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Coral Reefs Are Losing Ground

Coral reefs are called the rainforests of the oceans because they are home to more kinds of fish, plants, and microorganisms than any other part of the marine world. The coral reef is the result of years of accumulation of the calcium carbonate secreted by the coral animals that live on its surface. A coral reef can be hit by a hurricane and lose a substantial part of its structure, but it will slowly rebuild. However, the balance is shifting against coral reefs largely because of people's activities and we are losing reefs faster than they can rebuild.

Some reefs have a greater number of species, both of corals and their associates, than others. The focal point of reef biodiversity is in the central Indo-Pacific basin, sometimes called the golden triangle; reefs around Indonesia for instance, have ten times as many species as those in the Galapagos or Hawaii. A recent paper in *Science* found that the more suitable habitat for corals there is near an existing reef, the greater its diversity[1]. This new knowledge has implications for efforts to save and restore reefs; that is, size matters. Saving small patches of reefs as reserves will not only not save them but will condemn them to a slow steady decline. We spoke with Nancy Knowlton, a reef ecologist, about why corral reefs are declining in extent and in quality, and about what we can do to protect them.

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ER: Professor Knowlton, what is your academic background?

NK: I was very interested in animal behavior when I was a graduate student at the University of California at Berkeley back in the seventies. After getting my degree, I did a postdoc at the University of Liverpool, followed by a job teaching ecology and evolution at Yale University. After that I moved to the Smithsonian Tropical Research in Panama, where my husband also took a position. That turned out to be a great job, it transformed my career because it allowed me to live near reefs full-time. In 1998 I came to the Scripps Institution of Oceanography, but I still spend several months a year in the tropics and I still have a part-time position and a lab in Panama.

I was still working on animal behavior at Yale when hurricane Allen hit the north coast of Jamaica where I did my fieldwork. The hurricane just trashed the reefs and broke everything up into little bits and pieces. This presented an opportunity to learn how reefs work and how they recover, and so I started working on corals.

During this period, it seemed like every group I worked on turned out to have cryptic species; that is, well-known organisms that were thought to be a single species turned out to be complexes of distinct forms. I got interested in biodiversity per se, and that's what I spend most of my time studying now.

ER: How can scientists miss species-level differences between animals?

NK: Species are traditionally defined by systematists working with museum collections, but there are a number of species that are morphologically similar but quite ecologically distinct, and to study those, it helps to spend time in the field and see them alive, then you can distinguish these species by differences that are completely lost once you put them in a museum.

ER: Is it just the corals that are cryptic?

ER: What is the biggest demand for water?

CR: The biggest user of water from freshwater systems is agriculture. Currently about 40 percent of the food we grow comes from irrigated crops. But to feed the several billion people we're going to add to the planet in the next twenty-five years, we will need to increase irrigation because there are not that many areas remaining that can grow crops without irrigation.

Another use for water is hydropower, which currently provides 20 percent of the world's electricity. In Brazil almost 80 percent of the electricity is produced by hydropower.

Also, inland fisheries are important, particularly in Africa and in Southeast Asia. Many of the poorer communities depend on those fishes for their protein.

ER: I'm surprised that only 40 percent of agriculture comes from irrigated fields.

CR: Irrigation in Africa and in Latin America is minimal, and a lot of Asia depends on rain to grow crops. Most of the irrigation is in developed countries, and it tends to be very inefficient. The efficiency rate for a lot of irrigated agriculture is around 40 percent; that is, up to 60 percent of the water is lost to evaporation and infiltration. That's one big area where improvements in the management of water could help make more water available for both people and nature.

ER: Where does pollution fit in?

CR: In terms of pollution, developed countries have come a long way in treating point-source pollution, sewage, for example, and factory releases. We haven't been as successful with non-point-source pollution, runoff from agriculture or from cities.

In the developing countries by contrast, the pollution problems are with fertilizer runoff and pesticides, and in addition they have all the untreated sewage. In most of the developing world ninety percent of the sewage is untreated and that contributes to waterborne diseases. In China one of the biggest problems is the pollution of groundwater, and once groundwater gets polluted it's very hard to clean. That's another big contributor to the scarcity of fresh water.

The other important area for water scarcity that we don't mention in this paper is over-pumping of groundwater.

World Resources Institute's projections indicate that by the year 2025 almost half of the world's population (3.5 out of 7 billion people) will be living in conditions of water stress.

ER: Groundwater as opposed to what?

CR: As opposed to surface water. The surface water is connected to the groundwater. Some of the groundwater comes from deep aquifers (fossil water) which are isolated from the normal runoff cycle of water, but most of the groundwater comes from shallower aquifers that draw from the same global runoff that feeds rivers and streams. Overdrafting of groundwater can rob rivers of a significant portion of their flow. But there are also deeper aquifers that are not recharged as fast; for example, the Ogallala aquifer in the U.S.; there's another huge one underneath the Sahara Desert; there's one under Mexico City. All those are being pumped out faster than the aquifer can recharge.

ER: Is that called fossil water?

CR: Yes. The one underneath the Sahara is definitely fossil water. The one under Mexico City is not fossil water, it's a regular aquifer but it doesn't have time to get recharged because they're pumping so much out of it.

ER: People need water whether it's clean or not.

CR: That's a big problem with groundwater in Bangladesh. The development agencies invested a lot of money to put in tube wells to get groundwater so that people wouldn't have to drink surface water contaminated with parasites and pollution. But they have pumped the groundwater down to the extent that the arsenic that occurs naturally in the ground has been exposed to air, and when it's exposed to air it undergoes chemical changes that make it poisonous. As a result Bangladesh now has an epidemic of arsenic poisoning cases with many people dying from it[1]. But people have to have the water, and they're accustomed to have their own tube well in their back yard that it's not easy to persuade them to go back to using the surface water.

ER: What about rivers?

CR: We've been using rivers for transportation and the areas adjacent to rivers for settlement since the beginning of our civilization. Our analysis found that 60 percent of the rivers of

the world are either severely or moderately fragmented, which means they have dams and canals and water transfers, they're no longer free flowing rivers. The only rivers that are free flowing tend to be in areas where there are no people, in the northern latitudes or in small coastal basins in Latin America.

ER: But the number of dams is probably going to up as our population increases.

CR: Yes, especially in developing countries, but there are ways to build dams that are not as detrimental to the ecosystem. For example, to allow for migratory fish, it's preferable to have three smaller dams in a row than one huge dam. There are also more basin-level approaches to managing water: taking into account downstream uses and upstream land-use patterns so there's a comprehensive view of the whole basin.

ER: What does the report recommend be done?

CR: Reducing consumption of water and improving the efficiency of water use are the cheapest and most effective conservation steps. In the Third World, the most common sense action is of course, treating sewage.

There are also ways to monitor streams that are based more on the biological system instead of just measuring chemicals in the water, and this could help manage them in a better way. We usually just measure dissolved oxygen and phosphorus in the water and so on, but that doesn't tell you how the species in the river are doing. Ohio is using biological indicators to help them manage their rivers. The Ohio EPA has a pretty comprehensive system in which they use invertebrates and fish as biological indicators of water quality, which gives you a much better sense of how the stream is doing. And then at the policy level there are the management policies for pricing water; incorporating other benefits that we get from the freshwater system into the price of water. For example, water protection is not priced right now.

ER: Not even in the developed countries?

CR: Water all over the world tends to be under priced. It's almost always a controversial issue because water is so important; everybody needs water to live. If the price is too high then what are poor people going to do for water? But there are ways to price water that get a more realistic price for the water and still provide a safety net for the poor. One example of this is in South Africa where they're using what they call block tariffs where the first tier of the tariff is cheap, so everybody who uses water for their basic needs can afford it, but then the more you use, the higher the price you pay. An industry that uses a lot of water pays more but that also encourages efficiency. It's working pretty well in South Africa, and it has worked in Chile as well.

ER: I can't visualize any American politician touching this issue in a constructive way.

CR: Yes, a lot of the problem is political will; a lot of it is valuing the ecosystems for what they're worth, and that is something that takes education and reforms. I think it would work in the U.S. for example because there is money available to invest in drip irrigation so that farmers could be more efficient in the water they use in the West and the Southwest. Or they could change to crops that don't require as much water as growing cotton in Arizona. It is basically political will that's required to move this forward, but in general there is an increased tendency around the world to increase the price of water.

Some countries in Latin America are moving toward more privatization. There are movements in Europe to restore rivers that have been polluted and degraded because society is beginning to value water's contribution to biodiversity and food production. There are signs of hope, but it's a matter of public support and demand that the politicians change the rules. The private sector of course is interested in improving supply to poor communities because they want to make a profit, so there is quite a movement towards that.

Monitoring stations (for our rivers) have declined because the government stopped funding them, long before this administration.

ER: *Science* recently published a letter criticizing the present administration for not funding basic science on our water sources. What kind of information can the academic community provide about that?

CR: We know less about our water resources today than we did in the 1980s. Monitoring stations have declined because they stopped funding them long before this administration.

We don't even know how much water is used on a basin-by-basin basis. We don't know the quality of the water in most of our watersheds. There are many basic statistics that we don't know.

Groundwater is another area where we have hardly any information. How much water can we remove and still have a functioning river? Where are the thresholds? What is needed to maintain ecological functions? All those questions could be addressed by science, and the answers are needed in order to help us manage our rivers.

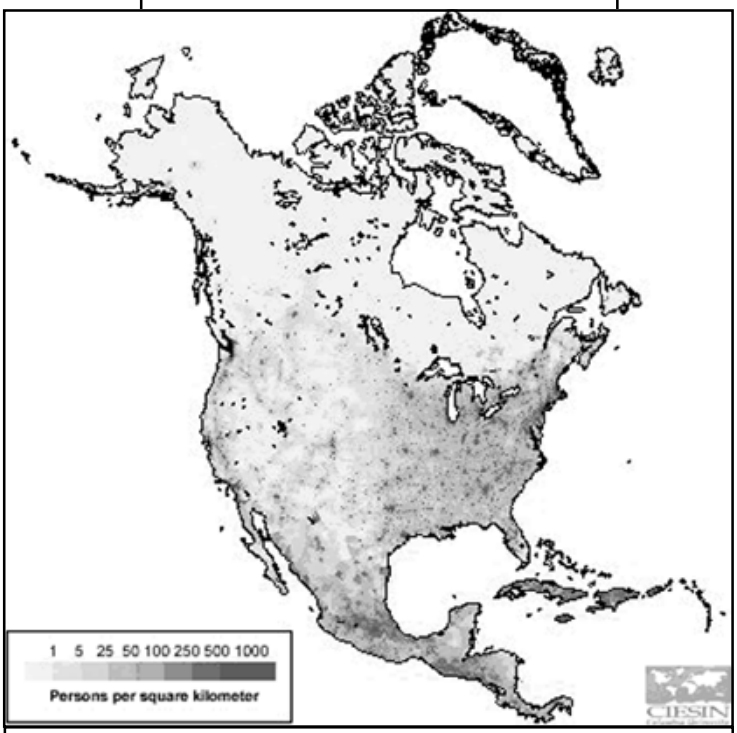
We next spoke with Jaime Echeverria, a co author of the report and an economist with World Resources Institute.

ER: Jaime, what is your training?

JE: I was trained as an environmental and natural resource economist at the University of Massachusetts in Amherst. I work on the evaluation of natural resources and how that relates to policies that can increase society's welfare. That's my academic background; as for my job, I'm a senior associate in the Economics Program at WRI. I'm involved with the Critical Flows Project in which we're looking at the economic tools we can use to increase efficiency in the use of water and also to be able to pay for biological diversity in the upper parts of a watershed.

ER: How is water underpriced?

JE: Governments and organizations generally use a benefit-cost analysis in making economic decisions. The problem is that no natural value is included in that analysis. Natural values should be included because for example, when we build a highway or when we develop an airport, we are incurring environmental costs. The field of environmental economics tries to measure those environmental costs so that they can be included in the benefit-cost analysis.



A population density map of North America. The darker the area, the greater the density.

ER: Why has it taken so long to realize we must pay attention to environmental costs?

JE: I think that is the focal problem, and the answer to your question is, until not long ago natural resources were considered to be so abundant as to be inexhaustible. It is not that people were stupid, but it was a matter of magnitude: there were relatively few people in the world and enormous quantities of forests, of clean rivers, of oceans, so the equation incorporated a zero value for those natural goods. Economics deals only with scarce resources; if there's no scarcity, there's no reason to worry about it. There was no scarcity of natural resources basically until about the 1950s.

How do we arrive at a pricing system? To do that we need to go through some hard times like California is now with their electricity. I read the other day that as a result of the huge price increases consumption in California has gone down 11 percent. Likewise, when people can see the end of their water supply, it will be easier to convince them to conserve and to pay a reasonable price.

It's been demonstrated that increases in the price of water pay off in the long term in countries as diverse India and Chile and Costa Rica. I was asked the other day by a Japanese journalist, Why do you want people to pay a lot for water? And my response was, We're not asking them to pay a lot, but to pay what is fair, to pay for the true cost of the water supply. Right now, because of the distortions in the market and because of political difficulties, water is subsidized all over the world. In order to get fair pricing the first step would be to get rid of subsidies, except for the poorest segments of the population.

ER: What costs of water are being subsidized?

JE: For a water project you have basically two major expenditures. One is the capital for the infrastructure; the second is for operations and management.

ER: Putting in the pipes and so forth.

JE: Exactly, and then the operation and management, which is just the cost of operating the system on an ongoing basis. In many cases those two costs are subsidized by the government, and I'm not talking only about the U.S.. There are many countries where the utility does not even recover that basic portion of the cost. In some big irrigation schemes in Central America, for example, they have projects that charge by the amount of land that you have, not the amount of water that you use. The government gets a loan from the Development Bank, then sets up a Water Irrigation Authority that generates some income from selling rights for the water, but that money doesn't even pay off the loan. Who has to pay the loan? The country as a whole. So it's a subsidy of the biggest water users by the taxpayers.

ER: Conservatives should like the idea of eliminating subsidies.

JE: That's the traditional economics point of view. That's what free marketers advocate and love: you should at least pay for what you use; you should not have some sectors subsidizing other sectors.

So far, I've only talked about the capital required to build a water system and that's just one line item. The other line item is operation and management and that too has been subsidized greatly all over the world. I would say the U.S. and other developed countries are ahead of the developing world because we recoup more of those expenses. But then we have the ecological cost of water to consider, and that includes the role of the watershed in protecting and maintaining the flow and the quality of water. What's the role of the forest? People agree that if you have a forest in a watershed you're going to have less sediment, you're going to spend less money in treating that water because it's going to be cleaner.

ER: But in general those natural goods and services have been left completely out of the price?

JE: Completely. In the whole world, I know about the New York example, and one example in Costa Rica where utilities are charging consumers an additional fee to protect the watershed. But as we have more people and less water, I think that's going to be more common.

ER: Free marketers should like that it's cheaper to have a functioning ecosystem rather than a treatment plant.

JE: Oh yes, and in business theory everybody agrees that it's cheaper to solve a problem at the source than try to fix it later. It's cheaper to prevent the ecosystem from getting damaged than afterwards trying to recoup those services.

ER: Our president is said to have an MBA but he must have missed that class.

JE: I think he was just a C student.

ER: You say scarcity will probably have to get worse before people deal with it, but we've had water wars in the West for 100 years.

JE: I'm not an expert in that issue, but I understand that in California you have a pretty well established water rights market, where water is allocated literally to the last drop. I understand that the Rio Grand River hasn't reached the ocean for the last two years. So yes, the pricing issue is hard.

On the other hand, if you want a practical solution, you may want to take a look at it more from the cost side and not from the benefits side. That means you can figure out how much it is going to cost to provide a certain level of protection to a watershed, and then distribute that cost among all the millions and millions of cubic meters of water, and you can at least be covering your costs.

There are more complicated schemes that can work; for example, water rights trading between different sectors. Not all sectors of the economy use water in the same way. Some use a lot of water to produce a cheap product, and others use very little water to

create a high-value product. If you allow for trading, then the most efficient sectors are going to buy water from the less efficient ones. But then the way of life of some people may be in danger. Some farmers that produce potatoes, for example, and the world market is choked full of potatoes, and maybe those farmers would be better off just selling their water rights and stop producing potatoes. But then what about the culture? What about their way of life? Those things have value too. I don't ignore that.

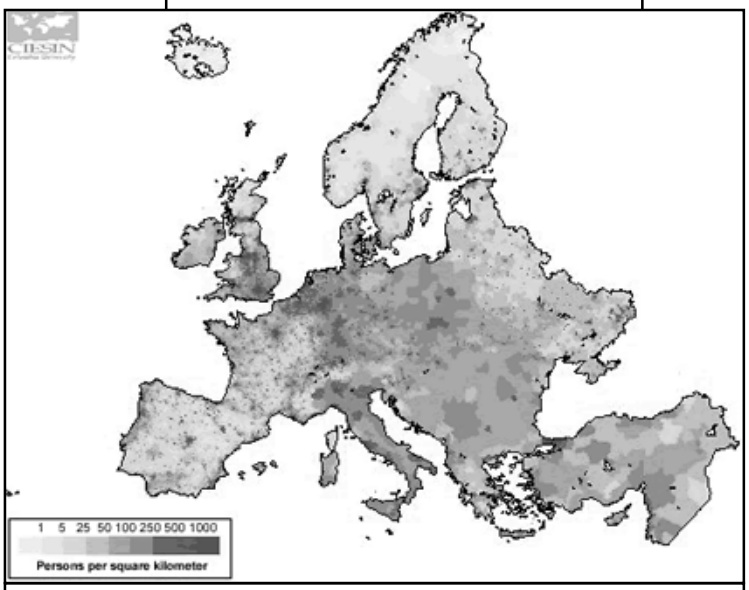
ER: That's part of the human ecosystem.

JE: Exactly. In the Northwest now they have a big problem with water because they have to decide between salmon going up the river, and dams generating electricity and farmers needing the water. These are hard choices.

ER: Are there other ways to achieve water conservation goals besides price?

JE: When we talked about the price, I talked about two things: I talked about capital, and operation and management, and that should include the management of the watershed. But I didn't include the cost of treating the effluents, and if you're polluting the water you should be paying for cleaning it up. Plugging in that cost will make firms more efficient in their water use. Some companies have already saved a lot of money by developing new processes for their production systems replacing something that used to use a lot of water with a different technology, and they not only reduce water pollution but they save money. Those kind of win-win situations are what we are constantly looking for, and there are many but you need to do your homework and do some research first.

ER: A lot of people are concerned about the poor. Let's talk about the distributional side and the equity side.



Much of central Europe will experience water scarcity because there are so many people.

JE: So am I but the thing is that the poor now are paying more for water than the rich in many cases because they don't have a water connection and they have to buy water from a truck by the liter at high prices.

ER: You know they're not wasting that water.

JE: I'm sure they're not. Or if they don't have to buy water then they have to walk an hour each way in many cases just to go get it. So don't believe those critics who say that we are against the poor or in favor of the rich. I think you can have small subsidies for people who need them.

ER: The idea is to subsidize the poor, not the rich.

JE: Exactly. Now we're subsidizing everybody. Remember, we said that the price of water should include capital costs and operating and management costs, including watershed management; a third cost is treating the effluents; a fourth cost could be a subsidy for the poor. Let's say 20 percent of the population is poor, then the other 80 percent can pay for these four costs in full and the poorest 20 percent can pay some small fraction of the true costs of the water.

The key point here is that water is scarce now in many parts of the world and there is competition between people and nature for water. The world in the last fifty years has gotten richer, so we're using a lot more water per capita now than what our parents or grandparents did. It's not that there are more of us, there are more of us and each one of us is consuming more, which depletes the ecosystems that provide the water.

ER: What about competing with nature for water?

JE: We have to keep in mind that we receive benefits from biological resources, from wildlife, from plants, and even microorganisms, that are important for society's future. Those

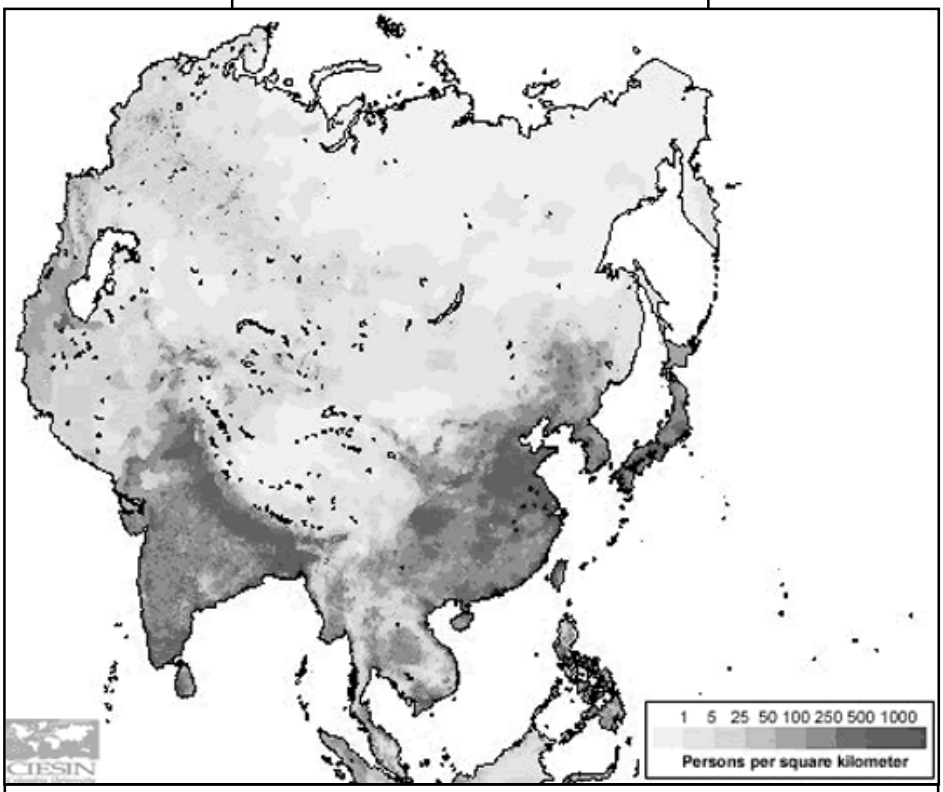
are also water users; we're competing with them too. So part of these pricing and water allocation ideas should make sure that in the end an adequate amount of water is left for nature. That's why we talk in the article about minimum flows for hydroelectric projects. But that's problematic too, because nobody knows what's a good or a proper minimum flow. I think that would be a great area for additional research. I know people have studied that in many instances, but it would be useful to determine not only the minimum flows required to preserve the ecosystem but the costs involved.

ER: If the minimum flow for the Colorado River turns out to be 50 percent, that could shut down Las Vegas overnight.

JE: Yes, if you have a river that is in the middle of nowhere and nobody's using that water, then a 50 percent flow might be fine. But if you have a river that has substantial economies based on it, then that's a big problem. I think this is where science can help in increasing the efficiency of water use so that we can produce the same economic goods with less water.

I don't know what the efficiency of use of water from the Colorado River is, but even if they come up with minimum flow of 25 percent, I'll be surprised if technology and American ingenuity cannot make do with 75 percent of its water instead of 100 percent.

ER: What about water pollution permits as a tool to reduce water use?



Freshwater is already scarce in the highly populated areas of India and Asia.

JE: In an ideal world you'll probably want pollution to stop completely but that's just not possible. If you're realistic and you want to make some progress, I think you have to compromise somewhere, at least that's my position, because as long as there are humans in this world there's going to be pollution and some damage to ecosystems. So I think that the issue is not how we get rid of all pollution but how we move forward and how we make progress, and pollution trading has been shown to be an effective way of dealing with the problem.

I'm an economist so maybe I'm a bit biased, but the reason we have environmental problems is an economic one. If fixing all the environmental problems had zero cost, we'd fix them all in one day. But each environmental problem has a cost, and maybe it's not a cost of fixing it, maybe it's an opportunity cost: we could stop driving our cars, but that would incur a huge cost in welfare for society.

So the question is, How do we improve the environment using the tools that we have and at the minimum cost? And it's turning out that trading in pollution is one of these least-cost alternatives. The alternative methods involve command and control, but that's been shown to be prone to corruption and it's expensive to enforce regulations.

In any economy some firms are leaders, they improve their technology, and then they can then sell their allocated pollution permits to companies that are not as efficient and in the end you at least are able to achieve your set environmental goals and standards. Permit trading is not that you're paying people to pollute, it's the

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other way around, you're paying people to reduce pollution.

ER: It's using incentives rather than disincentives.

JE: That's right. The idea is to find a way that is first of all going to work, and second, is going to inflict the least pain on society.

There's a controversy right now about a court decision dealing with the Clean Air Act. The court ruled that cost was not a consideration and that no matter how much it costs, the EPA needed to comply with the standards. That sounds great from an environmental advocacy point of view, but not from an economic point of view, and when I talk about economics, I'm not talking so much about money, I'm talking about the well being of society. If you protect too much X (whatever X is) you might be sacrificing your people's welfare to have more X than is necessary.

We need to find that balance in every case, and I think that in the case of water it's clear that the balance is against water and against nature, right now we're not conserving enough.

NEXT MONTH

HAS PROTECTION WORKED FOR THE PANDA IN CHINA?
Jack Liu

PLANS TO PROTECT THE NATIONAL GRASSLANDS
Greg Schenbeck

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