



FOCUS QUESTIONS

- What does it mean for a species to be a keystone species and what are some examples of these species?
- What is the role of seed dispersers in an ecosystem?
- What are some of the major anthropogenic (human caused) threats to the Earth's biodiversity and why?
- If some native species are now permanently extinct from a habitat, how can we still successfully restore their functions to those areas?
- How can the restoration and conservation of a few species lead to the conservation of additional species?

OVERVIEW

“Cada um desses animais é como se fosse uma pedrinha num quebra-cabeça. Então, é por isso que é importante a gente perceber quem está faltando e trazer esses animais de volta para a floresta para que ela possa funcionar de uma forma inteira, completa, como era no passado.” (Portuguese) Alexandra Pires

“Each of these animals is like a piece in a puzzle. So that's why it's important to perceive what is missing and bring those animals back to the forest so it will be able to function in an entire, complete way, as it did in the past.”

In ***Rewilding Rio*** we meet conservation biologist Alexandra Pires from the Federal Rural University of Rio de Janeiro and ecologist and reforestation expert Fernando Fernandez from the Federal University of Rio de Janeiro. The two biologists and their team, Project Refauna, have launched a unique and hopeful effort to bring the red-rumped agouti (*Dasyprocta leporina*), the endangered yellow-footed tortoise (*Chelonoidis denticulatus*), and the vulnerable brown howler monkey (*Alouatta guariba*) back to Tijuca National Park, a Brazilian Atlantic Forest reserve within the city limits of Rio de Janeiro. As seed dispersers, the three species function as critical keystone species because their absence from the rainforest, and other seed dispersers like them, severely reduces the ability of fruit trees, like the threatened Brazil nut “agouti” tree (*Bertholletia excelsa*), to maintain their populations.

KEY CONCEPTS

- **Threatened and Endangered Species:** The International Union for the Conservation of Nature lists more than 44,000 species threatened with extinction. Habitat loss and destruction and agriculture are the major threats for more than 85% of these species.
- **Biodiversity:** Allowing large tracts of habitat like forests to be returned to a more natural state can help mitigate biodiversity threats, but we are learning that if previously lost animals and the ecological processes they influence are not included in restoration efforts, a habitat will not return to its full functional potential.
- **Conservation biology:** The practice of conservation biology recognizes the intrinsic value of the Earth's natural diversity of organisms. Conservation biology works to understand how the natural world operates, how humans affect nature, and how we can use collective scientific and cultural knowledge to conserve Earth's biological diversity.
- **Defaunation:** The loss of both species and populations of wildlife, as well as local declines in abundance of individuals is a human-caused process similar in its seriousness to deforestation. Deforestation is dramatic in its appearance and is more easily tracked and communicated to the public through compelling images of the magnitude, rapidity, and extent of forest loss. However, defaunation is more of a largely invisible phenomenon because it can occur even in large protected habitats which makes it difficult to quantify without intensive surveys.
- **Refaunation:** To reverse defaunation and its disruption of critical ecological processes native fauna must be reintroduced to areas where they have been previously extirpated. Refaunation has the potential to



restore plant-animal interactions which can improve plant diversity and through seed dispersal mechanisms restore the age class structure within a plant species like large fruit-bearing trees.

- **Rewilding:** A primary goal of some ecological restoration projects is to go beyond conventional restoration, where some level of management is required to maintain ecosystem processes, and emphasize the importance of truly wild ecosystems by embracing their unpredictable and dynamic abiotic (e.g. droughts and floods) and biotic (e.g. food webs and population cycles) natural processes.
- **Keystone species:** Together, red-rumped agoutis, yellow-footed tortoises, and brown howler monkeys are keystone species because they function as essential seed dispersers of large fruit-bearing trees like the threatened Brazil nut tree.
- **Seed dispersal:** Seed dispersal is the process by which plants use wind, ejection, water, gravity, and animals to move their seeds far away from the parent plant. Various biodiversity threats including habitat fragmentation, overharvesting, biological invasions, and climate change interact negatively with a plant's ability to disperse seeds. In *Rewilding Rio* we learn that the local extinction of three major seed dispersing animals, the agouti, the yellow-footed tortoise, and the brown howler monkey has disrupted the ability of the large fruiting trees of the Atlantic coast of South America to disperse their seeds and maintain their populations.

BACKGROUND

For the last few decades and continuing today large tracts of forests and savannas in South America are being converted into agricultural and pasture lands. This habitat destruction and fragmentation leaves behind islands of small patches that can hardly sustain viable wild populations of large endemic animals with many species having been completely extirpated from some areas altogether. The disappearance of animal species is called defaunation and the phenomenon disrupts important ecosystem processes like seed dispersal, an essential mechanism for maintaining populations of large fruit trees. For example, the Brazil nut tree (*Bertholletia excelsa*) is a native Amazonian tree that is threatened with extinction in Brazil due to deforestation. Even in small, protected areas the trees struggle to sustain their populations because of their dependence on animals to disperse their seeds. However, as we learn in the film *Rewilding Rio* a group of conservation biologists are determined to reverse the damage by countering decades of defaunation with the rewilding of Tijuca National Park (TNP), a Brazilian Atlantic Forest reserve within the city limits of Rio de Janeiro.

The refaunation of TNP is an important landscape experiment because the park is considered the largest urban forest in the world with an area of 3,953 ha (15 sq miles). The area was farmed up to the 19th century and was then partly reforested. However, the reforestation did not include restoring the animals that were lost with the original forest. Researchers estimate that only 11 of the 33 large and medium-sized vertebrate species that should live in the park are actually found there. Enter conservation biologists Alexandra Pires and Fernando Fernandez and their research team, Project Refauna. Project Refauna began their efforts in 2010 by translocating red-rumped agoutis from a semi-captive population that was being maintained in an urban park in the center of Rio de Janeiro. The agouti is a keystone species in the Atlantic coast rainforests of South America because their strong teeth can break open the fruits of large trees and help disperse their seeds. Eleven males and 10 females were captured and moved to TNP in September of 2010. While more than half of the 21 individuals died within the weeks and months after reintroduction, the researchers were encouraged to see that by the eighth month four of the remaining females had produced 10 offspring. The researchers were also pleased to see that the proportion of the park used by individual agoutis was far larger than the range sizes suggested by earlier studies of agoutis in the wild. The agoutis were also observed eating the fruits of the Brazil nut "agouti" tree and burying the seeds for later consumption. But lucky for the trees, agoutis often fail to recover all the seeds they bury, a phenomenon which helps recruit new trees into the aging population. But one species is not enough to maintain an entire forest.



A second keystone species that has been reintroduced is the brown howler monkey. For decades the brown howler monkey has been suffering from hunting, deforestation and habitat fragmentation, and bouts of yellow fever. These threats have put the species at risk of extinction and they are listed among the 25 most endangered primates of the world. In an experiment in 2015, six individuals from the Rio de Janeiro Primatology Center were released in TNP. Two of the monkeys coupled and produced five offspring and additional individuals were released in 2022. While the monkeys are few, they have the ability to aid the agoutis in dispersing seeds by moving long distances and depositing the seeds in their dung far from the parent trees. However, the monkeys have been observed feeding on the fruits of 60 different species of animal dispersed plants!

A third keystone species was reintroduced to TNP in 2020 after at least a 200 year absence. While smaller, and a bit slower moving, the yellow-footed tortoise, like the agoutis and howler monkeys, functions as a keystone species by eating the fruits of dozens of plants and depositing the seeds in their dung. Indeed, a recent study found that the yellow-footed tortoise can disperse the seeds of up to 338 different species of fruiting plants and 84 of those plant species are threatened with extinction due to habitat loss. Moreover, the seeds remain in the guts of the tortoises for up to five days and the tortoises digestive acids make the seeds primed for germination as soon as they are excreted.

While all of the original 33 species of large and medium-sized vertebrates will likely never return to Tijuca National Park because it is simply too small to support them all, the agouti, howler monkey, and tortoise may be capable enough as keystone species to begin to restore some of the natural functions of the forest and help bring it back to equilibrium.

BIODIVERSITY THREATS

The major threats to the Earth's biodiversity can be grouped into seven categories that spell the easily recalled acronym H.I.P.P.O.: **H**abitat destruction and fragmentation, **I**ntroduced species, **P**ollution, **P**opulation growth, and **O**verharvesting. Many species are threatened by a combination of these factors, but habitat loss is the greatest threat to biodiversity. In *Rewilding* Rio we learn that even though Tijuca National Forest is a protected Brazilian forest reserve, a past history of deforestation, the growing human population of Rio de Janeiro, and the local extinction of three critical seed dispersing species has led to some large fruit trees in the forest to struggle to maintain their populations. However, these effects can be mitigated in large part by translocating individual agoutis, yellow-footed tortoises, and brown howler monkeys to the forest preserve where the animals can feed on the fruits of the trees and help spread their seeds.

DISCUSSION QUESTIONS

- [Before showing the film] Have students brainstorm what it means for a species to be a keystone species and have them list some species that they think function as keystone species.
- [Before showing the film] Have students discuss the ways in which seed plants disperse their seeds and maintain healthy populations and encourage them to consider the roles that animals may play in helping plants disperse their seeds.
- In the film we learn that dung beetles also play a role in the health of the forest. Have students create a simple model of the Tijuca National Park ecosystem nutrient cycle that includes the Brazil nut trees, the three keystone species from the film, and dung beetles.
- Ask students to outline the similarities and differences in how the agouti, howler monkey, and tortoise function as seed dispersers.
- Ask students to discuss the possible social challenges to refaunation of a large urban forest like Tijuca National Park and how might those challenges be overcome. Have students also consider why the researchers aim to return some but not all of the historically present animals to the ecosystem.



Curriculum Connections

NGSS

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS2.D: Social Interactions and Group Behavior
- LS4.D: Biodiversity and Humans

HS-LS4 Biological Evolution: Unity and Diversity

- LS4.C: Adaptation

ETS1.B: Developing Possible Solutions

AP Biology (2021)

Enduring Understandings

- Energetics (ENE)
 - ENE-4: Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment.
- Systems Interactions (SYI)
 - SYI-1: Living systems are organized in a hierarchy of structural levels that interact.
 - SYI-3: Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

IB Biology (First Exam May 2025)

A. Unity and Diversity: Common ancestry has given living organisms many shared features while evolution has resulted in the rich biodiversity of life on Earth.

- A3.1 Diversity of organisms
- A4.2 Conservation of biodiversity

B. Form and Function: Adaptations are forms that correspond to function. These adaptations persist from generation to generation because they increase the chances of survival.

- B4.1 Adaptation to environment
- B4.2 Ecological niches

C. Interaction and Interdependence: Systems are based on interactions, interdependence and integration of components. Systems result in emergence of new properties at each level of biological organization.

- C4.1 Populations and communities
- C4.2 Transfers of energy and matter

D. Continuity and Change: Living things have mechanisms for maintaining equilibrium and for bringing about transformation. Environmental change is a driver of evolution by natural selection.

- D4.2 Stability and change

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CREDIT

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