution and diversity of moss species with the corresponding soil characteristics.

The analytical capabilities of the R language were leveraged to process and integrate environmental variables across 30 plots. To mitigate the effects of multicollinearity, one variable from each pair exhibiting an absolute correlation coefficient exceeding 0.7 ($|r| > 0.7$) was selectively retained (Figure S1). The environmental parameters retained for subsequent analyses included the compound topographic index, solar radiation, water vapor pressure, soil water, carbon content, pH, sand content, annual temperature range, and precipitation of the wettest month.

2.4. Data Analyses

Cluster analysis based on the Bray–Curtis similarity coefficient was applied to the moss coverage plot matrix to determine the existence of distinct species forms within the 30 plots. The clustering of moss communities was then performed using the ward method within cluster analysis (CA).

To assess the impact of different environmental factors on moss diversity, a linear model was used [28]. The Shannon–Wiener diversity index is employed in this study for its ability to capture both species richness and evenness, providing a detailed picture of biodiversity in relation to environmental variables. It is adept at revealing the subtleties of ecosystems and the impact of dominant species, thereby offering a comprehensive measure of biodiversity across different habitats. The study evaluated the influence of various environmental parameters, including the compound topographic index, solar radiation, water vapor pressure, soil water, carbon content, pH, sand content, annual temperature range, and precipitation of the wettest month, on the Shannon–Wiener diversity index.

Non-metric multidimensional scaling (NMDS) was employed to elucidate compositional variances among moss community forms. Following this, we enhanced the analytical clarity of our data by implementing a Hellinger transformation on the species location matrix. This approach allowed us to define a typical form representation, marked by a 95% confidence ellipse around the centroid [29]. Furthermore, to rigorously ascertain distinctions between forms, an analysis of similarity (ANOSIM) was conducted, utilizing 999 permutations and based on the Bray–Curtis distance metrics [30].

The study used canonical correspondence analysis (CCA) to understand the relationship between moss community patterns and environmental factors. During this process, pairwise distances for each environmental variable were computed. Further intricacy in the association between moss community composition, life forms, and environmental parameters was untangled using the partial Mantel test with 9999 permutations.

The study used the partial least squares path modeling (PLS-PM) approach to unravel the intricate relationships among key environmental and biological variables: geography, climate, soil properties, and moss community structure. The latent variables for geography were indicated by the compound topographic index (CTI), climate by an array of parameters including solar radiation, temperature annual range (Bio7), precipitation of the wettest month (Bio13), and site water balance (SWB), and soil properties by factors such as water content and pH. The moss community was represented through NMDS1 and NMDS2 indices [31]. The model's robustness was evaluated using the goodness of fit (GoF) index, ranging from 0.40 to 1.00 [32]. This metric validated the model's capacity to accurately represent the underlying data structure, thereby reinforcing the reliability of the inferred relationships.

3. Results

3.1. Diversity of Mosses on Environmental Gradient

According to the survey, 13 families, 36 genera, and 84 species were identified (Supplementary Materials, File S1). In the cluster analysis of the environmental factors across 30 plots in Qinhuangdao, two forms were obtained (Figure S2). Form *Entodon compressus* is a community dominated by *Entodon compressus*, *Entodon smaragdinus*, and *Plagiomnium succulentum* (Table S1). Form *Plagiobryum demissum* is a community characterized by dominant species such as *Plagiobryum demissum*, *Hyophila nymaniana*, and *Trichostomum platyphyllum*. Among these, the diversity of Form *Entodon compressus* is higher than that of Form *Plagiobryum demissum* (Figure 1).

The analysis identified solar radiation as the key environmental factor influencing moss diversity, with an effect size of 0.076 in Qinhuangdao (Figure 2). Secondary factors included water vapor pressure, the compound topographic index, and annual temperature range with effect sizes of 0.027, 0.023, and 0.020. Other factors, such as soil water content, pH, site water balance, carbon content, and sand content, exhibited smaller impacts on diversity. Moss diversity is positively correlated with solar radiation and negatively correlated with bio7 (Figure S3).

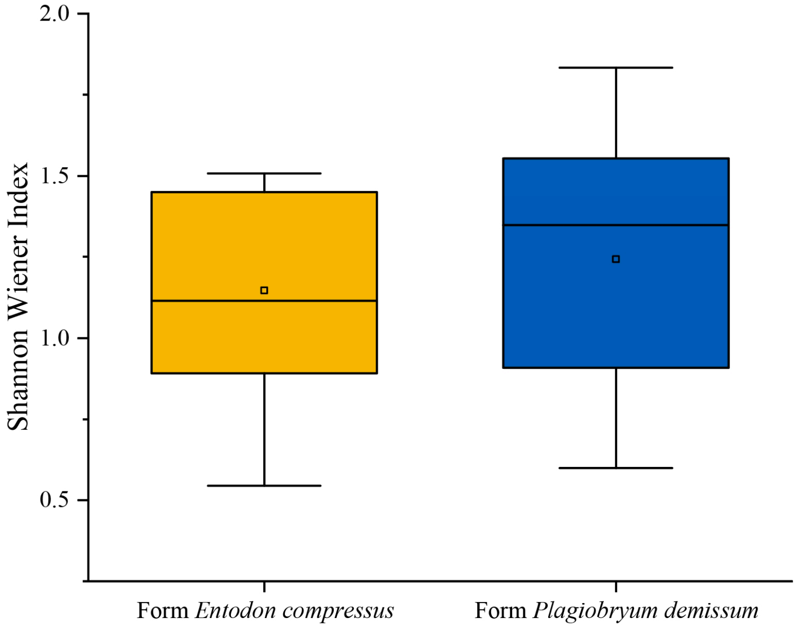

Figure 1. The moss Shannon–Wiener index of forms. The boxes represent the range of values between the third and the first quartile. The large square box in the graph represents the interquartile range (IQR), which encompasses the values between the first and third quartiles. Outliers are values that fall outside the range of 1.5 times the IQR, as denoted through the solid diamonds. Within each box, the horizontal black line represents the median, while the mean value is indicated through a hollow square.

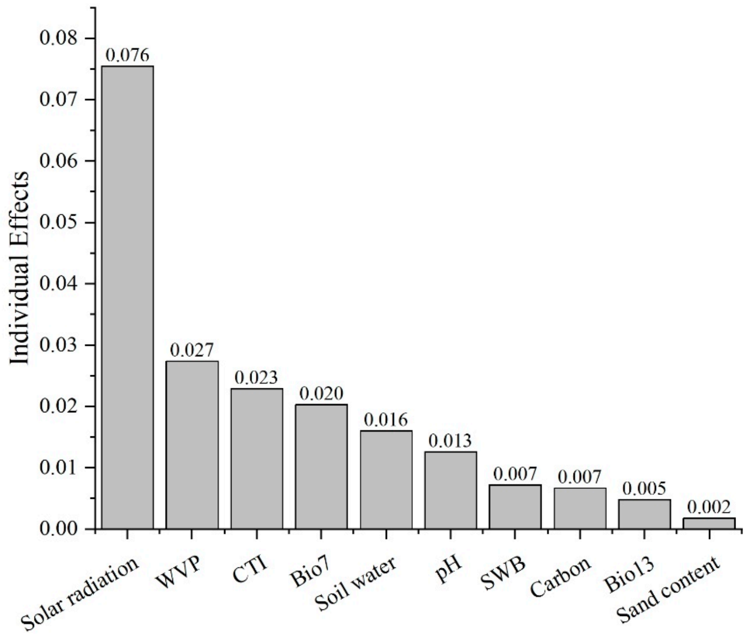

Figure 2. Impact of environmental factors on the diversity (Shannon–Weiner index) of moss. CTI, compound topographic index; WVP, water vapor pressure; SWB, site water balance; Bio7, temperature annual range; Bio13, precipitation of wettest month.

3.2. Environmental Gradients and Moss Distribution

The variation showed good representation in moss distribution across different forms (stress = 0.07, Figure 3A). There were significant differences between Form *Entodon compressus* and Form *Plagiobryum demissum* ($r = 0.124$, $p = 0.045$), confirming that the dissimilarities between forms are greater than those within forms (Figure 3B). The canonical correspondence analysis (CCA) indicates that the first two axes cumulatively explain 28.35% of the total variance, highlighting discernible distinctions across two forms (Figure 3A). Form *Entodon compressus* characteristics are suitable for growing in locations with higher soil carbon levels and higher solar radiation. However, Form *Plagiobryum demissum*, with *Trichostomum platyphyllum* as the predominant species, is correlated with higher soil pH and Bio7 (temperature annual range).

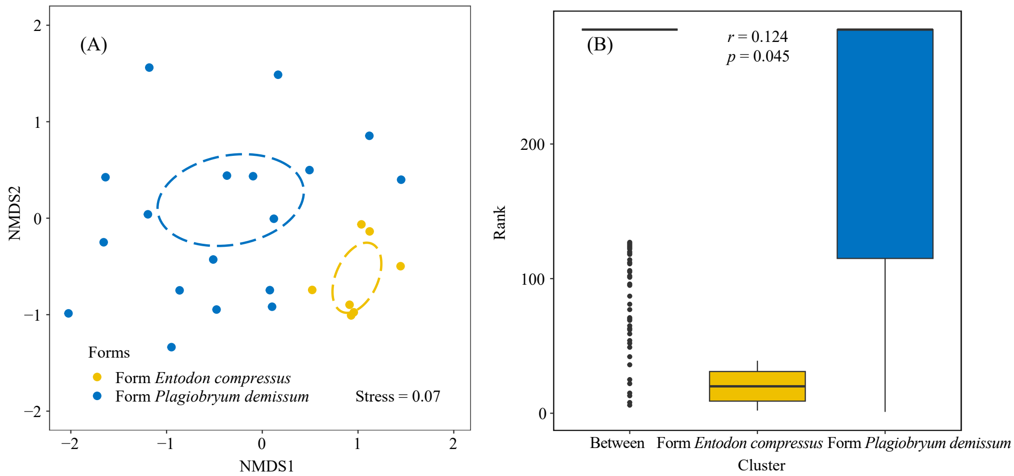

Figure 3. Variation in moss distribution across forms. (**A**) Illustration using NMDS (ordination method). Ellipses were formed around the barycenters and were significant at a 0.05 level of confidence. (**B**) Examination of differences in moss forms utilizing the Bray–Curtis similarity metric through ANOSIM. The large square box in the graph represents the interquartile range (IQR), which encompasses the values between the first and third quartiles. Outliers are values that fall outside the range of 1.5 times the IQR, as denoted through the filled dots. Within each box, the horizontal black line represents the mean value.

The analysis reveals a nuanced interplay between various environmental factors and the structure of moss communities. Climatic factors, particularly Bio7 (temperature annual range) showed significantly stronger associations (Figure 4B). This underscores the critical role of climatic variability in shaping moss communities. Solar radiation also showed significantly high correlations with community structures. This suggests that solar influences, while present, are the secondary driver. Other environmental factors showed less correlation, indicating a lesser effect on moss community structures.

3.3. Direct and Indirect Effects of Spatial, Geographical, Climatic, and Edaphic Influences on Shaping Moss Communities

PLSPM analysis revealed both direct and indirect interactions among environmental factors such as space, geography, climate, and soil, and their impact on biological communities, collectively illustrating the shape of moss communities (Figure 5).

Firstly, the spatial factor (space) had relatively minor direct impacts on other environmental factors (Figure 5B). However, through indirect pathways, space significantly influenced climate and soil. Notably, the total effect of space on climate was 0.854, indicating that spatial factors play a crucial role in shaping climatic patterns (Figure 5A).

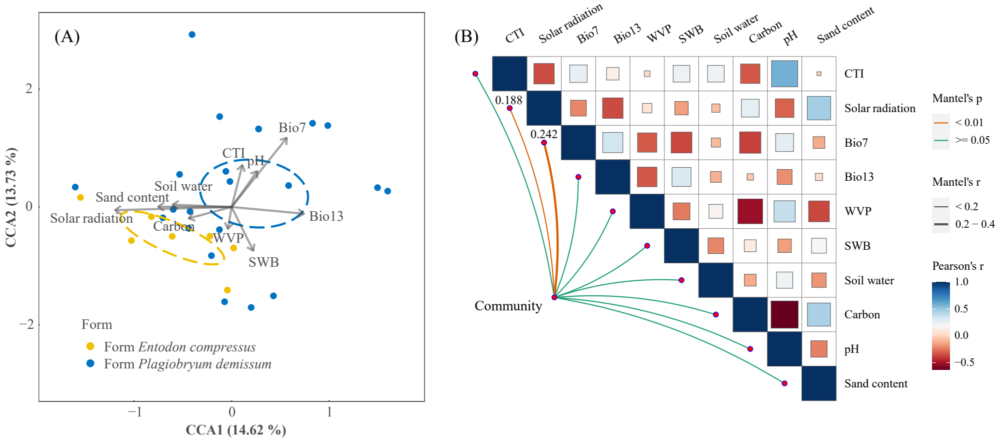

Figure 4. Influence of environmental factors on the moss communities. (**A**) CCA reveals differences across different forms. The ellipses were calculated around barycenters with a confidence level of 0.95. (**B**) A visual representation of environmental factors is presented, with different colors indicating Pearson's correlation values. The color of the boundaries represents the level of statistical significance. The thickness of the edges signifies Mantel's r. CTI, compound topographic index; WVP, water vapor pressure; SWB, site water balance; and Bio7, temperature annual range; Bio13, precipitation of wettest month.

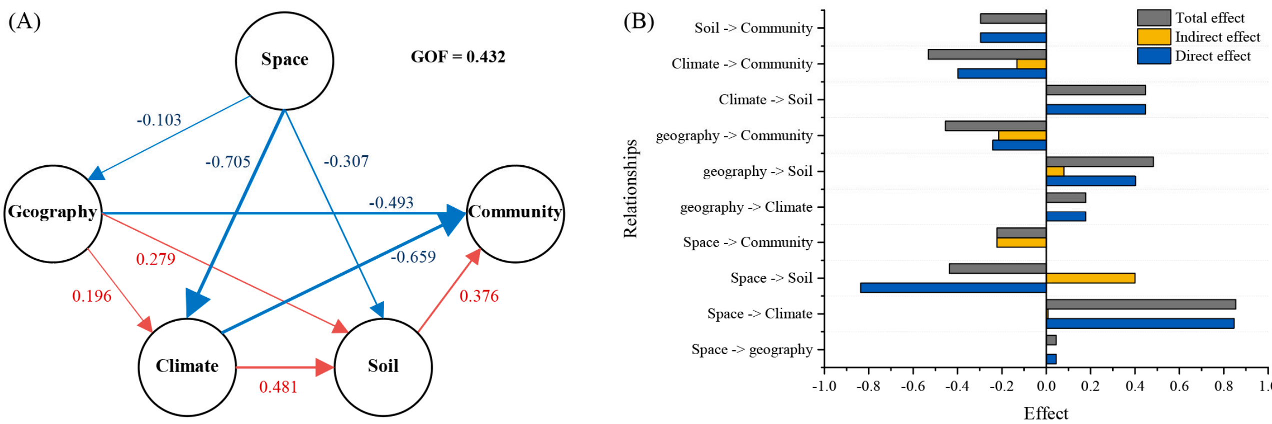

Figure 5. The direct and indirect effects of space, geography, climate, and soil on the bryophyte community based on partial least squares path modelling. (**A**) Relationships between space, geography, climate, soil, and community latent variables. (**B**) The total effect, direct effect, and indirect effect on the community. Each oval represents a latent variable (e.g., climate). The path with an arrowhead and a coefficient indicates a unidirectional causal relationship between variables, with the coefficient representing the strength and direction of this effect. Path coefficients are reflected by the widths of the arrows and the numbers next to the arrows. GOF indicates the goodness of fit. Red represents the positive effect; blue represents the negative effect.

Geographical factors (geography) directly influenced climate and soil, with a direct effect on climate of 0.178 and a total effect on soil of 0.483. These results emphasize the importance of geographic location in affecting climate and soil properties, and geographical factors affect soil properties more than climate. Geography showed a direct negative effect on community structure (−0.241). Additionally, there was a significant indirect effect (−0.214), leading to a total effect of −0.455. This suggests that geographic factors, both directly and through other mediators, significantly influence community composition.

The climatic factor (climate) had a significant direct impact on soil (effect of 0.448), demonstrating the key role of climate conditions in influencing soil properties. Additionally, climate had a substantial direct negative effect on communities (−0.399), with an additional indirect effect (−0.132). The total effect amounted to −0.531, indicating that climatic conditions are a major determinant of community structure and diversity. Soil demonstrated a direct negative effect on community structures (−0.296). This highlights the pivotal role of soil quality and characteristics in shaping the ecological community, emphasizing the direct link between soil properties and community composition.

In summary, climate has the most profound impact on the structure of biological communities, followed by geographical factors, and then soil factors. Spatial factors have the least impact on ecological communities, influencing them indirectly.

4. Discussion

4.1. The Importance of Key Climate Variability on Moss Ecology

Climatic factors have the most profound impact on biological communities because climate conditions directly determine the basic conditions necessary for the survival of these communities, such as temperature, precipitation, and interannual variations. This study reveals the significant role of climatic conditions, especially the annual temperature range (Bio7), in shaping moss ecology. Our results indicate that the structure of moss communities is closely related to the annual temperature range, echoing the findings of other studies. For instance, in one research study on Chinese moss ecosystems, it was observed that temperature fluctuations significantly affect moss distribution [33].

It is worth noting that the impact of the annual temperature range on moss communities may involve multiple mechanisms. Firstly, temperature fluctuations can directly affect physiological processes in mosses, such as photosynthesis and moisture regulation [13]. Secondly, changes in temperature may indirectly affect mosses by altering their growing environment, such as soil moisture and microbial activity [34,35]. This complex interaction pattern highlights the importance of considering multi-scale factors when predicting the impact of climate change on ecosystems.

Solar radiation is the primary environmental factor affecting moss diversity in the Qinhuangdao (Figure 2). This result indicates that solar radiation significantly impacts the composition and ecological function of moss communities. In bryology, solar radiation, as a fundamental environmental variable, manifests its influence through various pathways. Firstly, solar radiation directly affects the efficiency of photosynthesis in mosses, thereby influencing their growth rate and biomass accumulation [36,37]. Secondly, changes in solar radiation can affect the evaporation of moisture in mosses, further impacting their survival and reproductive capabilities [38]. Globally, similar studies have also identified the impact of solar radiation on moss diversity. For example, in some areas of Europe, solar radiation has a significant effect on the diversity and distribution patterns of mosses [39,40].

4.2. The Interplay of Spatial, Geographical, Climatic, and Soil Factors in the Structuring of Moss Communities

Geography plays an important role in influencing climatic factors and shaping soil properties. This finding is crucial, considering that soil properties are often viewed predominantly through the lens of climatic impact. Our results, however, suggest a more complex scenario, where geographic factors play a pivotal role. The data analysis from Qinhuangdao reveals a clear correlation between geographic factors and significant environmental variables like climate and soil characteristics. This correlation is evident in the variation in soil properties across different geographical areas, even under similar climatic conditions. While climatic factors such as solar radiation, temperature annual range (Bio7), the precipitation of the wettest month (Bio13), and site water balance (SWB) are traditionally deemed pivotal in shaping soil properties, the study reveals a nuanced view. It suggests that geographical factors have a pronounced impact on these properties [41]. This could be due to the intrinsic nature of geographic features in forming the foundational aspects of the local environment, including the composition and structure of the soil. These features may create microenvironments that significantly modify the local soil conditions beyond the broader climatic influences.

The influence of geographic factors extends beyond abiotic components to significantly impact the biotic realm, particularly the composition of moss communities. The study demonstrates that geographic factors directly influence moss community composition. There are indirect effects mediated through climatic and soil variables. The interplay between geography, climate, and soil properties creates a complex web of interactions that ultimately shapes the moss community. The findings contribute to a growing body of evidence that underscore the importance of considering geographic variables in ecological studies, particularly those focusing on community composition and biodiversity [42].

The study highlights the nuanced role of spatial factors in environmental dynamics. While the direct impact of spatial elements on environmental variables like soil composition and climatic conditions appears minor, their indirect influences are profound. A comparison of these findings with previous studies [43] reveals a consistent theme: spatial factors significantly influence moss plant community patterns. However, this research adds depth to the understanding by distinguishing between direct and indirect spatial influences. While some studies emphasize direct spatial impacts on biodiversity, this research suggests a more complex interaction, where indirect effects play a significant role.

In the context of Qinhuangdao, a region with unique geographic and climatic features, our findings gain additional relevance. The area's specific spatial characteristics, including its topography and proximity to different climatic influences, likely contribute to the indirect spatial impacts observed. This understanding is vital for targeted conservation strategies, such as those that are part of Qinhuangdao City's endeavor to become a National Environmental Protection Model City, underscoring the need for a comprehensive spatial approach in ecological planning and management.

4.3. Conservation Implications and Strategies for Moss Communities in Qinhuangdao

The intricate relationships elucidated between moss communities in Qinhuangdao and their environmental determinants provide crucial insights for the conservation of moss biodiversity and the maintenance of ecological balance. The study's revelation that solar radiation and temperature ranges are crucial in shaping moss diversity underscores the necessity of climate-adaptive conservation measures (Figure 3B). This could involve creating microhabitats to buffer sensitive moss species from the extremes of solar exposure and temperature variability. Furthermore, the significant role of soil properties suggests that efforts to maintain soil health, possibly through organic practices and reduced chemical use, are vital for preserving moss habitats. The influence of soil properties, such as pH and carbon content, underscores the need for a landscape-level approach in conservation planning. This approach should integrate the management of land use, climate action, and habitat protection to ensure the resilience and sustainability of moss ecosystems [44]. Identifying and protecting biodiversity hotspots, especially areas corresponding to Form *Entodon compressus* with higher moss diversity, is essential. The establishment of protected areas in these hotspots can safeguard critical habitats from urbanization and other anthropogenic disturbances.

Additionally, the conservation of moss-rich areas like Lianfeng Mountain, Zushan Mountain, and Tianma Mountain should be prioritized. Such holistic conservation strategies, informed by the nuanced findings of this study, could significantly contribute to the broader goals of biodiversity preservation and ecological balance, particularly in the face of accelerating climate change. There should be ongoing monitoring of moss communities to detect changes in diversity and distribution over time, which can serve as indicators of broader ecological shifts due to climate change. Conservation efforts should prioritize the protection of diverse and vulnerable moss habitats, especially those identified as biodiversity hotspots. Management practices should be adapted to consider the projected impacts of climate change on local and regional climates. This could involve creating microhabitats to buffer sensitive species from extreme conditions or managing landscapes to promote connectivity, allowing species to migrate in response to shifting climatic zones. Further research is needed to understand the specific physiological responses of different moss species to climatic variables such as temperature and solar radiation. Long-term data collection will be crucial for modeling the potential impacts of climate change on these ecosystems and for developing effective mitigation and adaptation strategies.

5. Conclusions

The study conducted an in-depth environmental gradient analysis of moss diversity in the Qinhuangdao area, revealing how environmental factors comprehensively affect the structure and distribution of moss communities. Meticulous surveys conducted across 30 plots in Qinhuangdao have uncovered remarkable diversity within the local moss flora. The study cataloged 84 species, encompassing 36 genera and 13 families. A significant correlation was discovered between moss diversity and various environmental variables, including topography, climate, and soil characteristics. Geographic and climatic conditions are essential to shaping moss community structures. Climatic conditions have the most significant impact on the moss community, with solar radiation playing a pivotal role in promoting moss biodiversity and temperature range affecting the distribution of moss communities. As secondary influences, geographical factors also play a positive role in creating microenvironments suitable for moss growth. Geographical factors can directly influence moss community structures and indirectly determine moss plants' growth conditions by affecting climate and soil characteristics. Additionally, the study reveals the indirect impact of spatial factors on climate and soil characteristics, which in turn affect the structure of biological communities. The study not only provides new insights into the ecological adaptation of mosses under different environmental conditions but also offers critical scientific foundations for biodiversity conservation and ecosystem management in Qinhuangdao.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f15030424/s1, Figure S1: Correlations between environmental factors. Figure S2: Cluster tree of sample plot based on environmental factors. Figure S3: Correlations between environment variables and moss diversity. Table S1: Relative coverage, relative frequency, and importance values of dominant species in different cluster. File S1: Species List on Qinhuangdao.

Author Contributions: Conceptualization: J.G. and G.Z.; methodology: J.G. and G.Z.; software: J.G.; validation: G.Z.; formal analysis: J.G. and G.Z.; investigation: J.G. and G.Z.; resources: G.Z.; data curation: J.G. and C.H.; writing—original draft preparation: J.G. and G.Z.; writing—review and editing: J.G. and W.Z.; visualization: J.G., Y.Z. and Z.G.; supervision: J.G., W.Z. and M.L.; project administration: G.Z.; funding acquisition: G.Z. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data that support the findings of this study are openly available in Supporting Information.

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Conflicts of Interest: The authors declare no conflicts of interest.

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