FOCUS QUESTIONS

- How does plastic pollution affect ocean health?
- What is the difference between bioaccumulation and biomagnification and how does ocean plastic pollution play a role in both of these processes?
- What technologies can be used to remove plastic pollution from an area as expansive as the Earth's oceans?

OVERVIEW

"For me, the turning point was when I woke up one morning and I opened my phone and then I saw this photograph of this mountain of plastic on the deck of our ship. That was truly the moment that I knew, okay, this can be done.""I think that in the not-too-distant future, we can have cleaned the ocean." - Boyan Slat Founder/CEO, The Ocean Cleanup

In ***The Great Ocean Cleanup*** we learn about the plastic waste crisis facing the world's oceans and its marine species. Fortunately, Boyan Slat and his The Ocean Cleanup organization are pioneering large-scale efforts to extract plastic pollution from both the ocean and its rivers. The group, with the help of local volunteers, has also spearheaded the development of river-based "Interceptor" systems—solar-powered barges that divert debris from 1,000 of the most polluted rivers—before it reaches the sea. Slat's dual-approach of "closing the tap" in rivers and cleaning legacy pollution at sea has positioned The Ocean Cleanup to potentially remove 90 % of floating plastic by 2040.

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 bioaccumulation of microplastics in marine animals can lead to a range of negative impacts, including physical damage, chemical contamination, and disruptions to their health and behavior. These effects can cascade through the food chain, potentially impacting entire ecosystems.
- Biomagnification: Some harmful chemicals can reach toxic levels as they are transferred from one trophic level to the next in a process called biomagnification. Biomagnification of microplastics in marine ecosystems can lead to a dangerous accumulation of microscopic plastic particles in marine animals, particularly those at higher trophic levels. As microplastics are ingested by organisms, they can accumulate in their tissues and then transfer to predators when consumed. This process can result in increased concentrations of microplastics and associated pollutants at each step of the food chain, potentially impacting the health and survival of marine animals.
- 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. Removing plastic pollution from the oceans and removing plastic debris before it reaches the sea can help reverse the negative impacts plastic pollution is having on marine animal life.

BACKGROUND

The invention of synthetic plastic in the early 20th century revolutionized manufacturing, but it was not until the 1950s and 60s that plastics—especially polyethylene and PET (polyethylene terephthalate)—became widely used for packaging, including bags (introduced in the U.S. in 1957) and plastic bottles (first mass-produced in the 1970s). Because plastic was cheap to produce, durable, and lightweight, it quickly replaced glass, metal, and paper in many consumer products.

By the 1970s and 80s, plastic bags and single-use water bottles were flooding the global market, while being promoted for convenience and cost-effectiveness. Global plastic production rose from 2 million metric tons in 1950 to over 400 million metric tons by 2015. However, the very qualities that have made plastic attractive—its resistance to degradation and low cost—also make it environmentally devastating. For example, by the end of 2015 it is estimated that 5.8 billion metric tons of plastic waste had been generated with only 30% of plastics ever produced still currently in use. By the year 2050, scientists estimate that humans will have produced over 25 billion metric tons of plastic waste since the 1950s.

Plastic waste accumulates so quickly because most plastic products are used briefly but they can persist in the environment for centuries. With inadequate waste management infrastructure in many parts of the world and a global economy built on disposability, millions of tons of plastic waste now enter the oceans each year. Much of this plastic waste, like floating translucent bags, can be mistaken as food by up to 1,400 different marine animal species, including marine mammals, birds, fish, and sea turtles. Upon ingestion, the plastics can kill the animals through choking or disrupting their digestive systems. Marine animals can also become tangled in plastics which can injure or kill them.

An additional problem is that plastic pollution easily breaks into extremely small plastic debris called microplastic. Microplastics can build up in an organism's body throughout its lifetime in a process called bioaccumulation and can then move up through trophic levels, increasing in mass relative to the mass of higher trophic levels, a process called biomagnification. Thus, ocean plastic pollution is affecting everything from plankton to whales. An additional concern is that the microplastics are now entering human food systems as nearly one third of the global human population relies on seafood as their primary source of protein. Data have now shown that microplastics can have toxic effects on various human systems, including the nervous, cardiovascular, endocrine, respiratory, and renal systems. Today, ocean plastic pollution is one of the planet's most pressing environmental crises, with an estimated 11 million metric tons of plastic entering the ocean annually—a number projected to nearly triple by 2040 if current trends continue.

Fortunately, the problem of ocean plastic pollution has a solution. In ***The Great Ocean Cleanup*** we meet Boyan Slat, the Dutch inventor and CEO of The Ocean Cleanup. Slat is a central figure in pioneering large-scale efforts to extract plastic pollution from both the ocean and its rivers. Inspired at age 16 by visible plastic in Greek waters, Boylan first began designing solutions as part of his high school science fair project. His ideas quickly caught the attention of the public and by 2013 Slat had drummed up investors and founded The Ocean Cleanup. He also spearheaded the development of river-based "Interceptor" systems—solar-powered barges that divert debris from 1,000 of the most polluted rivers—before it reaches the sea. Boylan's organization has also refined its ocean operations from early prototypes that struggled to retain waste to increasingly effective versions, which together with a fleet of support vessels have removed over 19,000 tons of plastic since 2019 and surpassed 100 000 kg from the Great Pacific Garbage Patch. Slat's dual-approach—"closing the tap" in rivers and cleaning legacy pollution at sea—has positioned The Ocean Cleanup to potentially remove 90% of floating plastic by 2040.

Slat's and his organization's efforts also benefit from volunteers and community involvement. In the film we meet Alecia Beaufort and her Clean Harbours Jamaica team. Alecia's team has, in partnership with The Ocean Cleanup, removed over 1 million kg of garbage from the river-based interceptor systems and by extension from the oceans. ***The Great Ocean Cleanup*** story demonstrates both bold innovation and tangible, hopeful impact in combating marine plastic pollution.

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 ***The Great Ocean Cleanup*** we are reminded of the environmental pollution caused by plastics, especially the plastic waste that ends up in the oceans. Plastics can be mistaken as food by marine animals and can injure or kill up to 1,400 different marine animal species. Today, ocean plastic pollution is one of the planet's most pressing environmental crises, with an estimated 11 million metric tons of plastic entering the ocean annually—a number projected to nearly triple by 2040 if current trends continue.

DISCUSSION QUESTIONS

- [Before showing the film] Have students research the history of plastic production, usage, and waste throughout the world. Some possible prompts are
    - When did plastics become widespread in the United States and other countries?
    - Why have plastic products become so popular?
    - How long do plastic products remain in use before becoming garbage?
    - What environmental problems have been created because of plastic production and usage?
    - What proportion of plastic garbage ends up in landfills and where does the rest of it go?
- After showing the film, have students discuss the concepts of bioaccumulation and biomagnification and how these two phenomena play a role in the ocean plastic garbage problem.
- In the film we hear Boylan Slat state that "It's definitely a lot wiser to prevent [plastic pollution] from going into the ocean than to deal with the downstream consequences." Have students spend a day, several days, or a week quantifying their own use of plastic products. In groups, students share their data and discuss strategies for reducing their own plastic waste production.
- In the film we learn about the latest technologies used by The Ocean Cleanup organization and their partners. Have students discuss ideas for improving the technology.
- In the film we learn about The Great Pacific Garbage Patch in the North Pacific Ocean. Have students investigate this phenomenon and the four other ocean gyres that have created garbage patches in the South Pacific, North Atlantic, South Atlantic, and Indian Oceans. What are these gyres and how do they form? How does the presence of the gyres influence our ability to clear the ocean of plastic pollution?
- As an extension, have interested students visit the website for the The Ocean Cleanup organization and learn more about the ocean cleanup efforts and technology.

Curriculum Connections

NGSS

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS4.D: Biodiversity and Humans

ETS1.B: Developing Possible Solutions

AP Biology (2021)

Big Ideas and Enduring Understandings

- 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.

- 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.

- C2.1 Chemical signaling
- C2.2 Neural signaling
- 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
- D4.3 Climate change

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CREDIT

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