CHAPTER 7

Dollars and Environmental Sense: Economics of Environmental Issues

A New England common illustrates the tragedy of the Commons, one of the key ideas of Environmental Economics.

LEARNING OBJECTIVES

Why do people value environmental resources? To what extent are environmental decisions based on economics? Other chapters in this text explain the causes of environmental problems and discuss technical solutions. The scientific solutions, however, are only part of the answer. This chapter introduces some basic concepts of environmental economics and shows how these concepts help us understand environmental issues. After reading this chapter, you should understand . . .

- How the perceived future value of an environmental benefit affects our willingness to pay for it now;
- What "externalities" are and why they matter;
- How much risk we should be willing to accept for the environment and ourselves;
- How we can place a value on environmental intangibles, such as landscape beauty.

CASE STUDY

Cap, Trade, and Carbon Dioxide

We hear a lot in the news these days about a public and congressional debate over "cap-and-trade" and the control of carbon dioxide emissions. The question our society is wrestling with is this: Assuming that carbon dioxide, as a greenhouse gas, can be treated like any other air pollutant legally and economically, how can its emissions best be controlled? "Best" in this context means reducing human-induced carbon dioxide emissions as much as possible, doing so in the least expensive way, and in a way that is fair to all participants. Among the most commonly discussed methods are the following:

Tax on emitters: The government levies a tax based on the quantity of pollution emitted.

Legal emissions limit: The law will limit the amount of emissions allowed from each source—individual, corporation, facility (e.g., a single power plant), or government organization. The control is applied individually, emitter by emitter, with each assigned a maximum.

Cap-and-trade: First, the government decides how much of a particular pollutant will be permitted, either as a *total amount* in the environment or as the *total amount emitted into the environment per year*. (This is one way that cap-and-trade differs from legal emissions limits, which are set per emitter.) Next, the limit is divided up among the sources of the pollutant, but the owners of those sources can trade among themselves. (In contrast, legal emissions limits allow no trading among participants.)

The rationale behind the tax on emitters is twofold. First of all, it raises tax money, which in theory could be used to find ways to reduce and better control the pollution. Second, it is supposed to discourage businesses from emitting pollution. But critics of a direct tax on emitters say it doesn't work and is bad for business. They say businesses simply pass on the cost of the taxes in their prices, so the tax burden is on the consumer but the likely economic result is fewer sales.

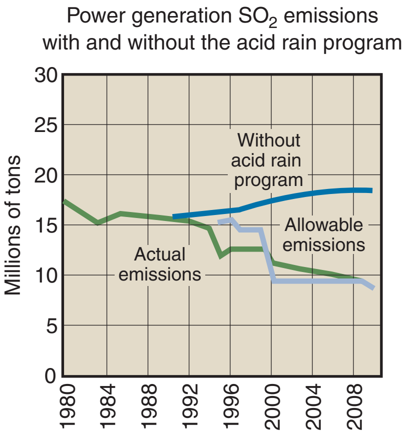
Critics of legal emissions limits say that since government sets the limits, this could be arbitrary and place an unfair burden on certain businesses. It also requires extensive, costly monitoring, placing a further burden on society's economics.

The potential problems of direct taxes and emissions limits led to the idea of cap-and-trade. Here's how it works. Suppose you own a coal-fired power plant and the government gives you a certain number of carbon allowances—tons of carbon dioxide you will be allowed to emit into the air each year. These allowances come to you as "ration coupons," something like food stamps, and you can either "spend" them yourself by emitting the amount of pollutant each stamp permits, or sell them to someone else. If you decide to build a solar power plant that replaces your coal plant, you can sell your pollution allowances to a power company that is still using coal and is emitting more than its allowed amount. That company could then increase its emissions. In theory, both you and the other company make money—you by simply selling your credits, the other company by not having to build a completely new power plant.

Does cap-and-trade work? The Environmental Protection Agency (EPA) now has three decades of experience with attempts to control air pollutants and has found that cap-and-trade works very well—for example, in reducing acid rain resulting from sulfur dioxide emissions from power plants (Figure 7.1).[1] Proponents of cap-and-trade argue that it places the benefits and disbenefits of pollution control directly in the hands of the polluters, rather than passing them on to consumers (which a tax usually ends up doing). Also, it keeps the activity in a kind of free market, rather than forcing specific actions on individuals, and in this way minimizes government interference.

Opponents of cap-and-trade argue that it is really just a tax in disguise, that its end result is the same as a direct tax—the corporations that produce electricity from fossil fuel will be burdened with a huge tax and put at a disadvantage versus corporations that turn to alternative energy sources. Advocates of cap-and-trade say that this is just the point—that the whole idea is to encourage our society to move away from fossil fuels, and that this has proved to be an efficient way to do it. Opponents counter that the net result will be a burden on everybody and that the average family's energy bill could go up an estimated $1,500 a year.[2] Proponents of cap-and-trade cite its success with acid rain from sulfur dioxide emissions (Figure 7.1), but critics say that, unlike sulfur dioxide, carbon dioxide isn't really a pollutant in the usual legal sense, and that because carbon dioxide is a global problem, cap-and-trade can't work without unusual treaties among nations.

You can see from the cap-and-trade example that what seems at first glance a simple and straightfor-



(a)


(b)

FIGURE 7.1 **Cap-and-trade helped the EPA reduce acid rain caused by sulfur dioxide emissions (a) from power plants like this coal-fired power plant in Arizona (b).**

ward solution can turn out to be much more difficult. Deciding whether cap-and-trade can be a good way to reduce carbon dioxide emissions into the atmosphere depends in part on scientific knowledge, but also on economic analyses. So it is with most environmental issues.

7.1 Overview of Environmental Economics

The history of modern environmental law can be traced back to the 1960s and the beginnings of the modern social and political movement we know as environmentalism. Its foundation is the "three E's": ecology, engineering, and economics.[3] Although in this environmental science textbook we will devote most of our time to the scientific basis—ecology, geology, climatology, and all the other sciences involved in environmental analysis—economics underlies much of the discussion. It is always a factor in finding solutions that work, are efficient, and are fair. This is why we are devoting one of our early overview chapters to environmental economics.

Environmental economics is not simply about money; it is about how to persuade people, organizations, and society at large to act in a way that benefits the environment, keeping it as free as possible of pollution and other damage, keeping our resources sustainable, and accomplishing these goals within a democratic framework. Put most simply, environmental economics focuses on two broad areas: controlling pollution and environmental damage in general, and sustaining renewable resources—forests, fisheries, recreational lands, and so forth. Environmental economists also explore the reasons why people don't act in their own best interests when it comes to the environment. Are there rational explanations for what seem to be irrational choices? If so, and if we can understand them, perhaps we can do something about them. What we do, what we can do, and how we do it are known collectively as **policy instruments**.

Environmental decision-making often, perhaps even usually, involves analysis of tangible and intangible factors. In the language of economics, a **tangible factor** is one you can touch, buy, and sell. A house lost in a mudslide due to altering the slope of the land is an example of a tangible factor. For economists, an **intangible factor** is one you can't touch directly, but you value it, as with the beauty of the slope before the mudslide. Of the two, the intangibles are obviously more difficult to deal with because they are harder to measure and to value economically. Nonetheless, evaluation of intangibles is becoming more important. As you will see in later chapters, huge amounts of money and resources are involved in economic decisions about both tangible and intangible aspects of the environment: There are the costs of pollution and the loss of renewable resources, and there are the costs of doing something about these problems.

In every environmental matter, there is a desire on the one hand to maintain individual freedom of choice, and on the other to achieve a specific social goal. In ocean fishing, for example, we want to allow every individual to choose whether or not to fish, but we want to prevent everyone from fishing at the same time and bringing fish species to extinction. This interplay between private good and public good is at the heart of environmental issues.

In this chapter we will examine some of the basic issues in environmental economics: the environment as a commons; risk-benefit analysis; valuing the future; and why people often do not act in their own best interest.

7.2 Public-Service Functions of Nature

A complicating factor in maintaining clean air, soils, and water, and sustaining our renewable resources is that ecosystems do some of this without our help. Forests absorb particulates, salt marshes convert toxic compounds to nontoxic forms, wetlands and organic soils treat sewage. These are called the **public-service functions** of nature. Economists refer to the ecological systems that provide these benefits as **natural capital**.

The atmosphere performs a public service by acting as a large disposal site for toxic gases. And carbon monoxide is eventually converted to nontoxic carbon dioxide either by inorganic chemical reactions or by soil bacteria. Bacteria also clean water in the soil by decomposing toxic chemicals, and bacteria fix nitrogen in the oceans, lakes, rivers, and soils. If we replaced this function by producing nitrogen fertilizers artificially and transporting them ourselves, the cost would be immense—but, again, we rarely think about this activity of bacteria.

FIGURE 7.2 Public-service functions of living things. Wild creatures and natural ecosystems carry out tasks that are important for our survival and would be extremely expensive for us to accomplish by ourselves. For example, bees pollinate millions of flowers important for food production, timber supply, and aesthetics. As a result, beekeeping is a commercial enterprise, with rewards and risks, as shown in this photograph.

Among the most important public-service providers are the pollinators, which include birds, bats, ants, bees, wasps, beetles, butterflies, moths, flies, mosquitoes, and midges. It is estimated that pollinating animals pollinate about $15 billion worth of crops grown on 2 million acres in the United States,[4, 5] that about one bite in three of the food you eat depends on pollinators, and that their total economic impact can reach $40 billion a year (Figure 7.2).[6] The cost of pollinating these crops by hand would be exorbitant, so a pollutant that eliminated bees would have large indirect economic consequences. We rarely think of this benefit of bees, but it has received wide attention in recent years because of a disease called Colony Collapse Disorder (CCD), which affected food costs, agricultural practices, and many companies that provide bees to pollinate crops.[7]

Public-service functions of living things are estimated to provide between $3 trillion and $33 trillion in benefits to human beings and other forms of life per year.[8] However, current estimates are only rough approximations because the value is difficult to measure.

7.3 The Environment as a Commons

Often people use a natural resource without regard for maintaining that resource and its environment in a renewable state—that is, they don't concern themselves with that resource's sustainability. At first glance, this seems puzzling, but economic analysis suggests that the profit motive, by itself, will not always lead a person to act in the best interests of the environment.

One reason has to do with what the ecologist Garrett Hardin called "the tragedy of the commons."[9] When a resource is shared, an individual's personal share of profit from its exploitation is usually greater than his or her share of the resulting loss. A second reason has to do with the low growth rate, and therefore low productivity, of a resource.

A **commons** is land (or another resource) owned publicly, with public access for private uses. The term *commons* originated from land owned publicly in

English and New England towns and set aside so that all the farmers of the town could graze their cattle. Sharing the grazing area worked as long as the number of cattle was low enough to prevent overgrazing. It would seem that people of goodwill would understand the limits of a commons. But take a dispassionate view and think about the benefits and costs to each farmer as if it were a game. Phrased simply, each farmer tries to maximize personal gain and must periodically consider whether to add more cattle to the herd on the commons. The addition of one cow has both a positive and a negative value. The positive value is the benefit when the farmer sells that cow. The negative value is the additional grazing by the cow. The personal profit from selling a cow is greater than the farmer's share of the loss caused by the degradation of the commons. Therefore, the short-term successful game plan is always to add another cow.

Since individuals will act to increase use of the common resource, eventually the common grazing land is so crowded with cattle that none can get adequate food and the pasture is destroyed. In the short run, everyone seems to gain, but in the long run, everyone loses. This applies generally: Complete freedom of action in a commons inevitably brings ruin to all. The implication seems clear: Without some management or control, all natural resources treated like a commons will inevitably be destroyed.

How can we deal with the tragedy of the commons? It is only a partially solved problem. As several scientists wrote recently, "No single broad type of ownership—government, private or community—uniformly succeeds or fails to halt major resource deterioration." Still, in trying to solve this puzzle, economic analysis can be helpful.

There are many examples of commons, both past and present. In the United States, 38% of forests are on publicly owned lands; as such, these forests are commons. Resources in international regions, such as ocean fisheries away from coastlines, and the deep-ocean seabed, where valuable mineral deposits lie, are international commons not controlled by any single nation.

The Arctic sea ice is a commons (Figure 7.3), as is most of the continent of Antarctica, although there are some national territorial claims, and international negotiations have continued for years about conserving Antarctica and about the possible use of its resources.

The atmosphere, too, is a commons, both nationally and internationally. Consider the possibility of global warming. Individuals, corporations, public utilities, motor vehicles, and nations add carbon dioxide to the air by burning fossil fuels. Just as Garrett Hardin suggested, people tend to respond by benefiting themselves (burning more fossil fuel) rather than by benefiting the commons (burning less fossil fuel). The picture here is quite mixed, however, with much ongoing effort to bring cooperation to this common issue.

FIGURE 7.3 Arctic sea ice and polar bears, which live in many areas of the Arctic, are part of a commons.

In the 19th century, burning wood in fireplaces was the major source of heating in the United States (and fuel wood is still the major source of heat in many nations). Until the 1980s, a wood fire in a fireplace or woodstove was considered a simple good, providing warmth and beauty. People enjoyed sitting around a fire and watching the flames—an activity with a long history in human societies. But in the 1980s, with increases in populations and vacation homes in states such as Vermont and Colorado, home burning of wood began to pollute air locally. Especially in valley towns surrounded by mountains, the air became fouled, visibility declined, and there was a potential for ill effects on human health and the environment. Several states, including Vermont, have had programs offering rebates to buyers of newer, lower-polluting woodstoves.[10] The local air is a commons, and its overuse required a societal change.

Recreation is a problem of the commons—overcrowding of national parks, wilderness areas, and other nature–recreation areas. An example is Voyageurs National Park in northern Minnesota. The park, within North America's boreal-forest biome, includes many lakes and islands and is an excellent place for fishing, hiking, canoeing, and viewing wildlife. Before the area became a national park, it was used for motorboating, snowmobiling, and hunting; a number of people in the region made their living from tourism based on these kinds of recreation. Some environmental groups argue that Voyageurs National Park is ecologically fragile and needs to be legally designated a U.S. wilderness area to protect it from overuse and from the adverse effects of motorized vehicles. Others argue that the nearby million-acre Boundary Waters Canoe Area provides ample wilderness, that Voyageurs can withstand a moderate level of hunting and motorized transportation,

FIGURE 7.4 Voyageurs National Park in northern Minnesota has many lakes well suited to recreational boating. But what kind of boating—what kinds of motors, what size boats—is a long-running controversy. In a commons such as a national park, these are the kinds of conflicts that arise over intangible value (such as scenic beauty) and tangible value (such as the opportunity for boat owners and guides to make a living). Here we see a guided tour on a motorized boat.

and that these uses should be allowed. At the heart of this conflict is the problem of the commons, which in this case can be summed up as follows:

- What is the appropriate public use of public lands?
- Should all public lands be open to all public uses?
- Should some public lands be protected from people?

At present, the United States has a policy of different uses for different lands. In general, national parks are open to the public for many kinds of recreation, whereas designated wildernesses have restricted visitorship and kinds of uses (Figure 7.4).

7.4 Low Growth Rate and Therefore Low Profit as a Factor in Exploitation

We said earlier that the second reason individuals tend to overexploit natural resources held in common is the low growth rate of many biological resources.[11] For example, one way to view whales economically is to consider them solely in terms of whale oil. Whale oil, a marketable product, and the whales alive in the ocean, can be thought of as the capital investment of the industry.

From an economic point of view, how can whalers get the best return on their capital? Keeping in mind that whale populations, like other populations, increase only if there are more births than deaths, we will examine two approaches: *resource sustainability* and *maximum profit*. If whalers adopt a simple, one-factor resource-sustainability policy, they will harvest only the net biological productivity each year (the number by which the population increased). Barring disease or disaster, this will maintain the total abundance of whales at its current level and keep the whalers in business indefinitely. If, on the other hand, they choose to simply maximize immediate profit, they will harvest all the whales now, sell the oil, get out of the whaling business, and invest their profits.

Suppose they adopt the first policy. What is the maximum gain they can expect? Whales, like other large, long-lived creatures, reproduce slowly, with each female typically giving birth to a calf every three or four years. Thus, the total net growth of a whale population is likely to be no more than 5% per year and probably more like 3%. This means that if all the oil in the whales in the oceans today represented a value of $100 million, then the most the whalers could expect to take in each year would be no more than 5% of this amount, or $5 million. Until the 2008 economic recession, 5% interest was considered a modest, even poor, rate of return on one's money. And meanwhile the whalers would have to pay for the upkeep of ships and other equipment, salaries of employees, and interest on loans—all of which would decrease profit.

However, if whalers opted for the second policy and harvested all the whales, they could invest the money from the oil. Although investment income varies, even a conservative return on their investment of $100 million would likely yield millions of dollars annually, and since they would no longer be hunting whales, this would be clear profit, without the costs of paying a crew, maintaining ships, buying fuel, marketing the oil, and so on.

Clearly, if one considers only direct profit, it makes sense to adopt the second policy: Harvest all the whales, invest the money, and relax. And this seems to have been the case for those who hunted bowhead whales in the 19th and early 20th centuries (Figures 7.5 and 7.6).[12] Whales simply are not a highly profitable long-term investment under the resource-sustainability policy. From a

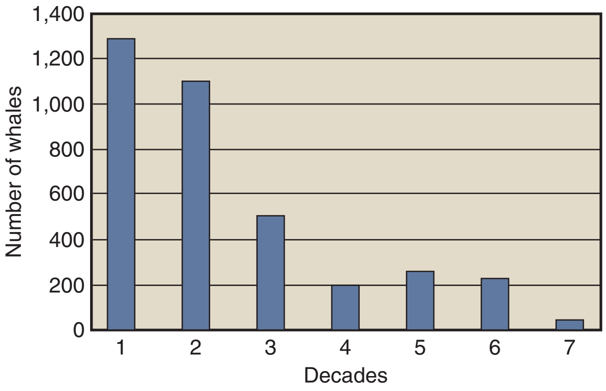


FIGURE 7.5 Bowhead whales caught and killed by Yankee whalers from 1849 to 1914. The number killed, shown for each decade, declined rapidly, indicating that the whale population was unable to reproduce at a rate that could replace the initial large catches, yet the whalers kept killing at a nonsustainable rate, as economics would predict. (*Source*: Redrawn from J.R. Bockstoce and D.B. Botkin, *The Historical Status and Reduction of the Western Arctic Bowhead Whale* (Balaena mysticetus) *Population by the Pelagic Whaling Industry, 1849–1914*. Final report to the U.S. National Marine Fisheries Service by the Old Dartmouth Historical Society, 1980; and J.R. Bockstoce, D.B. Botkin, A. Philp, B.W. Collins, and J.C. George, The geographic distribution of bowhead whales in the Bering, Chukchi, and Beaufort seas: Evidence from whaleship records, 1849–1914, *Marine Fisheries Review* 67(3) [2007]:1–43.)

FIGURE 7.6 Bowhead whale baleen (their modified teeth) on a dock in San Francisco in the late 19th century, when these flexible plates were needed for women's corsets and other uses where strength and flexibility were important. Baleen and whale oil were the two commercial products obtained from bowheads. When baleen was replaced by new forms of steel, the baleen market disappeared. Commercial bowhead whale hunting ended with the beginning of World War I. However, whale oil remained listed as a strategic material by the U.S. Department of Defense for decades afterward because of its lubricating qualities.

tangible economic perspective, without even getting into the intangible ethical and environmental concerns, it is no wonder that there are fewer and fewer whaling companies and that companies left the whaling business when their ships became old and inefficient. Few nations support whaling; those that do have stayed with whaling for cultural reasons. For example, whaling is important to the Eskimo culture, so some harvest of bowheads takes place in Alaska; and whale meat is a traditional Japanese and Norwegian food, so these countries continue to harvest whales for this reason.

Scarcity Affects Economic Value

The relative scarcity of a necessary resource is another factor to consider in resource use, because this affects its value and therefore its price. For example, if a whaler lived on an isolated island where whales were the only food and he had no communication with other people, then his primary interest in whales would be as a way for him to stay alive. He couldn't choose to sell off all whales to maximize profit, since he would have no one to sell them to. He might harvest at a rate that would maintain the whale population. Or, if he estimated that his own life expectancy was only about ten years, he might decide that he could take a chance on consuming whales beyond their ability to reproduce. Cutting it close to the line, he might try to harvest whales at a rate that would cause them to become extinct at the same time that he would. "You can't take it with you" would be his attitude.

If ships began to land regularly at this island, he could leave, or he could trade and begin to benefit from some of the future value of whales. If ocean property rights existed, so he could "own" the whales that lived within a certain distance of his island, then he might consider the economic value of owning this right to the whales. He could sell rights to future whales, or mortgage against them, and thus reap the benefits during his lifetime from whales that could be caught after his death. Causing the extinction of whales would not be necessary.

From this example, we see that policies that seem ethically good may not be the most profitable for an individual. We must think beyond the immediate, direct economic advantages of harvesting a resource. Economic analysis clarifies how an environmental resource should be used, what is perceived as its intrinsic value and therefore its price. And this brings us to the question of externalities.

7.5 Externalities

One gap in our thinking about whales, an environmental economist would say, is that we must be concerned with externalities in whaling. An **externality**, also called an **indirect cost**, is often not recognized by producers as part of their costs and benefits, and therefore not normally accounted for in their cost-revenue analyses.[11] Put simply, externalities are costs or benefits that don't show up in the price tag.[13] In the case of whaling, externalities include the loss of revenue to whale-watching tourist boats and the loss of the ecological role that whales play in marine ecosystems. Classically, economists agree that the only way for a consumer to make a rational decision is by comparing the true costs—including externalities—against the benefits the consumer seeks.

Air and water pollution provide good examples of externalities. Consider the production of nickel from ore at the Sudbury, Ontario, smelters, which has serious environmental effects. Traditionally, the economic costs associated with producing commercially usable nickel from an ore were only the **direct costs**—that is, those borne by the producer in obtaining, processing, and distributing a product—passed directly on to the user or purchaser. In this case, direct costs include purchasing the ore, buying energy to run the smelter, building the plant, and paying employees. The externalities, however, include costs associated with degradation of the environment from the plant's emissions. For example, prior to implementation of pollution control, the Sudbury smelter destroyed vegetation over a wide area, which led to increased erosion. Although air emissions from smelters have been substantially reduced and restoration efforts have initiated a slow recovery of the area, pollution remains a problem, and total recovery of the local ecosystem may take a century or more.[14] There are costs associated with the value of trees and soil, with restoring vegetation and land to a productive state.

Problem number one: What is the true cost of clean air over Sudbury? Economists say that there is plenty of disagreement about the cost, but that everyone agrees that it is larger than zero. In spite of this, clean air and water are traded and dealt with in today's world as if their value were zero. How do we get the value of clean air and water and other environmental benefits to be recognized socially as greater than zero? In some cases, we can determine the dollar value. We can evaluate water resources for power or other uses based on the amount of flow of the rivers and the quantity of water storage in rivers and lakes. We can evaluate forest resources based on the number, types, and sizes of trees and their subsequent yield of lumber. We can evaluate mineral resources by estimating how many metric tons of economically valuable mineral material exist at particular locations. Quantitative evaluation of the tangible natural resources—such as air, water, forests, and minerals—prior to development or management of a particular area is now standard procedure.

Problem number two: Who should bear the burden of these costs? Some suggest that environmental and ecological costs should be included in costs of production through taxation or fees. The expense would be borne by the corporation that benefits directly from the sale of the resource (nickel in the case of Sudbury) or would be passed on in higher sales prices to users (purchasers) of nickel. Others suggest that these costs be shared by the entire society and paid for by general taxation, such as a sales tax or income tax. The question is whether it is better to finance pollution control using tax dollars or a "polluter pays" approach.

7.6 Valuing the Beauty of Nature

The beauty of nature—often termed *landscape aesthetics*—is an environmental intangible that has probably been important to people as long as our species has existed. We know it has been important since people have written, because the beauty of nature is a continuous theme in literature and art. Once again, as with forests cleaning the air, we face the difficult question: How do we arrive at a price for the beauty of nature? The problem is even more complicated because among the kinds of scenery we enjoy are many modified by people. For example, the open farm fields in Vermont improved the view of the mountains and forests in the distance, so when farming declined in the 1960s, the state began to provide tax incentives for farmers to keep their fields open and thereby help the tourism economy (Figure 7.7).

One of the perplexing problems of aesthetic evaluation is personal preference. One person may appreciate a high mountain meadow far removed from civilization; a second person may prefer visiting with others on a patio at a trailhead lodge; a third may prefer to visit a city park; and a fourth may prefer the austere beauty of a desert. If we are going to consider aesthetic factors in environmental analysis, we must develop a method of aesthetic evaluation that allows for individual differences—another yet unsolved topic.

One way the intangible value of landscape beauty is determined is by how much people are willing to pay for it, and how high a price people will pay for land with a beautiful view, compared with the price of land without a view. As apartment dwellers in any big city will tell you,

FIGURE 7.7 **How much is a beautiful scene worth?** Consider, for example, this view in New Hampshire looking west to the Connecticut River and Vermont. Is landscape beauty an externality?

the view makes a big difference in the price of their unit. For example, in mid-2009, the *New York Times* listed two apartments, both with two bedrooms, for sale in the same section of Manhattan, one without a view for $850,000 and one with a wonderful view of the Hudson River estuary for $1,315,000 (Figure 7.8).

Some philosophers suggest that there are specific characteristics of landscape beauty and that we can use these characteristics to help us set the value of intangibles. Some suggest that the three key elements of landscape beauty are coherence, complexity, and mystery—mystery in the form of something seen in part but not completely, or not completely explained. Other philosophers suggest that the primary aesthetic qualities are unity vividness, and variety.[15] *Unity* refers to the quality or wholeness of the perceived landscape—not as an assemblage but as a single, harmonious unit. *Vividness* refers to that quality of landscape that makes a scene visually striking; it is related to intensity, novelty, and clarity. People differ in what they believe are the key qualities of landscape beauty, but again, almost everyone would agree that the value is greater than zero.

FIGURE 7.8 A view from a New York City apartment greatly increased its price compared with similar apartments without a view.

7.7 How Is the Future Valued?

The discussion about whaling—explaining why whalers may not find it advantageous to conserve whales—reminds us of the old saying "A bird in the hand is worth two in the bush." In economic terms, a profit now is worth much more than a profit in the future. This brings up another economic concept important to environmental issues: the future value of anything compared with its present value.

Suppose you are dying of thirst in a desert and meet two people. One offers to sell you a glass of water now, and the other offers to sell you a glass of water if you can be at the well tomorrow. How much is each glass worth? If you believe you will die today without water, the glass of water today is worth all your money, and the glass tomorrow is worth nothing. If you believe you can live another day without water, but will die in two days, you might place more value on tomorrow's glass than on today's, since it will gain you an extra day—three rather than two.

In practice, things are rarely so simple and distinct. We know we aren't going to live forever, so we tend to value personal wealth and goods more if they are available now than if they are promised in the future. This evaluation is made more complex, however, because we are accustomed to thinking of the future—to planning a nest egg for retirement or for our children. Indeed, many people today argue that we have a debt to future generations and must leave the environment in at least as good a condition as we found it. These people would argue that the future environment is not to be valued less than the present one (Figure 7.9).

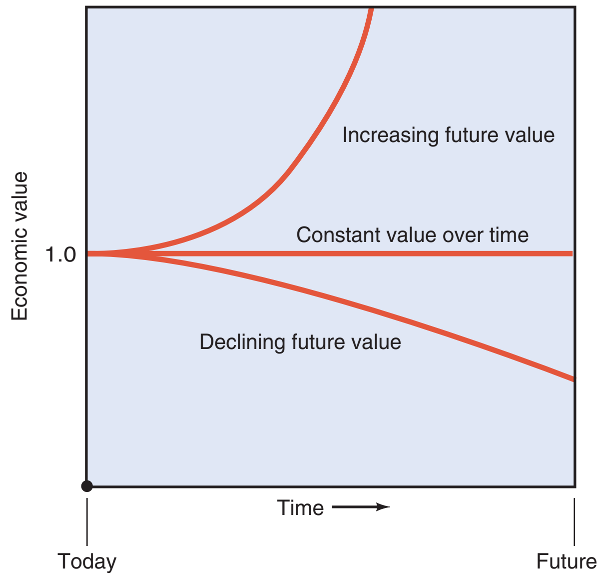


FIGURE 7.9 Economic value as a function of time—a way of comparing the value of having something now with the value of having it in the future. A negative value means that there is more value attached to having something in the present than having it in the future. A positive value means that there is more value attached to having something in the future than having it today.

Since the future existence of whales and other endangered species has value to those interested in biological conservation, the question arises: Can we place a dollar value on the *future* existence of anything? The future value depends on how far into the future you are talking about. The future times associated with some important global environmental topics, such as stratospheric ozone depletion and global warming, extend longer than a century. This is because chlorofluorocarbons (CFCs) have such a long residence time in the atmosphere and because of the time necessary to realize benefits from changing energy policy to offset global climate change.

Another aspect of future versus present value is that spending on the environment can be viewed as diverting resources from alternative forms of productive investment that will be of benefit to future generations. (This assumes that spending on the environment is not itself a productive investment.)

A further issue is that as we get wealthier, the value we place on many environmental assets (such as wilderness areas) increases dramatically. Thus, if society continues to grow in wealth over the next century as it has over the past century, the environment will be worth far more to our great-grandchildren than it was to our great-grandparents, at least in terms of willingness to pay to protect it. The implication—which complicates this topic even more—is that conserving resources and environment for the future is tantamount to taking from the poor today and giving to the possibly rich in the future. To what extent should we ask the average American today to sacrifice now for richer great-great-grandchildren? How can we know the future usefulness of today's sacrifices? Put another way, what would you have liked your ancestors in 1900 to have sacrificed for our benefit today? Should they have increased research and development on electric transportation? Should they have saved more tall-grass prairie or restricted whaling?

Economists observe that it is an open question whether something promised in the future will have more value then than it does today. Future economic value is difficult enough to predict because it is affected by how future consumers view consumption. But if, in addition, something has greater value in the future than it does today, then that leads to the mathematical conclusion that in the very long run, the future value will become infinite, which of course is impossible. So in terms of the future, the basic issues are (1) that since we are so much richer and better off than our ancestors, their sacrificing for us might have been inappropriate; and (2) even if they had wanted to sacrifice, how would they have known what sacrifices would be important to us?

As a general rule, one answer to the thorny questions about future value is: Do not throw away or destroy something that cannot be replaced if you are not sure of its future value. For example, if we do not fully understand the value of the wild relatives of potatoes that grow in Peru but do know that their genetic diversity might be helpful in developing future strains of potatoes, then we ought to preserve those wild strains.

7.8 Risk-Benefit Analysis

Death is the fate of all individuals, and almost every activity in life involves some risk of death or injury. How, then, do we place a value on saving a life by reducing the level of a pollutant? This question raises another important area of environmental economics: **risk-benefit analysis**, in which the riskiness of a present action in terms of its possible outcomes is weighed against the benefit, or value, of the action. Here, too, difficulties arise.

With some activities, the relative risk is clear. It is much more dangerous to stand in the middle of a busy highway than to stand on the sidewalk, and hang gliding has a much higher mortality rate than hiking. The effects of pollutants are often more subtle, so the risks are harder to pinpoint and quantify. Table 7.1 gives the lifetime risk of death associated with a variety of activities and some forms of pollution. In looking at the table, remember that since the ultimate fate of everyone is death, the total lifetime risk of death from all causes must be 100%. So if you are going to die of something and you smoke a pack of cigarettes a day, you have 8 chances in 100 that your death will be a result of smoking. At the same time, your risk of death from driving an automobile is 1 in 100. Risk tells you the chance of an event but not its timing. So you might smoke all you want and die from the automobile risk first.

One of the striking things about Table 7.1 is that death from outdoor environmental pollution is comparatively low—even compared to the risks of drowning or of dying in a fire. This suggests that the primary reason we value lowering air pollution is not to lengthen our lives but to improve the quality of our lives. Considering people's great interest in air pollution today, the quality of life must be much more important than is generally recognized. We are willing to spend money on improving that quality rather than just extending our lives. Another striking observation in this table is that natural *indoor* air pollution is much more deadly than most outdoor air pollution—unless, of course, you live at a toxic-waste facility.

It is commonly believed that future discoveries will help to decrease various risks, perhaps eventually allowing us to approach a zero-risk environment. But complete elimination of risk is generally either technologically impossible or prohibitively expensive. Societies differ in their views of what constitutes socially, psychologically, and ethically acceptable levels of risk for any cause of death or injury, but we can make some generalizations about the acceptability of various risks. One factor is the number of people affected. Risks that affect a small population (such as employees at nuclear power plants) are usually more

Table 7.1 RISK OF DEATH FROM VARIOUS CAUSES

CAUSE	RESULT	RISK OF DEATH (PER LIFETIME)	LIFETIME RISK OF DEATH (%)	COMMENT
Cigarette smoking (pack a day)	Cancer, effect on heart, lungs, etc.	8 in 100	8.0%	
Breathing radon-containing air in the home	Cancer	1 in 100	1.0%	Naturally occurring
Automobile driving		1 in 100	1.0%	
Death from a fall		4 in 1,000	0.4%	
Drowning		3 in 1,000	0.3%	
Fire		3 in 1,000	0.3%	
Artificial chemicals in the home	Cancer	2 in 1,000	0.2%	Paints, cleaning agents, pesticides
Sunlight exposure	Melanoma	2 in 1,000	0.2%	Of those exposed to sunlight
Electrocution		4 in 10,000	0.04%	
Air outdoors in an industrial area		1 in 10,000	0.01%	
Artificial chemicals in water		1 in 100,000	0.001%	
Artificial chemicals in foods		less than 1 in 100,00	0.001%	
Airplane passenger (commercial airline)		less than 1 in 1,000,000	0.00010%	

Source: From *Guide to Environmental Risk* (1991), U.S. EPA Region 5 Publication Number 905/91/017.

acceptable than those that involve all members of a society (such as risk from radioactive fallout).

In addition, novel risks appear to be less acceptable than long-established or natural risks, and society tends to be willing to pay more to reduce such risks. For example, in the late part of the 20th century, France spent about $1 million each year to reduce the likelihood of one air-traffic death but only $30,000 for the same reduction in automobile deaths.[16] Some argue that the greater safety of commercial air travel versus automobile travel is in part due to the relatively novel fear of flying compared with the more ordinary fear of death from a road accident. That is, because the risk is newer to us and thus less acceptable, we are willing to spend more per life to reduce the risk from flying than to reduce the risk from driving.

People's willingness to pay for reducing a risk also varies with how essential and desirable the activity associated with the risk is. For example, many people accept much higher risks for athletic or recreational activities than they would for transportation- or employment-related activities (see Table 7.1). People volunteer to climb Mt. Everest even though many who have attempted it have died, but the same people could be highly averse to risking death in a train wreck or commercial airplane crash. The risks associated with playing a sport or using transportation are assumed to be inherent in the activity. The risks to human health from pollution may be widespread and linked to a large number of deaths. But although risks from pollution are often unavoidable and unseen, people want a lesser risk from pollution than from, say, driving a car or playing a sport.

In an ethical sense, it is impossible to put a value on a human life. However, it is possible to determine how much people are willing to pay for a certain amount of risk reduction or a certain probability of increased longevity. For example, a study by the Rand Corporation considered measures that would save the lives of heart-attack victims, including increasing ambulance services and initiating pretreatment screening programs. According to the study, which identified the likely cost per life saved and people's willingness to pay, people favored government spending of about $32,000 per life saved, or $1,600 per year of longevity. Although information is incomplete, it is possible to estimate the cost of extending lives in terms of dollars per person per year for various actions (Figure 7.10 and Table 7.1). For example, on the basis of direct effects on human health, it costs more to increase longevity by reducing air pollution than to directly reduce deaths by adding a coronary-ambulance system.

Such a comparison is useful as a basis for decision-making. Clearly, though, when a society chooses to reduce air pollution, many factors beyond the direct, measurable health benefits are considered. Pollution not only directly affects our health but also causes ecological and aesthetic damage, which can indirectly affect human health (see Section 7.4). We might want to choose a slightly higher risk of death in a more pleasant environment rather than increase the chances of living longer in a poor environment—spend money to clean up the air rather than increase ambulance services to reduce deaths from heart attacks.

Comparisons like these may make you uncomfortable. But like it or not, we cannot avoid making choices of this kind. The issue boils down to whether we should improve the quality of life for the living or extend life expectancy regardless of the quality of life.[17]

The degree of risk is an important concept in our legal processes. For example, the U.S. Toxic Substances Control Act states that no one may manufacture a new chemical substance or process a chemical substance for a new use without obtaining clearance from the EPA. The Act establishes procedures for estimating the hazard to the environment and to human health of any new chemical before its use becomes widespread. The EPA examines the data provided and judges the degree of risk associated with all aspects of the production of the new chemical or process, including extraction of raw materials, manufacturing, distribution, processing, use, and disposal. The chemical can be banned or restricted in either manufacturing or use if the evidence suggests that it will pose an unreasonable risk to human health or to the environment.

But what is unreasonable?[18] This question brings us back to Table 7.1 and makes us realize that deciding what is "unreasonable" involves judgments about the quality of life as well as the risk of death. The level of acceptable pollution (and thus risk) is a social-economic-environmental trade-off. Moreover, the level of acceptable risk changes over time in society, depending on changes in scientific knowledge, comparison with risks from other causes, the expense of decreasing the risk, and the social and psychological acceptability of the risk.

When adequate data are available, it is possible to take scientific and technological steps to estimate the level of risk and, from this, to estimate the cost of reducing risk and compare the cost with the benefit. However, what constitutes an acceptable risk is more than a scientific or technical issue. The acceptability of a risk involves ethical and psychological attitudes of individuals and society. We must therefore ask several questions: What risk from a particular pollutant is acceptable? How much is a given reduction in risk from that pollutant worth to us? How much will each of us, as individuals or collectively as a society, be willing to pay for a given reduction in that risk?

The answers depend not only on facts but also on societal and personal values. What must also be factored into the equation is that the costs of cleaning up pollutants and polluted areas and the costs of restoration programs can be minimized, or even eliminated, if a recognized pollutant is controlled initially. The total cost of pollution control need not increase indefinitely.

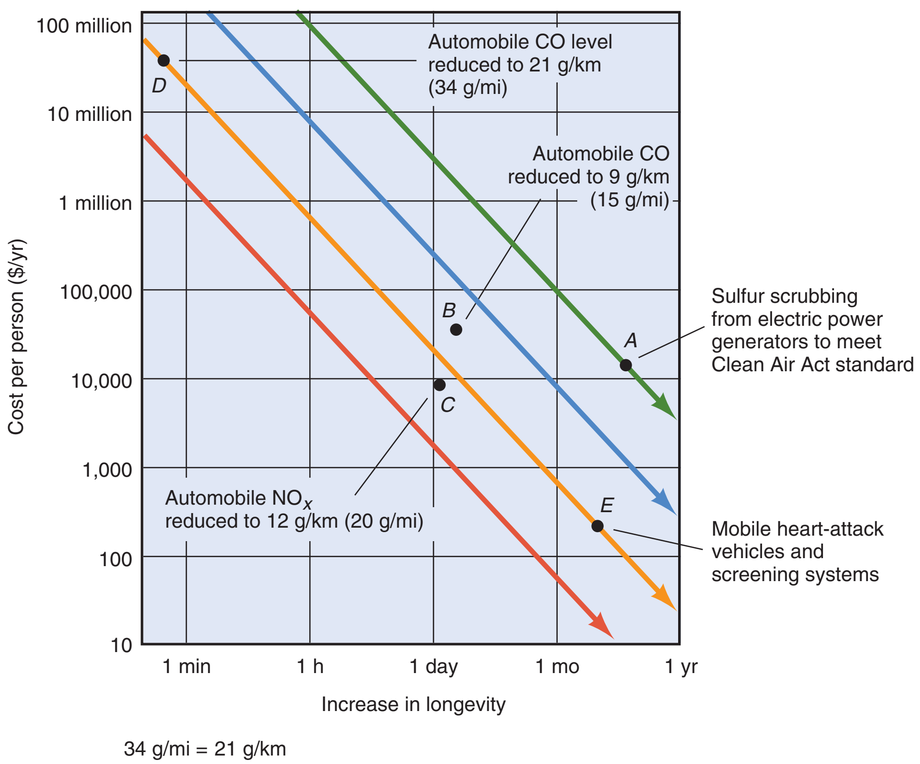


FIGURE 7.10 The cost of extending a life in dollars per year is one way to rank the effectiveness of various efforts to reduce pollutants. This graph shows that reducing sulfur emissions from power plants to the Clean Air Act level **(A)** would extend a human life 1 year at a cost of about $10,000. Similar restrictions applied to automobile emissions **(B, C)** would increase lifetimes by 1 day. More stringent automobile controls would be much more expensive **(D)**; mobile units and screening programs for heart problems would be much cheaper **(E)**. This graph represents only one step in an environmental analysis. (*Source:* Based on R. Wilson, Risk-benefit analysis for toxic chemicals, *Ecotoxicology and Environmental Safety* 4 [1980]: 370–83.)

CRITICAL THINKING ISSUE

Georges Bank: How Can U.S. Fisheries Be Made Sustainable?

The opening case study discussed several ways that economists help make policy. Ocean fishing in Georges Bank—a large, shallow area between Cape Cod, Massachusetts, and Cape Sable Island in Nova Scotia, Canada—illustrates different ways of making a policy work. Both overfishing and pollution have been blamed for the alarming decline in groundfish (cod, haddock, flounder, redfish, pollack, hake) off the northeastern coast of the United States and Canada. Governments' attempts to regulate fishing have generated bitter disputes with fishermen, many of whom contend that restrictions on fishing make them scapegoats for pollution problems. The controversy has become a classic battle between short-term economic interests and long-term environmental concerns.

The oceans outside of national territorial waters are *commons*—open to free use by all—and thus the fish and mammals that live in them are common resources. What is a common resource may change over time, however. The move by many nations to define international waters as beginning 325 kilometers (200 miles) from their coasts has turned some fisheries that used to be completely open common resources into national resources open only to domestic fishermen.

In fisheries, there have been four main management options:

1. Establish total catch quotas for the entire fishery and allow anybody to fish until the total is reached.
2. Issue a restricted number of licenses but allow each licensed fisherman to catch many fish. (This is equivalent to the ***legal emissions limit*** explained in the opening case study.)
3. Tax the catch (the fish brought in) or the effort (the cost of ships, fuel, and other essential items). (This is equivalent to the ***tax on emitters*** in the opening case study.)
4. Allocate fishing rights—that is, assign each fisherman a transferable and salable quota (see the ***cap-and-trade*** option in the opening case study.)

With total-catch quotas, the fishery is closed when the quota is reached. Whales, Pacific halibut, tropical tuna, and anchovies have been regulated in this way. Although regulating the total catch can be done in a way that helps the fish, it tends to increase the number of fishermen and encourage them to buy larger and larger boats. The end result is a hardship for fishermen—huge boats usable for only a brief time each year. When Alaska tried this, all of the halibut were caught in a few days, with the result that restaurants no longer had halibut available for most of the year. This undesirable result led to a change in policy: The total-catch approach was replaced by the sale of licenses.

Issues relating to U.S. fisheries are hardly new. In the early 1970s, fishing was pretty open, but in 1977, in response to concerns about overfishing in U.S. waters by foreign factory ships, the U.S. government extended the nation's coastal waters from 12 to 200 miles (from 19 to 322 km). To encourage domestic fishermen, the National Marine Fisheries Service provided loan guarantees for replacing older vessels and equipment with newer boats carrying high-tech equipment for locating fish. During this same period, demand for fish increased as Americans became more concerned about cholesterol in red meat. Consequently, the number of fishing boats, the number of days at sea, and fishing efficiency increased sharply, and 50–60% of the populations of some species were landed each year.

The international battle over Georges Bank led to a consideration by the International Court of Justice in The Hague. This court's 1984 decision intensified competition. Overfishing continued, and in 1992 Canada was forced to suspend all cod fishing to save the stock from complete annihilation. Later that year, Canada prohibited fishing at certain times and in certain areas on Georges Bank, mandated minimum net sizes, and set quotas on the catch.

These measures were intended to cut the fishing effort in half by 1997. A limited number of fishing permits were issued, limiting the number of days at sea and number of trips for harvesting certain species. High-tech monitoring equipment ensured compliance. Still, things got worse. Recently, portions of Georges Bank were closed indefinitely to fishing for some fish species, including yellowtail, cod, and haddock.

In the spring of 2009, fishermen suggested that the limit on individual fishermen be replaced by a group quota, a variation on Management Option 4 (above). Fishermen would work together in groups called "sectors," and each sector could take a set percentage of the annual catch of one species. This approach is being used elsewhere in U.S. waters. It places fewer restrictions on individual fishermen, such as limiting each one's number of trips or days at sea.

Recent economic analysis suggests that taxes taking into account the cost of externalities (such as water pollution from motorboat oil) can work to the best advantage of fishermen and fish. Allocating a transferable and salable quota to each fisherman produces similar results. However, after decades of trying to find a way to regulate fishing so that Georges Bank becomes a sustainable fishery, nothing has worked well. The fisheries remain in trouble.

Critical Thinking Questions

1. Which of the policy options described above attempt to convert the fishing industry from a commons system to private ownership? How might these measures help prevent overfishing? Is it right to institute private ownership of public resources?

2. Thinking over the choices discussed in this chapter, what policy option do you think has the best chance of sustaining the fisheries on Georges Bank? Explain your answer.
3. What approach to future value (approximately) do each of the following people assume for fish?

   Fisherman: If you don't get it now, someone else will.
   Fisheries manager: By sacrificing now, we can do something to protect fish stocks.
4. Develop a list of the environmental and economic advantages and disadvantages of ITQs. Would you support instituting ITQs in New England? Explain why or why not.
5. Do you think it is possible to reconcile economic and environmental interests in the case of the New England fishing industry? If so, how? If not, why not?

SUMMARY

- Economic analysis can help us understand why environmental resources have been poorly conserved in the past and how we might more effectively achieve conservation in the future.
- Economic analysis is applied to two different kinds of environmental issues: the use of desirable resources (fish in the ocean, oil in the ground, forests on the land) and the minimization of pollution.
- Resources may be common property or privately controlled. The kind of ownership affects the methods available to achieve an environmental goal. There is a tendency to overexploit a common-property resource and to harvest to extinction nonessential resources whose innate growth rate is low, as suggested in Hardin's "tragedy of the commons."
- Future worth compared with present worth can be an important determinant of the level of exploitation.
- The relation between risk and benefit affects our willingness to pay for an environmental good.
- Evaluation of environmental intangibles, such as landscape aesthetics, is becoming more common in environmental analysis. Such evaluation can be used to balance the more traditional economic evaluation and to help separate facts from emotion in complex environmental problems.
- Societal methods to achieve an environmental goal include moral suasion, direct controls, market processes, and government investment. Many kinds of controls have been applied to pollution and the use of desirable resources.

REEXAMINING THEMES AND ISSUES

Human Population

The tragedy of the commons will worsen as human population density increases because more and more individuals will seek personal gain at the expense of community values. For example, more and more individuals will try to make a living from harvesting natural resources. How people can use resources while at the same time conserving them requires an understanding of environmental economics.

Sustainability

From this chapter, we learn why people sometimes are not interested in sustaining an environmental resource from which they make a living. When the goal is simply to maximize profits, it is sometimes a rational decision to liquidate an environmental resource and put the money gained into a bank or another investment, to avoid such liquidation, we need to understand economic externalities and intangible values.

Global Perspective

Solutions to global environmental issues, such as global warming, require that we understand the different economic interests of developed and developing nations. These can lead to different economic policies and different valuation of global environmental issues.

Urban World

The tragedy of the commons began with grazing rights in small villages. As the world becomes increasingly urbanized, the pressure to use public lands for private economic gain is likely to increase. An understanding of environmental economics can help us find solutions to urban environmental problems.

People and Nature

This chapter brings us to the heart of the matter: How do we value the environment, and when can we attach a monetary value to the benefits and costs of environmental actions? People are intimately involved with nature. While we seek rational methods to put a value on nature, the values we choose often derive from intangible benefits, such as an appreciation of the beauty of nature.

Science and Values

One of the central questions of environmental economics concerns how to develop equivalent economic valuation for tangible and intangible factors. For example, how can we compare the value of timber with the beauty people attach to the scenery, trees intact? How can we compare the value of a dam that provides irrigation water and electrical power on the Columbia River with the scenery without the dam, and the salmon that could inhabit that river?

KEY TERMS

commons **130**
direct costs **134**
environmental economics **129**
externality **133**
indirect cost **133**
intangible factor **129**
natural capital **130**
policy instruments **129**
public-service functions **130**
risk-benefit analysis **136**
tangible factor **129**

STUDY QUESTIONS

1. What is meant by the term *the tragedy of the commons?* Which of the following are the result of this tragedy?
(a) The fate of the California condor
(b) The fate of the gray whale
(c) The high price of walnut wood used in furniture

2. What is meant by risk-benefit analysis?

3. Cherry and walnut are valuable woods used to make fine furniture. Basing your decision on the information in the following table, which would you invest in? (*Hint:* Refer to the discussion of whales in this chapter.)
(a) A cherry plantation
(b) A walnut plantation
(c) A mixed stand of both species
(d) An unmanaged woodland where you see some cherry and walnut growing

Species	*Longevity*	*Maximum Size*	*Maximum Value*
Walnut	400 years	1 m	$15,000/tree
Cherry	100 years	1 m	$10,000/tree

4. Bird flu is spread in part by migrating wild birds. How would you put a value on (a) the continued existence of one species of these wild birds; (b) domestic chickens important for food but also a major source of the disease; (c) control of the disease for human health? What relative value would you place on each (that is, which is most important and which least)? To what extent would an economic analysis enter into your valuation?

5. Which of the following are intangible resources? Which are tangible?
(a) The view of Mount Wilson in California
(b) A road to the top of Mount Wilson
(c) Porpoises in the ocean
(d) Tuna in the ocean
(e) Clean air

6. What kind of future value is implied by the statement "Extinction is forever"? Discuss how we might approach providing an economic analysis for extinction.

7. Which of the following can be thought of as commons in the sense meant by Garrett Hardin? Explain your choice.
   (a) Tuna fisheries in the open ocean
   (b) Catfish in artificial freshwater ponds
   (c) Grizzly bears in Yellowstone National Park
   (d) A view of Central Park in New York City
   (e) Air over Central Park in New York City

FURTHER READING

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Hardin, G., Tragedy of the Commons, *Science* 162: 1243–1248, 1968. One of the most cited papers in both science and social science, this classic work outlines the differences between individual interest and the common good.