Plastic waste in the ocean – where does it all come from?

Educator guide

PAPER DETAILS

Original title: Plastic waste inputs from land into the ocean

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Authors: Jenna R. Jambeck, Roland Geyer, Chris Wilcox, Theodore R. Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan, Kara Lavender Law

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Annotator(s): Sabrina Powell

TABLE OF CONTENTS

DISCUSSION QUESTIONS

	LEARNING STANDARDS
1. What are the challenges associated with extrapolating data? How do the authors deal with uncertainty?	SEP4 SP5
2. What obligations do individual countries in the world have toward cleaning up plastic debris that has already accumulated in the ocean?	SEP8 ESS3.C
3. What steps can governments take towards reducing the amount of plastic debris entering the ocean?	SEP8 ESS3.C
4. What are the tradeoffs with using plastic? What other materials could be utilized as alternatives to plastic?	SEP7 ETS1.B
5. What can you do to address the issue of plastic pollution in the ocean?	ESS3.C

ACTIVITIES FOR INTERACTIVE ENGAGEMENT

	LEARNING STANDARDS
Writing an abstract Students write a new abstract for the article at a grade-appropriate reading level.	RST.9-10.2 RST.11-12.2 NS1
Locating this study in the larger field Students use the annotated list of references to explain how this research builds on the published work of at least one other independent group of scientists. Students will evaluate whether data from this research supports or contradicts previous conclusions and reflect on the statement that scientific knowledge is a "community effort."	SEP5 Patterns RST.9-10.8 RST.11-12.8 VC6 NS1
Science in the news Students explore news stories in the Related Resources tab and evaluate the stories for tone, accuracy, missing information, etc. They may then write their own news stories on the article.	RST.9-10.5 RST.11-12.5 RST.9-10.6 RST.11-12.6 RST.9-10.8 RST.11-12.8
Prototype designing Students will design a device to prevent river-borne plastic debris from entering the ocean. This can be done entirely on paper, or students could build prototypes.	SEP6 SP3 ESS3.C ETS1.B
Results and conclusions Students diagram each of the experiments presented in the study (divided up by figure, if appropriate). They then consider the results depicted in each figure, and how these results support the conclusions of the study.	SEP5 Cause and effect SP5 VC3 NS4
The next steps Based on the trends in Figure 2 of the Jambeck et al. paper, predict the cumulative mass of mismanaged plastic waste that will enter the ocean from 2025-2050.	SEP4 Cause and effect SP5

ARTICLE OVERVIEW

Article summary (recommended for educator use only)

Plastic debris is found all over the world's oceans, and the problem is made worse by the fact that we do not know exactly how much plastic there is in the ocean or where much of it comes from. Because plastic degrades so slowly, plastic in the ocean is a long-term problem. Jambeck et al. combine population data with information about how various countries handle solid waste to predict current and future rates of plastic waste accumulation in the world oceans. If no changes are made, the authors predict a large increase in the amount of plastic waste entering the ocean in the future.

Importance of this research

The prevalence and persistence of plastic in the world's oceans is a widely recognized problem, but there is no available data on the amount and origin of plastic waste entering the ocean. Jambeck et al. extrapolated by combining currently available data on population density and solid waste processing methods to predict the current and future amount of plastic debris that will enter the oceans. The authors also present potential mitigation strategies to minimize the amount of plastic waste entering the oceans in the future.

Experimental methods

- Extrapolation: using inference to predict future trends from known data. This can be done by extending a graph or curve.
- The authors estimated per capita waste generation rates and percentage of plastic in the waste stream, the global percentage of mismanaged waste, and the resulting input of mismanaged plastic waste to the ocean, and then projected the amount of mismanaged plastic waste likely to enter the ocean by the year 2025.

Conclusions

- Jambeck et al.'s estimate of plastic waste currently entering the ocean is 10-1000 times greater than the mass of plastic reported to be floating in the mid-ocean gyres.
- The countries which send the greatest amount of mismanaged plastic waste to the world oceans are China, Indonesia, the Philippines, and Vietnam.
- If no changes are made to waste management infrastructure, the amount of plastic waste entering the world's oceans in 2025 is predicted to be 10 times greater than the current amount of plastic waste entering the ocean.

LEARNING STANDARDS ALIGNMENT

The following tables provide an overview of the learning standards covered by this article, including the A Framework for K-12 Science Education (Framework), Common Core State Standards English Language Arts-Literacy (CCSS ELA), Common Core State Standards Statistics and Probability (CCSS HSS), AP Science Practices, and Vision and Change for Undergraduate Education. Where applicable, activities and information will be marked with specific standards to which they are linked.

A Framework for K-12 Science Education		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data (SEP4) Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. **Using mathematics and computational thinking (SEP5)** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. **Constructing explanations and designing solutions (SEP6)** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Engaging in Argument from Evidence (SEP7)** Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). **Obtaining, Evaluating, and Communicating Information (SEP8)** Communicate scientific and technical information (e.g. about the process of development or the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**ESS3.C Human Impacts on Earth Systems** Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **ETS1.B Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts	**Patterns** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. **Cause and Effect** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Common Core State Standards English Language Arts-Literacy		
Key Ideas and Details	Craft and Structure	Integration of Knowledge and Ideas
RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. **RST.9-10.2** Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	**RST.9-10.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics. **RST.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy). **RST.9-10.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address. **RST.11-12.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics. **RST.11-12.5** Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. **RST.11-12.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.	**RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. **RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. **RST.11-12.8** Evaluate the hypotheses, data, analyses, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

AP Science Standards	
AP Science Practices	AP Biology Content Standards
Science Practice (SP3) The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the course. **Science Practice (SP5)** The student can perform data analysis and evaluation of evidence.	**Essential knowledge 2.D.3 (EK2.D.3)** Biological systems are affected by disruptions to their dynamic homeostasis. **Essential knowledge 4.A.6 (EK4.A.6)** Interactions among living systems and with their environment result in the movement of matter and energy.

Connections to the Nature of Science	
Vision and Change for Undergraduate Biology Education Core Competencies and Disciplinary Practices	A Framework for K-12 Science Education Understandings About the Nature of Science
Ability to use modeling and simulation (VC3) All students should understand how mathematical and computational tools describe living systems. **Ability to understand the relationship between science and society (VC6)** Biologists have an increasing opportunity to address critical issues affecting human society by advocating for the growing value of science in society, by educating all students about the need for biology to address pressing global problems, and by preparing the future workforce. Biologists need to evaluate the impact of scientific discoveries on society, as well as the ethical implications of biological research.	**Scientific investigations use a variety of methods (NS1)** Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. New technologies advance scientific knowledge. **Science models, laws, mechanisms, and theories explain natural phenomena (NS4)** Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.