FOCUS QUESTIONS

- What are the general steps of primary ecological succession and what role might seabirds play in helping life take hold on newly formed land like volcanic islands?
- In what ways do introduced invasive plant and animal species affect native species, especially on islands?
- Most seabirds breed on land but feed in saltwater. How did this dual life history strategy lead to their millions of years of success while also presenting a challenge to seabird survival?
- What are some strategies for reversing the decline of seabird populations across the globe?

OVERVIEW

"Before humans came here, there were so many seabirds that they would blacken the skies." - Jay Penniman, Ecologist

Seabird Sanctuary chronicles the efforts of ecologists from the Maui Nui Seabird Recovery Project to help recover several populations of declining shearwater seabirds. This effort includes eliminating invasive predators, restoring native plants, and monitoring burrows for fledgling success. Through their hopeful efforts, the team is giving seabirds a chance to raise the next generation on the very islands they helped bring to life.

KEY CONCEPTS

- Threatened and Endangered Species: The International Union for the Conservation of Nature (IUCN) lists more than 44,000 species threatened with extinction, which includes almost half of the world's 346 seabird species.
- Ecological succession: The volcanic Hawaiian Islands have continually undergone the process of primary ecological succession where plants and animals first colonize a lifeless and barren landscape like that of new volcanic rock. The rate and sequence of this process has been dependent in large part on the deposition of ocean-derived nutrients from the guano of seabirds.
- Ecosystem engineers: By modulating nutrient availability in the terrestrial component of their ecosystems as well as building nest burrows seabirds chemically and physically engineer their nesting habitats and control the types of plants and animals that can live there.
- Biodiversity: The nesting activity of shearwaters disrupts the landscape in a way that makes it difficult for some plants to grow in the burrow-pocked landscape of nesting sites, so plant diversity is actually lower in nesting habitats than non nesting areas. However, seabird activity can also encourage the competitive and overbearing presence of invasive exotic plant species that crowd out important endemic species.
- Introduced (exotic) invasive species: One of the key threats to biodiversity and ecosystem function is the movement of species by humans to locations other than their historical geographic ranges. For example, scientists estimate that of all the world's vascular plant species 3.9% have been introduced by humans. Since humans began arriving on the islands, they brought with them both plant and animal species from the mainland that wreak havoc on endemic species through competition for resources and predation.
- Restoration ecology: Centuries of unsustainable human activities have degraded the Earth's terrestrial, freshwater, and marine ecosystems. Restoration ecology is focused on reversing this degradation by restoring natural habitats and processes. An example of this approach illustrated in ***Seabird Sanctuary*** is on the island of Maui where volunteers and researchers have transformed land that had been previously used for cattle grazing into a safe nesting site for seabirds.
- 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.

BACKGROUND

The Hawaiian archipelago consists of eight major volcanic islands that emerged from the Pacific Ocean between 28 million (Kure Atoll) and 400,000 (Hawai'i, "the big island") years ago. From their origin, and to this day on the still volcanically active island of Hawai'i, the Hawaiian archipelago has continually undergone the process of primary ecological succession where plants and animals first colonize a lifeless and barren landscape like that of newly formed volcanic rock. The rate and sequence of this process has been dependent in large part on the deposition of ocean-derived nutrients from the guano of seabirds. The feeding of seabirds in the ocean followed by their nesting presence on land provides a "nutrient express" for moving ocean-derived nitrogen, phosphorus, and potassium into the soil of plant communities. By modulating nutrient availability in the terrestrial component of their ecosystems as well as building nest burrows seabirds chemically and physically engineer their nesting habitats and help life take hold and persist.

The nutrient express and nest burrow building of seabirds has a significant effect on the local biodiversity by providing essential nutrients and unique habitat structure to areas that would not have them otherwise. However, the effect on biodiversity is not in the direction one would expect. Plant diversity studies comparing nesting habitats to non-nesting habitats have shown that plant diversity is actually lower in the nesting habitats due to the difficulty of some plants to grow in the burrow-pocked landscape that seabird nesting creates. This effect is coupled with the competitive and overbearing presence of invasive exotic plant species that crowd out many of the 956 plant species that are native to the Hawaiian Islands. Scientists estimate that approximately 75% of the ancestors to these 956 plant species arrived to the islands with the aid of birds, 23% arrived by ocean currents, and 2% arrived by wind dispersal. Animals arrived from the mainland by flight and on debris rafts. However, since humans began arriving on the islands, they brought with them additional plant and animal species from the mainland that can wreak havoc on endemic species through competition for resources and predation. One answer to the challenge introduced invasive species pose to nesting seabirds is to purposefully restore native plant species and remove those that do not belong while also restricting access by introduced predators. An example of this approach illustrated in ***Seabird Sanctuary*** is on the island of Maui where volunteers and researchers have transformed land that had been previously used for cattle grazing into a safe nesting site for seabirds.

Seabird Sanctuary highlights two species of seabirds called shearwaters, the Wedge-tailed Shearwater (*Puffinus pacificus*) and the Newell's Shearwater (*Puffinus newelli*). Shearwaters are medium-sized seabirds with long wings in the Petrel family (Procellariidae) that, like most seabirds, feed in saltwater and breed on land. Modern seabirds likely have their origin at the end of the Cretacious Period around 66 million years ago. However, seabirds are not recognized as a united taxonomic group because the group in its entirety does not share a single common ancestor. For tens of millions of years seabirds, including shearwaters, have successfully functioned as important ecosystem engineers providing nutrients for plant growth and building unique physical habitats along seashores, but especially on islands like the Hawaiian archipelago. Unfortunately, almost half of all 346 seabird species are suspected or known to be in decline. Ninety-seven species (28%) are globally threatened, and an additional 10% are listed as Near Threatened. The Newell's Shearwater we learn about in ***Seabird Sanctuary*** is listed as endangered on the IUCN Red List and is also listed as threatened and protected at both the federal (US) level and throughout the state of Hawaii.

But there is hope for seabirds. In the film we learn about the efforts of ecologists Jay Penniman, Jenni Learned, and Martin Frye of the Maui Nui Seabird Recovery Project and volunteer Martha Martin who, along with many other researchers, volunteers, and community members are working to help recover and protect several populations of declining shearwater seabirds. The team locates active seabird nesting sites, educates the local population about the plight and importance of the birds, and monitors their nesting success. The Seabird Recovery Project group also initiates predator and invasive plant species removal from coastal restoration sites

to allow for the regeneration of native plants and rescues and rehabilitates seabirds that are injured or malnourished so they can be successfully released back into the wild. These efforts are making a significant positive impact on the islands' seabird populations and have become models for other communities where seabirds are in decline. For example, we learn in the film that the Wedge-tailed Shearwater population in one location has increased from 16 active nesting burrows in 2001 to over 3,000 in 2021.

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 ***Seabird Sanctuary*** we learn that habitat loss through urban development on or near shearwater nesting grounds is causing a decline in their populations. But seabirds like shearwaters are also threatened by introduced predators that include cats, dogs, rats, mongoose, and pigs which consume adults, eggs and young chicks.

DISCUSSION QUESTIONS

- [Before showing the film] Have students brainstorm and discuss how islands like the Hawaiian archipelago transitioned from barren, newly emerged volcanic rock to ecosystems rich with plant and animal life. How is this process ongoing?
- [Before showing the film] Have students brainstorm and discuss what effects they think introduced species can have on local ecosystems and their functions.
- Ask students to explain how seabirds are directly involved in the cycling of matter and transferring of energy in their ecosystems.
- Have students describe the disruptions seabirds have experienced to their environment and how those disruptions have impacted seabird populations.
- What solutions do we learn in the film are available to the inhabitants of the Hawaiian Islands and similar seashore communities for protecting and restoring their seabird populations?

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
- PS3.D: Energy in Chemical Processes

HS-LS4 Biological Evolution: Unity and Diversity

- LS4.C: Adaptation

ETS1.B: Developing Possible Solutions

AP Biology (2021)

Enduring Understandings

- Energetics (ENE)
  - ENE-1: The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
  - 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-2: Competition and cooperation are important aspects of biological systems.
    - 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.
    - A1.1 Water
    - 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.
    - B4.2 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.
    - D3.1 Reproduction
    - D4.2 Stability and change

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CREDIT

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