FOCUS QUESTIONS

- Why do lead-based bullets pose such a risk for raptors like golden eagles when raptors are not the animals targeted by hunters?
- What are the similarities and differences between the processes of bioaccumulation and biomagnification?
- What are some strategies for convincing hunters to use lead-free bullets?

OVERVIEW

“Golden eagles, besides for the fact that they're ridiculously cool and amazing creatures, are really good indicators of ecosystem health.”

“Knowing that everything we do to use lead free options out there is helping a bird. That gives me a ridiculous amount of hope.” - Bryan Bedrosian, Conservation Director with the Teton Raptor Center, Director of Sporting Lead-Free.

In ***Unleaded*** we learn about the ongoing plight of raptors in North America with a particular focus on the golden eagle (*Aquila chrysaetos*). The eagle population and populations of other raptors were decimated between the 1940s and 1960s due to the use of the pesticide dichlorodiphenyltrichloroethane (DDT), but they have bounced back since the 1972 ban of DDT use in the United States. However, raptors, including the eagle, now suffer from lead poisoning by ingesting the lead fragments of bullets found in gut piles of animals taken by hunters. Raptor conservationist, Bryan Bedrosian, and his colleagues, including Sporting Lead-Free Program Director, Hannah Leonard, have shown how the lead fragments form and can kill raptors after they scavenge the gut piles. Their research and efforts to educate hunters have significantly reduced the lead levels found in golden eagles and their raptor kin.

KEY CONCEPTS

- Bioaccumulation: Some harmful chemicals can accumulate in the tissues of an organism faster than they can be detoxified and eliminated. For example, the heavy metal lead can reach toxic levels in both plants and animals, including humans. In ***Unleaded*** we learn that when lead accumulates in raptors like golden eagles it can cause kidney failure, blindness, paralysis, and seizures. These same effects can happen in humans.
- Biomagnification: Some harmful chemicals can reach toxic levels as they are transferred from one trophic level to the next in a process called biomagnification. While the overall mass of a toxic chemical like lead does not change as it moves through food chains and up trophic levels, the proportion of its mass to the mass of the trophic level can increase by orders of magnitude because the overall biomass of the trophic level decreases.
- Epistemology: Also known as the theory of knowledge, epistemology deals in large part with the acquisition of knowledge and its limitations. A major knowledge claim in the film is that lead-based bullets are causing lead poisoning in raptors but the limitation of this knowledge is that it would be unethical to conduct a controlled experiment that includes feeding lead fragments to raptors to see its direct effects.
- Corridor ecology: Wildlife have many reasons for needing to travel across large swaths of land but human activity has removed that ability by fragmenting large contiguous ecosystems into small isolated island habitats while also bisecting the fragments with roads and highways which create dangerous barriers to animal movement. Corridor ecology studies how and why animals like raptors move throughout the Earth’s landscapes and how we can restore this essential ecosystem process.

- Apex predators: Animals that are at the top of their food chains and have no natural predators of their own are known as apex predators. Raptors, like golden eagles, are apex predators due to their specialized hunting adaptations and their position at the top of their food chains. Their powerful talons, hooked beaks, keen eyesight, and agility allow them to capture and consume a wide variety of prey, effectively regulating populations of other animals.
- Umbrella species: An umbrella species is a species whose conservation efforts indirectly protect other species that share the same habitat or ecosystem. This critical indirect effect is because umbrella species often have large home ranges, broad habitat needs, or specific habitat requirements that, when protected, also benefit other species in the same area. Umbrella species often serve as flagship species because, like the golden eagles that play a central role in ***Unleaded***, flagship species are usually large and charismatic, and efforts focused on saving them have a wide-ranging positive impact on other species.
- 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. Convincing hunters to use non lead bullets reduces lead poisoning of raptors and boosts efforts to conserve these important apex predators.

BACKGROUND

Raptors, or birds of prey, represent only 5% of all birds yet they have an outsized effect on ecosystem function by regulating prey and consuming decaying dead animals (carrion). However, raptors are of global conservation concern because 18% are threatened with extinction and over half have declining global populations. Raptors face a variety of threats that have led to population declines worldwide. One of the most significant threats is habitat loss and fragmentation, which reduces nesting and hunting territories. Electrocution and collisions with power lines and wind turbines pose significant mortality risks, as do illegal shooting and poisoning, often due to conflicts with humans or secondary ingestion of rodenticides. Climate change is also emerging as a long-term threat, shifting prey availability and suitable habitats. Pesticide exposure, particularly organochlorines like dichlorodiphenyltrichloroethane (DDT), historically caused reproductive failure in species such as the Bald Eagle and Peregrine Falcon, and although many of these chemicals have been banned in many countries, including DDT in the United States in 1972, these chemicals still persist in ecosystems. The threat focused on in ***Unleaded*** is heavy metal pollution, specifically lead bullet fragments that end up in gut piles left behind by hunters that are then scavenged by raptors like golden eagles.

Heavy metal poisoning in animals disrupts normal physiological processes by interfering with enzyme function, cellular respiration, and ion regulation. Metals such as lead, mercury, cadmium, and arsenic can mimic essential elements like calcium or zinc, allowing them to enter cells and bind to critical enzymes or structural proteins, rendering them nonfunctional. For example, lead interferes with the synthesis of heme, the oxygen carrying component of hemoglobin, by inhibiting the function of critical enzymes, leading to anemia and neurological dysfunction. Mercury compounds can disrupt mitochondrial activity and increase oxidative stress, resulting in cellular damage and neurotoxicity. Heavy metals often accumulate in soft tissues like the liver, kidneys, and brain where they can cause chronic toxicity, immunosuppression, and reproductive failure. The inability of an animal to metabolize or excrete these metals efficiently makes them especially dangerous because they bioaccumulate in the animal's tissues over time and while also magnifying their effects up through the food chain in a process called biomagnification.

A major way that lead enters ecosystems and their food webs is through the lead shot and lead-based bullets used by hunters. Efforts to address lead poisoning in birds, specifically waterfowl, began in the late 1950s when Illinois naturalist Frank Bellrose published seminal research estimating that 2–3% of North American waterfowl

succumbed annually to lead shot ingestion, largely mistaking the spent lead pellets in and near ponds and wetlands for grit. Bellrose's 1959 paper titled "Lead Poisoning as a Mortality Factor in Waterfowl Populations" became a catalyst for change and in 1972, the U.S. Fish and Wildlife Service initiated pilot bans in high-use "hot spots," particularly across the Atlantic Flyway. Over the next decade, these restrictions expanded amid legal challenges and advocacy, until a 1985 court ruling under the Endangered Species Act prompted a phased nationwide ban. By 1991, the use of lead shot for migratory waterfowl hunting was prohibited across the country. The ban has since been credited with significant declines in lead poisoning among ducks and eagles, validating Bellrose's early warnings and the policy actions they inspired. However, as we learn in ***Unleaded***, lead-based bullets that are still legally used in hunting remain a significant source of poisoning in raptors. Fortunately, Raptor conservationist, Bryan Bedrosian, and his colleagues, including Sporting Lead-Free Program Director, Hannah Leonard, are now leading an effort to reduce the lead poisoning threat to raptors. The conservationists, who are also hunters themselves, have shown how the lead fragments form and can kill raptors after they scavenge the gut piles. Their research and efforts to educate hunters have significantly reduced the lead levels found in golden eagles and their raptor kin, providing hope for the current and future populations of these important species.

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 ***Unleaded*** we are reminded of the environmental pollution caused by the use of DDT from the 1940s to 1960s that created a crisis for various species of raptors. Now another form of environmental pollution, lead fragments from the lead bullets of hunters, is poisoning the birds.

DISCUSSION QUESTIONS

- [Before showing the film] Have students brainstorm what they think the risks are to raptors in North America. If students struggle to come up with many ideas, coax them toward the major risks raptors currently face: habitat loss, collisions with structures (powerlines, vehicles, wind turbines, buildings), pesticides, disease, and persecution. It is unlikely that students will think of lead poisoning.
- After showing the film, assign students one of the heavy metals that are toxic if ingested by animals, including humans: arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel. Have students research how their assigned metal can poison the animal that ingests it.
- In the film we hear Sporting Lead-Free Program Director, Hannah Leonard, state that "hunters are the original conservationists." In a typical class, there will be some students who agree with this claim and some who disagree. Have students discuss whether or not they agree with Hannah and explain why.
- As an extension activity, have students visit the Teton Raptor Center and Sporting Lead-Free websites and read more about their raptor conservation efforts. Students can also read more about movement ecology and habitat mapping, population ecology, bioacoustics, and genetics and lead research.
- The ***Unleaded*** film takes place in the Greater Yellowstone Ecosystem of Wyoming, Idaho, and Montana. This important landscape is part of the Yellowstone to Yukon Conservation Initiative (y2y.net). As an additional extension activity have students visit the y2y website and determine the following: (i) the geographic area the y2y group is working to conserve and protect and what political and indigenous areas it encompasses; (ii) the species and types of habitat the group's efforts are focused on; (iii) the types of human communities the group is working with to achieve their goals; (iv) the vision of the *nature positive* approach.

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
- LS4.D: Biodiversity and Humans

HS-LS4 Biological Evolution: Unity and Diversity

- LS4.C: Adaptation

ETS1.B: Developing Possible Solutions

AP Biology (2021)

Big Ideas and 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.

- C3.1 Integration of body systems
- 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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