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Adaptive Variation in Mammalian Genomes in Terrestrial and Water Ecosystems

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Abstract The study aims to analyze the characteristics and importance of adaptive variation in mammalian genomes in terrestrial and water ecosystems. To explore the basic concepts and measures of genome adaptive variation through insights into the context of the ecosystem and the role of mammals in it. The study covered the adaptive variation of mammals in terrestrial and water ecosystems, and examined the ecological factors affecting adaptive variation, such as niche, climate change and population genetic structure, and also explored the impact of environmental variation on adaptive variation and the importance of protecting mammalian diversity. The study provided valuable insights for deepening the understanding of adaptive variation in mammalian genomes and provided scientific basis for future research and conservation work in ecology and evolutionary biology.

Keywords Genomic adaptive variation; Mammals; Ecosystems; Ecological factors; Climate change

With the continuous progress of science and technology and the deepening of ecological research, genome adaptive variation has become a highly concerned field. Ecologists and evolutionary biologists have been working hard to understand how organisms adapt to different environmental conditions through variations in their genomes. Research in this field not only helps to unravel the mysteries of life evolution, but also provides important application value for fields such as biomedicine, ecology, and agriculture.

Adaptive variation refers to the varying degrees of adaptability of individuals to environmental conditions during survival and reproduction due to genomic variations (Charlesworth et al., 2017). This kind of variation may involve individual genes, multiple genes, or overall changes in the genome. With the development of genome sequencing technology, scientists are now able to delve deeper into the molecular mechanisms of adaptive variation, thereby revealing how organisms survive and reproduce in different environments. The motivation of the study is to delve deeper into the mechanisms of genomic adaptive variation and its importance in ecology and evolutionary biology.

The study of genomic adaptive variation is of profound importance in multiple fields. It helps us better understand the adaptive changes of organisms during the evolutionary process and provides key data and evidence for evolutionary biology. For ecology, it is crucial to understand how adaptive variation shapes the ecological niche of species and affects their role in ecosystems. The study of genomic adaptive variation also has potential applications for agriculture and ecosystem management, helping to improve crop quality, resist invasive species, and protect endangered species.

The study will mainly focus on the adaptive variation of mammalian genomes in ecosystems, but it will also cover some related biological issues. The study does the best to provide a comprehensive perspective to reveal the importance of adaptive variation for ecosystems and species, while also considering potential future research directions and challenges. Through research, the study aims to contribute to a better understanding of the mechanisms of genomic adaptive variation and the theory of ecological evolution, providing a strong basis for ecosystem management and protection.

1 Ecosystem Background

Ecosystems are an indispensable part of the natural world on Earth, including various biological and abiotic components of land, water, and air that interact and jointly sustain life on Earth. Mammals play multiple roles in these ecosystems, maintaining ecological balance and ecosystem functions. Protecting and managing these ecosystems and their mammals is a shared responsibility to ensure ecological diversity and sustainability on Earth.

1.1 Characteristics of terrestrial ecosystems

Terrestrial ecosystems include a wide range of ecological diversity, from grasslands to forests, deserts to mountains, each with its unique characteristics. The main differences between these ecosystems lie in climate, vegetation type, and geographical location. For example, tropical rainforests are typically located near the equator, with high temperatures and humidity, dense growth of trees and plants, and are also one of the hotspots of global biodiversity. On the contrary, desert ecosystems have dry and high-temperature climate conditions, with relatively sparse vegetation and plants adapting to arid environments.

The characteristics of terrestrial ecosystems also include a variety of wild animals and plants, from herbivorous animals such as elephants (*Elephantidae*) and zebras (*Equus quagga*) to carnivorous animals such as lions (*Panthera leo*) and leopards (*Leopard*). The interactions between these organisms form the food chain and ecological network of the ecosystem, maintaining ecological balance. In addition, soil is also an important component of terrestrial ecosystems, supporting plant growth, storing water, and serving as a habitat for many microorganisms and insects. The Amazon rainforest is considered one of the largest terrestrial ecosystems on Earth. This ecosystem is located in South America, with rich vegetation and wildlife diversity. The Amazon rainforest not only provides important services for global climate regulation, but also contains thousands of plant and animal species, including jungle cats (*Felis chaus*), sloths (*Folivora*), pythons (*Pythonmolurus*), and various monkeys (Figure 1).

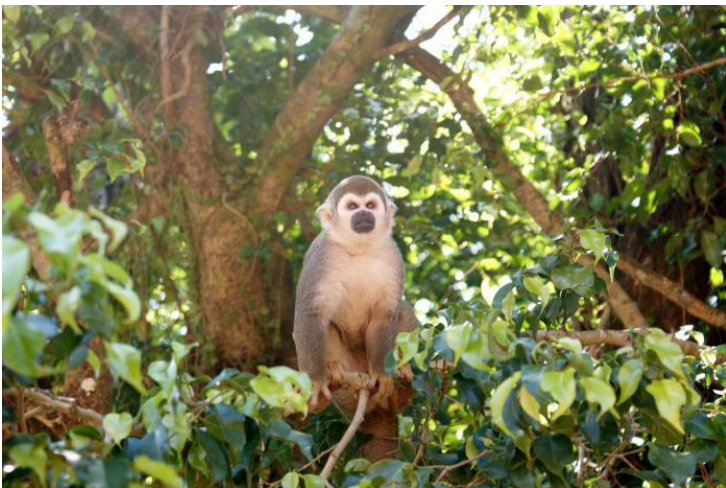


Figure 1 The restrial ecosystem of the Amazon rainforest

1.2 Characteristics of aquatic ecosystems

The aquatic ecosystem includes different types of water bodies such as oceans, freshwater lakes, rivers, and wetlands. They cover a considerable area on Earth, providing rich ecological diversity and resources. The marine ecosystem is one of the largest ecosystems on Earth, with a vast ocean and seabed environment. These ecosystems play a crucial role in global climate and ecological balance.

In aquatic ecosystems, water bodies of different depths and temperatures form differences in ecological diversity. For example, coral reef ecosystems are typically located in warm shallow water areas and are hotspots of marine biodiversity, including colorful corals and various fish species (Figure 2). Deep sea ecosystems, on the other hand, exist deep in the ocean floor, where organisms adapt to extreme pressure and cold conditions, including deep-sea fish and unique benthic organisms.

The aquatic ecosystem also provides important resources, such as fisheries and freshwater supply. These resources are crucial for global food security and water resource management. At the same time, aquatic ecosystems also play an important role in the carbon cycle, absorbing a large amount of carbon dioxide and helping to mitigate climate change. For example, the freshwater lake system in the Great Lakes region of the United States is one of the largest freshwater lake clusters in the world, supporting a large number of fishing and water supply needs. These lakes are not only important resources for local communities, but also play a crucial role in global ecological balance.



Figure 2 A coral reef ecosystem

1.3 The role of mammals in ecosystems

Mammals play important roles in various ecosystems, as they are one of the key members of the ecological food chain and also play the role of ecosystem engineers.

1.3.1 Part of the food chain

Mammals occupy different positions in the food chain. Some mammals are herbivorous, such as cows, deer, and elephants, which maintain life by feeding on plants and become a source of food for carnivores. Other mammals, such as lions, tigers, and jackals, are carnivorous and obtain food by preying on other animals. The interaction of these food chains maintains ecological balance in the ecosystem. For example, on the African savannah, herbivorous animals such as zebras and wildebeests are the main prey of lions and leopards, maintaining the balance of the grassland ecosystem (Figure 3).



Figure 3 Food-chain relationships in mammals

1.3.2 Seed disseminators

Some mammals, such as rodents and civets, play the role of seed spreaders in ecosystems. They take the fruits or seeds of plants to different places by consuming them, which helps to disperse and spread the plants. This seed dispersal is crucial for maintaining plant diversity and ecosystem stability. For example, squirrels often store pine nuts, but sometimes forget their storage location, which helps with the growth of new trees (Figure 4).



Figure 4 Squirrels store pine cones to produce seed dispersal

1.3.3 Soil tillers

Some mammals, such as hamsters and wild boars, search for food by digging and flipping the soil, while also altering the soil structure. The activities of these animals contribute to soil ventilation and nutrient cycling, which are crucial for maintaining soil health and vegetation growth. For example, the groundhog in North America helps to ventilate the soil and promote the growth of grasslands during the excavation process (Figure 5).



Figure 5 Soil tillers - groundmice

1.3.4 Ecosystem indicators

The presence and quantity of mammals can serve as indicators of ecosystem health. For example, if the number of carnivorous mammals in a forest ecosystem suddenly decreases, it may be a sign of other problems in the ecosystem, such as excessive prey or habitat destruction. Therefore, monitoring mammalian populations can help people understand and manage the health status of ecosystems.

2 Basic Concepts of Genome Adaptive Variation

Genomic adaptive variation is an important and complex concept in biology (Charlesworth et al., 2017), which involves how biological populations adapt to their environment through genomic variation. Genomic adaptive

variation is a key process in how biological populations adapt to different environmental conditions. By measuring and understanding adaptive variation, people can better understand the formation and maintenance of biodiversity, as well as the stability and evolution of ecosystems. This is of great significance for ecology, genetics, and the protection of biodiversity.

2.1 Definition of adaptive evolution and genomic adaptive variation

Adaptive evolution refers to how a biological population adapts to its environment to improve its chances of survival and reproduction. This adaptability typically involves mutations in the genome that can provide a certain survival advantage under specific environmental conditions. Genomic adaptive variation refers to these genomic variations with adaptive advantages. A certain insect may produce a special enzyme when facing the toxicity of a specific plant, which helps it break down toxins. The production of this enzyme depends on specific genetic variations, enabling this insect to adapt to the toxicity of that plant. It can be inferred that genomic adaptive variation refers to the genetic variation that enables this insect to survive and reproduce in a specific environment.

2.2 Measurement methods for adaptive variation

Measuring genomic adaptive variation is complex and diverse, often requiring a combination of molecular biology, genetics and ecological methods (Verma et al., 2004). Genome sequencing: By sequencing the genomes of different individuals in a population, variations at different loci can be identified. This helps to determine which genetic variations are related to environmental adaptability. Modern high-throughput sequencing technology has made large-scale genome sequencing possible. Genetic experiments: In the laboratory, researchers can conduct genetic experiments by crossing individuals of different genotypes to observe the survival and reproductive ability of offspring under different environmental conditions. This can help determine which genotypes have adaptive advantages. Polymorphism research: By studying gene polymorphism in a population, it is possible to understand which gene loci play a key role in adaptability. This usually involves analyzing the relationship between gene frequency and genotype with environmental factors. Ecological observation: Ecological observation can reveal how biological populations interact with their environment to achieve adaptability. For example, observing the food acquisition strategies and reproductive behavior of birds in different environments can help us understand their adaptive variations.

2.3 The relationship between adaptive variation and ecosystem interaction

2.3.1 Niche differentiation

Adaptive variation can lead to different individuals or populations occupying different ecological niches. Niche differentiation helps reduce competition and enables different species to coexist in the same ecosystem. For example, lizard populations on islands may undergo natural selection, producing different mouth types to adapt to eating different types of food resources. This adaptive variation can reduce competition for food resources and help different types of lizards coexist on the same island.

2.3.2 Stability of ecosystems

Adaptive variation contributes to the stability of ecosystems as it enables species to better cope with environmental changes. Species with higher adaptability are more likely to survive in the face of stress and interference. For example, in a lake ecosystem, fish populations may undergo adaptive variation, allowing some individuals to tolerate water pollution. When the water quality of the lake decreases, fish with higher adaptability may still be able to reproduce, maintaining the stability of the ecosystem.

2.3.3 Ecosystem evolution

Adaptive variation can drive the evolution of ecosystems, leading to the evolution paths of different biological populations. This evolution can alter the structure and function of ecosystems. For example, plants in a certain grassland ecosystem may undergo adaptive variation to adapt to dry climate conditions. This may lead to different types of plants dominating the ecosystem, thereby altering the vegetation structure and survival strategies of wildlife.

3 Adaptive Variation of Mammalian Genomes in Terrestrial Ecosystems

Mammals play various important roles in terrestrial ecosystems, and their genomic adaptive variations enable them to survive and reproduce under different environmental conditions (Seeber et al., 2022).

3.1 Adaptive variation in alpine ecosystems

Alpine ecosystems typically have extreme climate and terrain conditions, including low oxygen, low temperatures, and steep terrain. Mammals exhibit unique adaptive variations under these conditions. Some alpine mammals, such as snow leopards and ferrets, have dense fur to resist the cold. The color of its hair is usually integrated with the surrounding environment, providing camouflage. In addition, some alpine animals such as red deer have larger lungs and hearts to better cope with hypoxic environments. High mountain vegetation may be sparse, leading to scarcity of food resources. Some alpine mammals, such as snow rabbits, have developed special food strategies, such as eating rhizomes, moss, and underground plant parts to meet their energy needs.

3.2 Adaptive variation in forest and grassland ecosystems

Forest and grassland ecosystems provide diverse habitats, and mammals exhibit different adaptive variations in these environments. In forest ecosystems, arboreal mammals such as squirrels and monkeys typically have superior climbing and jumping abilities to obtain food in the canopy and avoid predators. Terrestrial mammals such as foxes and wolves adapt by chasing prey on the ground. The types of plants and prey in different types of forest and grassland ecosystems vary. Mammalian food selection and digestive ability may develop different adaptive variations. For example, giant pandas have evolved a digestive system specifically for eating bamboo in the bamboo forest ecosystem.

3.3 Adaptive variation in polar and desert ecosystems

Polar and desert ecosystems are one of the most extreme environments on Earth, and mammals require special adaptations to address these challenges. In polar ecosystems, temperatures are extremely low and ice and snow cover most of the time. Mammals such as polar bears and penguins have special fur or feathers to maintain body temperature, while also possessing a thick layer of fat to provide additional warmth and energy reserves. Desert ecosystems typically have characteristics of high temperature and low moisture. Mammals such as desert foxes and camels have developed efficient water conservation mechanisms that can survive without water sources. Their hair and behavioral habits also help lower body temperature.

3.4 Protection and management of genomic adaptive variations

The adaptive variation of the mammalian genome is crucial for its survival and reproduction. However, climate change and human activities may have negative impacts on these ecosystems, threatening the adaptability of mammals. Therefore, protecting and managing these ecosystems has become particularly important. This can be achieved by establishing nature reserves, implementing sustainable resource management measures, and mitigating climate change to ensure that mammals continue to exhibit adaptive variation in various ecosystems.

4 Adaptive Variation of Mammalian Genomes in Aquatic Ecosystems

The aquatic ecosystem includes freshwater and marine environments, as well as wetlands and estuaries. These waters provide diverse habitats, and mammals exhibit different adaptive variations in these environments (Micheletti et al., 2018; Liggins et al., 2020). Mammals in aquatic ecosystems exhibit diverse adaptive variations, enabling them to survive and reproduce in different aquatic environments. However, these ecosystems face multiple threats and require protection and management measures to ensure that the adaptability of mammals can be maintained and promoted. These efforts not only contribute to protecting the diversity of mammals, but also contribute to maintaining the stability and health of aquatic ecosystems.

4.1 Adaptive variation in freshwater ecosystems

Freshwater ecosystems include lakes, rivers, and freshwater wetlands, which are widely distributed worldwide. Mammals face unique adaptive challenges in freshwater environments. Some mammals, such as beavers and hippos, have aquatic adaptability and live and reproduce in water. Their limbs and hair structure enable them to swim and dive in water while maintaining body temperature and buoyancy. The food resources in freshwater

ecosystems are rich and diverse, and different mammals have evolved different food selection strategies. For example, waterfowl such as ducks obtain food by filtering plankton from the water, while bears in rivers may catch fish and other aquatic organisms.

4.2 Adaptive variation in marine ecosystems

Marine ecosystems cover most of the surface of the Earth, and their characteristics include factors such as saltwater, pressure, and tides. Mammals exhibit unique adaptive variations under these conditions. Marine mammals such as whales and dolphins have special respiratory adaptations, as they can hold their breath for long periods of time and dive deep into the deep sea to prey and escape predators. Their lungs and blood systems enable them to effectively utilize oxygen and quickly adapt to changes in depth and water pressure. Some marine mammals, such as polar bears and sea dragons, exhibit migratory and seasonal behavior. They travel across vast oceans and adapt to different ecological conditions based on seasonal food and reproductive needs.

4.3 Adaptive variation in wetland and estuarine ecosystems

Wetlands and estuarine areas are the intersection of freshwater and marine ecosystems, providing unique habitats. Mammals exhibit adaptive variation in these environments. Some mammals, such as beavers and water deer, have adapted to wetland life. Their body shape and behavior enable them to search for food and build nests by the water's edge. The estuarine ecosystem is usually a rich gathering place for food resources, attracting many mammals. Some mammals, such as seals and beavers, use fish, shellfish, and aquatic plants in estuaries to obtain food.

4.4 Protection and management of genomic adaptive variations

Mammals in aquatic ecosystems face challenges in survival and reproduction, including habitat destruction, climate change, and pollution. Protecting and managing these ecosystems is crucial to ensure that the adaptive variation of mammals is maintained. Establishing nature reserves and water conservation areas helps to maintain mammalian habitats, reduce human interference and development. This can provide relatively stable ecological conditions and help maintain adaptive variation. Sustainable water resource management is crucial for maintaining freshwater ecosystems. Ensuring appropriate water flow and quality helps maintain the food chain and habitat, promoting the adaptability of mammals. Climate change has had adverse effects on marine and aquatic ecosystems, including rising sea levels and rising water temperatures. Taking measures to mitigate climate change can help reduce these impacts and help protect the adaptability of mammals.

5 Ecological Factors Affecting Adaptive Variation

Adaptive variation is one of the key factors in how mammals adapt to their survival and reproductive needs under different environmental conditions (MacColl, 2011). This adaptive variation is influenced by various ecological factors, including niche and resource utilization, climate change and environmental pressure, as well as population genetic structure. Protecting and managing adaptive mutations helps ensure that mammals can survive and reproduce under different environmental conditions, maintaining the stability and biodiversity of ecosystems. This requires comprehensive protection measures, including habitat protection, population management, and climate change mitigation.

5.1 Niche and resource utilization

Niche refers to the specific status and role of a biological population in an ecosystem, covering how they obtain food, choose their habitat, and interact with other species. The food choices and resource utilization of mammals are influenced by their ecological niches. Different types of mammals have evolved different food selection strategies, reflecting their position in the food chain. For example, carnivorous animals such as lions are adapted to prey on other animals, while herbivorous animals such as elephants are adapted to feed on plants. Niche also affects the way mammals choose their habitat. Some mammals adapt to aquatic life, living in lakes, rivers, and oceans, while others are more adapted to terrestrial habitats. This choice is influenced by habitat types, competition, and food resources.

5.2 Climate change and environmental pressure

Climate change and environmental pressure are important factors affecting adaptive variability. Climate change has had direct and indirect impacts on the adaptability of mammals. Climate change may lead to changes in habitats, such as vegetation distribution and availability of food resources. Mammals may need to adapt to these changes, changing their behavior, migration patterns, or food choices. Environmental pressure includes factors such as natural disasters, habitat destruction, and pollution. These pressures may lead to habitat loss, food shortages, or exposure to toxins. Mammals need to adapt to these pressures, possibly through behavioral changes or physiological adaptation.

5.3 Population genetic structure

Population genetic structure refers to the gene flow and genetic diversity within mammalian populations. Gene flow refers to gene exchange between individuals, which can increase genetic diversity within a population. Greater gene flow helps with adaptive variation, as it can spread beneficial mutations between populations and improve adaptability. Genetic diversity within a population is crucial for adaptive variation. Genetic diversity enables populations to cope with environmental changes, as it provides a diverse pool of genes, including adaptable genotypes. Genetic drift refers to random changes in gene frequency that may lead to the loss of beneficial mutations. Smaller populations are more susceptible to genetic drift, so maintaining a sufficiently large population size is crucial for maintaining adaptive variation.

5.4 Protection and management of adaptive variations

Protecting and managing adaptive mutations is crucial for maintaining the survival and reproduction of mammals. Maintaining appropriate habitats is crucial for protecting the adaptive variation of mammals. Protecting natural habitats, establishing nature reserves, and implementing sustainable land use planning are key measures. Maintaining a sufficiently large population size and genetic diversity is crucial for maintaining adaptive variation. Population management includes measures to avoid gene loss and genetic drift, such as supplementing populations, genetic management, and population monitoring. Mitigating climate change is crucial for reducing the impact of climate change on mammals, such as rising temperatures, rising sea levels, and extreme climate events. Reducing greenhouse gas emissions, adopting renewable energy sources, and promoting sustainable development are key measures to address climate change.

6 Conclusion and Outlook

Mammals have diverse genomic adaptive variations that enable them to successfully survive and reproduce in different ecosystems. Adaptive variation not only involves adaptive characteristics in terms of morphology, physiology, and behavior, but also includes various adaptive characteristics such as food selection and reproductive strategies. Different types of ecosystems, such as land, water, mountains, forests, grasslands, polar regions, and deserts, exert different selection pressures on the adaptive variation of mammals, leading to diverse adaptive strategies. In addition, factors such as climate change, environmental pressure, and human activities have also had a profound impact on the adaptive variation of mammals. These factors may lead to new adaptive mutations or threaten existing adaptations.

Adaptive variation endows mammals with the ability to survive and reproduce in different environments. This diversity not only enriches the ecosystem, but also provides opportunities for mutual benefit for other species in the ecosystem. For example, some mammals play important roles as predators or seed spreaders in the food chain, affecting the stability and health of the entire ecosystem. Adaptive variation reflects the responsiveness of mammals to environmental changes. The adaptive variation of mammalian genomes enables them to cope with climate change, habitat loss, and other ecological challenges, thereby improving their chances of survival. This is crucial for maintaining biodiversity and ecosystem stability. Finally, adaptive variation also reflects the process of evolution. Adaptive variation drives the formation and evolution of mammalian species through natural selection and genetic evolution. Adaptive variation in mammalian populations can guide species' adaptation and differentiation over a long evolutionary time scale.

Protecting mammalian diversity is crucial for maintaining the health and functionality of ecosystems. As an important component of the ecosystem, mammals play a crucial ecological role. Their position in the food chain, access to food resources, and control of other species populations all have direct and indirect impacts on ecosystems. However, mammals face increasingly serious threats, including habitat destruction, climate change, illegal hunting, and poaching. These threats result in a decrease in the number of mammalian species, population pressure, loss of genetic diversity, and impaired ecosystem function.

Protecting mammalian diversity is not only a moral responsibility, but also beneficial for humanity itself. The diversity of mammals maintains the stability of ecosystems, helps control pests, maintain plant diversity, protect water resources, and promote soil health. In addition, mammals are also an important component of ecotourism and cultural heritage, which have a positive impact on the tourism industry and cultural heritage.

In order to protect the diversity of mammals, a series of comprehensive measures need to be taken, including establishing nature reserves, implementing sustainable land use and mining management, combating illegal hunting and poaching, and promoting climate action to mitigate the impact of climate change. In addition, educating the public and raising awareness of conservation are also crucial, as only by working together can we ensure the maintenance of mammalian diversity, ecosystem health, and biodiversity.

In the future, people should continue to focus on studying the adaptive variation, ecological and evolutionary significance of mammals, as well as the importance of protecting mammalian diversity. Only through global cooperation and sustainable conservation measures can researchers ensure that mammals continue to thrive on the shared Earth and maintain the stability and health of ecosystems.

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