JAY WITHGOTT · SCOTT BRENNAN

ESSENTIAL ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

SECOND EDITION

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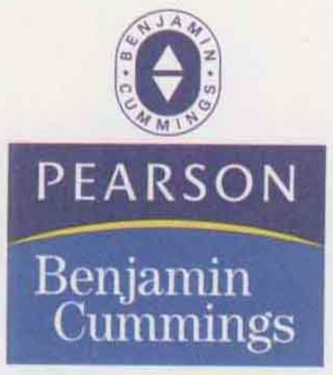


About the Authors

Jay H. Withgott is a science and environmental writer with a background in scientific research and teaching. He holds degrees from Yale University, the University of Arkansas, and the University of Arizona. As a researcher, he has published scientific papers on topics in ecology, evolution, animal behavior, and conservation biology in a variety of journals including *Proceedings of the National Academy of Sciences, Proceedings of the Royal Society of London B, Evolution*, and *Animal Behavior*. He has taught university-level laboratory courses in ecology, ornithology, vertebrate diversity, anatomy, and general biology.

As a science writer, Jay has authored articles for a variety of journals and magazines including *Science, New Scientist, BioScience, Smithsonian, Conservation in Practice*, and *Natural History*. He combines his scientific expertise with his past experience as a reporter and editor for daily newspapers to make science accessible and engaging for general audiences.

Jay lives with his wife, biologist Susan Masta, in Portland, Oregon, and takes every opportunity he can to explore the diverse landscapes of Oregon and the American West.

Scott Brennan has taught environmental science, ecology, resource policy, and journalism at Western Washington University and at Walla Walla Community College. He has also worked as a journalist, photographer, and consultant.

Scott has cultivated his expertise in environmental science and public policy by serving as Campaign Director of Alaskans for Responsible Mining, as Executive Conservation Fellow of the National Parks Conservation Association in Washington, D.C., and as a consultant to the U.S. Department of Defense Environmental Security Office at the Pentagon.

When not at work, Scott is likely to be found exploring the Chugach Mountains and the Bristol Bay drainages in southwest Alaska. He lives with his wife, Angela, and their dogs Raven and Hatcher, in south-central Alaska's Chester Creek Watershed.

How do environmental issues affect

Integrated Central Case Studies begin each chapter and are further developed throughout the chapter text. These highlight real people and real places to bring environmental issues to life, making general concepts more understandable and interesting to learn.

5 *Species Interactions and Community Ecology*

Aggregation of zebra mussels

Upon successfully completing this chapter,you will be able to:

- Compare and contrast the major types of species interactions
- Characterize feeding relationships and energy flow, using them to construct trophic levels and food webs
- Distinguish characteristics of a keystone species
- Characterize the process of succession
- Perceive and predict the potential impacts of invasive species in communities
- Explain the goals and methods of ecological restoration
- Describe and illustrate the terrestrial biomes of the world

people and places?

INVESTIGATE it! on the Withgott/Brennan Companion Website provides an additional **120 case studies** beyond those presented in the text. Browse by topic or geographic region to access 100 recent articles from The New York Times and 20 abc NEWS clips that explore environmental issues that are in the news today.

Do you understand the **science** behind

The Science behind the Story highlights how scientists develop hypotheses, test predictions, and analyze and interpret data. Each ***Science behind the Story*** carefully walks you through the scientific process—not only *what* scientists have discovered, but *how* they discovered it. These engaging accounts help you understand "how we know what we know" about environmental issues.

The Science behind the Story

Inferring Zebra Mussels' Impacts on Fish Communities

When zebra mussels appeared in the Great Lakes, people feared for sport fisheries and estimated that fish population declines could cost billions of dollars. The mussels would deplete the phytoplankton and zooplankton that fish depended on, people reasoned, and many fewer fish would survive. However, food webs are complicated systems, and disentangling them to infer the effects of any one species is fraught with difficulty. Thus, even after 15 years, scientists had little solid evidence of widespread harm to fish populations.

So, aquatic biologist David Strayer of the Institute of Ecosystem Studies in Millbrook, New York, joined Kathyrn Hattala and Andrew Kahnle of New York State's Department of Environmental Conservation (DEC). They mined datasets on fish populations in the Hudson River, which zebra mussels had invaded in 1991.

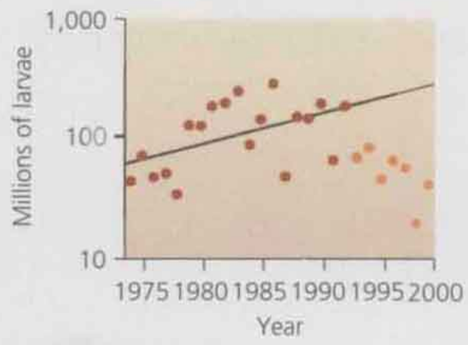
Strayer and others had already been studying effects of zebra mussels on aspects of the community for years. Their data showed that since the species' introduction to the Hudson:

- Biomass of phytoplankton fell 80%.
- Biomass of small zooplankton fell 76%.
- Biomass of large zooplankton fell 52%.

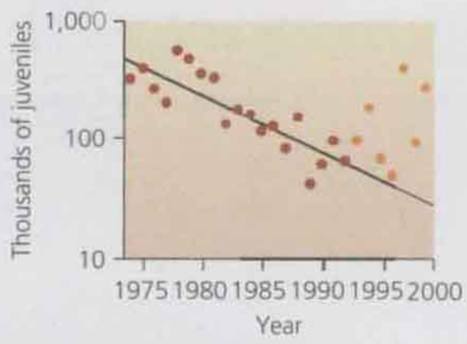
Zebra mussels increased filter-feeding in the community 30-fold, thereby depleting the phytoplankton and small zooplankton, and leaving all sizes of zooplankton with less phytoplankton to eat. Overall, the zooplankton and invertebrate animals of the open water that are eaten by open-water fish declined by 70%.

However, Strayer's work had also found that *benthic*, or bottom-dwelling, invertebrates in shallow water (especially in the nearshore, or *littoral*, zone) had increased by 10%, and likely much more, because the mussels' shells provide habitat structure and their feces provide nutrients.

These contrasting trends in the benthic shallows and the open deep water led Strayer's team to hypothesize that zebra mussels would harm open-water fish that ate plankton but would help littoral-feeding fish. They predicted that after zebra mussel introduction, larvae and juveniles of six common open-water fish species would decline in number, decline in growth rate, and shift downriver toward saltier water, where mussels are absent. Conversely, they predicted that larvae and juveniles of 10 littoral fish species would increase in number, increase in growth rate, and shift upriver to regions of greatest zebra mussel density.



(a) American shad



(b) Tessellated darter

Larvae of American shad (a), an open-water fish, had been increasing in abundance before zebra mussels were introduced (red points and trend line). After zebra mussel introduction, shad larvae decreased in abundance (orange points). Juveniles of the tessellated darter (b), a littoral zone fish, had been decreasing in abundance before zebra mussels were introduced (red points and trend line). After zebra mussel introduction, they increased in abundance (orange points).
Source: Strayer, D., et al. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. *Can. J. Fish. Aquat. Sci.* 61: 924–941.

To test their predictions, the researchers analyzed data from eat them; fish that eat phytoplankton and zooplankton; larger fish that eat the smaller fish; and lampreys that parasitize the fish. The food web would include a number of native mussels and clams and, since 1988, the zebra mussel that is outcompeting them. It would include diving ducks that used to feed on native bivalves and now are preying on zebra mussels. This food web would also show that crayfish and other bottom-dwelling invertebrates feed from the refuse of zebra mussels. Finally, the food web would include underwater plants and macroscopic algae, whose

the news stories?

We are placing a greater burden on the planet's systems each year. The ongoing rise in human population amplifies nearly all of our environmental impacts—and our consumption of resources has risen even faster than our population growth. The rise in affluence has been a positive development for humanity, and our conversion of the planet's natural capital has made life more pleasant for us so far. However, rising per capita consumption amplifies the demands we make on our environment. Moreover, affluence and consumption have not risen equally for all the world's citizens. Today the 20 wealthiest nations boast 40 times the income of the 20 poorest nations—twice the gap that existed four decades earlier. The ecological footprint of the average citizen of a developed nation such as the United States is considerably larger than that of the average resident of a developing country (Figure 1.15). Within the United States, the richest fifth of people claim nearly half the income, whereas the poorest fifth receive only 5%.

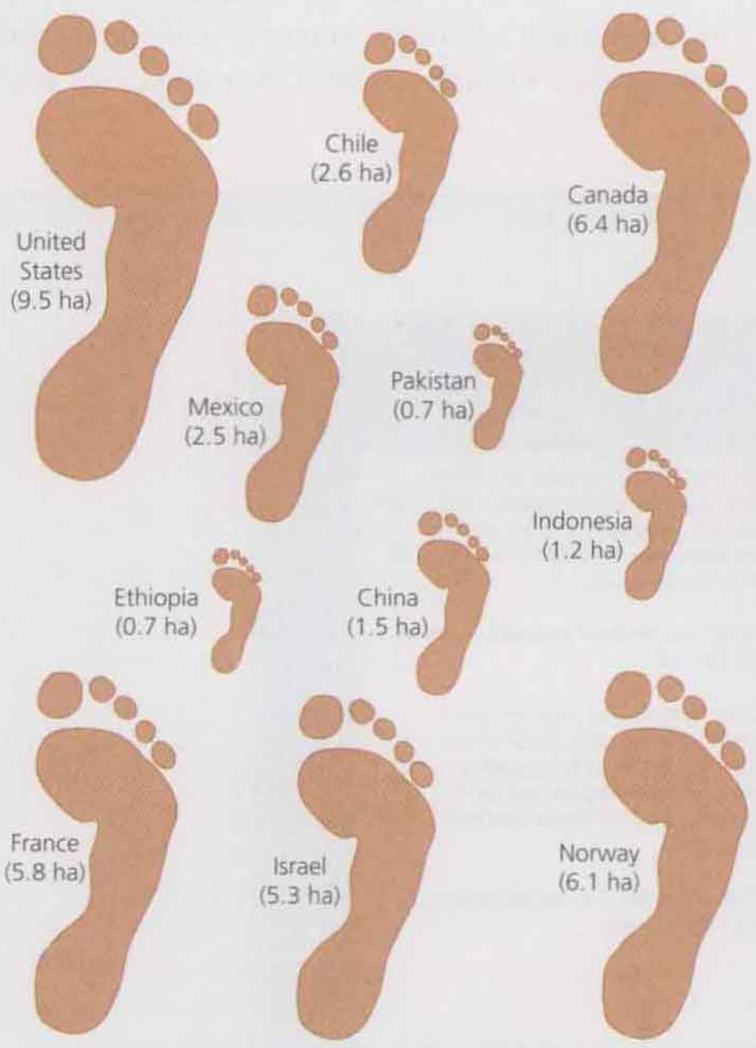


FIGURE 1.15 Citizens of some nations have larger ecological footprints than citizens of others. U.S. residents consume more resources—and thus use more land—than residents of any other nation. Shown are ecological footprints for average citizens of several developed and developing nations, as of 2001. Data from Global Footprint Network, 2005.

The most comprehensive scientific assessment of the present condition of the world's ecological systems and their ability to continue supporting our civilization was completed in 2005. In that year, over 2,000 of the world's leading environmental scientists from nearly 100 nations completed the **Millennium Ecosystem Assessment.** The four main findings of this exhaustive project are summarized in Table 1.1. The Assessment makes clear that our degradation of the world's environmental systems is having negative impacts on all of us, but that with care and diligence we can still turn many of these trends around.

Sustainability need not require great sacrifice of us. We will naturally always desire to enhance our quality of life, and there are many ways we can do so while also encouraging a more sustainable lifestyle. Indeed, this is the goal of **sustainable development**, the use of resources for economic advancement in a manner that satisfies people's current needs without compromising the future availability of resources.

Sustainability depends largely on the ability of the current human population to limit its environmental impact. Doing so will require us to make an ethical commitment and also to apply knowledge we gain from the sciences. Science can help us devise ways to limit our impact and maintain the functioning of the environmental

Table 1.1 Main Findings of the Millennium Ecosystem Assessment

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, freshwater, timber, fiber, and fuel. These changes have resulted in a substantial and largely irreversible loss in the diversity of life on Earth.
- The changes made to ecosystems have contributed to substantial net gains in human well-being and economic development, but the costs of achieving these gains have been growing. The costs include the degradation of ecosystems and the services they provide for us, and the exacerbation of poverty for some groups of people.
- Ecosystem degradation could grow significantly worse during the first half of this century.
- The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially overcome. However, doing so will require that we significantly change many policies, institutions, and practices.

Adapted from *Millennium Ecosystem Assessment, Synthesis Report*, 2005.

Environmental issues change quickly, so Withgott/Brennan uses the most current data available.

References are clearly cited so you can trace the source of the information presented.

Do you know how to interpret graphs

Calculating Ecological Footprints activities at the end of each chapter let you work with numbers to evaluate the impact of actions—including your own—on local and global scales.

CALCULATING ECOLOGICAL FOOTPRINTS

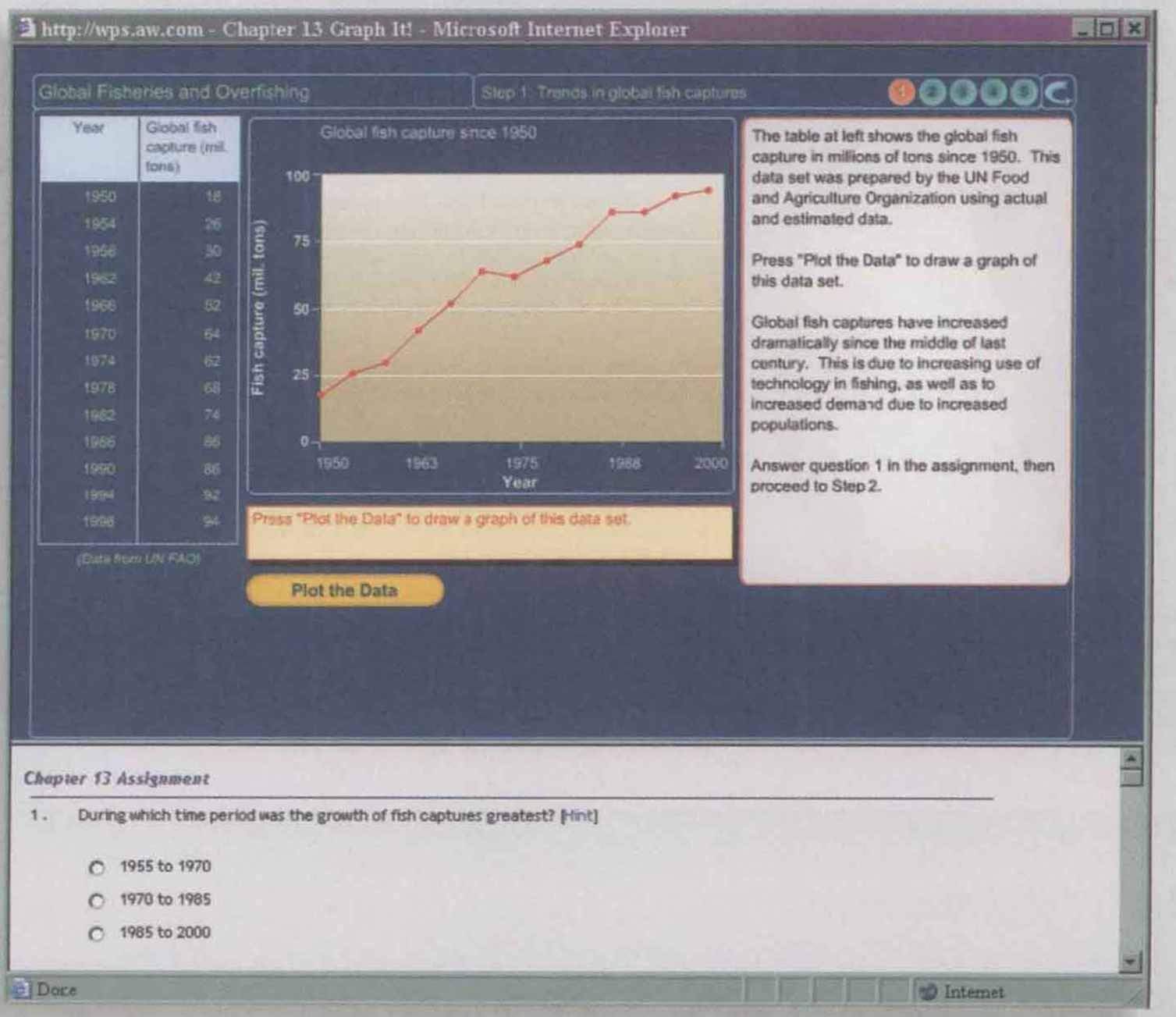
In 2004, coffee consumption in the United States topped 2.7 billion pounds (out of 14.8 billion pounds produced globally). Most coffee is produced on large tropical plantations, where coffee is the only tree species and is grown in full sun. However, approximately 2% of coffee is produced in small groves where coffee trees and other species are intermingled. These *shade-grown* coffee forests maintain greater habitat diversity for tropical rainforest wildlife. Given the information above, estimate the coffee consumption rates in the table.

	Population	Pounds of coffee per day	Pounds of coffee per year
You (or the average American)	1	0.025	9
Your class			
Your hometown			
Your state			
United States			

Data from O'Brien, T. G. and M. F. Kinnaird. 2003. Caffeine and conservation. *Science* 300: 587; and International Coffee Organization.

1. What percentage of global coffee production is consumed in the United States? If only shade-grown coffee were consumed in the United States, how much would shade-grown production need to increase to meet that demand?
2. How much extra would you be willing to pay for a pound of shade-grown coffee, if you knew that your money would help to prevent habitat loss or extinction for animals such as Sumatran tigers, rhinoceroses, and the many songbirds that migrate between Latin America and North America each year?
3. If everyone in the United States were willing to pay as much extra per pound for shade-grown coffee as you are, how much additional money would that provide for conservation of biodiversity in the tropics each year?

GRAPH it! exercises on the Withgott/Brennan Companion Website help you to better understand how to work with and interpret graphs.

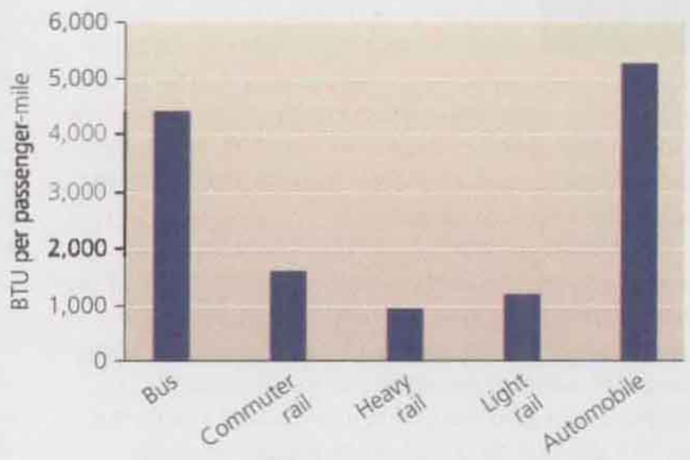


and data?

An ***appendix on graphs*** (see pages A-1 through A-3 near the end of the book) guides you through the types of graphs you will see throughout the book.

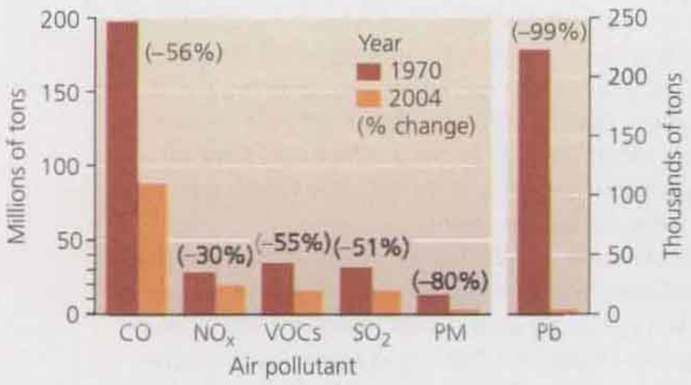
Bar Chart

A bar chart is most often used when one of the variables represents categories rather than numerical values (Figure A.3; see Figure 9.6a, ▸ p. 202). Bar charts allow us to visualize how a variable differs quantitatively among categories.



Energy consumption for different modes of transit

FIGURE A.3



Declines in six major air pollutants, 1970 vs. 2004

FIGURE A.4

It is often instructive to graph two or more variables together to reveal patterns and relationships (Figure A.4; see Figure 12.6a, ▸ p. 278). Many of the bar charts you will see in this book illustrate several types of information at once in this manner.

Are you prepared to make informed

The *Viewpoints* feature in each chapter presents two opposing views on an environmental issue related to the chapter's central theme, allowing you to consider multiple sides of the story.

Reach your own conclusion on *Viewpoints* questions by accessing the *Viewpoints* link on the companion website. There you'll find questions to consider when exploring the issues further, and links to websites that support each opinion.

VIEWPOINTS

Genetically Modified Foods

Proponents of GM foods say these products can alleviate hunger and malnutrition while posing no known threats to human health or the environment. Opponents say that these foods help only the large corporations that sell them and that they do pose risks to human health, wild organisms, and ecosystems. **What do you think? Should we encourage the continued development of GM foods? If so, what, if any, restrictions should we put on their dissemination?**

A Global Experiment without Controls

Genetic engineering, specifically transgenesis, gives us the unprecedented capacity to move DNA. In so doing, this technology breaches boundaries established through millions of years of evolution. As such, we should expect fundamental alterations in ecosystems with the release of transgenic crops, fish, insects, microbes, and so forth into uncontrolled areas. These alterations are similar in nature to those caused by the introduction of exotic species into new environments. Both processes are unpredictable and could have serious consequences.

Yet because of political and short-term economic imperatives, releases of transgenic organisms have continued unabated for at least a decade. Science has barely started to imagine the ecological and evolutionary consequences of releasing transgenic crops. We not only are experiencing a global experiment without controls, but also lack the tools to document it. Serious research, although extremely scarce, has already confirmed some of the theoretical fears concerning transgenesis aired by scientists a quarter century ago.

Today, we have cataclysmic world hunger paired with food surpluses. The claim that transgenesis can solve this problem is merely a diversion tailored to conceal how transgenesis manipulates the biosphere. Molecular biology might one day become part of the solution to world hunger, but it is certainly not the science most relevant to address the problem today.

What checks should be placed on the release of transgenic organisms? Every check. Through the unaccountable releases so far, we have seen enough, and possibly caused enough, environmental insult for me to say today that we should stop. We need to take stock of the consequences of transgenesis and continue researching under strictly regulated conditions.

Ignacio H. Chapela is associate professor (microbial ecology) in the Department of Environmental Science, Policy, and Management at the University of California at Berkeley. He helped found the Mycological Facility: Oaxaca, Mexico, where he serves as scientific director.

The United States Should Begin a Phased Deregulation of Biotech Crops

During the past two decades the international scientific community, biotechnology industry, and regulatory agencies in many countries have accumulated and critically evaluated a wealth of information about the production and use of biotech crops and products. Biotech crops have been planted since 1996 on more than 1 billion acres of farmland in nearly 20 countries. More than 1 billion humans and hundreds of millions of farm animals have consumed biotech foods and products. Yet there is not a single instance in which biotech crops and foods have been shown to cause illness in humans or animals or to damage the environment.

In spite of this exemplary safety record, a small but well-organized, well-financed, and vocal anti-biotechnology lobby has alleged that biotech crops and products are unsafe for humans and a danger to the environment, demanding a moratorium or outright ban on biotech crops. The rhetoric of the anti-biotechnology groups is alarming, confusing, and frightening to the public, but it is devoid of any substance, because they have never provided any credible scientific evidence to support their allegations.

Any further delay in combining the power of biotechnology with conventional breeding will seriously endanger future food security, political and economic stability, and the environment. Plant biotechnology is still the best hope for meeting the food needs of the ever-growing world population. Biotech crops are already helping to conserve valuable natural resources, reduce the use of harmful agro-chemicals, produce more nutritious foods, and promote economic development.

Twenty years ago, the United States set the precedent by developing regulations for the development and use of biotech crops. Now, as the world leader in plant biotechnology, it is imperative that it lead again by phasing out these redundant regulations in an organized and responsible manner.

Indra K. Vasil is graduate research professor emeritus at the University of Florida (Gainesville, Florida). His research focuses on the biotechnology of cereal crops, and he has been recognized as one of the world's most highly cited authors in the plant and animal sciences.

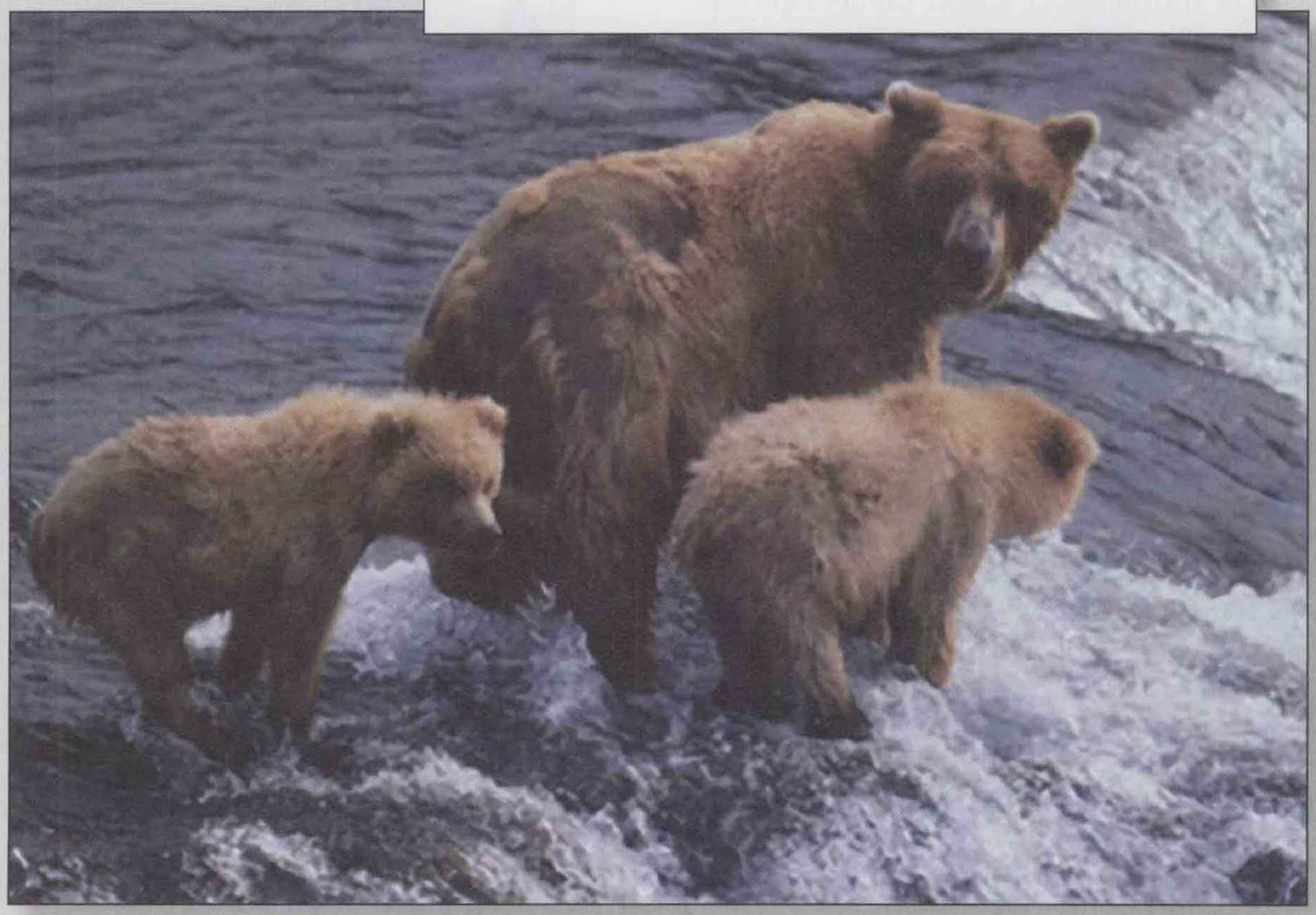
Explore this issue further by accessing **Viewpoints** at www.aw-bc.com/withgott.

decisions on environmental issues?

Issues in environmental science often lack black-and-white answers, so critical thinking skills help you navigate the gray areas. ***Weighing the Issues*** questions throughout each chapter encourage you to grapple with questions about science, policy, and ethics.

Weighing the Issues:
Ecosystems Where You Live

Think about the area where you live. How would you describe that area's ecosystems? How do these systems interact with one another? If one ecosystem were greatly disturbed (say, if a wetland or forest were replaced by a shopping mall), what impacts might that have on nearby natural systems?



You Decide activities on the Withgott/Brennan Companion Website allow you to play the role of decision maker as you study the data, then form your own plan for saving endangered grizzlies or stopping global warming.

Preface

We live in extraordinary times. Human impact on our environment has never been so intensive or so far-reaching. The future of Earth's systems and of our society depends more critically than ever on the way we interact with the natural systems around us. Fundamental aspects of nutrient cycling, biological diversity, atmospheric composition, and climate are changing at dizzying speeds. Yet thanks to environmental science, we now understand better than ever how our planet's systems function and how we influence these systems. Understanding environmental science helps us to characterize human-induced problems and also illuminates the tremendous opportunities we have before us for effecting positive change.

The field of environmental science captures the very essence of this unique moment in history. This interdisciplinary pursuit stands at the vanguard of the current need to synthesize academic disciplines and to incorporate their contributions into a big-picture understanding of the world and our place within it.

We wrote this book because we feel that the vital importance of environmental science in today's world makes it imperative to engage, educate, and inspire a broad audience of today's students—the citizens and leaders of tomorrow. We have therefore tried to implement the very best in modern teaching approaches and to clarify how the scientific process can inform human efforts. We also have aimed to maintain a balanced approach and to encourage critical thinking as we flesh out the social debate over many environmental issues. Finally, we have resolved to avoid gloom and doom and instead provide hope and solutions.

As environmental science has grown, so have the length and expense of the textbooks that cover it. With this volume, we aim to meet the needs of introductory environmental science courses that require a more succinct and affordable book. We have distilled the most essential content from our full-length book, *Environment: The Science behind the Stories*, now in its second edition. We have reconceptualized and streamlined the organization of chapters and sections, and we have carefully crafted our rewriting to make *Essential Environment: The Science behind the Stories* every bit as readable, informative, and engaging as its parent volume.

In this second edition of *Essential Environment*, we have updated the text with the most current information and have introduced new figures, an enhanced art style, and exercises enabling students to calculate the environmental impacts of their own choices and then see how individual impacts scale up to impacts at the societal level.

We have also retained the major features that make our books unique and that are proving so successful in classrooms across North America:

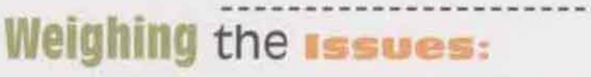
- **Integrated Central Case Studies.** Our teaching experiences, together with feedback from colleagues across the continent, clearly reveal that telling compelling stories about real people and real places is the best way to capture students' interest. Providing narratives with concrete detail also helps teach abstract concepts, because it gives students a tangible framework with which to incorporate new ideas. Whereas many textbooks these days serve up case studies in isolated boxes, we have chosen to integrate each chapter's central case study into the main text, weaving information and elaboration throughout the chapter. In this way, we use the concrete realities of the central case study to help illustrate the topics we cover. We are gratified that students and instructors using our first edition have consistently applauded this approach, and we hope it can help bring about a new level of effectiveness in environmental science education.

- **The Science behind the Story.** Our goal is not simply to present facts, but to engage students in the scientific process of testing and discovery. To do this, we discuss the scientific method and the social context of science in our opening chapter, and we describe hundreds of real-life studies throughout the text. We also feature in each chapter "The Science behind the Story," which elaborates on particular studies important to the chapter topic, guiding readers through the details of the research. In this way we show not merely *what* scien-

tists discovered, but also *how* they discovered it. Instructors using our first edition have confirmed that this feature enhances student comprehension of each chapter's material and deepens understanding of the scientific process—a key component of effective citizenship in today's science-driven world.

- **Viewpoints.** In our text we have striven to present a balanced picture of environmental issues, informed by the best science that bears upon them. Yet we all know that sometimes intelligent people can examine the same data and come to dramatically different conclusions. To ensure that students are exposed to a diversity of interpretations on key issues, we include in each chapter the *Viewpoints* feature, which consists of paired essays authored by invited experts who present different points of view on particular questions of importance. The essays provide students a taste of informed arguments directly from individuals who are actively involved in work—and debate—on environmental issues. To encourage critical thinking, we refer students to an online resource at the book's website that presents questions they can use to critically examine and discuss the ideas in these essays and that provides links to Web sites that support the contributors' viewpoints.

- **Weighing the Issues.** Because the multifaceted issues in environmental science often lack black-and white answers, students need critical-thinking skills to help navigate the gray areas at the juncture of science, policy, and ethics. We have aimed to help develop these skills with our end-of-chapter questions and with our "Weighing the Issues" feature. Two to three "Weighing the Issues" questions are dispersed throughout each chapter, serving as stopping points for students to absorb and reflect on what they have read, and to wrestle with some of the complex dilemmas in environmental science.



- **An emphasis on solutions.** The complaint we hear most frequently from students in environmental science courses is that the deluge of environmental problems can seem overwhelming. In the face of so many problems, students often come to feel that there is no hope or that there is little they can personally do to make a difference. We have aimed to counter this impression by drawing out innovative solutions that have worked, are being implemented, or can be tried in the future. Although we do not paint an unrealistically rosy picture of the challenges that lie ahead, we portray dilemmas as opportunities and try to instill hope and encourage action. Indeed, for every problem that human carelessness has managed to create, human ingenuity can devise one—and likely multiple—solutions.

Essential Environment: The Science behind the Stories has grown directly from our professional experiences in teaching, research, and writing. Jay Withgott has synthesized and presented science to a wide readership. His experience in distilling and making accessible the fruits of scientific inquiry has shaped our book's content and the presentation of its material. Scott Brennan has taught environmental science to thousands of undergraduates and has developed an intimate feeling for what works in the classroom. His knowledge and experience have shaped the pedagogical approaches we have taken in this book.

We have also been guided in our efforts by extensive input from our professional colleagues and from hundreds of instructors from around North America who have served as reviewers for our chapters and as advisors in focus group meetings arranged by Benjamin Cummings. The participation of so many learned and thoughtful experts has improved this volume in countless ways.

We sincerely hope that our efforts will come close to being worthy of the immense importance of our subject matter. We invite you, students and instructors alike, to let us know how well we have achieved our goals and where you feel we have fallen short. We are committed to continual improvement, and we value your feedback. Please write the authors in care of Chalon Bridges (chalon.bridges@aw.com), Benjamin Cummings Publishing, 1301 Sansome Street, San Francisco, California, 94111. At this most historic time to study environmental science, we are honored to serve as your guides in the quest to better understand our world and ourselves.

Jay Withgott and Scott Brennan

Instructor Supplements

The Withgott/Brennan Media Manager
0-8053-9622-5
This powerful media package is organized chapter-by-chapter and includes all teaching resources in one convenient location. You'll find 5-minute *ABC News* Lecture Launcher videos, PowerPoint presentations, active lecture questions to facilitate class discussions (for use with or without clickers), and an image library that includes all art and tables from the text.

Instructor's Guide and Test Bank
0-8053-9433-8
This comprehensive resource provides chapter outlines, key terms, a listing of Web site and media resources, and teaching tips for lecture and classroom activities. A printed version of the Test Bank is conveniently included in the manual, offering hundreds of multiple-choice, short-answer, and essay questions to use on tests and quizzes. New to this edition are scenario-based questions to test students' critical-thinking abilities.

Computerized Test Bank
0-8053-9618-7
Hundreds of multiple-choice, short-answer, essay, and scenario-based questions are provided on a cross-platform CD-ROM, categorized by chapter objective for the instructor's ease in searching for question types.

Transparency Acetates
0-8053-9617-9
For the instructor's use, we provide 300 full-color acetates of all the art and tables from the text.

Acknowledgments

A textbook is the product of *many* more minds and hearts than one might guess from the names on the cover. The two of us are exceedingly fortunate to be supported and guided by the tremendous staff at Benjamin Cummings and by a small army of experts in environmental science who have generously shared their time and expertise. Although we alone, as authors, bear responsibility for any inaccuracies, the strengths of this book result from the collective labor and dedication of innumerable people.

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We dedicate this book to today's students, who will shape tomorrow's world.

Jay Withgott and Scott Brennan

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