International Journal of Molecular Evolution and Biodiversity 2024, Vol.14, No.1, 26-33
http://ecoevopublisher.com/index.php/ijmeb

Research Report Open Access

A Study on the Differential Patterns of Selective Constraints in Different Ecological Niches

Morita Hawk
Animal Science Research Center, Cuixi Academy of Biotechnology, Zhuji, 311800, Zhejiang, China
Corresponding author email: Hawk.m@cuixi.org
International Journal of Molecular Evolution and Biodiversity, 2024, Vol.14, No.1 doi: 10.5376/ijmeb.2024.14.0004
Received: 15 Dec., 2023
Accepted: 22 Jan., 2024
Published: 09 Feb., 2024

Preferred citation for this article:
Hawk M., 2024, A study on the differential patterns of selective constraints in different ecological niches, International Journal of Molecular Evolution and Biodiversity, 14(1): 26-33 (doi: 10.5376/ijmeb.2024.14.0004)

Abstract Niche differentiation and selective constraints are core concepts in biodiversity and evolutionary ecology. This study aims to explore the differential patterns of selective constraints in different niches, in order to reveal the mechanism of niche differentiation and the role of niches in biological communities. By understanding the concept of niche and the basic concepts of selective constraints, one can grasp the differential patterns of selective constraints in different niches. Through case studies and the impact of niche characteristics, the changes in selective constraints under different environmental conditions were elucidated. In addition, the impact of selective constraints on niche differentiation and evolution was also explored, emphasizing the importance of future research. This study aims to deepen the understanding of the diversity and niche differentiation of selective constraints in different niches, and provide scientific basis for biodiversity conservation and ecosystem management.
Keywords Niche; Selective constraints; Niche differentiation; Niche characteristics; Biodiversity

Selective constraint, as one of the key concepts in the fields of biology and ecology, represents one of the key impacts faced by the evolution of biological populations. It involves environmental constraints on individual survival and reproduction, forming the foundation of biodiversity and ecosystems (Chang et al., 2020). Selective constraints refer to the different effects of natural selection on specific traits or genotypes, which reflect the differences in adaptability of organisms to environmental conditions (Shtolz and Mishmar, 2019). In the long river of evolution, selective constraints are a key driving factor for species morphological diversity and niche differentiation. By delving into the mechanisms and effects of selective constraints, we can better understand diversity and interaction in the biological world.

In nature, biological populations are distributed in different ecological niches, which provide them with unique resources and environmental conditions. However, organisms in different ecological niches face different selective constraints. These differences may be caused by various factors such as resource availability, competitive pressure, and predator pressure. Understanding the differential patterns of selective constraints in different niches is crucial for revealing the adaptive evolution and niche differentiation of organisms (Yan et al., 2021). The purpose of this study is to explore in depth the differential patterns of selective constraints in different ecological niches, in order to reveal the basis for the adaptive evolution strategies and interactions of organisms in different ecological niches.

This study will introduce the concept of niche, delve into the definition and types of selective constraints, discuss the differential patterns of selective constraints in different niches, and use case studies and the impact of niche characteristics as support to elucidate how selective constraints exhibit changes under different environmental conditions. Starting from the impact of selective constraints on niche differentiation and evolution, as well as how they drive species diversity in ecosystems, discuss the significance of these results in the fields of ecology and evolutionary biology, as well as potential contributions to future research. By delving into the differential patterns of selective constraints in different niches, the aim is to provide scientific basis for the study of biodiversity and niche differentiation.

1 The Concept of Ecological Niche

1.1 Defining niche and its role in ecology

Niche is a key concept used to describe the functional roles and resource utilization strategies of species in their living environment. In short, niches represent how a species interacts with its surrounding environment to acquire the necessary resources for survival, including food, habitat, and ways of survival (Zhang et al., 2018). Each species occupies a different ecological niche in the ecosystem, and this diversity helps maintain the stability and biodiversity of the ecosystem.

The concept of ecological niche plays a crucial role in ecology. It helps us understand why different species can coexist in the same environment without competing with each other. Each species avoids excessive competition and achieves resource allocation and collaborative survival through its unique ecological niche (Feng et al., 2019). In addition, niches also contribute to the stability of ecosystems, as species in different niches depend on each other, forming complex food webs and ecological chains, maintaining ecosystem balance.

1.2 The importance of niche diversity and niche differentiation

Niche diversity refers to the richness of different niches in an ecosystem (Sánchez-Lanzas et al., 2020). The presence of more species with different ecological niches in an ecosystem typically indicates higher diversity in the ecosystem. The increase in niche diversity helps to improve the stability of ecosystems, as it reduces competition pressure between species. In diverse ecological niches, different species can find their own unique resource utilization strategies, thereby reducing the intensity of resource competition and competition.

Niche differentiation refers to the differentiation of ecological niches between different species to avoid direct competition. During the long-term evolution process, species gradually adjust their resource utilization strategies to occupy different ecological niches, which is called niche differentiation (Dent and Estrada-Villegas, 2021). Niche differentiation is an important factor in biodiversity in ecosystems, providing opportunities for collaborative survival among different species while maintaining the functionality and stability of the ecosystem.

2 Basic Concepts of Selective Constraints

2.1 Definition and types of selective constraints

Selective constraint is one of the key concepts in the process of biological evolution, which describes the limitations or tendencies on certain characteristics or genes of organisms. Selective constraints refer to the influence of natural selection on specific traits or genes (Massip et al., 2019). Selective constraints can be divided into forward selective constraints, reverse selective constraints, neutral selective constraints, and weak selective constraints.

Positive selective constraints promote the rapid diffusion of a trait or gene within a species, as they provide significant adaptive advantages. This constraint typically involves adaptive characteristics, such as resistance or reproductive success traits under certain environmental conditions. Negative selectivity constraint is the selection of unfavorable effects on a certain trait or gene, which usually leads to its reduction in the species. This constraint typically involves harmful mutations or maladaptive features. Neutral selective constraints occur without significant adaptive advantages or adverse effects. In this case, the evolution of traits or genes is influenced by random factors, such as genetic drift. Weak selectivity constraints involve a relatively small impact of selection on traits or genes, with relatively weak adaptive advantages. In this case, there may be some variation in traits or genes within the species, but there is no clear selection trend.

2.2 How to measure and analyze selective constraints

In order to understand and analyze selective constraints, biologists use various methods to measure and study different types of selective constraints. One of the most common methods is to compare gene sequences and protein structures (Bai et al., 2020) to look for signs of selective constraints.

Comparative genomics: By comparing the genomes of different species, researchers can identify genes that are selectively constrained in evolution. This can be achieved by analyzing the conservation of homologous genes in different species, where genes with higher conservation are often subject to strong selective constraints. Comparing protein structures: Researchers can also analyze the structure of proteins to determine which parts of the protein are selectively constrained. If the functional parts of a protein are strongly selectively constrained, the structure of these parts will remain highly conserved across different species.

2.3 The role of selective constraints in ecological niches

Selective constraints play a crucial role in ecological niches, affecting biodiversity, population dynamics, and species adaptability (Yan et al., 2021). Niche is the sum of the roles and resource utilization of species in an ecosystem, while selective constraints determine how species adapt and respond to environmental changes.

In ecological niches, positive selective constraints help populations adapt to new environmental conditions, thereby promoting species diversity. For example, in new habitats, species may experience positive selective constraints to adapt to new resource utilization strategies. This constraint drives resource allocation and niche differentiation, leading to the formation of new niches.

Negative selective constraints hinder the spread of maladaptive features or genes, helping to maintain the adaptability of organisms. It can maintain biodiversity because harmful features are less likely to spread within populations. However, excessive negative selective constraints may lead to species having overly conservative ecological niches, limiting their adaptability.

Neutral selectivity constraints and weak selectivity constraints are usually related to randomness and genetic drift in evolution. Their role in different ecological niches is relatively small, but they can influence the evolutionary path of species over a long period of time.

Selective constraints play an important role in the formation and maintenance of ecological niches, and different types of selective constraints shape the ecological niche and adaptability of species. Further research on the role of selective constraints can help to better understand the maintenance of biodiversity and the stability of ecosystems.

3 Differences in Selective Constraints in Three Ecological Niches

Selective constraints in niches are an important field of ecological and evolutionary biology research, and the study of the differential patterns of selective constraints in different niches provides an opportunity to gain a deeper understanding of the mechanisms of niche differentiation and biological adaptation. Niche characteristics shape the performance of selective constraints in different niches, promoting species diversity and ecosystem stability.

3.1 Research on the differential patterns of selective constraints in different ecological niches

Biocommunities in different ecological niches face different environmental pressures and resource availability, which leads to differences in selective constraint patterns in different ecological niches (Li and Han, 2022). Research has shown that the nature and degree of selective constraints are influenced by factors such as the characteristics of biological communities, resource distribution, and competitive relationships. Taking herbivores as an example, different herbivorous species face different selective constraints in different ecological niches such as grasslands and forests. In grasslands, herbivorous animals face more intense competition, resulting in stronger selective constraints that encourage them to develop higher herbivorous efficiency and faster response abilities. In forests, resources are relatively abundant and selective constraints are weak, resulting in some forest herbivorous animals being more diverse in size and life history strategies.

In the ecological niche of the African savannah, wild zebras and wildebeests are two typical herbivores. They face selective constraints due to limited vegetation and intense food competition. Wild zebras adapt to grassland ecological niches with their agile running and quick reaction ability, in order to timely avoid predators and obtain food (Figure 1). In contrast, wildebeests have developed higher herbivorous efficiency to more effectively utilize scarce plant resources. This selective constraint difference leads to adaptive differences in life history strategies, behaviors, and physiological characteristics between the two.

Figure 1 Selective constraints of wild zebra and wildebeest

The differential pattern of selective constraints is also evident in carnivores. There are significant differences in predatory strategies between raptors and carnivorous mammals in different ecological niches. Raptors such as eagle birds often appear in open grasslands or mountainous ecological niches, requiring fast flight and sharp vision to capture fast-moving prey. In contrast, ground predators such as leopards live in dense forest niches, and selective constraints have relatively low visual requirements, but higher requirements for muscle strength and strategies for quietly approaching prey.

3.2 Case study on selective constraints based on different ecological niches

How selective constraints in different niches affect the evolution and adaptation of species. Sparrows are a type of bird widely distributed in urban and rural areas, which experience different selective constraints in these two different ecological niches, leading to differences in evolutionary adaptation (Zhang et al., 2018). In urban environments, sparrows face high levels of artificial light pollution and noise pollution. To adapt to these challenges, sparrows in cities often have shorter wingspans, which makes them more flexible in flying between urban buildings to obtain food and avoid danger (Figure 2).

Figure 2 The birds in the cities have a shorter wingspan

The singing frequency of sparrows in the city has also changed to avoid interference with urban noise. In contrast, the selective constraints faced by sparrows in rural areas mainly come from food availability and predator pressure. This leads to differences in dietary habits among rural sparrows, who are more focused on feeding on insects and plant seeds rather than artificial food sources in cities. Meanwhile, the colors and feathers of rural sparrows may also adapt to more natural environments to reduce the risk of being preyed upon by natural enemies.

Fish in aquatic environments also exhibit differences in selective constraints across different ecological niches. Fish in freshwater and seawater environments also experience different selective constraints, leading to differences in physiological and behavioral adaptability. In marine environments, fish face multiple challenges from salinity, water temperature, and food availability. To address these challenges, some marine fish have developed highly salt tolerant humoral regulation abilities to maintain normal internal salinity. In addition, they may have a highly streamlined body shape to adapt to the water flow and predation in seawater.

Freshwater fish typically live in environments with relatively stable salinity, but may face different challenges such as temperature changes and seasonal changes in food resources. Therefore, their fluid regulation ability may not be as strong as that of marine fish, but they may exhibit adaptability to low temperatures. In addition, the body size and dietary choices of freshwater fish may also vary to adapt to different freshwater ecological niches and food resources.

3.3 How ecological niche characteristics affect the performance of selective constraints

Niche characteristics play a crucial role in the selective constraint performance of different niches. These characteristics include resource availability, food types, degree of competition, and habitat complexity (Yu et al., 2022). Taking birds as an example, there are significant differences in ecological niche characteristics among carnivorous bird populations residing in different geographical regions. In resource scarce desert niches, the red bellied Whistler in Australia has undergone significant adaptive changes in its mouth shape and feeding habits to more effectively capture scarce insect food. Their mouths become longer and thinner, helping to catch flying insects in the air.

In resource rich niches, such as the rainforests of South America, there are different populations of carnivorous birds, such as the Pitta sordida (Figure 3). The ecological niche characteristics of these birds are significantly different from those of the red bellied thrush. Due to the abundance of insects in rainforest environments, their mouth shapes may be more suitable for hunting different types of insects, such as butterflies and beetles. These different ecological niche characteristics reflect differences in resource availability and food types, which have a significant impact on the performance of selective constraints.

Figure 3 The mouth shape of the green breasted eight colored thrush can prey on different types of insects

The degree of competition and habitat complexity also play a crucial role in selectively constraining the ecological niche. In highly competitive niches, species may experience stronger selective constraints, leading to more significant adaptive changes. The complexity of habitats, such as the vegetation structure in forests, can also affect the way selective constraints are applied. Species may evolve adaptive characteristics in different habitats to better survive and reproduce under specific environmental conditions.

4 Niche Differentiation and Evolution

Niche differentiation is a key concept in biological evolution, which involves how different species co evolve in the same habitat to avoid excessive competition. The selective constraints in different niches play a crucial role in niche differentiation.

4.1 Mechanism of niche differentiation

Niche differentiation refers to the evolution of different niches by different species in a common habitat to avoid direct competition (Dent and Estrada-Villegas, 2021), such as hummingbird species on Pacific islands. These islands have a large number of hummingbird species, but they have evolved their own ecological niches based on different food resources. Some hummingbird species have evolved long and slender mouths to feed on deep nectar, while others have evolved short and robust mouths to prey on insects. This differentiation is due to the fact that deep nectar and insects are the main food resources on specific islands. This differentiation allows different hummingbird species to coexist in the same region, reducing resource competition and thus maintaining ecological balance.

4.2 Selective constraints promote or hinder niche differentiation

The study of the differential patterns of selective constraints in different niches reveals how selective constraints promote or hinder niche differentiation (Liu et al., 2021). Taking giant pandas and red pandas as examples, they both belong to herbivorous animals but live in different habitats and are therefore subject to different selective constraints. Giant pandas mainly eat bamboo, which causes their digestive system to adapt to this food, while red pandas mainly eat insects and small mammals. The different food choices of these two lead to niche differentiation, despite having similar ancestors.

Selective constraints can also hinder niche differentiation. When the ecological niche overlap between species is significant and competition is intense, selective constraints may lead to increased competition pressure, making niche differentiation more difficult. Two bird species with similar food resources may not be able to evolve significant niche differences due to competition.

4.3 Ecological and evolutionary significance of niche differentiation

Niche differentiation has significant implications for ecology and evolution. From an ecological perspective, niche differentiation helps maintain the stability and diversity of ecosystems (Zheng and Gong, 2019). When different species occupy different niches in the same ecosystem, they can avoid direct competition for the same resource and reduce competition pressure. This resource segmentation facilitates species coexistence and promotes an increase in species diversity in ecosystems. Plants can obtain different nutrients at different depths in the soil, reducing competition and forming multi-level plant communities.

From the perspective of evolutionary chemistry, niche differentiation is a pathway for the formation of new species. When species adapt to different ecological niches, they may face different environmental pressures and resource utilization methods, leading to the accumulation of adaptive differences. Over time, these accumulated adaptive differences may lead to differences in species morphology, physiological characteristics, and behavior, ultimately leading to species differentiation. In island ecosystems, the same ancestral species adapt to different island environments, ultimately forming different species with specific characteristics and habits.

Niche differentiation provides opportunities for the generation of biodiversity. It promotes the formation of new species by creating new ecological niches, increasing the diversity of species and functions in the ecosystem. This is crucial for the stability of ecosystems, as the diversity of species composition can enhance their ability to resist environmental changes and disturbances.

5 Conclusion

There are significant differences in selective constraint patterns among different ecological niches. Biological populations face different selective constraints under different environmental conditions, which play a crucial role in adaptive evolution. Selective constraints may vary due to factors such as availability of niche resources, competitive pressures, and predatory pressures. The ecological niche characteristics have a significant impact on the performance of selective constraints. The functional characteristics, behavioral habits, and niche utilization strategies of organisms can shape the nature of selective constraints. The biological populations in different niches may experience different types of selective constraints due to the different characteristics of their niches.

Selective constraints are closely related to niche differentiation and evolution. Selective constraints can promote niche differentiation, leading to differences in resource allocation among different populations in similar niches. This further promotes the evolution of niches and the maintenance of species diversity in ecosystems. This study delves into the differential patterns of selective constraints in different niches to explore their importance in the fields of ecology and evolutionary ecology.

The significance of this study lies in providing a profound understanding of selective constraints in different niches. It helps to explain and predict the adaptive evolution of biological populations. Understanding the differential patterns of selective constraints in different niches helps us understand why certain species thrive under specific environmental conditions while others are restricted. This is crucial for protecting and managing biodiversity, especially in the face of threats such as climate change and habitat destruction. This type of research helps to better understand the construction and function of niches. Niche is a core concept in ecosystems, which involves how different populations coexist and synergistically utilize resources. The study of selective constraints helps to explain how biodiversity is maintained in different niches and provides profound insights for improving ecosystem management and restoration strategies. By delving into the differential patterns of selective constraints, we can better predict the response of biological species to future environmental changes. This is crucial for the sustainability and management of ecosystems, as it requires understanding the potential adaptability and vulnerability of biological populations in different niches.

Despite providing important insights into the differential patterns of selective constraints in different niches in this study, there are still many potential research areas and contributions. More cross niche comparative studies are needed to further confirm the differences in selective constraint patterns. This will help us determine which niche factors have the greatest impact on the differences in selective constraints. Studying how selective constraints affect the relationship between biodiversity and ecosystem function will be an important direction for future research. This helps us understand the stability and resilience of ecosystems. By utilizing advanced molecular biology and ecological technologies, we can further explore the molecular basis and niche utilization strategies of selective constraints. This will help reveal the link between selective constraints and genomic evolution and niche adaptation. These future studies will help to better manage and protect the ecosystems on Earth.

References

Bai H., Lu H.Z., Wang L., Wang S.S., Du W.L., and Zhang T., 2020, Tissue differential expression and analysis of protein structure and function of mouse CYP2J5 gene, Shengwuxue Zazhi (Journal of Biology), 37(1): 20-25.

Chang H., Qiu Z., Yuan H., et al. Evolutionary rates of and selective constraints on the mitochondrial genomes of Orthoptera insects with different wing types[J]. Molecular phylogenetics and evolution, 2020, 145: 106734.
https://doi.org/10.1016/j.ympev.2020.106734
PMid:31972240

Dent D.H., Estrada-Villegas S., Uniting niche differentiation and dispersal limitation predicts tropical forest succession[J]. Trends in Ecology & Evolution, 2021, 36(8): 700-708.
https://doi.org/10.1016/j.tree.2021.04.001
PMid:33966918

Feng X., Park D.S., Liang Y., et al. Collinearity in ecological niche modeling: Confusions and challenges[J]. Ecology and evolution, 2019, 9(18): 10365-10376.
https://doi.org/10.1002/ece3.5555
PMid:31624555 PMCid:PMC6787792

Li J.M., and Han X.Z., 2022, The effects of trait-mediated niche construction on evolutionary distribution dynamics of species with resource competition, Shengtai Kexue (Ecological Science), 41(6): 167-175.

Liu K., Yu N.J., Yu C.G., Zheng J., Xu Y.J., Yan W.C., Han L., Liu H., Sun B.B., and Dai D.X., 2021, The spatial niche and differentiation of major fish species in the waters east of the Zhoushan Islands in spring and autumn, Zhongguo Shuichan Kexue (Chinese Aquatic Science), 28(1): 100-111.
https://doi.org/10.3724/SP.J.1118.2021.20136

Massip F, Laurent M, Brossas C, et al. Evolution of replication origins in vertebrate genomes: rapid turnover despite selective constraints[J]. Nucleic Acids Research, 2019, 47(10): 5114-5125.
https://doi.org/10.1093/nar/gkz182
PMid:30916335 PMCid:PMC6547456

Sánchez-Lanzas R, Kalampalika F, Ganuza M. Diversity in the bone marrow niche: classic and novel strategies to uncover niche composition[J]. British Journal of Haematology, 2022, 199(5): 647-664.
https://doi.org/10.1111/bjh.18355
PMid:35837798 PMCid:PMC9796334

Shtolz N., and Mishmar D., The mitochondrial genome-on selective constraints and signatures at the organism, cell, and single mitochondrion levels[J]. Frontiers in Ecology and Evolution, 2019, 7: 342.
https://doi.org/10.3389/fevo.2019.00342

Yan W., Fen X.J., Zhang W., Zhang R., and Jiao N.Z., 2021, Research advances on ecotype and sub-ecotype differentiation of Prochlorococcus and its environmental adaptability, Zhongguo Kexue (Chinese Academy of Sciences), 51(1): 35-45.

Yu J., Bai X.J., and Wang Z.Y., 2022, Niche characteristics and competitive relationship of Larix gmelinii between different age classes in Greater Khingan Range secondary forest area, Shengtai Xuebao (Acta Ecologica Sinica), 42(12): 4912-4921.
https://doi.org/10.5846/stxb202106231667

Zhang J., Zhao C.Z., Ren Y., Li X.P., and Lei L., 2018, Study of the dominant bird population ecological niche in Zhangye National Wetland Park of Gansu Province, Shengtai Xuebao (Acta Ecologica Sinica), 38(6): 2213-2220.
https://doi.org/10.5846/stxb201701140116

Zheng Y., and Gong X., 2019, Niche differentiation rather than biogeography shapes the diversity and composition of microbiome of Cycas panzhihuaensis[J]. Microbiome, 2019, 7(1): 1-19.
https://doi.org/10.1186/s40168-019-0770-y
PMid:31791400 PMCid:PMC6888988