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The Impact of The Invasion of Alternanthera Philoxeroides in the Background of Climate Change on the Local Biodiversity

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Abstract. Global climate change is reshaping the structure and function of terrestrial and aquatic ecosystems, becoming a significant natural driving force for frequent biological invasions. Alternanthera philoxeroides, as a typical invasive alien plant in China, has extremely strong climate adaptability. Under the background of climate change, its colonization, diffusion ability, and invasion risk have significantly increased. The successful invasion of this species has caused serious and continuous negative impacts on the native biodiversity of aquatic and terrestrial ecosystems from three dimensions: species diversity, genetic diversity, and ecological diversity. It has disrupted the stability of the local ecosystem and threatened regional ecological security. This article takes Alternanthera philoxeroides as a research case. It analyzes the driving mechanism of its invasion under climate change from two aspects: changes in survival and reproduction conditions and the reconfiguration of interspecific competition. It explores the multi-dimensional impacts of its invasion on native biodiversity. On this basis, it reveals the intrinsic relationship and functional laws between climate change, typical invasive species invasion, and native biodiversity, with the aim of providing theoretical references for understanding the maintenance mechanism of biodiversity under global change and providing a scientific basis for the prevention and control of typical invasive species and the protection of native biodiversity.

Keywords: Climate change, species invasion, biodiversity, ecosystem, Alternanthera philoxeroides

1. Introduction

After the Industrial Revolution, with the large-scale development of various industrial production and emerging technology industries, global climate change has become an environmental issue that all of humanity must confront together. According to the Fifth Assessment Report of the IPCC, the global average surface temperature increased by 0.85℃ from 1880 to 2012, and it is predicted that the temperature will rise by 0.3-4.8 ℃ by the end of the 21st century [1]. In addition, the precipitation pattern has undergone large-scale changes, and the frequency of natural disasters such as heat waves, droughts, and floods has significantly increased. This not only affects the living environment of all living beings but also disrupts the stability of the biosphere, triggering a series of

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chain reactions. At the same time, species invasion, as one of the main drivers of biodiversity loss, has also become more common along with the acceleration of economic globalization, the gradual establishment of the human community of common destiny, and increasingly frequent international trade and population exchanges.

The academic community has gradually realized that these two issues are not isolated ecological problems; they interact with each other and form a synergistic effect, further exacerbating the destruction of local biodiversity. Currently, various international conferences have adopted documents such as the "Rio Declaration on Environment and Development", and there have been more studies on the impact of individual factors (such as climate change or species invasion) on biodiversity. However, there is still a lack of systematic exploration of the impact of their synergy and the corresponding strategies.

Alternanthera philoxeroides is one of the first invasive alien species listed in China. It originated from South America and was introduced to China in the 1930s. Since then, it has invaded most areas of the country, causing severe damage to the native biodiversity in water-land transitional zones, wetlands, and farmlands. This species has an extremely wide range of adaptability to climate factors such as temperature and precipitation. Its geographical expansion and survival and reproduction capabilities show a significant coupling relationship with climate change, making it a typical example for studying the mechanism of species invasion driven by climate change. Based on this, this article uses Alternanthera philoxeroides as a case study to look at how climate change drives the invasion of this species and how it affects native biodiversity in many ways. The objective is to elucidate the intrinsic relationship and operational principles between climate change and the proliferation of typical invasive species, offering theoretical insights for comprehending the mechanisms that sustain biodiversity amid global change, while also supplying a scientific foundation for devising targeted strategies aimed at preventing and safeguarding typical biological invasions and biodiversity conservation, thereby fostering the sustainable development of ecosystems and the effective preservation of ecological security.

2. The driving effect of climate change on Alternanthera philoxeroides

Climate change changes important environmental factors like temperature, precipitation, and hydrology, which changes the places where species can survive and reproduce and the relationships between species in the Earth's ecosystem. It becomes a major natural force that drives species to invade [2]. Alternanthera philoxeroides is a common invasive species that can adapt to different climates. It has amazing ways of responding to temperature, precipitation, and the timing of extreme weather events. Climate change not only makes it easier for this species to survive and reproduce, but it also makes it much more competitive with native species. This breaks the original ecological balance of species and makes it easier for this species to spread, colonize, and cause outbreaks in many parts of China, including the north and south. This has led to an expanding invasion range and an increasing degree of harm.

2.1. Climate change alters the survival and reproduction conditions of Alternanthera philoxeroides

The temperature is the most important thing that affects where Alternanthera philoxeroides grows and how it works. Global warming has directly broken the geographical limits that low temperatures put on this species, which has allowed it to slowly spread northward into northern China and into high-altitude, rough areas. Climate warming is therefore regarded as the principal catalyst for the

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geographical dissemination of Alternanthera philoxeroides [3]. Alternanthera philoxeroides is a species that grows in tropical and subtropical areas. Low temperatures used to be the main reason it couldn't spread north, but winter temperatures in northern China have gone up a lot, which has helped the underground and creeping stems of this species survive the winter. The rate of survival in the winter has gone up from less than 10% to more than 30%.It has successfully taken over the Huanghuai River Basin and parts of northern China. As temperatures rise, they will also change how Alternanthera philoxeroides metabolizes. This species can handle changes in temperature between 5 and 35 degrees Celsius. As the temperature rises, its enzymes work faster and photosynthesis works better. The growth and development cycle gets shorter, and the rate of germination and extension of creeping stems goes up a lot. Experimental data indicate that for each 1-2℃ rise in temperature, the germination rate of creeping stems can increase by 15%-25%, and the nutritional reproductive capacity significantly improves, establishing the basis for the rapid population growth.

The alteration of precipitation patterns is another important way through which climate change affects the survival and reproduction of Alternanthera philoxeroides. Regional increases in precipitation, intensification of aridity, or imbalance in the seasonal distribution of precipitation all restructure the water conditions of the habitat. Alternanthera philoxeroides possesses the growth characteristics of being aquatic, mesic, and xerophytic, and its adaptability to water conditions is far superior to that of most native species [4]. In humid areas with increased precipitation, such as the Yangtze River Basin and the Pearl River Basin, sufficient water provides favorable conditions for the aquatic growth of Alternanthera philoxeroides. Its root system rapidly extends in the water body, and stem nodes spread along the water flow, quickly occupying lake, river, and wetland water habitats. In arid regions, such as the karst areas in southwestern China, the succulent stems of this species have extremely strong water storage capacity, with a water utilization efficiency 20%-40% higher than that of native plants. It can store and reproduce in habitats with lower soil moisture content. Moreover, the frequent occurrence of extreme precipitation events helps the stem nodes and propagules of Alternanthera philoxeroides to spread over long distances through erosion and runoff, while destroying the integrity of native vegetation, creating a large number of bare habitat areas, providing blank ecological niches for the colonization of invasive species, significantly increasing the probability of their successful invasion. Extreme climate events thus become an important "window period" for the colonization of invasive species [5].

2.2. Climate change alters the relative competitiveness of Alternanthera philoxeroides with native species

The reshaping of species competitiveness by climate change essentially occurs by altering the acquisition and adaptation capabilities of different species for environmental resources, thereby disrupting the long-established interspecies competition balance within the native ecosystem [6]. Native aquatic and terrestrial herbaceous plants have formed a highly coordinated adaptive relationship with the local climate, soil, and biological environment during long-term natural selection. Their growth, reproduction, and interspecies interactions all rely on relatively stable environmental conditions. However, the sudden changes in environmental factors brought about by climate change make it difficult for native species to rapidly adjust their adaptation mechanisms, resulting in problems such as growth and development being hindered, reduced resource utilization efficiency, and decreased reproductive success. Their ability to occupy and defend habitat resources is significantly weakened. In contrast, Alternanthera philoxeroides, with its extremely strong phenotypic plasticity and evolutionary adaptability, occupies an absolutely dominant position in resource competition.

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When the temperature and amount of rain change in a habitat, Alternanthera philoxeroides can change how it photosynthesizes and takes in nutrients more quickly. This limits its access to light, water, and soil nutrients, and makes it harder for native species to live there. For instance, when the temperature rises, Alternanthera philoxeroides photosynthesizes 20% to 30% faster than reed, which is the native aquatic dominant species. It can quickly grow a canopy that blocks sunlight, which makes the native submerged plants die because they don't get enough light. In wetland habitats, its roots are densely spread out on the soil surface, and it is better at taking in nutrients than native species like water chestnut and lotus, which causes native species to die because they don't get enough nutrients. Climate change will also indirectly make Alternanthera philoxeroides more competitive by changing how it interacts with other species. The alteration in intermediate relationships induced by climate is regarded as a significant indirect mechanism for enhancing the species' competitiveness [7]. The leaf beetle of Alternanthera philoxeroides is a specialized predator of Alternanthera philoxeroides that comes from South America. The temperature has a big effect on how it grows, develops, and reproduces. In the winter, not enough heat will lower the rate of survival during the winter, and in the summer, very high temperatures will lower the rate of hatching of its eggs.C limate anomalies significantly diminish the natural regulatory effect of Alternanthera philoxeroides on indigenous species, facilitating a rapid increase in its population. Furthermore, warm and humid climatic conditions foster the reproduction of rhizobia and phosphate-solubilizing bacteria within the rhizosphere of Alternanthera philoxeroides, establishing a stable symbiotic relationship that markedly enhances the species' capacity to absorb soil nutrients, thereby providing it with a competitive advantage over native species. Extreme climate events will have a huge impact on the native biological community, leading to a sharp drop in the number of native species and a breakdown of the community structure. Alternanthera philoxeroides, on the other hand, is better able to handle extreme conditions. It can quickly regrow after floods and droughts and form a monoculture community in areas that are bare, slowly replacing native species as the most common species in the community, which completes the invasion and occupation of the habitat.

3. The impact of the invasion of Alternanthera philoxeroides on the local biodiversity

When an invasive species successfully invades and colonizes and spreads in the local ecosystem, it will exert continuous negative impacts on the local biodiversity through direct interspecific interactions and indirect ecological environment modifications at multiple levels, such as species, genetics, and ecosystems [8]. Alternanthera philoxeroides, as an invasive species that is both aquatic and terrestrial, has an invasion range covers various habitats such as wetlands and lakes. Through various means such as competitive exclusion, habitat modification, and gene exchange, it causes all-around and deep damage to the local species diversity, genetic diversity, and ecological diversity, seriously disrupting the structural balance of the local ecosystem and leading to the gradual degradation of its ecological functions, threatening the safety of regional biodiversity.

3.1. The direct harm caused by the invasion of Alternanthera philoxeroides to the biodiversity of native species

Interspecific competition is the most direct way for invasive species to harm the biodiversity of native species. The invasive species that successfully establish themselves often have characteristics such as a fast growth rate, strong reproductive ability, and high resource utilization efficiency. They have an absolute edge in the competition with native species over limited resources like light, water, soil nutrients and living space leading to delays in growth and development of native species as well

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as a drastic decrease in reproductive success. Certain native herbaceous and shrub species, like grasses and shrubs, can even slowly disappear out of their original environment, leading to a great loss of species richness in some locations. This adverse effect will further rise because the distribution of the invasive species will keep on increasing [9]. The data of field investigations show that in the most invaded parts of the Taihu Lake Basin (Alternanthera philoxeroides) the number of native aquatic plants species have reduced by 40-60 percent and the number of dominant species, such as reed, lotus and duckweed, have reduced by more than 50 percent. This invasion has led to a 30-50% decline in native herbaceous species (cocksfoot, cowpea grass and plantain) in terrestrial wetland habitats. Such resource competition is more fatal to the native species which are endangered and scarce. Wild Lotis is a Chinese national second-level protected plant, which grows in the shallow water of freshwater lakes. The thick growth of Alternanthera philoxeroides will soon overtake the area where it lives and Wild Lotus will soon be entirely extinct in parts it has been overrun by it, worsening its endangered condition.

Other significant direct pathways on which Alternanthera philoxeroides leads to the extinction of native species are predation and indirect habitat disturbance. This invasive species thus becomes a major cause of extinction of the native species and such effects are normally underestimated because they do not have monitoring [10, 11]. Though Alternanthera philoxeroides does not exhibit overt predatory actions, the monoculture community created by the invasion has significant effects on the survival and feeding aspects of the native animals thus leading to a sudden decrease in population of the native animal species. Its prolific growth in water bodies will block the movement and grazing of fish, causing a 30-40% decline in the population of native small fish, including sticklebacks, blackfish and crucian carp; and the extensive reproduction of Alternanthera philoxeroides in water bodies will diminish the habitat diversity of benthic animals, including snails, clams and mosquito larvae, to In the terrestrial setting, the leaves of Alternanthera philoxeroides have secondary metabolites that cannot be consumed or used by native herbivorous insects, leading to a 30-40% reduction in the population of native insects like aphids, cabbage moths, and locusts, and hence the food sources of insect eating birds like sparrows, white-browed tits and war Additionally, the invasive growth of Alternanthera philoxeroides will take up the survival space of the native nectar plants, reduce the number and species of pollinating insects like bees and butterflies indirectly impacting the sexual reproduction of native plants and increasing the loss of native species diversity. This kind of competitive exclusion and ecological niche replacement can alter the evolutionary trajectory of native species via such mechanisms, wherein native species may decline or even become extinct in direct interspecific competition with the invasive species [12].

3.2. The disruption of native genetic diversity and ecological diversity by species invasion

The invasion of Alternanthera philoxeroides causes damage to the native genetic diversity mainly through two aspects: gene exchange with native related species and changes in the genetic structure of native species populations. When the invasive species have the possibility of hybridization with native related species, the hybrid offspring will carry foreign genes. If these hybrid individuals can reproduce normally, they will gradually integrate the foreign genes into the gene pool of the native species, resulting in the loss of unique genes of the native species and a sharp decline in the number of native species populations due to the invasion. This also triggers genetic drift and inbreeding depression phenomena, leading to the continuous loss of native genetic diversity [13]. Alternanthera philoxeroides is the native related species of Alternanthera philoxeroides. Both belong to the genus Alternanthera of the family Amaranthaceae and have the possibility of natural hybridization. Studies have shown that in the invasion area of Alternanthera philoxeroides, the hybrid offspring of the two

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species have stronger climate adaptability and resilience, and can reproduce normally. The emergence of hybrid offspring results in the disappearance of special genes of native Alternanthera philoxeroides, and the population size of pure population declines over 70% in the invasion region. The genotypes of the native Alternanthera philoxeroides slowly deteriorate and genetic variation has been considerably reduced. Meanwhile, the competitive stress of Alternanthera philoxeroides causes the aquatic and terrestrial populations of species to reduce drastically. Others are small detached populations, like the small group of native submerged plant Salvinia within the invasion area which is likely to experience genetic drift and inbreeding depression. The diversity in the genetic makeup of the population becomes reduced and the capacity to adapt to environmental changes becomes undermined which further contributes to the loss of the native genetic diversity and creates a vicious circle.

The elimination of the native ecological diversity by Alternanthera philoxeroides is basically through the alteration of the native habitat features, annihilation of the heterogeneity of the ecosystem and consequently the reduction of habitat diversities and the variety of ecosystem types [9]. The capacity of this species to alter the environment is highly high and it can easily establish a monoculture community both in water and on land, replacing the original native vegetation types, making the vegetation structure of the habitat more and more homogeneous. Concomitantly, it will alter the physical and chemical environment of the water body and soil and kill the stability of the native habitat, forcing the native plants and animals that were accustomed to the native habitat to lose their habitats and relocate out of the region.In the aquatic habitat, the massive reproduction of Alternanthera philoxeroides will lead to a 10%-30% decrease in dissolved oxygen content in the water body, a pH value shift towards alkalinity, and the decomposition of its residues will release a large amount of nitrogen and phosphorus nutrients, causing water body eutrophication, destroying the microenvironment of the freshwater ecosystem, leading to the simplification of the community structure of native planktonic algae and zooplankton, and the replacement of dominant planktonic algae such as diatoms and chrysophytes by cyanobacteria, a significant reduction in the types of protozoa and rotifers. In the terrestrial habitat, its rhizosphere will secrete secondary metabolites such as phenols and terpenoids, not only inhibiting the germination of native plant seeds and the growth of seedlings, but also changing the structure of the soil microbial community, leading to a decrease in the number of actinomycetes and nitrogen-fixing bacteria, a balance of the ratio of bacteria and fungi, and a 10%-20% decrease in soil organic matter content, and a blockage of the nutrient cycling in the soil [14].

In addition, the thick growth of the Alternanthera philoxeroides at the boundaries of water and land will alter the connectivity of the ecosystem, separate the living space of native species, and create fragments of habitats, preventing native species, which depend on continuous habitats, to perform life activities such as migration and reproduction easily. This also contributes to habitat degradation. An instance is its high growth on the banks of rivers where its dense growth will impede the movement and communication of the riverbanks water and land organisms causing the blocking of the amphibious breeding channels and the decrease of the population of the organisms which originally adapted to the various wetland habitats forcing them to retreat resulting in a tendency to one type of wetland ecosystem. The disruption of Alternanthera philoxeroides on the material circulation and energy flow of the local ecosystem will alter several important components of the ecosystem, including nutrient cycling and hydrological features of the ecosystem, leading to the eventual loss of some unique ecosystems functions, including the important weakening of water quality purification and climate regulation functions of wetlands, and the ecological diversity will

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decline significantly, which will consequently affect the stability and anti-interference ability of the entire ecosystem [8].

4. Comprehensive intervention measures for the invasion of Alternanthera philoxeroides under the background of climate change

In response to the situation where the invasion of Alternanthera philoxeroides is exacerbated by climate change and continues to threaten the local biodiversity, a comprehensive intervention system that is climate-adapted, implemented in a zoned manner, and involves multiple technologies working together is needed to achieve precise prevention and ecological restoration.

In terms of monitoring and early warning, by combining temperature, precipitation and the dynamics of extreme climate events, climate models are used to simulate potential invasion areas. The focus is on monitoring climate zones suitable for expansion such as North China and the Huaihai region. A regular monitoring network for overwintering survival rate and diffusion speed is established. The invasion window period is promptly identified and the transmission paths of propagules are blocked. Biological control should be in line with the climate pattern. In regions with significant warming, the release timing and population size of cold-resistant Eupatorium sessile-pectinatum nymphs should be optimized to restore the natural control ability of natural enemies. At the same time, the root microbiota community should be regulated to weaken its nutrient absorption advantage and reduce the population expansion potential. Physical and chemical control should be adapted to local conditions. For aquatic habitats, manual harvesting and mechanical cleaning are the main methods, combined with water oxygenation to improve water quality; for terrestrial habitats, deep plowing to suppress growth, physical barriers, and cautious use of chemical agents should be adopted to avoid damage to native organisms and the soil environment.

Ecological restoration is a long-term approach. After removing invasive plants, local dominant species such as reeds, sedges, and duckweed can be quickly planted to fill the ecological niche gap and enhance the stability of the community. It also restores the connectivity between water and land and the heterogeneity of habitats, restores the living and breeding spaces for local organisms, and strengthens the ecosystem's ability to resist interference and self-repair.

5. Conclusion

Climate change and biological invasion jointly exacerbate the destruction of local ecosystems and biodiversity. This article systematically analyzes the driving mechanisms of climate warming, changes in precipitation patterns, and extreme climate events on the survival and reproduction, as well as interspecific competition of Alternanthera philoxeroides. It clarifies the multiple negative impacts of its invasion on local species, genetics, and ecological diversity. The results show that climate warming, changes in precipitation patterns, and extreme climate events provide favorable conditions for the colonization and spread of Alternanthera philoxeroides at the levels of survival and reproduction, interspecific competition, etc. However, its large-scale invasion will reduce the functions of the ecosystem such as carbon sequestration and water purification, intensify climate anomalies, and form a vicious cycle.

The invasion of Alternanthera philoxeroides has a comprehensive impact on the biodiversity of the local area. It directly leads to a decrease in species richness and endangers endangered species through resource competition and habitat disturbance. Indirectly, it damages genetic diversity and ecological diversity through gene hybridization and habitat modification, causing the degradation of

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ecosystem structure and weakened functions. Local species are at risk of local extinction under the double pressure, and the protection of wetland and freshwater ecosystems is in a serious situation.

In the future, research should be conducted by integrating climate models, molecular mechanisms and long-term monitoring. In terms of time, it is necessary to combine early warning, precise biological control, differentiated governance, and strengthening local ecological restoration. Addressing climate change and biological invasion requires global collaboration, integrating climate adaptation with species control, in order to effectively safeguard ecological security and the sustainable development of biodiversity.

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