RESOURCES

RESOURCES FOR THE FUTURE FALL 1992, NO. 109

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Contracts for Transferring Rights to Indigenous Genetic Resources

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Pharmaceutical companies and other organizations are prospecting for potentially valuable chemicals derived from natural organisms in tropical rain forests. Such prospecting would increase protection of these forests if the countries in which they are located were paid for the use of their genetic resources. Complex contracts may be needed for the transfer of these resources to ensure that neither buyers nor sellers will be exploited. Although most of the tasks required to commercialize genetic resources are performed by buyers, many sellers wish to conduct their own research on these resources. Their reasons for doing so must be examined carefully. Unwise investments in research capacity may lead to excessive costs, inefficient contracts, and reduced incentives to preserve irreplaceable ecosystems.

The chemicals produced by natural organisms to resist infections or repel pests might be valuable in agricultural, industrial, and, especially, pharmaceutical applications. Since of all ecosystems tropical rain forests may have the greatest variety of life, these ecosystems may yield the greatest number of chemicals that could be used in the development of new products such as pesticides and drugs. Payments for the use of genetic resources—the natural organisms from which the chemicals are taken—could aid in the development of the poor countries in which most of these forests are found. Such payments would also provide greater incentives for poor countries to preserve their rain forests. Given that these forests are disappearing at an alarming rate, this is an important consideration.

Genetic resources are unusual in one respect. As nonrival goods—that is, goods that can be used or consumed by one person without affecting the ability of another person to use or consume them—they can be exploited by any number of people. This may affect the ability of the countries in which they are first found to obtain payment for their use.

Chemicals to be used in commercial products must be manufactured in large quantities. Once it has been established that an organism is the source of a valuable chemical, it is generally more efficient to produce the chemical by some means other than harvesting the organism in its original environment. For example, the organism may be cultivated on farms outside its original habitat. Its genes might also be transplanted into other organisms, which would then produce the desired chemical. In addition, the molecular structure of the chemical can sometimes be used as a

model for developing a similar synthetic chemical. Under each of these production alternatives, a person who sells the chemical or a product containing the chemical would not need to rely on the original source of the organism to acquire the chemical. Thus, if the country from whose plants and animals commercial products are developed is to reap any benefits, it must have some way of controlling access to these organisms.

If those who have the power to destroy ecosystems rich in genetic resources are not paid for the products derived from these resources, they will have less incentive to preserve biologically diverse natural environments.

Historically, genetic resources have been commercialized without any payments to the countries or other parties that originally provided them. For example, Europeans found plants such as quinine, rubber, and potatoes in the New World, but they never made payments to the peoples on whose ancestral lands these plants were grown or in whose cultures their uses were first discovered. Because the plants were regarded as products of nature, no person could claim to have created them, and hence no person could claim to deserve payment for them.

This attitude is now changing. Perhaps no one can claim to be the creator of plants or animals that will later be found to be the source of valuable chemicals, but certain people do have the power to preserve or destroy these resources. Population growth and development are threatening to ravage habitats and extinguish species at catastrophic rates. If those who have the power to destroy ecosystems rich in genetic diversity are not paid for the products that may be derived from them, they will have less incentive to preserve them.

This realization motivates in part the Biodiversity Convention offered for signature at the recent United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro. Although the United States has refused to sign the convention, it is likely that some of its provisions will come to be generally accepted. Among these are declarations that countries have sovereign rights in their indigenous genetic resources and that such resources cannot be used by others without the prior informed consent of the country. In essence, the Biodiversity Convention establishes that countries have property rights in their genetic resources. This is an important first step in creating economic incentives to use these resources efficiently and to preserve the areas in which they are found. However, countries wishing to commercialize their genetic resources must either develop ways in which to transfer them to foreign firms that have greater expertise in research, development, and marketing, or they must acquire such expertise themselves.

The necessity of contracts

Simple arrangements for the transfer of genetic resources are unlikely to work; these resources cannot simply be sold in a single, once-and-for-all transaction. This is because large amounts of raw materials from which genetic resources are obtained may be needed to conduct research to develop new products. In the development of pharmaceuticals, for example, initial tests of chemicals may require a few kilograms of sample materials, but if the tests show promise, several hundred kilograms of the materials may be required for the next round of tests. If the latter tests show promise, thousands of kilograms of the material may be needed for clinical trials. Production of commercial quantities of drugs may require millions of kilograms. Even if the drugs are to be produced from organisms cultivated on farms outside their original habitats or are eventually to be synthesized from inorganic materials, several stages of testing and large quantities of the organisms are likely to be required.

It would be impractical to collect very large quantities of organisms before any tests are conducted, however. Experts estimate that only about 1 in 10,000 natural materials sampled yields a commercial product. It would be grossly inefficient to collect many samples of materials to be tested when the probability that any one of these materials will be useful is so low. The practical implication is that a researcher testing natural materials will need to have continuing access to the source of the materials.

The need for continuing access may raise several problems that, in turn, explain the creation of complex contracts between buyers and sellers of genetic resources. The first problem is that the buyer may fear exploitation if he or she requests more materials of the type originally purchased. If the buyer makes such a request, the seller may infer that the buyer has found something useful. The seller would then want to charge the buyer more for the next batch of samples. If the buyer anticipates that the seller will behave in this way, he or she would have little incentive to begin research in the first place: if a discovery is made, the buyer knows that the seller will try to deprive him or her of the profits by increasing the price of samples. A contract in which the price of subsequent samples is specified in advance will relieve such worries.

The second problem that necessitates contracts is that destruction of tropical forests may limit or curtail the continuing availability of sample materials. Rain forests are disappearing because people in the countries where they are located perceive it to be more lucrative to chop them down than to maintain them. As long as rain forests represent a potential

Photo courtesy of the Rainforest Alliance

Vincristine sulfate, the drug of choice in the treatment of childhood leukemia, was discovered in the Madagascan periwinkle plant *(Catharanthus roseus)*. Pharmaceutical companies and other organizations are prospecting for useful drugs that may be derived from other natural organisms found in tropical rain forests.

payoff, however, they will be preserved. This suggests that a once-and-for-all payment for the right to prospect for genetic resources is unwise. Once such a payment is made, there is no further incentive for conservation.

Of course, a contract might require a seller to take specific steps to maintain the ecosystem from which the buyer takes samples. Promises to do so may not be credible, however. It is often difficult for a buyer to discern how much effort the seller is putting into ongoing conservation activities. The buyer may not be able to tell why some prospecting activities are unsuccessful. Were the resources the buyer had hoped to find lost due to the seller's negligent conservation efforts, or did they not exist in the first place?

Given that poor performance cannot be observed directly and thus cannot be punished, a buyer would want to provide an incentive for conservation efforts rather than rely on promises. Such an incentive would be a guarantee that the seller would be rewarded if a valuable chemical is discovered. Contract terms that call for royalty payments contingent on discovery would give the seller a continuing incentive to make discoveries more probable by conserving ecosystems.

Not all of the problems that motivate contracts arise from the buyer's concerns about the seller's performance. Once the buyer has amassed enough material that he or she no longer needs to depend on the seller, the seller may worry about whether or not the buyer will fulfill his or her obligations. If the seller has accepted a contract in which he or she will be paid royalties, for example, he or she may want the contract to contain provisions for auditing the buyer to be sure he or she is not being cheated.

Vertical integration and contracting

Contracts are means, often imperfect means, of committing one party to perform in a way that another party desires it to perform. The problems that necessitate complex contracts would not arise if the same party were responsible for all stages of the commercialization of genetic resources. To avoid these problems, one party may attempt to vertically integrate these stages. The degree of vertical integration is the extent to which the same organization engages in the collection of wild species, the classification of these species, the testing of the chemicals they contain, the development of products containing the chemicals or synthetic variants, and, ultimately, the marketing of the products.

Complete vertical integration in the commercialization of genetic resources is unlikely. A major pharmaceutical company is not likely to incur the expense of a purchase of vast tracts of tropical forest, even if it could overcome objections to such a purchase on the grounds of national sovereignty. Nor are many developing countries where tropical forests are found likely to have the financial resources to buy a major pharmaceutical company or the technical know-how to establish one. However, countries rich in tropical rain forests are interested in partial vertical integration. They have expressed a wish to acquire the capability to undertake domestically at least some of the tasks required to produce pharmaceuticals derived from their genetic resources. Such tasks might include collection and classification of natural organisms, extraction of chemicals from the organisms, and some testing of the chemicals.

There are several reasons why a seller of genetic resources might wish to undertake part of the commercialization process. One is cost advantage. A seller may have greater knowledge about the location of raw materials and thus a better vantage point from which to direct collection activities than the buyer. In

addition, he or she may have greater knowledge about which organisms may be valuable or about the uses to which the organisms may be put. It should be noted that if the seller can realize a cost advantage in performing certain tasks, it is to the advantage of both the seller and the buyer to let the seller do so. The more efficient the commercialization process is, the more profits both parties may realize. Thus, in the absence of other considerations, the party that can perform a task most efficiently should be entrusted with the task.

Another reason why a seller might wish to perform collection or other commercialization activities is to lower the cost of monitoring the performance of the buyer. Although buyers have an incentive to discover any valuable chemicals produced by the organisms with which they are supplied, they do not necessarily have an incentive to be honest about their profits from sales of these chemicals. Sellers may be compelled to monitor buyers to ensure that they receive their fair share of these profits. However, if a seller knows that one of the resources he or she sold is a promising antibiotic, for example, he or she could simply monitor the buyer's sales of antiobiotics rather than monitor all of the buyer's revenues. Thus, by conducting some amount of research and testing, a seller might reduce the cost of ensuring that he or she is not cheated in royalty payments.

Yet another reason why sellers may prefer to perform commercialization tasks themselves is to improve their bargaining position. In general, sellers make more attractive deals when there is a lot of competition among buyers for their genetic resources. In the absence of such competition, a seller may offset the advantage enjoyed by a single powerful buyer by developing capabilities similar to those of the buyer.

A number of large and sophisticated pharmaceutical and chemical companies might bid for access to a particular seller's genetic resources. None of these companies is likely to have an appreciable advantage in terms of technology and general research expertise. It is possible, however, that one of the companies might have greater experience in working with natural organisms or with the types of organisms offered by the seller. In this situation, a less-well-informed company knows that if it receives the contract to commercialize the seller's genetic resources it will be because it has offered more than its better-informed rival, who, presumably, has a better idea of what the resources are worth. Thus less-well-informed bidders will bid less aggressively for contracts. The better-informed company will take this into account, and the seller can expect to receive less than he or she would have if all potential buyers had the same information. In this scenario, sellers may find it advantageous to establish their own research capacity in order to increase their knowledge about the value of their genetic resources and pass this knowledge on to buyers. A similar, albeit more complex, argument suggests that the seller would like to provide information to bidders when all have different, but not objectively better, information.

When one buyer dominates the market due to his or her information about the value of a seller's genetic resources, the seller may want to establish his or her own research capability in order to pass on information to all would-be buyers, thereby stimulating competition.

However, a seller may encounter several problems in providing this information. On one hand, buyers would anticipate the seller's incentive to make self-serving announcements; they would not believe unsubstantiated claims. On the other hand, verifiable claims—a statement, for example, that a particular plant contains a compound that will cure cancer—might be an invitation for unauthorized appropriation. Large quantities of sample materials may be required to identify a useful compound when research on the materials is starting from scratch, but much smaller lots might suffice to develop a product of proven value.

These problems, to the extent that they are in fact problems, are not insurmountable. Legal institutions may evolve to prevent unauthorized appropriation of valuable products. Contracts that emphasize royalties rather than upfront payments may make it unnecessary for sellers to provide information about the value of their products. A seller who is confident in the value of the product he or she provides should be willing to rely on royalties, and this willingness may reveal the value of the product.

Although several developing countries with tropical forests have expressed interest in acquiring relatively advanced research capabilities, their rationales for wishing to vertically integrate research activities should be examined carefully. Cost advantage may not explain this interest. If developing countries have a comparative advantage in pharmaceutical research, why have they not already been chosen to host research facilities? The argument that sellers could reduce the expense of monitoring the activities of buyers if they conducted their own research might be more relevant. While foreign research organizations are likely to have appropriate incentives to work hard in making discoveries, it may be difficult for a country that provides genetic material to collect the payments it is due. The argument that the seller would be able to strike a better bargain with would-be buyers if they conducted their own research can make sense. When one buyer dominates the market due to superior information, it may be in the seller's interest to generate com-

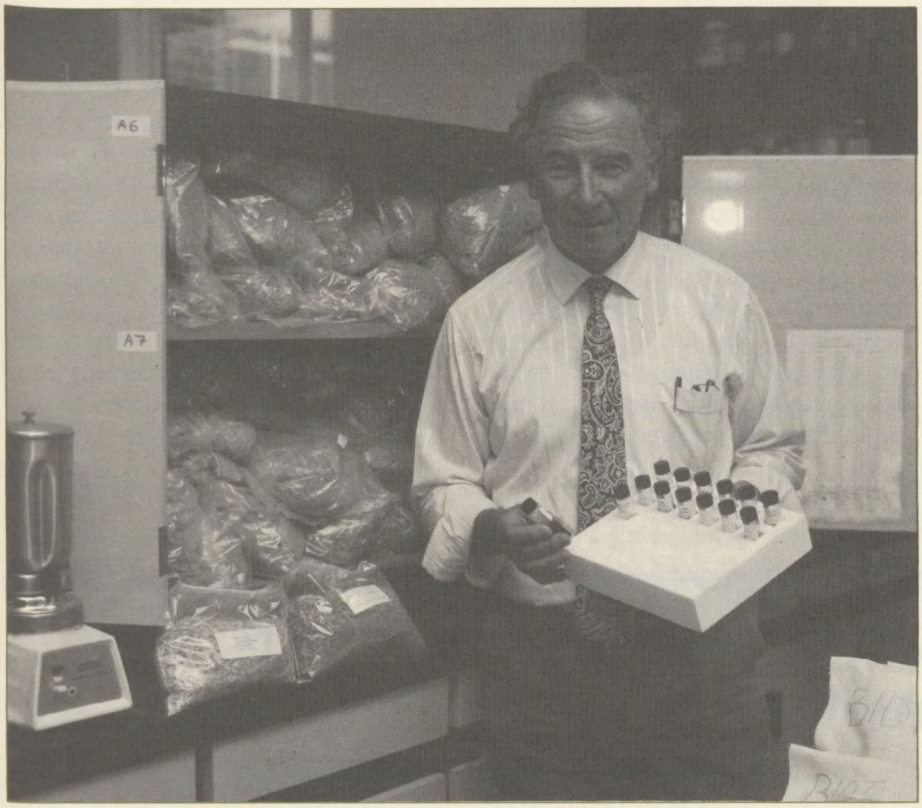

Photo courtesy of Biotics

Dr. Robert Thomas of Biotics displays samples of natural organisms found in tropical countries. The British firm, which serves as a broker of genetic resources, has negotiated contracts with suppliers in Ghana, Malaysia, and other countries that specify royalty payments.

petition by conducting its own research and passing the results on to all potential buyers. However, the decision to do so should be made carefully, as it may further complicate contracting.

The evolution of contracts

In recent years a number of organizations have entered into contracts for the commercialization of genetic resources. The National Cancer Institute (NCI) of the United States has negotiated contracts for access to genetic resources in Zimbabwe, Madagascar, Tanzania, and the Philippines. Biotics—a British firm that matches sellers of genetic resources with buyers and provides some extraction and processing services—has negotiated contracts with suppliers in Ghana, Malaysia, and New Zealand. Perhaps the most sophisticated agreement is that recently signed by Merck and Company, a leading U.S. pharmaceutical firm, and the Instituto Nacional de Biodiversidad (INBio), a quasi-governmental organization charged with oversight of Costa Rica's biological diversity.

All these contracts require that the parties promise to perform continuing or contingent obligations. The standard contract forms employed by NCI and Biotics provide for royalties to be paid in the event of discovery. While the Merck/INBio contract calls for a one million dollar up-front payment, there are also provisions for potentially substantial royalties. Reliance on royalties might seem somewhat strange, since sellers might be expected to prefer the certainty of receiving a smaller sum of money in the present to the remote possibility of receiving a larger sum of money in the future. As noted above, however, royalties are a way of creating incentives for the preservation of ecosystems.

Without credible contracts for transferring genetic resources, there may be even fewer incentives to preserve irreplaceable ecosystems than now exist.

In addition to royalties and up-front payments, some contracts specify that buyers will provide assistance to sellers who wish to increase their research capability. Biotics is helping some source countries increase such capability under its agreements with these countries. INBio's agreement with Merck calls for Merck to provide equipment to be used by Costa Rica for pharmaceutical research. Many countries are likely to follow Costa Rica's lead in establishing institutions like INBio, which has undertaken a massive project to catalogue Costa Rica's entire biological inventory in order to develop domestic collection and research capabilities.

Existing arrangements for the commercialization of genetic resources contain many different provisions for distributing risks, motivating conservation of biologically diverse ecosystems, revealing information about the potential value of genetic resources, and assisting in the development of the sellers' research capability. To some extent, the substantial variation among the terms of the contracts negotiated between buyers and sellers of genetic resources reflects the different circumstances of sellers. The fact that INBio has entered into the most sophisticated of such contracts, and the only one in which substantial up-front payments have been made, is probably related to the fact that Costa Rica enjoys greater political stability than many

developing countries in the tropics. It is unlikely that the different circumstances of sellers explain all the variation in contract forms, however.

As parties learn from trial and error, they may adopt different contract forms and different divisions of the tasks required to commercialize genetic resources. However, it may be unwise to simply wait for the most efficient contract forms to evolve. A lack of credible contracts may translate into a lack of incentives to preserve irreplaceable ecosystems.

It would be both unfair and inaccurate to describe existing arrangements as arising from random experimentation. Contracts are often structured in accordance with expert advice from attorneys and natural scientists. There is, however, an extensive economics literature on risk sharing, incentives, vertical integration, and related issues from which insights should be drawn. Researchers at Resources for the Future are applying and extending the methods of economic analysis to issues arising in the commercialization of genetic resources. Some of the implications of this study have been sketched above. A more detailed treatment of these implications is likely to be of great value in drafting contracts, making investment decisions for new research capability, and, by extension, promoting the conservation of endangered ecosystems.

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Responding to the Potential Health Effects of Electric and Magnetic Fields

H. Keith Florig

Some epidemiological evidence suggests that the electric and magnetic fields (EMFs) emitted by electric power, telecommunication, radar, and other electric and electronic systems might be harmful to health. Although federal authorities have not found this evidence compelling enough to regulate exposure to EMFs, public concerns have prompted political, legal, and market responses to the specter of EMF-induced health hazards. The economic impact of these responses probably exceeds $1 billion per year. Less certain is whether the health risk posed by EMFs warrants such a cost. Unfortunately, research to assess this risk may prove difficult because EMF bioeffects may be both subtle and unrelated to easily measurable aspects of exposure. This increases the importance of promoting fairness in the processes by which risks of exposure to EMFs are distributed across society.

During this century, the dramatic growth in the use of electric and electronic devices has been accompanied by a parallel increase in human exposures to the electric and magnetic fields (EMFs) that these devices emit. Electric power and telecommunication systems, electric and electronic appliances, broadcast facilities, and radar systems have contributed to rising background levels of EMFs in modern living and working spaces. While the benefits of electric and electronic technologies are clearly enormous, the pervasiveness of their EMF emissions has raised concerns about whether exposure to typical levels of EMFs in the environment are harmful to health.

Overall, the scientific evidence about the health risks of exposure to EMFs is suggestive of deleterious health effects but is not compelling. Although no regulatory action has been taken by federal authorities thus far, health concerns have prompted a number of legislative, administrative, legal, and market reactions that carry significant economic impacts. These include delays in the siting and licensing of new power lines, radar systems, and communications antennas; the filing of court cases involving claims of impaired health due to exposure to EMFs; decreases in the value of residential properties located near electric-power transmission lines and broadcast facilities; and the introduction of "low-field" power lines and consumer and office products that are more costly than power lines and product models not designed to lower EMF emissions.

The costs of these actions bear directly on what society should be willing to spend on research to learn whether the health threat posed by EMFs is real. The fact that so much risk management activity is undertaken even though there is no scientific consensus about this threat suggests that sociopolitical and ethical factors play a large role in driving society's response to the EMF problem.

Biological effects

Investigations of the biological effects of EMFs have been under way in the United States for several decades. To date, federal, state, and industry sponsors have spent several hundred million dollars on research to understand the biological effects of EMFs at frequencies ranging from 60 cycles per second (the frequency of the electric power system) to billions of cycles per second (the frequency of microwave ovens). While it is clear that EMFs at higher frequencies and strengths can damage biological systems through heating (the operating principle of the microwave oven), scientists do not know whether the health risks of long-term exposure to weaker or lower-frequency EMFs are significant. However, public concerns are mounting as a result of a number of epidemiological studies that report increased risks of cancer among persons who live near heavy-duty power lines or who work around electrical equipment. These studies suggest that the increased risk of death from cancer for these people is in the neighborhood of a few chances per 100,000 people per year. This level of risk, if real, is greater than the level of risk at which U.S. regulatory agencies have, on occasion, acted to mitigate other threats to human health, such as carcinogenic chemicals or ionizing radiation. Because of possible confounders and biases in most of the epidemiological studies performed to date, scientific opinion about whether the evidence from these studies represents a real EMF health effect varies enormously.

Some scientists have argued on theoretical grounds that environmental levels of power-frequency EMFs—that is, EMFs emitted by electric power systems and electrical devices—can have no biological effects because the electrical signals that they induce in body tissues are less intense than those that are produced naturally by electrical noise and the activity of the human nervous system. Other scientists contend that power-frequency EMFs might still be able to influence biological processes if cells or tissues have structures that respond to the special properties of the power-frequency signal—namely, coherence and spatial uniformity. Although there are many reports of observable biological effects of weak power-frequency EMFs, systematic efforts to replicate these findings in independent laboratories are only now getting under way.

Experiments to discern the biological effects of EMFs reveal some effects that are nonmonotonic functions of the intensity of exposure—that is, effects that are observed only within a narrow range of field strengths. For instance, studies have shown that human heart rates are slightly depressed by exposure to power-frequency EMFs typical of those beneath high-voltage transmission lines, but that they are not affected by fields 50 percent stronger or weaker.

Evidence that some biological effects of EMFs are observed only within a narrow range of field strengths implies that measures to reduce human exposure to EMFs could be counterproductive.

Evidence of nonmonotonic effects has three important implications for EMF risk assessment and management. First, it complicates the interpretation of epidemiological studies that, for the most part, have looked only for correlations between risk and exposure measures that are increasing functions of field strength. Second, it limits the confidence with which the risk associated with strong EMFs—a risk measured in laboratory studies using animals—can be extrapolated to the risk associated with weak EMFs that humans typically encounter. Third, evidence of nonmonotonic effects has significance for proposals to mitigate exposures to EMFs, since it implies that measures to reduce the strength of these exposures could sometimes be counterproductive.

Rationales for mitigation

The possibility that EMFs may be harmful has created risk management problems that involve many sources of power-frequency EMFs, including high-voltage transmission lines, neighborhood power-distribution circuits, home and office wiring, electrical appliances, and office equipment. These problems might be ameliorated by any of a number of actions aimed at modifying people's exposure to EMFs. For instance, transmission lines can be placed on wider rights-of-way or routed to avoid homes and businesses; power-distribution wires can be close-packed to promote mutual cancellation of the field from each wire; office spaces can be arranged so that work areas are not adjacent to rooms where power transformers and other power-handling equipment are located; and electrical appliances can incorporate technologies for shielding or canceling their EMF emissions.

For management, a principal question is which, if any, of these mitigative actions can be justified. The answer depends largely on the rationales upon which mitigation decisions are based. Possible grounds include (1) balancing mitigation costs and potential health benefits, (2) assuring that no one bears an unfair burden of potential risk, (3) reducing delays in the approval of new and upgraded power lines, (4) diminishing liability risk, (5) cutting the expected costs of future retrofits, and (6) enhancing product marketability. A public agency charged with the protection of human health might base its decisions on the first two rationales, an electric utility might consider all but the last, and an electric appliance manufacturer might be concerned primarily with the last three.

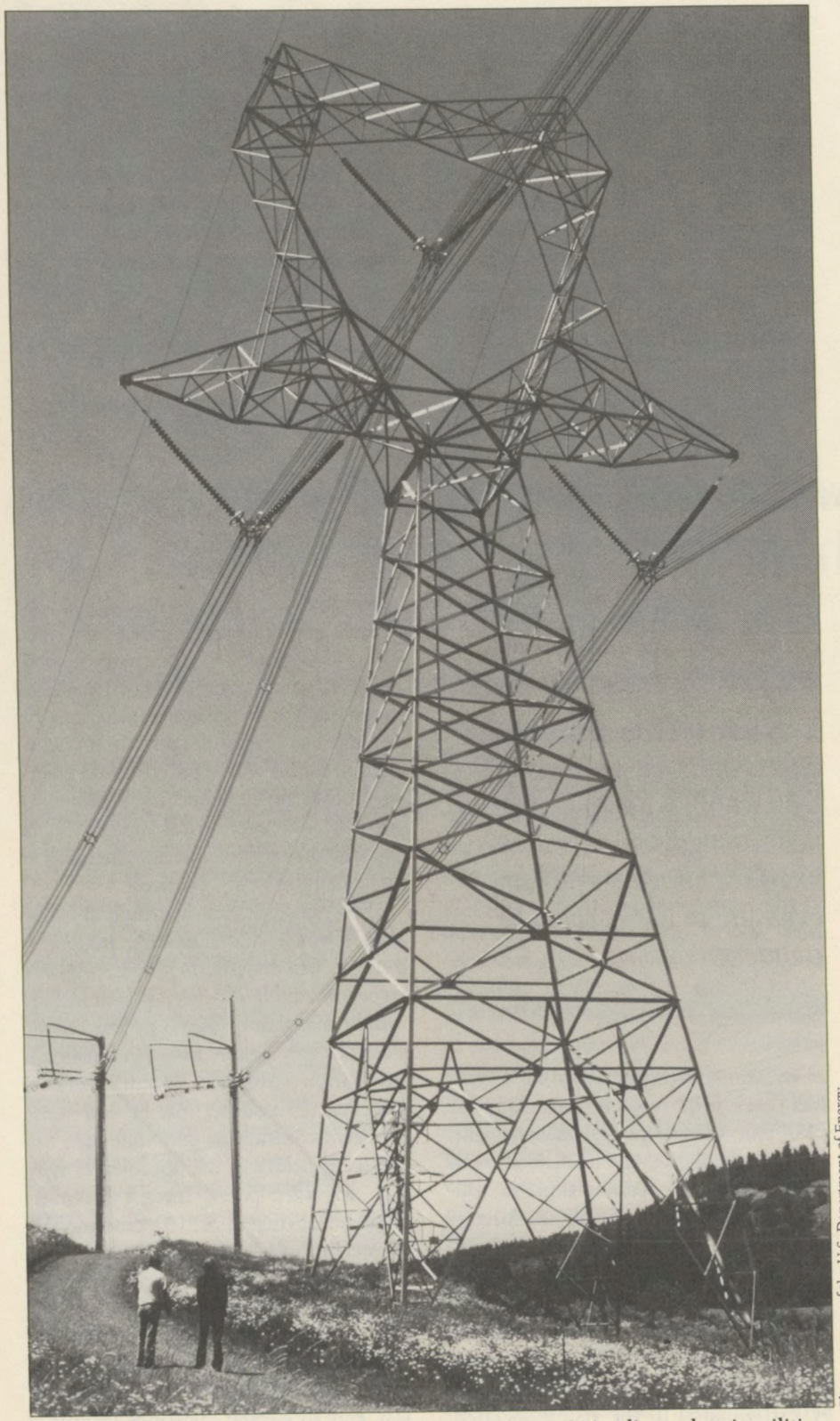

Photo courtesy of the U.S. Department of Energy

To resolve conflicts over the siting of electric-power transmission lines, electric utilities could offer to purchase private property near these lines and conduct siting auctions to identify corridors for new lines.

It should be noted that any measures to mitigate exposure to EMFs need to be carefully considered, since they can increase other kinds of risks to human health. Altering the electrical design of power lines and appliances to reduce EMF emissions, for instance, can have negative effects on safety. Compacting overhead power wires increases maintenance workers' risk of electrocution. Similarly, changing the design of an electric blanket to include a grounded shield increases the risk that the blanket will catch fire or shock users.

Economic impacts

Because the scientific evidence on EMF bioeffects is both complicated and contradictory, regulatory bodies and organizations concerned with scientific standards have been unable to reach a consensus on prescriptive approaches to EMF risk management. While scientific opinion varies widely about whether the EMF-cancer connection is real, public apprehension over potential EMF hazards has prompted a host of ad hoc responses, each with significant economic impacts. These impacts are evidenced in five trends.

First, concerns about EMFs have complicated and delayed the permit and siting process for new electric-power transmission and substation facilities. Some state and local legislative bodies have proposed or enacted outright moratoria on the construction of transmission lines; yet the net benefits of electric-power trading and increased reliability of electric service that even a single new transmission line can provide can be as high as tens of millions of dollars per year.

Second, the public's desire to avoid exposure to EMFs is reflected in the falling value of property along transmission-line routes. In the United States, approximately 10 million acres of land and 1 million homes lie close enough to a transmission line to have EMF levels in excess of typical background levels in

most households. A decline of even 1 percent in the value of these properties amounts to a nationwide market loss of about $1 billion.

Third, the filing of court cases that involve claims of damaged health as a result of exposure to EMFs is becoming more common. Because juries are ill-equipped to deal with the complexities of evidence concerning EMF bioeffects, many of these claims have been settled out of court for undisclosed amounts.

Fourth, whether to avert litigation, avoid future retrofits of electric power lines, or exercise prudence with respect to public health, many electric utilities are unilaterally changing the design of new electric-power distribution circuits in residential areas and placing more power lines underground, on higher poles, or in more compact configurations. The cost of these measures can range from a few percent to 25 percent of the total cost of power lines. Given that electric utilities nationwide invest about $10 billion annually in the construction of power distribution circuits, these EMF mitigation practices, if widely adopted, would cost roughly $1 billion per year.

Finally, to reduce risk of liability and enhance product marketability, manufacturers of some consumer and office appliances have begun to offer "low-field" product models at prices that are a few percent higher than models not designed to lower EMFs. Both the $2 billion market for video display terminals and the $100 million market for electric blankets are expected to deal only in low-field models within a few years.

Although difficult to assess, it seems likely that the total economic cost of the above responses to potential EMF hazards now exceeds $1 billion dollars annually, a cost that will probably grow in years to come. Whether any of these responses are worth their price depends on the health benefits that they produce. These benefits can become better known only through additional research on EMF bioeffects.

In the meantime, it is instructive to compare society's current expenditures to avert or mitigate exposure to EMFs with the expenditures that might be justified under a cost-benefit model if health risks associated with EMFs prove to be as large as existing epidemiological evidence suggests—that is, if EMFs cause between 100 and 1,000 cancer deaths per year in the United States. Studies of risk valuation reveal that the value people place on reducing such comparatively small risks varies widely. A typical amount that people are willing to pay for risk reductions of 1 in 1 million is about $3, but the amount varies across the population and across different risks by at least a factor of two. If the United States wanted to restrict spending on the reduction of EMF risks to levels that are comparable to those spent to avert other risks, the most it could justify spending on EMF mitigation would be about 10 billion dollars per year. This may not be much more than the cost of current ad hoc efforts and represents just several percent of the total cost of electricity to consumers.

Limits of science

Public and private resources in the amount of about $20 million per year are spent in the United States on epidemiological and laboratory research on the bioeffects of power-frequency EMFs. Various bills now in Congress would, over the next few years, double or triple the annual federal commitment to this research, which is roughly $7 million in Fiscal Year 1992.

Two possible outcomes of future research would have a dramatic effect on the EMF debate. One would be the identification of one or more confounders or biases that would "explain" the existing epidemiological evidence that EMFs promote cancer. For instance, further studies might show that the apparent connection between EMFs and cancer was really due to a lack of randomness in the selection of study subjects. Public concerns might then be significantly quelled. Another highly significant outcome of future research would be the unambiguous replication of some EMF-induced bioeffect in a number of independent laboratories. Such replication would put to rest theoretical arguments that weak power-frequency EMFs cannot affect biological systems.

Additional research may not lead to scientific consensus about the magnitude of health risks posed by EMFs; even if it did, the public's distrust of risk management institutions might keep some EMF issues alive.

Although additional research might answer some important nagging questions, there is no guarantee that it will lead to scientific consensus about the magnitude of the health risks posed by EMFs. As the continuing scientific debates over the risk of cancer due to low-level exposures to ionizing radiation and carcinogenic chemicals show, scientific tools for risk assessment are often too blunt to tease out small but socially significant risks. Laboratory experiments on the reaction of cells and tissues to potentially harmful substances have limited relevance to the reaction of whole animals to these substances. In addition, the statistical power of epidemiological studies is rather weak, given the thresholds of risk that society seems to consider significant. The statistical power of animal experiments is greater than that of epidemiological studies, but only when exposures in those experiments are strong enough to produce an effect in a large fraction of the animal population tested. As mentioned above, the validity of extrapolating risks from exposures to strong EMFs

used in animal experiments to risks from exposures to weak EMFs encountered by people is limited by evidence that EMF effects may not be monotonic. Even if scientists were to reach consensus on health risks due to EMFs, the public's growing distrust of risk management institutions may keep the most contentious EMF issues—for example, the siting of electric-power transmission lines—alive in perpetuity.

Promoting fairness in EMF risk management

Like other environmental issues, the EMF issue is as much about sociopolitical and ethical concerns as it is about health risk. It has a sociopolitical dimension because it pits property owners, workers, and consumers concerned about exposure to risks against large organizations such as electric utilities, manufacturers, and government agencies. The issue has an ethical dimension because it involves balancing individuals' desires to eliminate involuntarily imposed risks (however small) with society's need to have reliable electric power and electric products at an affordable price..

Ongoing EMF-bioeffects research programs should be complemented by a program of social science research that would explicitly deal with these sociopolitical and ethical concerns. Such a program could assess people's willingness to pay to avoid exposure to EMFs, devise ways to incorporate the public's values in risk management decisions concerning EMFs that are made on its behalf, and articulate the moral basis for imposing involuntary risk such as that borne by persons living and working on property along new electric-power transmission corridors. It could also evaluate the potential of various ways to resolve conflicts over the siting of electric power lines. These could include offers by electric utilities to purchase private property near power lines, guarantees by these utilities that property would not be devalued by its proximity to new lines, and siting auctions whereby utilities identified corridors for new lines by asking property owners along all possible routes to bid on their willingness to accept a power line on their property.

EMF risk management can be fair only if stakeholders are well informed about the evidence on EMF bioeffects, and about the feasibility and costs of modifying human exposure to EMFs. Unfortunately, the complexity of these subjects makes the public particularly vulnerable to selective reporting about them. Such reporting has been exploited by interest groups on both sides of the EMF debate. Much work is needed to understand the information needs of various groups and to develop channels to address those needs. Recent initiatives by the U.S. Department of Energy, the U.S. Environmental Protection Agency, the state of California, and the electric utility industry represent moves in the right direction.

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Evaluating Alternatives for Increasing Fish Stocks in the Columbia River Basin

Kris Wernstedt, Jeffrey B. Hyman, and Charles M. Paulsen

A number of salmon stocks in the Columbia River and its tributaries are threatened by regional economic activities. Researchers at Resources for the Future have been assisting regional planners to evaluate proposed combinations of actions to increase the numbers of fish in these stocks. The legislation enacting the region's fish recovery program assigns essentially infinite value to the recovery of fish stocks, so the researchers developed a cost-effectiveness analysis that illustrates the trade-offs between the economic costs and biological effectiveness of recovery alternatives. Through this analysis, they are attempting to identify unique combinations of actions, taken throughout the Columbia River basin, that can efficiently meet various biological objectives.

Encompassing nearly a quarter-million square miles and spread over parts of seven states, the U.S. portion of the Columbia River basin is now the site of one of the country's most complex environmental challenges—namely, how the states in the basin can continue to make economic use of the Columbia River system and still protect the health of the basin's ecosystem. Protection of one of the integral components of the ecosystem—

fish—has been of particular concern in recent years. While human exploitation of the resources of the Columbia River and its tributaries for hydroelectric-power production, recreation, irrigation, and navigation has mushroomed in the last fifty years, fish populations have declined precipitously. In the last year, one salmon stock has been declared endangered and two other stocks have been declared threatened under the federal Endangered Species Act. (Salmon stocks are identified as salmon that spawn in a particular subbasin or portion of the river system at a particular season and that generally do not interbreed with salmon in other locations or with salmon in the same location in other seasons.) The American Fisheries Society has identified many additional fish stocks in the Columbia basin that it believes are at risk of extinction.

Scientists estimate that the annual production of adult salmon in the basin has dropped by about 80 percent over the last 150 years. However, some actions to mitigate declines in the basin's fish populations and to restore these populations threaten to curtail or increase the cost of the hydroelectric-power production, navigation, irrigation, and recreation provided by the Columbia River. By the fall of 1993, for example, utilities that purchase hydroelectric power generated by the dams on the river may face an increase of 5 to 10 percent in wholesale electricity rates as a result of the mitigation and recovery actions that the region has decided to implement.

Problems for fish

A number of activities have brought about the decline in fish populations in the Columbia River basin. Logging, mining, and grazing have hindered the reproduction of anadromous fish (fish that ascend rivers from the sea for breeding) by promoting the erosion of soil, which then settles on the gravel streambeds, and by altering the topography and degrading the water quality of many spawning and rearing areas. Irrigation for agricultural production has also impeded reproduction by necessitating diversion dams that block access to these areas, intake pipes that draw fish into irrigation canals and onto fields where they are left stranded, and water withdrawals that have dried up some streams. Commercial and sport fishing kill more than 80 percent of the adult fish of some stocks.

Many smolts are killed by the turbines of downstream dams, and the slower water flow in the pools above the dams increases the time it takes smolts to migrate downstream, increasing their susceptibility to predation.

Production of hydroelectric power has also played a large role in the decline of fish populations. The extensive system of dams on the Columbia and Snake rivers and their major tributaries provide inexpensive electric power and flood protection to the region, but the dams also interfere with the migration and the reproduction of anadromous fish such as Pacific salmon and steelhead. These fish must make two migrations during their lifetime: one migration downstream from tributary streams as juveniles and one migration upstream from the ocean as adults. Unfortunately, hydroelectric-power dams are obstacles to both downstream and upstream migration.

Chief Joseph Dam on the Columbia River and Hells Canyon Dam on the Snake River completely block upstream migration, since adult salmon traveling back to tributary streams to spawn cannot get over or around them. Absent construction of immensely costly fish ladders, areas upstream of these dams will remain inaccessible to the salmon for the foreseeable future. Other, smaller dams on these rivers have fish ladders that allow upstream migration; although the majority of the adult salmon successfully traverse the ladders, the mortality rate at each of the dams is 5 to 15 percent.

Salmon migrating downstream to the ocean as juveniles (smolts) face other dangers. Mortality rates can be high as smolts pass through the turbines of as many as nine downstream dams. Under poor conditions at a single dam, up to 30 percent of the smolts that pass through the dam can die. The fish that successfully avoid the turbines are slowed in their migration to the ocean by the slack water in the pools above the dams. For example, a trip from Idaho or northeastern Washington that took smolts 7 to 14 days before the construction of the dams now averages 20 to 30 days. The increase in travel time makes the smolts more susceptible to predation and may prevent them from reaching the ocean during the time frame in which they can make the physiological transition from fresh water to salt water.

Ironically, hatchery programs, which were intended as part of the solution to dwindling fish runs, may be part of the problem. Many researchers believe that hatchery programs have several pernicious effects on natural stocks. For instance, the programs may foster overly high harvest rates in mixed-stock fisheries, where natural and hatchery-bred fish are indistinguishable. They may also promote genetic mixing of hatchery-bred fish and wild fish, thereby threatening the long-term viability of wild fish populations by reducing the chances that the desirable genetic traits of wild fish will continue to be passed on from generation to generation. In addition, hatchery programs may force wild fish and hatchery-bred fish to compete with each other for food and other

resources and increase the possibility that diseases of hatchery-bred fish will be transmitted to naturally spawning fish.

Efforts to increase fish populations in the Northwest

Since the passage of the Pacific Northwest Electric Power Planning and Conservation Act (often referred to as the Northwest Power Act) in 1980, efforts to increase the number of salmon have intensified. The Northwest Power Planning Council, which was established by the act, has designed and adopted a fish and wildlife program that contains a variety of actions to accomplish this goal. These include passage actions, which facilitate migration through the mainstem Columbia and Snake rivers; harvest actions, which reduce the number of fish that can be caught in the ocean, mainstem rivers, and tributaries; and propagation actions, which mitigate degradation of fish habitats in subbasins or increase the number of fish through hatchery programs.

Passage actions facilitate migration; harvest actions reduce the number of fish that can be caught; and propagation actions improve fish habitats and increase numbers of fish through hatchery programs.

Unlike harvest and propagation actions, passage actions can affect all fish stocks. Individual passage actions are designed to accomplish one of four objectives: (1) to guide smolts around powerhouse turbines at major mainstem dams, (2) to move smolts downstream more rapidly, (3) to reduce their susceptibility to predation while migrating downstream, or (4) to facilitate the upstream migration of adults. In the Columbia River basin, bypass facilities are being installed to accomplish the first objective. To accomplish the second objective, smolts are being transported downstream in barges, and water velocities are being increased by raising the volume of water flows or lowering the elevation of reservoirs. To accomplish the third objective, programs to reduce the population of squawfish and other fish that prey on salmon have been implemented. To accomplish the fourth objective, fish ladders have been built at many dams.

Harvest actions can be an effective but politically charged method for increasing fish runs. Fisheries managers can regulate harvests to some degree by adjusting the timing and location of harvests, changing fishery quotas, and controlling which stocks may be caught by commercial and sport fishers. There has been some discussion about creating an incentive to reduce fish harvests in the Columbia River through a program to purchase the fishing licenses of harvesters. Unfortunately, harvest actions are not well integrated with passage or propagation actions, in part because the administration of harvest management across the Columbia River basin is highly fragmented.

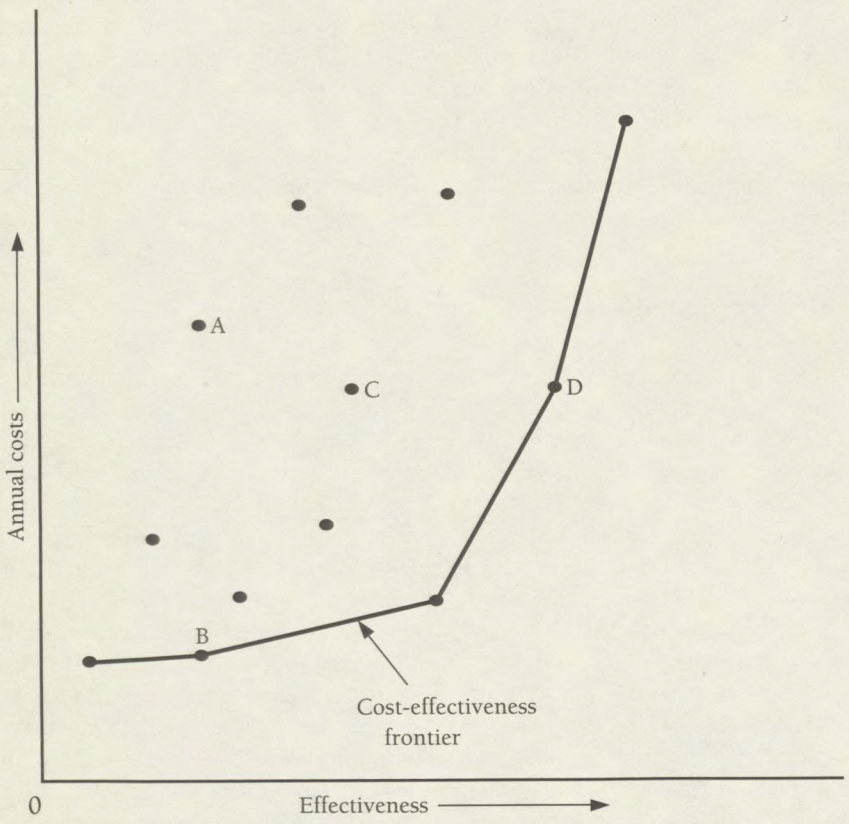
The majority of actions already implemented and proposed to increase the numbers of fish are propagation actions. Widely accepted practices for mitigating habitat problems in the Columbia River subbasins include the removal of barriers to migration, the improvement of stream habitat, and the screening of irrigation-canal intakes. A more controversial propagation action is the breeding of fish in hatcheries, because of the problems that potentially arise when hatchery-bred fish are mixed with naturally spawning fish. Recently proposed hatchery programs take much greater account of these problems.

In general, passage actions are the most expensive actions to implement. For example, due to the decrease in hydropower production that it would entail, the proposal by the Northwest Power Planning Council to increase water velocities by increasing water flows would cost in excess of $70 million per year. Extensive predator control also can be quite costly, although it is estimated to be nearly one order of magnitude less expensive than some water-flow options. The costs of commercial fish-harvest reductions in the ocean and rivers are unknown since large-scale reductions that include compensation for commercial fishers have not taken place. The overwhelming majority of propagation actions require expenditures of $5,000 to $250,000 per year.

Assessing the cost-effectiveness of possible strategies

For the past seven years, researchers at Resources for the Future (RFF) have been assisting the Bonneville Power Administration and regional planners to evaluate the trade-offs among proposed combinations of actions to increase fish populations in the Columbia River basin. (These combinations of actions are referred to as strategies. There are three types of strategies: passage strategies, each of which consists of a different combination of passage actions; harvest strategies, consisting of a different combination of harvest actions; and propagation strategies, consisting of a different combination of propagation actions.) Their approach has been to assess the cost-effectiveness of each recovery alternative, which is a combination of a passage strategy, a propagation strategy, and a particular harvest rate. In contrast to cost-benefit analysis, which attempts to compare the economic value of benefits with the economic cost of attaining them, cost-effectiveness analysis attempts to reveal the

Cost-effectiveness frontier of hypothetical fish recovery alternatives



Note: Each point on the graph represents a hypothetical recovery alternative. The alternative represented by point B is equally effective but less costly than the alternative represented by point A. The alternative represented by point D is more effective and costs the same as the alternative represented by point C.

least-cost way of achieving prescribed objectives, thereby avoiding the economic evaluation of benefits. Such analysis is consistent with the Northwest Power Act—the legislative backbone of the region's fish recovery program—which explicitly states that if there are equally effective means of achieving the same biologically sound objective, the alternative that costs the least should be implemented. This statement suggests that infinite value should be assigned to the recovery of fish stocks and that, once biological objectives have been articulated, the major question is: which recovery alternative will meet objectives at least cost?

But what if decision makers are unsure of their objectives or are willing to consider alternative objectives? In such cases, they would benefit from an illustration of the potential trade-offs between the costs and effectiveness of alternatives for meeting various objectives. One way to help decision makers visualize the trade-offs is to develop a cost-effectiveness frontier by plotting the costs and level of biological effectiveness of each proposed alternative on a graph (see figure, this page). On the graph, each alternative is represented by a single point; its placement in relation to the vertical axis indicates the alternative's cost and its placement in relation to the horizontal axis indicates the alternative's level of effectiveness. The cost-effectiveness frontier is constructed by connecting the points indicating the lowest costs at each level of effectiveness with a line. Points on the frontier represent alternatives that are equally effective but less costly than alternatives not on the frontier (compare points B and A in the figure), or alternatives that are more effective but cost the same or less than alternatives not on the frontier (compare points D and C in the figure). In theory, a cost-effectiveness frontier becomes steeper as the level of effectiveness increases because the costs of obtaining each increment of effectiveness (the marginal costs) increase, although this is not necessarily true in real-world analyses. Regardless of its shape, however, the frontier can be a useful tool for analyzing trade-offs between costs and desired levels of effectiveness.

Other concerns besides cost and effectiveness can be allowed to constrain the types of actions to be considered in a cost-effectiveness analysis.

Obviously, other concerns besides cost and effectiveness play important roles in choosing among alternatives. For example, the genetic mixing of hatchery-bred stocks and wild stocks allowed by some hatchery programs may make these programs unacceptable even though they might be superior to other fish-recovery programs in terms of cost and short-term effectiveness. However, genetic mixing and other concerns can be allowed to constrain the types of actions to be considered in a cost-effectiveness analysis or to shape the objectives that are sought prior to this analysis. Thus it is possible to explore trade-offs between the costs and

the effectiveness of actions to achieve less generic objectives (such as minimizing the risk of genetic mixing, promoting natural flow conditions in rivers, and rebuilding critically low stocks) as well as more generic objectives (such as providing specific numbers of fish to be harvested and to remain unharvested).

Examining the basinwide effects of recovery alternatives

To date, RFF researchers have used the cost-effectiveness framework to analyze millions of alternatives for restoring more than 100 naturally spawning and hatchery-bred fish stocks in the Columbia River basin above Bonneville Dam, which is located on the Columbia River 40 miles upstream from Portland, Oregon. The enormous number of alternatives is the result of the number of stocks involved, the number of harvest rates in tributaries that might be desired, and the fact that each passage and propagation action can be implemented in conjunction with other actions. Thus there are many combinations of actions, target stocks, and harvest rates to be taken into account.

Taking a broad perspective in analyzing the propagation, harvest, and passage actions that could be implemented across the Columbia River basin is the only way to promote the maximum effectiveness of these actions at the lowest cost. Absent analysis of how a passage action would affect the entire basin, there is no way to know whether a decision to maximize the survival of one stock would jeopardize the survival of other stocks. Moreover, it is only by examining each action in the context of other actions that analysts can determine which combinations of strategies will meet objectives and will do so in the most cost-effective manner. A propagation strategy that appears cost-effective in conjunction with one passage strategy may not be cost-effective in conjunction with another passage strategy. For example, a propagation strategy that involves a large number of relatively expensive propagation actions might be undertaken if it is assumed that the passage strategy will not greatly enhance the survival of stocks. If it is assumed that another passage strategy will be more effective in enhancing survival, a different, less expensive propagation strategy might be implemented.

The results of analysis

The RFF analysis of passage, propagation, and harvest-rate alternatives in the Columbia River basin is based on the integration of information derived from two sources: computer modeling of the life cycle of Pacific salmon and steelhead populations in the basin and a database developed primarily from fish restoration plans produced by the Northwest Power Planning Council and the Columbia Basin Fish and Wildlife Authority for each major subbasin of the basin. The goal of the analysis is to inform decision makers about which combinations of passage and propagation strategies and harvest rates would be most cost-effective and to give them an appreciation of which assumptions are critical to the results and conclusions of the analysis.

Although measures to increase water flows do not appear on the cost-effectiveness frontier, they are popular because their costs are evenly distributed among people who use the resources of the Columbia River.

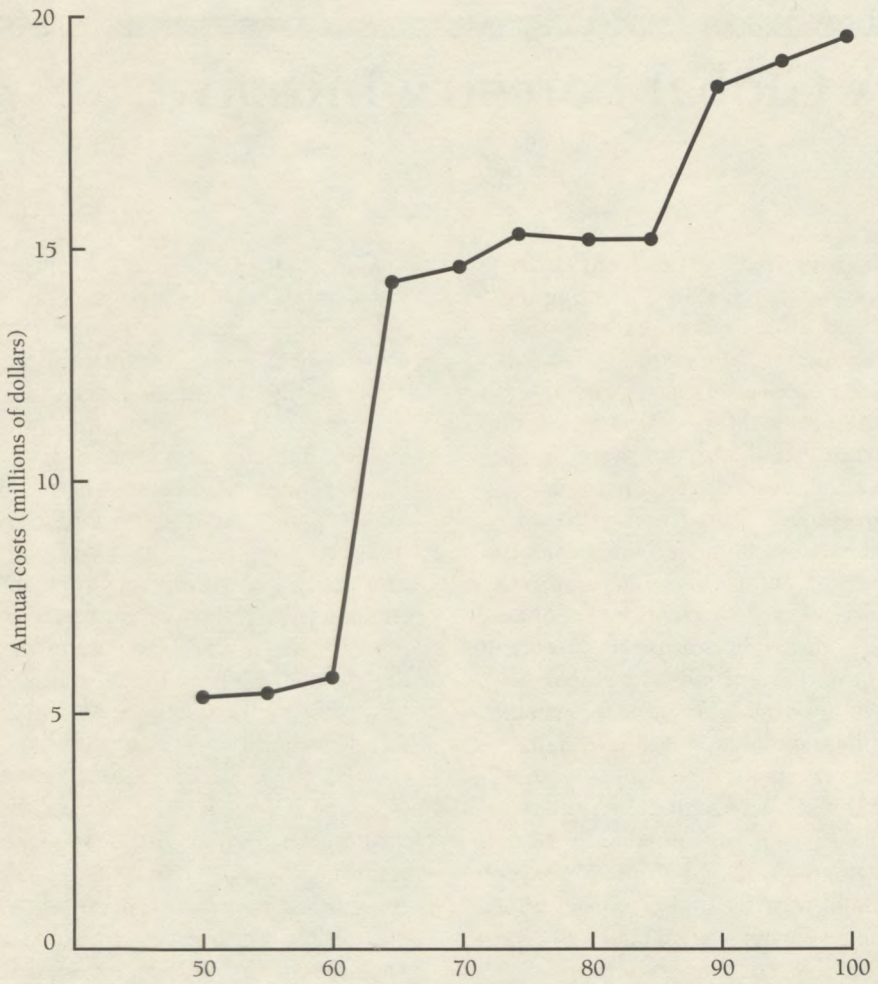
In their efforts to find least-cost basinwide alternatives, RFF researchers examined 8 passage strategies and more than 2,000 propagation strategies. They attempted to identify combinations of these strategies that would meet the objectives set by regional planners for both terminal harvest (the number of fish in each stock that would be available for harvesting in tributary rivers) and spawning escapement (the number of naturally spawning fish in each stock that would be left after commercial, sport, and ceremonial tribal harvests). The researchers also attempted to address the concern that some alternatives might impose unacceptable risks by promoting the genetic mixing of hatchery-bred stocks and naturally spawning stocks. To do this, they eliminated from consideration any hatchery action that would introduce hatchery-bred fish into a wild population. The elimination of these actions did not change the basinwide alternative that the researchers identified as meeting the planners' objectives at least cost as long as three salmon stocks were not considered in the analysis. They found that no combination of genetically acceptable actions would achieve the terminal harvest and spawning escapement objectives for these stocks.

The combination of strategies recommended by the RFF analysis to meet the planners' objectives is, by itself, not very intriguing. Because these objectives are to some extent arbitrary and could be subject to change, a more interesting and useful output of the analysis is the cost-effectiveness frontier that emerged when the original terminal-harvest and spawning-escapement objectives for each stock were lowered by as much as 50 percent. This frontier shows the way in which total costs increase as the number of fish specified for terminal harvest and spawning escapement for each stock rises from 50 to 100 percent of the number originally specified by planners for each stock. These costs rise sharply at two points (see figure, p. 15). The sharpest increase—$8 million per year—occurs when the number of fish for terminal harvest and spawning escapement for each stock increases

from 60 percent to 65 percent of the number originally specified. This increase is due to the introduction of an expensive passage action aimed at predator control. Another sharp increase—$3 million per year—occurs when the number of fish for terminal harvest and spawning escapement for each stock increases from 85 percent to 90 percent of the number originally specified. In this case, the increase is due to a large increase in propagation costs.

The shape of the cost-effectiveness frontier is somewhat contrary to expectations. The marginal costs incurred in achieving each 5-percent increase in the number of fish above the 65-percent level are not always higher than the marginal costs incurred in achieving each 5-percent increase in the number of fish from the 50-percent to the 65-percent level. This oddity results in part from the modeling methods used in the RFF analysis, but it also reflects the fact that an expensive predator-control action is needed to ensure the survival of at least 65 percent of the number of fish originally specified for terminal harvest and spawning escapement for each stock. Once this action is implemented, no additional passage actions (beyond those already planned before the recent changes in the Northwest Power Planning Council's fish and wildlife program) are required. Instead, propagation actions, which are less costly than passage actions, can drive further increases in the numbers of fish.

Cost-effectiveness frontier of alternatives for recovering salmon and steelhead stocks in the Columbia River basin



One revelation of the RFF cost-effectiveness analysis is of particular interest: the Northwest Power Planning Council's proposed water-flow measure, which calls for water flows to be increased, never appears on the cost-effectiveness frontier. Instead, all the alternatives on the frontier include actions that maintain current (1989–1991) water flows. In facilitating the downstream migration of smolts, these actions are considerably less costly than and nearly as effective as the council's water-flow measure. Actions to maintain current water flows appear cost-effective even when the beneficial effects of non-flow passage actions are assumed to be much lower. For example, when estimates of the effectiveness of both proposed predator-control and existing smolt-transport programs are reduced by 50 percent, current water flows are still the most cost-effective way to achieve the planners' original terminal-harvest and spawning-escapement objectives. However, to compensate for the decrease in the assumed effectiveness of these programs, additional propagation actions have to be implemented, resulting in a 40-percent increase in the total costs of these actions.

Because the data on the effectiveness of all water-flow measures are both limited and open to a wide range of interpretations, there is a need to investigate further the sensitivity of the results of the RFF analysis to changes in assumptions about the relationship between water flows and the survival rate of smolts. However, even with more sensitivity testing, the debate over the merits of each alternative flow measure is likely

to continue. Flow measures, such as the one proposed by the Northwest Power Planning Council, enjoy a high level of support among key interest groups in the region, in part because the costs of these measures are relatively evenly distributed among all the people who use the resources of the Columbia River.

The importance of objectives

A cost-effectiveness analysis provides information about how to achieve a set of objectives at least cost. It is important to remember that the objectives are almost never set by the scientists conducting the analysis but emerge from some administrative or social process. Thus the Pacific Northwest region must clearly articulate specific objectives concerning the fish populations of the Columbia River basin.

As clearly shown in the cost-effectiveness analysis conducted by the RFF researchers, the least-cost alternative can change if the number of fish specified in an objective changes. It can also change if the type of objective changes. For instance, doubling the size of the run of each stock and doubling the aggregate run size of all stocks are two distinct objectives, and the accomplishment of each may require the implementation of different fish-recovery alternatives. Certain objectives may even eliminate some alternatives without regard to their cost or effectiveness. For example, if the objective is to increase the number of fish in wild stocks but to do so without genetic mixing of hatchery-bred fish and wild fish, all propagation strategies that rely on hatchery operations would be rejected. The point is that without clear articulation of possible objectives by the policymaking community, analysts are often hard-pressed to provide relevant information to policymakers interested in exploring the trade-offs between the cost and the effectiveness of actions to achieve those objectives.

However, cost-effectiveness analysis is valuable even when the policymaking community is unable to articulate clear objectives. The RFF researchers' cost-effectiveness analysis of alternatives for restoring stocks of anadromous fish in the Columbia River basin demonstrates that such analysis can provide a framework for articulating objectives as well as for developing information about the costs and effectiveness of alternatives to meet these objectives. Cost-effectiveness analysis can also illustrate the trade-offs among possible objectives and alternatives for achieving them. In addition, it can allow decision makers to explore how economic and biological uncertainties can influence the choice of alternatives. Thus, in the context of regionwide decision making, cost-effectiveness analysis is wasted if it is used only to identify a single least-cost alternative to meet an objective.

Kris Wernstedt, Jeffrey B. Hyman, and Charles M. Paulsen are fellows in the Quality of the Environment Division at RFF. This article is based on ongoing research conducted by the authors and senior fellows Allen V. Kneese and Walter O. Spofford, Jr.

A Global Forestry Initiative

Roger A. Sedjo

As evidenced by the recent Earth Summit, interest in protecting the world's forests is growing. Turning this interest into action is difficult due to concerns that an effective international forest protection effort would entail a binding agreement that might infringe on national sovereignty. Recognizing that the global environmental and ecological outputs of forests can be protected only through international cooperation, researchers at Resources for the Future have proposed a global system of tradable forest management obligations that would internalize the benefits of forest conservation to forest owners, thereby providing incentives for sustainable forest management. Modeled on the U.S. system of tradable emissions permits, the proposed system could emerge from a recent forestry initiative, which envisions voluntary forest partnerships between the developed and the developing countries.

Just before the United Nations Conference on Environment and Development, the so-called Earth Summit held in Rio de Janeiro in June 1992, President Bush announced an initiative that would commit the United States to substantially increasing its current expenditures to protect the world's forests, particularly tropical forests. Far from being a feeble last-minute effort to gain credibility with the environmental community, the "Forests for the Future" initiative was actually the outgrowth of the Houston Communique drafted in July 1990 by the Group of Seven (G7) member countries—the United States, Canada, the United Kingdom, France, Germany, Italy, and Japan. The communique called for negotiations to be completed by 1992 on an international convention or agreement to curb deforestation, protect biodiversity, stimulate positive forestry actions, and address threats to the world's forests.

The forestry protection efforts urged by the Houston Communique appear

to be more concrete and substantive than the highly general set of "forest principles" that emerged from the Earth Summit. These principles express concerns, goals, and intentions regarding forests, forest management, and forest protection. The nonbinding "Statement of Forest Principles" adopted at the summit stresses that "forest lands should be sustainably managed to meet [the] social, economic, ecological, cultural, and spiritual human needs of present and future generations." In addition to affirming the responsibility of countries to ensure that forestry activities within their jurisdiction or under their control do not cause damage to the environment, the statement explicitly acknowledges the sovereign right of individual countries to exploit their own forest resources. Indeed, it was the reluctance of countries to relinquish sovereignty in domestic activities that precluded a binding agreement that would prescribe, for example, specific forest management efforts and the quantity of forest each country must protect and preserve.

Although it appears modest, the "Forests for the Future" initiative announced by Bush may prove to be a greater catalyst for increasing protection of forests than the "Statement of Forest Principles." On the surface, the initiative consists simply of a unilateral pledge to increase the current sum of $120 million for forest conservation efforts in the developing world, Eastern Europe, and the former Soviet Union to $270 million in 1993, and to further increase monetary assistance in the future if other countries also contribute to these efforts. When viewed in the context of the Houston Communique, however, it is clear that the real import of the initiative is not the pledge of financial assistance but the intention of precipitating major commitments to forest conservation by the other industrialized nations.

To avoid the problem of encroachment on sovereignty that has plagued most attempts to develop forestry programs that could be accepted in the context of a global agreement, the "Forests for the Future" initiative envisions voluntary forest partnerships between developed countries and developing countries. Through these partnerships, the developed countries would finance forest protection, conservation, and restoration projects proposed by the developing countries. Since it is unlikely that all of these projects could be funded, donor countries would allocate money to the countries they felt had developed the best proposals. To bring potential donors and recipients together, the initiative calls for the convening of a forest partnership forum as early as the end of 1992.

The importance of the Bush initiative lies in the intention to precipitate commitments to forest protection by other industrialized nations.

The concept of partnerships between the developed and developing countries was echoed in a communique issued at the G7 summit in Munich in July 1992. This communique calls for "rapid and concrete action" to create "worldwide partnerships" to follow through on the initiatives emerging from the Earth Summit, and it specifically mentions the "Statement of Forest Principles" in connection with these partnerships.

Global environmental and ecological outputs of forests

Why should the world's forests need the special protection urged by the "Forests for the Future" initiative, the Houston Communique, and the "Statement of Forest Principles"? The answer is that not all of the outputs of forests can be captured and allocated by markets or nonmarket actions on the part of individual governments. Those that cannot be captured and allocated are undervalued and, as a result, are likely to be degraded over time.

Two types of forest outputs are likely to be valued and thus protected within national economies. These are commodity and direct service outputs, such as timber and recreation, and local environmental outputs, such as local watershed protection. Markets provide incentives for the efficient capture and allocation of commodity and direct service outputs, with socially desirable results. Local environmental outputs, on the other hand, often require nonmarket interventions such as government regulation if they are to be captured in any orderly way. These interventions can be made on a local level and would not benefit from the involvement of other countries.

In contrast, the capture of two other kinds of forest output—global environmental outputs, such as carbon sequestration, and global ecological outputs, such as biodiversity—requires international cooperation. It is the realization that neither existing markets nor actions by individual governments are likely to protect these outputs that have led the G7 to seek a global forest agreement.

Alternative approaches to global protection of forests

Several approaches to preserving the global environmental and ecological outputs of forests have been suggested. The basic dilemma of these approaches is to achieve real protection of forests without undermining national sovereignty.

One approach would be a binding agreement that sets forth (for example) country-by-country forest-cover quotas and prescriptions for sustainable forest management. Such an agreement could substantially increase forest protection because it could impose tough compli-

Photo courtesy of Greenpeace

Under the proposed system of tradable forest management obligations, industrialized countries might fulfill their "surplus" obligations by investing in efforts to curb destruction of the Amazonian and other rain forests.

ance and monitoring standards. However, many countries view the imposition of such standards as unacceptable due to considerations of national sovereignty.

Another approach would be a series of nonbinding principles or expressions of intent. While avoiding the politically unacceptable constraints imposed by a binding agreement, such principles and expressions are often shallow and typically lead to little, if any, action. Thus the forest principles agreed to at the recent Earth Summit are likely to generate little forest protection.

The problems with the two above approaches suggest that if any international system of forest protection is to be effective without infringing on national sovereignty, it must meet four criteria. First, such a system must create incentives for producing global environmental and ecological goods that will balance the already existing market incentives to produce commodity and direct service goods and the political incentives to produce local environmental goods. Second, it must allocate responsibilities for forest protection to all nations. Third, it must allow flexibility in how these responsibilities are met. And fourth, it must promote cost-efficient ways of meeting them.

Applying the concept of tradable emissions permits

The system of tradable emissions permits that is increasingly used in the United States to control air pollution could provide a model for a global system of forest protection that satisfies the criteria noted above. The permit system is implemented by fixing an acceptable amount of pollution, issuing emissions permits equal to that amount, and establishing some system for fairly distributing the permits to the entities creating the pollution. These entities are allowed to emit more pollution than the amount specified by the permits they hold, but they are free to sell their permits or buy those of other entities. Because the permits can be traded, they become an asset. Even though permits are initially received free of charge, their use precludes their sale and thus involves opportunity costs.

The number of permits created and thus the amount of pollution allowed is a nonmarket decision, as is the distribution of permits. Once the permits have

been distributed, however, the market reallocates them so as to penalize increases and reward reductions in pollution. In this way the polluter is forced to bear a cost that had been borne collectively by society. This cost creates an incentive to reduce pollution.

Under a global system of tradable forest protection obligations, poor countries would, in effect, be compensated for the environmental and ecological benefits provided by their forests.

The concept of tradable pollution permits could be applied to forestry activities with the objective of internalizing the benefits of forest conservation to forest owners, thereby providing incentives for the sustainable management of forests. To do this, researchers at Resources for the Future have proposed a global system of tradable forest protection obligations whereby countries would voluntarily accept the responsibility to maintain or improve the quality of forests within their own jurisdictions, within other countries, or both. This system would be implemented by creating a set number of obligations and distributing them among countries. Like emissions permits, the obligations would be tradable. Countries could fulfill them directly or induce another country to assume them, presumably in return for payment.

One of the attractive aspects of the proposed system is that, through the distribution of obligations, poor countries would be compensated for the environmental and ecological benefits provided by their forests. Poor countries, particularly those with large amounts of forested land, would assume obligations to protect less forested land than actually exists within their boundaries. Wealthy countries, on the other hand, would assume obligations to protect more forested land than actually exists within their boundaries. Thus they would fulfill their "surplus" obligations by protecting forests in poorer countries.

To fulfill these obligations, wealthy countries could provide payments to poor countries to facilitate efforts to protect critical forests. These efforts could include the establishment of forest preserves, the restoration of forest habitats, or the introduction of sustainable management practices. In some cases, payment might be made only after countries were successful in maintaining the integrity of protected areas for some specified period of time. Thus the payments could be tied to actual performance and not simply to promises.

Under the proposed system, protection of any one acre of forest would not necessarily be equivalent to protection of any other one acre of forest. In fact, the system would be fairly complex in operation. It would recognize that forests differ in type and in condition and management, and therefore differ in their capacity to generate global environmental and ecological outputs. Thus the system would make distinctions in the value of protecting, for example, ten acres of virgin wet tropical forests, which are rich in biodiversity, and the value of protecting ten acres of northern boreal forests, which are less rich in biodiversity and far more abundant than virgin wet tropical forests. This means that if a country fulfilled its obligations by protecting tropical forests, it would have to protect fewer acres than if it fulfilled its obligations by protecting northern boreal forests.

The proposed system would recognize that forests differ in their capacity to generate global environmental and ecological outputs, and thus would make distinctions in the value of protecting different types of forests.

Transition to a system of tradable obligations

A global system of tradeable forest obligations would have to be implemented gradually because it would constitute a sharp departure from the usual manner in which foreign assistance is allocated and because initially only the wealthy countries would be in a financial position to assume obligations. However, Bush's "Forests for the Future" initiative could be the first step in the transition to such a system.

The major achievement of the initiative is that it encourages the participation of the G7 countries and other industrialized countries in forest protection efforts that are in the spirit of the "Statement of Forest Principles" that emerged from the Earth Summit. Like the proposed system of tradable obligations, the initiative calls for these countries to make investments in forest management in developing countries. While the initative only proposes fixed monetary expenditures (as opposed to fixed obligations) for this management, it is similar to the proposed system in that it considers forest conservation to include not only the creation of protected areas, but the promotion of broad multiple uses of the world's forests. Moreover, the forest partnership forum proposed in the "Forests for the Future" initiative could serve as a clearinghouse for facilitating creative investments in these uses under a global system of tradable obligations.

Roger A. Sedjo is a senior fellow in the Energy and Natural Resources Division at Resources for the Future.

Photo courtesy of Greenpeace

INSIDE RFF NEWS AND PUBLICATIONS

Applicants sought for RFF award programs

Resources for the Future is seeking applicants for two of its award programs—the Gilbert F. White Postdoctoral Fellowship Program and the RFF Small Grants Program.

Two resident fellowships will be awarded for the 1993–1994 academic year under the Gilbert F. White Postdoctoral Fellowship Program. They are intended for postdoctoral researchers who wish to devote a year to scholarly work related to natural resources, energy, or the environment.

The RFF Small Grants Program provides funding for new research projects or supplementary support to complete specific aspects of ongoing research related to the environment, natural resources, or energy. Grants are made only to individuals through universities or other tax-exempt institutions.

Applications for the Gilbert F. White and the Small Grants programs are due by March 1, 1993. Awards will be announced in April 1993. For more information about any of the award programs described above, write to Christine A. Mendes at the Office of the Vice President, Resources for the Future, 1616 P Street, NW, Washington, DC 20036-1400. Telephone 202- 328-5067.

Recent contributions and grants

Resources for the Future has recently received corporate contributions from the following corporations and corporate foundations: Amoco Foundation, Inc.; BankAmerica Foundation; Champion International Corporation; Chemical Manufacturers Association; Consumers Power Company; The Dow Chemical Company; DowElanco; Pennsylvania Power & Light Company; Shell Oil Company Foundation; Southern California Edison Company; The Southern Company; and USX Corporation.

The William and Flora Hewlett Foundation awarded a challenge grant to encourage individual donors to provide unrestricted operating support for RFF research and education programs. The grant is contingent upon RFF raising $50,000 per year in matching funds from new individual donors.

About contributions to RFF

Resources for the Future sustains its programs through its endowment and through income from foundations, government agencies, corporations, and individuals. RFF accepts grants on the condition that it is solely responsible for the conduct of its research and the dissemination of its work to the public. RFF does not perform proprietary research.

All contributions to RFF, a publicly funded organization under Section 501(c)(3) of the Internal Revenue Code, are tax deductible. For more information, please contact Debra Montanino, Director of External Affairs, Resources for the Future, 1616 P Street, NW, Washington, DC 20036-1400. Telephone: 202-328-5016. Fax: 202-939-3460.

Discussion papers

RFF discussion papers convey the preliminary findings of research projects for the purpose of critical comment and evaluation. Unedited and unreviewed, they are available at modest cost to interested members of the research and policy communities. Price includes postage and handling. Prepayment is required. To order discussion papers, please send a written request, accompanied by a check, to the Publications Office, Resources for the Future, 1616 P Street NW, Washington, DC 20036-1400.

The following papers have recently been released.

Energy and Natural Resources Division

- "Global Warming and Urban Smog: The Cost Effectiveness of CAFE Standards and Alternative Fuels," by Alan J. Krupnick, Margaret A. Walls, and Carol T. Collins. (ENR92-13) $5.00

- "In Pursuit of a Sustainable Space Environment: Economic Issues in Regulating Space Debris," by Molly K. Macauley. (ENR92-14) $5.00

Quality of the Environment Division

- "The Value of Information and the Cost of Advocacy," by Winston Harrington and Molly K. Macauley. (QE92-20) $2.25

- "Benefit Transfer and Social Costing," by Alan J. Krupnick. (QE92-21) $2.25

- "Environmental Costing for Agriculture: Will It Be Standard Fare in the Farm Bill for 2000?" by V. Kerry Smith. (QE92-22) $2.25

A message from the development committee chair

Dear *Resources* Reader:

Resources for the Future depends on support from individuals, foundations, corporations, and government agencies to conduct its research and education programs. Will you consider becoming a supporter of RFF by making a tax-deductible gift today?

Your gift today may have a double impact on RFF, thanks to a $250,000 challenge grant to RFF from the William and Flora Hewlett Foundation. Recognizing the importance to RFF of unrestricted support from individuals, the Hewlett Foundation announced in July 1992 that it would match (up to $50,000 per year) the unrestricted gifts of all new individual RFF supporters.

As RFF celebrates its fortieth anniversary, it is appropriate to look back at the significant contributions RFF has made to public policy debates regarding environmental and natural resources issues. RFF plans to play an even more important role in the future, and to make that possible support from individuals is essential.

Perhaps RFF's central accomplishment has been to establish resource and environmental economics as a respected and comprehensive research discipline. Recognition of this work is may be best exemplified by the recent award of the Volvo Environmental Prize to RFF's Allen Kneese and John Krutilla. As the prize committee noted, "the advances to date in environmental economics are based exclusively on (their) outstanding pioneering work."

RFF's accomplishments were initially made possible in large part by the extraordinary commitment of the Ford Foundation, which provided the funding necessary to establish RFF and operate it for its first three decades. The Ford Foundation's unrestricted support provided RFF researchers such as Dr. Krutilla and Dr. Kneese with enormous academic freedom to pursue topics that cross disciplinary boundaries and are unlikely to receive support from traditional funding agencies.

During the past decade, RFF has diversified its sources of support to include a number of other private foundations, corporations, and government funding agencies. As a result, RFF's total funding remains strong. However, these sources do not provide the unrestricted support that is increasingly essential for RFF to continue its interdisciplinary basic and applied research.

As RFF looks forward to the challenges ahead, its directors, including myself, have made a strong commitment to ensure that sources of unrestricted funding are available for RFF researchers in the coming years.

Your gift will provide operating support for:

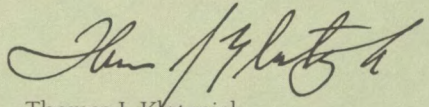
- *impartial research*, the demand for which is at an all-time high in view of the recent Earth Summit, the politicization of environmental policy here at home, and the demands of the citizenry for a healthy environment *and* a sound economy;
- *education*, including summer internships for graduate and undergraduate students at RFF, weekly RFF seminars open to the public, and small grants for researchers at universities.

Another important part of RFF's mission is its outreach role. For example, more than 20,000 people receive *Resources* four times a year free of charge. This service is an essential part of RFF's mission: to disseminate its research findings to policymakers at the federal, state, and local levels and to advocacy groups, academics, corporations, and individuals interested in public policy issues concerning the environment and natural resources. As concern about environmental issues grows, so does RFF's mailing list: your support will help ensure that *Resources*, RFF books, and other publications are made available to as wide an audience as possible.

If you believe, as I do, that RFF's independent research is an essential element in making sound public policy regarding the environment, you will agree that it is important to disseminate this research to the right people. The overwhelming response to our recent survey of *Resources* readers shows that it is indeed an informative and valuable source for people interested in public policy.

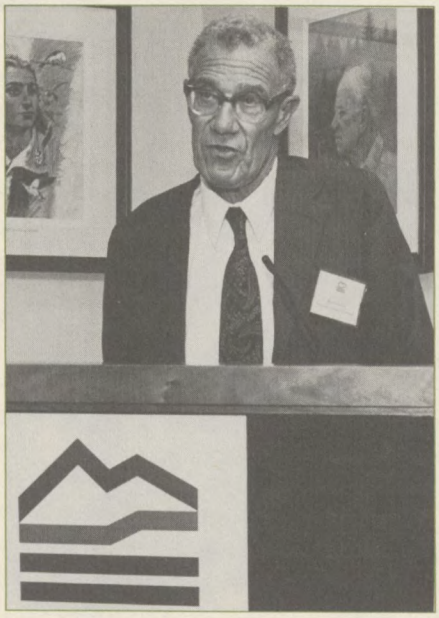
I hope you enjoy reading about RFF research, education, and outreach programs in this issue of *Resources* and that you will become a supporter of these important programs by making a gift to RFF today.

Sincerely,



Thomas J. Klutznick
Member, RFF Board of Directors

P.S. Please use the reply envelope enclosed with this issue of Resources to make your gift. Thank you for your support of RFF!



Speakers at the RFF fortieth anniversary celebration in Washington, D.C., on October 8: Nobel laureate Robert Solow (above), Secretary-General Maurice Strong of the United Nations Conference on Environment and Development (top right), and RFF President Robert W. Fri (bottom right).

RFF's fortieth anniversary

The board, officers, and staff of Resources for the Future joined with invited guests to celebrate the organization's fortieth anniversary at two events held on October 8 in Washington, D.C. Nobel laureate Robert Solow, whose work in natural resource economics has influenced environmental policymaking for decades, in an afternoon lecture suggested how economic theory could improve the way people talk and think about the economy in relation to our endowment of natural resources. At an evening reception and dinner held at the Decatur Carriage House, Maurice Strong, Secretary-General for the United Nations Conference on Environment and Development and a former RFF director, offered his perspective on the future course of economic and ecological sustainability.

New appointment

James Boyd was appointed a fellow in the Energy and Natural Resources Division on September 15. Boyd received his Ph.D. in May 1992 from the Department of Public Policy and Management at the Wharton School at the University of Pennsylvania. He will be working with fellow Molly K. Macauley on research related to the Toxic Substances Control Act and the social benefits and costs of remote sensing information.

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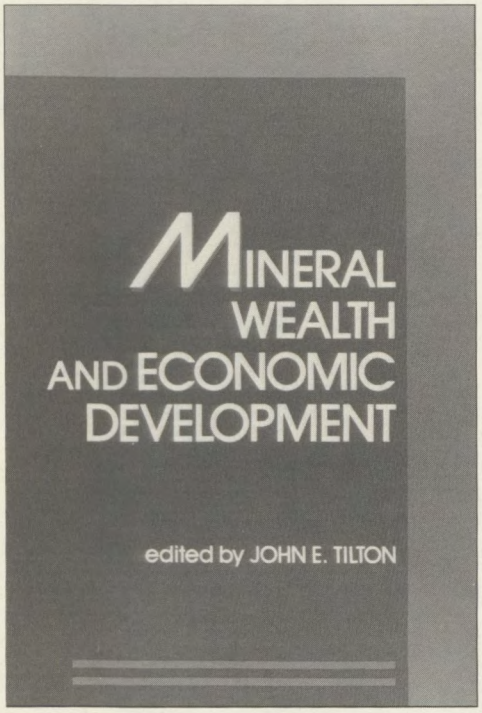

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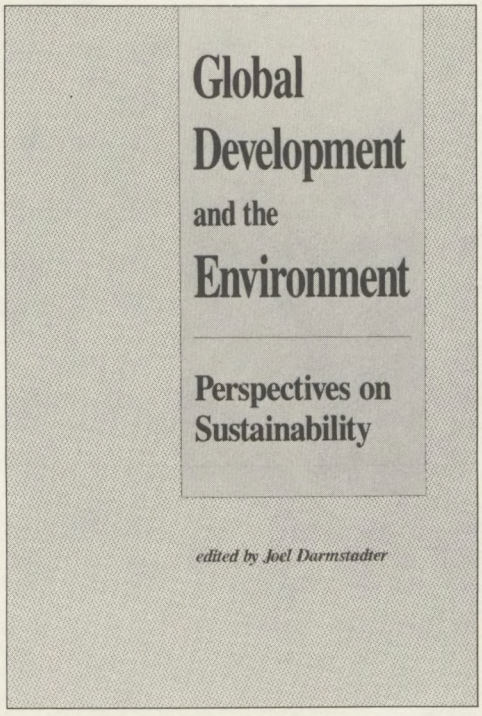

Published by Resources for the Future

1616 P Street, NW
Washington, DC 20036-1400
Telephone 202-328-5000

Managing editor, Samuel Allen
Staff writer, Melissa Edeburn

Published since 1959, *Resources*® (ISSN 0048-7376) is a quarterly publication containing news of research and policy analysis regarding natural resources and the environment. The views offered in *Resources* are those of the contributors and should not be attributed to Resources for the Future, its directors, or its officers. Unless otherwise noted, articles appearing in *Resources* may be reproduced, providing appropriate credit is given and a copy of the reproduced text is sent to *Resources.*

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Resources for the Future, founded in 1952, is an independent organization that conducts research on the development, conservation, and use of natural resources and on the quality of the environment.

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