Environment and Society

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Dr. Bradley H. Brewster

Bright Idea of Tire Reef Now Simply a Blight

Peter Whoriskey

(*The Washington Post*, October 2, 2006)

Fort Lauderdale, Florida — Now the idea seems daft. But in the spring of 1972, the dumping of a million or so tires offshore here looked like ecological enlightenment.

From the scrap tires, artificial reefs would grow and fish would throng, or so it was thought. A flotilla of more than 100 private boats with volunteers turned out to help. A Goodyear blimp christened the site by dropping a gold-painted tire.

"A potential grouper haven," a county report opined. Artificial reefs made from tires "appear to be the next best thing to recycling."

What happened instead is a vast underwater dump—a spectacular disaster spawned from good intentions. Today there are no reefs, no fishy throngs, just a lifeless underwater gloom of haphazardly dropped tires stretching across 35 acres of ocean bottom.

It's not just a matter of botched scenery. Because they can roll around, the tires are pounding against natural reefs nearby.

"It's depressing as hell," said Ken Banks, a reef specialist for Broward County, who recently explored the site. "We dove in and swam for what seemed like an hour and never came to the end of it. It just went on and on."

Robin Sherman, a professor at Nova Southeastern University, led a project a few years ago to retrieve some of the tires most directly damaging Fort Lauderdale's natural reefs.

Two months later, she dived in the area again.

"It was completely recovered with tires—it was even hard to find where we had worked," she said. "That's when I realized we have to clean up the whole thing."

So, after years in which the site was studied and then neglected, officials here are planning to clean up the environmental experiment gone awry.

Coastal America, a partnership of federal agencies, state and local governments and private groups, is trying to organize a cleanup using military salvage teams that would use the tire retrieval as a training exercise. Once the divers pulled the tires up, they would be disposed of by the state at a cost of about $3 million to $5 million.

The scale of the project—some say there are as many as 2 million tires below—and the number of different specialties required had prevented previous bureaucratic efforts from going forward.

Will Nuckols, project coordinator for Coastal America, called the rolling tires a "coastal coral destruction machine."

"For the past several decades, people have looked at this task and then at each other and said, 'Well I can't do that,'" he said.

With each dive team retrieving about 700 tires a week, officials estimate that the effort would take three years. They plan to begin in 2008.

"It's easy to throw something into the water," said Keith Mille of the Florida Fish and Wildlife Conservation Commission. "What we're finding is it's extremely expensive to remove something from the water."

The first documented artificial reef in the United States was created off South Carolina in the 1830s. Over time, people have sunk rocks, trees, concrete, ships and barges to create reefs. When successful, they were—and continue to be—popular attractions with anglers and divers alike.

Artificial reefs made from scrap tires began in the United States in the late 1950s or early '60s, when the country was facing the monumental task of disposing of millions of automobile tires. At the time, stockpiled tires were creating fire hazards, fostering mosquito breeding and blighting the landscape.

Reefs made from tires seemed like an easy solution.

While coastal communities around the country—in Texas, California, Florida, North Carolina and elsewhere—embraced the idea, few projects, if any, were conceived on the grand scale as the one off Fort Lauderdale. Proponents touted it as the largest scrap tire reef in the world.

A 1974 Goodyear pamphlet boasted, “Worn out tires may be the best things that have happened to fishing since Izaak Walton,” the author of the classic The Compleat Angler.

“There was a lot of local enthusiasm,” said Ray McAllister, one of the founders of a local group that pushed for the tire reef and now professor emeritus of ocean engineering at Florida Atlantic University. “We all thought we were doing a good job for the environment.”

A tire reef had seemed to work in New England, he said, and organizers figured it would work here.

The project had received a permit from the Army Corps of Engineers and had active support from Broward County, officials said.

While there were initial hopeful reports, it was clear after a decade that the idea wasn't working. Sea creatures didn't grow on the tires. Today, the tires look the same as they did they day they were dropped.

Tires that had been lashed together for stability broke loose, making it easier for them to roll around. With the tires mobile, it was difficult for sea life to make a home there.

Today, most states have restricted or banned tires in artificial reefs, according to a 2004 joint publication of the Gulf and Atlantic States Marine Fisheries Commission.

In retrospect, McAllister said, “it was a terrible mistake and I hate to admit it. … The conventional wisdom, or whatever you want to call it, was not such a bright idea.”

Precautionary Principle

Michael Pollan

(*The New York Times*, December 9, 2001)

New technologies can bring mankind great benefits, but they can also cause accidental harm. How careful should society be about introducing innovations that have the potential to affect human health and the environment? For the last several decades, American society has been guided by the "risk analysis" model, which assesses new technologies by trying to calculate the mathematical likelihood that they will harm the public. There are other ways, however, to think about this problem. Indeed, a rival idea from Europe, the "precautionary principle," has just begun making inroads in America.

The problem with risk analysis, which came out of the world of engineering and caught on during the late 70's, is that it hasn't done a very good job predicting the ecological and health effects of many new technologies. It is very good at measuring what we can know—say, the weight a suspension bridge can bear—but it has trouble calculating subtler, less quantifiable risks. (The effect of certain neurotoxins on a child's neurological development, for example, appears to have more to do with the timing of exposure than with the amount.) Whatever can't be quantified falls out of the risk analyst's equations, and so in the absence of proven, measurable harms, technologies are simply allowed to go forward.

In Europe, a different approach has taken hold. When Germany, for example, discovered in the 70's that its beloved forests were suddenly dying, there was not yet scientific proof that acid rain was the culprit. But the government acted to slash power-plant emissions anyway, citing the principle of Vorsorge, or "forecaring." Soon, Vorsorgeprinzip—the forecaring, or precautionary, principle—became an axiom in German environmental law. Even in the face of scientific uncertainty, the principle states, actions should be taken to prevent harms to the environment and public health.

Germany's idea has since gone international. It has popped up in the preamble of the U.N. Treaty on Biodiversity and was written into a slew of protocols and rules issued by the European Union in the 90's. It informs treaties like the 2000 Cartagena Protocol on Biosafety, which allows countries to bar genetically modified organisms on the basis of precaution. The idea has not prevailed over risk analysis, however, at least not yet. The E.U.'s ban on American beef treated with hormones, for example, is based on the precautionary principle. But since world-trade rules are based on risk analysis rather than precaution, and the health risk of eating hormone-treated beef has not been proved, the World Trade Organization has ruled that the ban is illegal.

What explains the W.T.O.'s resistance to the precautionary principle? It doesn't sound like a revolutionary idea. Indeed, it sounds like common sense: better safe than sorry; look before you leap. But, in fact, the precautionary principle poses a radical challenge to business as usual in a modern, capitalist, technological civilization. As things stand, whenever questions are raised about the safety of, say, antibiotics in livestock feed, not until someone finds the smoking gun can anything be done about it. When President Bush earlier this year challenged the Clinton administration's tougher standards for arsenic levels in drinking water, he did it on the grounds that "the science isn't in yet." (He subsequently relented.) The problem very often is that long before the science does come in, the harm has already been done. And once a technology has entered the marketplace, the burden of bringing in that science typically falls on the public rather than on the companies selling it.

If introduced into American law, the precautionary principle would fundamentally shift the burden of proof. The presumptions that flow from the scientific uncertainty surrounding so many new technologies would no longer automatically operate in industry's favor. Scientific uncertainty would no longer argue for freedom of action but for precaution and alternatives.

Just how revolutionary an idea this really is is just now dawning on thinkers tied to American industry. In April, a fellow at the Hoover Institution published an attack on the precautionary principle, calling it, quite rightly, "a wolf in sheep's clothing." The Bush administration has adopted a hard line in international negotiations. In the spring, its delegates to the Codex Alimentarius Commission, the world body that sets food safety standards for world trade, scuttled an agreement rather than allow precautionary language into a single footnote.

Critics argue that the precautionary principle is "antiscientific." No and yes. No, in the sense that it calls for more science in order to dispel the uncertainties surrounding new technologies and to develop less harmful alternatives. And yet there is a sense in which the idea is "antiscientific," if by scientific we mean leaving it to scientists to tell us what to do. For the precautionary principle recognizes the limitations of science—and the fact that scientific uncertainty is an unavoidable breach into which ordinary citizens sometimes must step and act.

Uncertainty, Resource Exploitation, and Conservation: Lessons from History

Donald Ludwig, Ray Hilborn, Carl Walters

There are currently many plans for sustainable use or sustainable development that are founded upon scientific information and consensus. Such ideas reflect ignorance of the history of resource exploitation and misunderstanding of the possibility of achieving scientific consensus concerning resources and the environment. Although there is considerable variation in detail, there is remarkable consistency in the history of resource exploitation: resources are inevitably overexploited, often to the point of collapse or extinction. We suggest that such consistency is due to the following common features: (i) Wealth or the prospect of wealth generates political and social power that is used to promote unlimited exploitation of resources. (ii) Scientific understanding and consensus is hampered by the lack of controls and replicates, so that each new problem involves learning about a new system. (iii) The complexity of the underlying biological and physical systems precludes a reductionist approach to management. Optimum levels of exploitation must be determined by trial and error. (iv) Large levels of natural variability mask the effects of overexploitation. Initial overexploitation is not detectable until it is severe and often irreversible.

In such circumstances, assigning causes to past events is problematical, future events cannot be predicted, and even well-meaning attempts to exploit responsibly may lead to disastrous consequences. Legislation concerning the environment often requires environmental or economic impact assessment before action is taken. Such impact assessment is supposed to be based upon scientific consensus. For the reasons given above, such consensus is seldom achieved, even after collapse of the resource.

For some years the concept of maximum sustained yield (MSY) guided efforts at fisheries management. There is now widespread agreement that this concept was unfortunate. Larkin (*1*) concluded that fisheries scientists have been unable to control the technique, distribution, and amount of fishing effort. The consequence has been the elimination of some substocks, such as herring, cod, ocean perch, salmon, and lake trout. He concluded that an MSY based upon the analysis of the historic statistics of a fishery is not attainable on a sustained basis. Support for Larkin's view is provided by a number of reviews of the history of fisheries (*2*). Few fisheries exhibit steady abundance (*3*).

It is more appropriate to think of resources as managing humans than the converse: the larger and the more immediate are prospects for gain, the greater the political power that is used to facilitate unlimited exploitation. The classic illustrations are gold rushes. Where large and immediate gains are in prospect, politicians and governments tend to ally themselves with special interest groups in order to facilitate the exploitation. Forests throughout the world have been destroyed by wasteful and short-sighted forestry practices. In many cases, governments eventually subsidize the export of forest products in order to delay the unemployment that results when local timber supplies run out or become uneconomic to harvest and process (*4*). These practices lead to rapid mining of old-growth forests; they imply that timber supplies must inevitably decrease in the future.

Harvesting of irregular or fluctuating resources is subject to a ratchet effect (*3*): during relatively stable periods, harvesting rates tend to stabilize at positions predicted by steady-state bioeconomic theory. Such levels are often excessive. Then a sequence of good years encourages additional investment in vessels or processing capacity. When conditions return to normal or below normal, the industry appeals to the government for help; often substantial investments and many jobs are at stake. The governmental response typically is direct or indirect subsidies. These may be thought of initially as temporary, but their effect is to encourage overharvesting. The ratchet effect is caused by the lack of inhibition on investments during good periods, but strong pressure not to disinvest during poor periods. The long-term outcome is a heavily subsidized industry that overharvests the resource.

The history of harvests of Pacific salmon provides an interesting contrast to the usual bleak picture. Pacific salmon harvests rose rapidly in the first part of this century as markets were developed and technology improved, but most stocks were eventually overexploited, and many were lost as a result of overharvesting, dams, and habitat loss. However, in the past 30 years more fish have been allowed to spawn and high seas interception has been reduced, allowing for better stock management. Oceanographic conditions appear to have been favorable: Alaska has produced record catches of salmon and British Columbia has had record returns of its most valuable species (*5*).

We propose that we shall never attain scientific consensus concerning the systems that are being exploited. There have been a number of spectacular failures to exploit resources sustainably, but to date there is no agreement about the causes of these failures. Radovitch (*6*) reviewed the case of the California sardine and pointed out that early in the history of exploitation scientists from the (then) California Division of Fish and Game issued warnings that the commercial exploitation of the fishery could not increase without limits and recommended that an annual sardine quota be established to keep the population from being overfished. This recommendation was opposed by the fishing industry, which was able to identify scientists who would state that it was virtually impossible to overfish a pelagic species. The debate persists today.

After the collapse of the Pacific sardine, the Peruvian anchoveta was targeted as a source of fish meal for cattle feed. The result was the most spectacular collapse in the history of fisheries exploitation: the yield decreased from a high of 10 million metric tons to near zero in a few years. The stock, the collapse, and the associated oceanographic events have been the subject of extensive study, both before and after the event. There remains no general agreement about the relative importance of El Niño events and continued exploitation as causes of collapse in this fishery (*7*).

The great difficulty in achieving consensus concerning past events and a fortiori in prediction of future events is that controlled and replicated experiments are impossible to perform in large-scale systems. Therefore there is ample scope for differing interpretations. There are great obstacles to any sort of experimental approach to management because experiments involve reduction in yield (at least for the short term) without any guarantee of increased yields in the future (*8*). Even in the case of Pacific salmon stocks that have been extensively monitored for many years, one cannot assert with any confidence that present levels of exploitation are anywhere near optimal because the requisite experiments would

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(*Continued from page 17*)

involve short-term losses for the industry (*9*). The impossibility of estimating the sustained yield without reducing fishing effort can be demonstrated from statistical arguments (*10*). These results suggest that sustainable exploitation cannot be achieved without first overexploiting the resource.

The difficulties that have been experienced in understanding and prediction in fisheries are compounded for the even larger scales involved in understanding and predicting phenomena of major concern, such as global warming and other possible atmospheric changes. Some of the time scales involved are so long that observational studies are unlikely to provide timely indications of required actions or the consequences of failing to take remedial measures.

Scientific certainty and consensus in itself would not prevent overexploitation and destruction of resources. Many practices continue even in cases where there is abundant scientific evidence that they are ultimately destructive. An outstanding example is the use of irrigation in arid lands. Approximately 3000 years ago in Sumer, the once highly productive wheat crop had to be replaced by barley because barley was more salt-resistant. The salty soil was the result of irrigation (*11*). E. W. Hilgard pointed out in 1899 that the consequences of planned irrigation in California would be similar (*12*). His warnings were not heeded (*13*). Thus 3000 years of experience and a good scientific understanding of the phenomena, their causes, and the appropriate prophylactic measures are not sufficient to prevent the misuse and consequent destruction of resources.

Some Principles of Effective Management

Our lack of understanding and inability to predict mandate a much more cautious approach to resource exploitation than is the norm. Here are some suggestions for management.

1) Include human motivation and responses as part of the system to be studied and managed. The shortsightedness and greed of humans underlie difficulties in management of resources, although the difficulties may manifest themselves as biological problems of the stock under exploitation (*2*).

2) Act before scientific consensus is achieved. We do not require any additional scientific studies before taking action to curb human activities that effect global warming, ozone depletion, pollution, and depletion of fossil fuels. Calls for additional research may be mere delaying tactics (*14*).

3) Rely on scientists to recognize problems, but not to remedy them. The judgment of scientists is often heavily influenced by their training in their respective disciplines, but the most important issues involving resources and the environment involve interactions whose understanding must involve many disciplines. Scientists and their judgments are subject to political pressure (*15*).

4) Distrust claims of sustainability. Because past resource exploitation has seldom been sustainable, any new plan that involves claims of sustainability should be suspect. One should inquire how the difficulties that have been encountered in past resource exploitation are to be overcome. The work of the Brundland Commission (*16*) suffers from continual references to sustainability that is to be achieved in an unspecified way. Recently some of the world's leading ecologists have claimed that the key to a sustainable biosphere is research on a long list of standard research topics in ecology (*17*). Such a claim that basic research will (in an unspecified way) lead to sustainable use of resources in the face of a growing human population may lead to a false complacency: instead of addressing the problems of population growth and excessive use of resources, we may avoid such difficult issues by spending money on basic ecological research.

5) Confront uncertainty. Once we free ourselves from the illusion that science or technology (if lavishly funded) can provide a solution to resource or conservation problems, appropriate action becomes possible. Effective policies are possible under conditions of uncertainty, but they must take uncertainty into account. There is a well-developed theory of decision-making under uncertainty (*18*). In the present context, theoretical niceties are not required. Most principles of decision-making under uncertainty are simply common sense. We must consider a variety of plausible hypotheses about the world; consider a variety of possible strategies; favor actions that are robust to uncertainties; hedge; favor actions that are informative; probe and experiment; monitor results; update assessments and modify policy accordingly; and favor actions that are reversible.

Political leaders at levels ranging from world summits to local communities base their policies upon a misguided view of the dynamics of resource exploitation. Scientists have been active in pointing out environmental degradation and consequent hazards to human life, and possibly to life as we know it on Earth. But by and large the scientific community has helped to perpetuate the illusion of sustainable development through scientific and technological progress. Resource problems are not really environmental problems: They are human problems that we have created at many times and in many places, under a variety of political, social, and economic systems (*19*).

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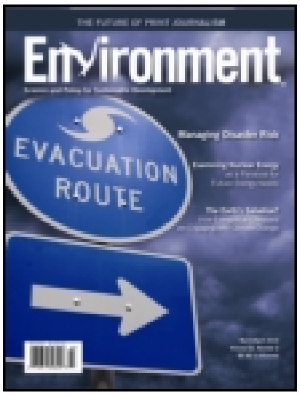

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Defining Precaution

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Defining Precaution

UNESCO's World Commission on the Ethics of Scientific Knowledge and Techonology Report: *The Precautionary Principle*

Reviewed by Charles Weiss

The precautionary principle is frequently invoked as a basic principle of risk management and an essential guide to decisions on issues as varied as climate change, biodiversity loss, and food safety. The principle has many critics, on the other hand, who regard it as a vaguely worded doctrine sometimes used as a screen for shoddy science, trade protectionism, or anti-technology sentiment. This difference of opinion underlies many of the environmental controversies between the United States and Europe. Given that the principle itself exists in a number of alternative formulations, a clear and agreed-upon definition would be a useful contribution.

The Precautionary Principle, the United Nations Economic, Scientific and Cultural Organization (UNESCO) panel report,[1] is the latest in a long series of efforts to define the precautionary principle and, in so doing, underline its importance and defend it from its critics. It steps back from the fray to draw lessons from experience and argue for longer time horizons and a more rational approach to environmental decisionmaking. Its discussion of precaution is clear and coherent.

The UNESCO report begins with a discussion of the history of precaution, citing environmental and public health cautionary tales, such as those of cholera and asbestos, recounted in a volume edited by the late Danish environmentalist Poul Harremoës and his colleages.[2] In subsequent chapters, it sets this discussion into the broad context of the ethical and philosophical aspects of precaution, the theory of causality in complex systems, the practice of cost-benefit analysis in situations of uncertainty, and the practical setting of science policy decisionmaking. In a section devoted to legal issues, it puts the best face on the somewhat ambiguous status of the precautionary principle, concluding that it is "legally relevant and cannot be disregarded" but stopping short of saying that it is legally binding.[3]

As the opening background section of the UNESCO report indicates, the precautionary principle is easier to invoke than to define. In its so-called weak version, it states that precautionary measures to defend the environment need not wait for definitive scientific proof of danger.[4] In other words, the *lack* of definitive scientific understanding is *not* a valid excuse for *in*action, a triple negative that provides little guidance about what measures should be taken in any particular situation. The so-called strong version of the principle, by contrast, holds that precautionary measures should be taken when scientific evidence is inconclusive,[5] a doctrine that can also be read to block desirable innovation on the basis of shaky science.

Both of these versions of the principle leave important practical questions unanswered. For example, when are policymakers justified in invoking the principle? What should they do to implement it? How much scientific proof of danger should they require in any given situation? How are they to take into account the benefits of a risky innovation, in addition to its risks and costs?

The lengthy but reasonably clear working definition of the precautionary principle in the report of the UNESCO panel is worth quoting in full:

When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm. Morally unacceptable harm *refers to harm to humans or the environment that is*

- *threatening to human life, or*
- *serious and effectively irreversible, or*
- *inequitable to present or future generations, or*
- *imposed without adequate consideration of the human rights of those affected.*

The judgment of plausibility *must be grounded in scientific analysis. Analysis should be ongoing so that chosen actions are subject to review.*

Uncertainty *may apply to, but need not be limited to, causality or the bounds of the possible harm.*

Actions *are interventions that are undertaken before harm occurs that seek to avoid or diminish the harm. Actions should be chosen that are proportional to the seriousness of the potential harm, with consideration of their positive and negative consequences, and with an assessment of the moral implications of both action and inaction. The choice should be the result of a participatory process.*[6]

This formulation of the precautionary principle addresses many of the issues raised by its critics. It is clear enough to guide decisionmaking in practical situations. It acknowledges that the level of precaution should be influenced by the level of prospective benefits of the action being assessed. It discusses in some detail the standard of proof to be applied to the scientific evidence for precautionary action, specifying that "[a] mere fantasy or crude speculation that an activity or new technology causes harm is not enough to trigger" the precautionary principle. On the contrary, the panel argues, precautionary intervention must be backed by judgments based on scientific analysis that gives "reasonable grounds for concern." This in turn is defined as concern based on evidence that is "plausible or scientifically tenable (that is, not easily refuted)."[7] It would have been preferable to have a somewhat stronger standard of proof, namely evidence giving rise to reasonable belief, but this is a legitimate difference of opinion.

On the other hand, the UNESCO panel's definition of "morally unacceptable" activities is exceptionally broad. It pays insufficient attention to the possible costs of precautionary intervention. Its coverage of harm that is "inequitable to present or future generations, or imposed without adequate consideration of the human rights of those affected"[8] incorporates virtually the whole concept of sustainable development into the idea of precaution—an admirable goal, perhaps, but an unmanageable burden on a principle already weighted down with controversy. Moreover, nowhere does the UNESCO panel report include the idea that less certain dangers justify less extensive precautionary measures, other things being equal, than do more certain dangers of comparable size. And the lengthy text that follows the definition provides wiggle room for possible overreach in future cases.

The UNESCO report is a considerable advance over the European Commission's (EC) 2000 communication on the precautionary principle, a report that for many years was widely quoted as the definitive restatement on the subject.[9] The EC report was concerned primarily with procedure: what kinds of analysis must be carried out, what facts must be considered, and who must be consulted before precautionary measures are taken. It was drafted at least in part to defend the EC against the charge that its environmental concerns were thinly veiled measures of protection against U.S. agricultural imports. Its major concern is with measures like the banning of imports that might be deemed to be in violation of the international trade regime managed by the World Trade Organization (WTO).

On the other hand, the EC report did enunciate some useful principles that have survived in subsequent analyses. It acknowledged that inaction, too, may entail risk, and so may well-meaning interventions motivated by precaution, so that cost-benefit analyses should be performed with regard to action as well as inaction. It endorsed the idea that precautionary action should be proportional to the seriousness of the potential harm; however, it says little about assessing the probability that such harm will actually come to pass or the size of potential benefits of the human action being considered. It states that "[a]ll interested parties should be involved to the fullest extent possible in the study of various risk management options" and that precautionary action should be subject to review in light of new scientific information.[10]

As an operational document, however, the EC report still leaves much to be desired. Its focus is almost entirely on the risks of human action—to the exclusion of its possible benefits. And it does not address important questions of operational policy. Once all the proper procedures have been followed, and the formal analytic and fact-finding requirements are met, how is one to decide? How much extra cost is to be borne and how many benefits foregone to avoid or mitigate uncertain risks in any given situation?

Much of the more recent literature on the precautionary principle attempts to apply it to the complexities of the real

The working definition of the precautionary principle in the report of the UNESCO panel addresses many issues raised by the principle's critics and is clear enough to guide decisionmaking in practical situations.

world. For example, the Precautionary Principle Project, a joint initiative led by IUCN-The World Conservation Union, begins with an acknowledgement that resource management decisions involving biodiversity inevitably involve careful selection of objectives and choices among risks and trade-offs between competing objectives.[11] The latter contrasts with the many discussions of precaution that focus on the risks of innovation rather than those of present practice. Reviewing the multiple versions of the principle found in a long list of environmental agreements, the IUCN paper accurately concludes that the "core of the principle can be understood as *countering the presumption in favour of development*" that threatens biodiversity, shifting the balance to "'prudent foresight,' in favour of monitoring, preventing or mitigating uncertain potential threats."[12]

The IUCN report goes further than earlier treatments in calling attention to the distributional effects of precautionary policies—that is, the disproportionate impact of biodiversity conservation on poor or otherwise disadvantaged peoples who depend on fragile environments for their livelihoods. The IUCN report criticizes WTO for its interpretation of precaution (which the report terms "restrictive") and for placing the burden of proof on those who defend environmentally oriented trade restrictions, arguing that this results in "disharmony between the WTO and the multilateral environmental regime."[13] In the end, however, IUCN is forced to fall back on the need to make policy decisions based on a weighing of the costs and benefits, broadly defined, of alternative costs of action.

The precautionary principle is an important corrective to the pressure to push technology in unnecessarily risky directions.

Missing from these treatments is the fact that the impact of the precautionary principle depends in large measure on when it is invoked. If precautionary measures are put forward that would block or delay a human action for which plans are well advanced—such as a highway, a commercial product, or a change in land use policy—they are sure to meet opposition on the grounds that such measures would hold up innovation and progress. Far better to ask questions at early stages before positions have hardened; while objectives are still being formulated; while alternative ways to achieve them are still available; and while there is still time to assess consequences, gather additional information, and look for ways to avoid or mitigate harmful effects.

The work of Joel A. Tickner, a University of Massachusetts Lowell professor of environmental health, and his collaborators in their book *Precaution, Environmental Science and Preventive Public Policy* offers useful insights.[14] Rather than assume that a pre-cooked proposal is up for comment and that last-minute precautionary measures must be justified or defended, the authors of the Tickner volume ask how such a conflict can be avoided by asking the right questions and adopting precautionary measures early on: What are the objectives, and what are the alternative ways of achieving them? What information is needed for a better decision? What are the risks associated with the various alternatives, and how can they be avoided or mitigated by timely foresight?

Applied in this manner, Tickner and his colleagues argue, the precautionary principle can lead to precautionary actions that can achieve desirable results and at the same time avoid or mitigate risks. Moreover, this kind of precaution can be a source of innovation rather than an obstacle, as for example the development of substitutes for chlorofluorocarbons when these chemicals were found to be destroying the stratospheric ozone layer.

Even with a more reasoned planning process, in which facts are gathered, consequences assessed, and stakeholders consulted, the moment of decision will eventually arrive when someone must decide how high a cost to accept, or how many benefits to forego, to avoid or mitigate risks of uncertain magnitude and probability. This recalls the question of decisionmaking under uncertainty. Here the UNESCO report cites a particularly poignant dilemma. Xenotransplantation—transplanting replacement organs from pigs or other animals in human patients—promises someday to restore the health of desperately ill human beings but could also transmit new viruses and unleash deadly epidemics. The risk/reward ratio is not clear.

As it has evolved, then, the precautionary principle expresses two related but separate concepts. The first, and potentially the more important, is a long-range approach to planning and adaptive management: look before you leap. Think long-range, get your objectives straight, assess alternatives, do research, and think about how to avoid or mitigate risk before you are committed to a possibly risky path. Keep up the research and analysis as you proceed and be prepared to change course if need be. This is sound advice from Tickner and his colleagues and a useful potential antidote to the overselling that is often needed if a proposed project is to survive the political process.

The second is a decision criterion: better safe than sorry. Even in the UNESCO formulation, precaution is concerned almost exclusively with costs and risks rather than benefits. Fair enough. The world has paid a price for "cowboy economics" and hell-for-leather technological enthusiasm. But there is another aphorism that also has validity: "Nothing ventured, nothing gained." In practice, proponents of the precautionary principle have wished to apply it on the side of minimizing risk and foregoing possible benefits. Perhaps we need another principle to balance precaution and insure that desirable innovations are not blocked by an excess of precaution before their consequences are well understood.[15]

The precautionary principle, then, is an important corrective to the pressure from enthusiasts and vested interests to push technology in unnecessarily risky directions. As the UNESCO panel points out, it is a principle, not an algorithm or formula, and cannot eliminate the need for human judgment.

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NOTES

1. World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), *The Precautionary Principle* (Paris: United Nations Economic, Scientific and Cultural Organization, 2005), http://unesdoc.unesco.org/images/0013/001395/139578e.pdf.
2. P. Harremoës et al., eds., *The Precautionary Principle in the 20th Century: Late Lessons from Early Warnings* (London: Earthscan Publications, 2002). The title of this book notwithstanding, most of its examples do not illustrate failures of precaution—at least not in the usual sense of failure to take proactive measures in the face of scientific uncertainty. They rather illustrate scandalous ignoring or outright suppression of clear scientific evidence of harm that was plainly being caused by such pollutants as benzene and radium. To be sure, the potential for such behavior could be cited as an extra justification for precaution.
3. Although the precautionary principle has been invoked in numerous international treaties, it has never been accepted as binding by any international tribunal. The Codex Alimentarius Commission, which is the body under the Food and Agricultural Organization of the United Nations and the World Health Organization with responsibility for international standards and guidelines for food safety, declined to adopt the principle at its meeting in July 2007.
4. "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Principle 15, Rio Declaration on Environment and Development, United Nations Conference on Environment and Development, Rio de Janeiro, June 1992. See http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163.
5. "When an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." The Wingspread Consensus Statement on the Precautionary Principle, a declaration of a meeting of nongovernmental experts held in Wingspread, WI, January 1998.
6. COMEST, note 1 above, page 14.
7. COMEST, note 1 above, page 50.
8. COMEST, note 1 above, page 14.
9. Commission of the European Communities (EC), *Communication from the Commission on the Precautionary Principle* (Brussels, February 2000), http://ec.europa.eu/comm/dgs/health_consumer/library/pub/pub07_en.pdf.
10. Ibid., page 17.
11. R. Cooney, *The Precautionary Principle in Biodiversity Conservation and Natural Resource Management: An Issues Paper for Policy-Makers, Researchers and Practitioners* (Gland, Switzerland, and Cambridge, U.K.: IUCN-The World Conservation Union, 2004), http://www.pprinciple.net/publications/PrecautionaryPrincipleissuespaper.pdf.
12. Ibid., page 5.
13. Ibid., page 24.
14. J. A. Tickner, ed., *Precaution, Environmental Science and Preventive Public Policy* (Washington: Island Press, 2003). See also J. A. Tickner, C. Raffensperger, and N. Myers, *The Precautionary Principle in Action: A Handbook* (Windsor, North Dakota: Science and Environmental Health Network, 1999), available at http://www.biotech-info.net/handbook.pdf.
15. The author proposed such a principle in C. Weiss, "Can There Be Science-Based Precaution?" *Environmental Research Letters* 1 (2006): 014003 and references therein.