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The Uses of Scientific Information in Environmental Decisionmaking

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THE USES OF SCIENTIFIC INFORMATION IN ENVIRONMENTAL DECISIONMAKING

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I. SCIENTIFIC AND LEGAL CONCEPTS OF PROOF

Regulatory agencies are increasingly being asked to decide how much of a given activity such as the discharge of emissions or the application of chemical pesticides should be allowed. They are also being asked to decide if an activity should be prohibited or modified because of its environmental impact.[1] Restrictions on the discharge of residuals and limitations on the modification of natural ecosystems are now generally recognized as necessary to prevent our basic life support systems from becoming "overstressed." The National Environmental Policy Act of 1969[2] and legislation regulating air and water pollution and the use of chemical pesticides have established the maintenance of natural ecosystem stability as a resource use norm. NEPA, at a minimum, reverses our historic preference for resource exploitation by placing the burden of justification on those who seek to modify a natural ecosystem.[3] Air and water pollution legislation,[4] especially the

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1. It is desirable to distinguish two kinds of environmental costs. One is pollution . . . . The other is the transformation and loss of whole environments as would result, for example, from clear cutting a redwood forest, or developing a hydroelectric project in the Grand Canyon.

Fisher, Krutilla & Cicchetti, *The Economics of Environmental Preservation: A Theoretical and Empirical Analysis*, 62 AM. ECON. REV. 605 (1972).

2. 42 U.S.C. §§ 4321 *et seq.* (1970).

3. It has been recently argued that section 101

strongly suggests a nondegradation policy, which, when interpreted in light of the plain wording of the statute and its legislative history, may restrict agency decision making to the preservation and enhancement of environmental quality, especially where pollution is the degradation threatened. Of course that latter, establishes a nondegradation policy with respect to specific resources, and the Federal Environmental Pesticide Control act of 1972[5] seeks to confine the use of harmful chemical pesticides to situations where their use is necessary to achieve major societal benefits which outweigh the risk of harm to the environment.

Assuming the validity of this legislative strategy, its implementation assumes that adequate scientific information exists so that baseline standards can be set and applied to specific resource users.[6] However, frequently, standards and regulations are directed not at alleviating existing hazards but at minimizing the potential risks of secondary and tertiary adverse environmental impacts, and must necessarily be based on inferences drawn from incomplete scientific data. The necessity to make decisions under conditions of uncertainty is not, of course,

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> policy would not require that no tree be cut or that no river be dammed. But it might require that forest management practices that allow slow degradation, be discarded, or that an overall 'river improvement' project be modified or abandoned.

F. ANDERSON, NEPA IN THE COURTS: A LEGAL ANALYSIS OF THE NATIONAL ENVIRONMENTAL POLICY ACT 265 (1973). The conflicting considerations balanced in section 101 suggest, however, that it is more reasonable to consider NEPA as a burden of proof shift. Degradation is still allowed but more justification must be advanced before an activity which causes degradation will be allowed. *See* EDF v. Corps of Engineers, 492 F.2d 1123, 6 ERC 1513 (5th Cir. 1974) (NEPA does not require the agency to articulate a scheme of values for the environmental and developmental factors traded-off in the process of deciding whether to construct a project). *See* Tarlock, *Balancing Environmental Considerations and Energy Demands: A Comment on Calvert Cliffs' Coordinating Committee, Inc. v. AEC,* 47 IND. L.J. 645, 657-70 (1972). *Cf.* City of New York v. United States, 337 F. Supp. 150, 159 (E.D.N.Y. 1972).

4. *E.g.,* 42 U.S.C. §§ 1857 *et seq.* (1970); 33 U.S.C. §§ 1251 *et seq.* (Supp. II, 1972).

5. 7 U.S.C. § 136 (Supp. II, 1972). In deciding whether to register a pesticide the Administrator of the EPA must determine whether the pesticide

> will perform its intended function without unreasonable adverse effects on the environment; and when used in accordance with widespread and commonly recognized practice it will not generally cause unreasonable adverse effects on the environment.

Id. § 136a(c)(4)(C)-(D). The Administrator can deuy registration if the above requirement is not satisfied. If registration is not denied and the pesticide "may generally cause . . . unreasonable adverse effects on the environment" the Administrator must classify the chemical for restricted as opposed to general use. A restricted use pesticide can only be applied under conditions imposed by the Environmental Protection Agency. *Id.* § 136a(d)(1)(C). FEPCA generally incorporates the balancing required by the courts under a construction of the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. § 135-135k (1970). Environmental Defense Fund, Inc. v. Ruckelshaus, 439 F.2d 584 (D.C. Cir. 1971).

6. *See* L. CALDWELL, ENVIRONMENT: A CHALLENGE TO MODERN SOCIETY 91-190 (1970) for an excellent discussion of the problems of formulating policy based on limited information.

a new problem. Information is a costly resource and in many situations the costs of acquiring it exceed the benefits. The problem is, however, becoming more acute as societal demands for environmental quality and the minimization of exposure to risks of future adverse impacts are outrunning available scientific knowledge. This Article explores the response of the legal system to the uncertainty which is inherent in the scientific analysis of environmental impact.

A principal function of a legal system is to determine who must bear the responsibility for acts which injure specific individuals or society as a whole. The first principle of due process is that the assignment of responsibility correspond with the actor who did in fact cause the injury.[7] We argue that existing concepts of cause-in-fact, the foundation of liability,[8] place potentially severe constraints on the ability of the legal system to respond to the need to minimize the risks of future environmental injury. Further, these constraints exist to some degree regardless of whether the prohibitions or restrictions take the form of adjudication, administrative rulemaking or legislation. In any of these contexts a court or agency applying a standard or reviewing a regulation may respond to the claim that an activity should not be allowed because of its potential future adverse impact by deciding that it would be speculative to conclude that the activity might cause harm, or that the party seeking to assign responsibility has merely es-

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7. One function of due process requirements is "to insure the reliability of the determination-making process." Newman, *The Process of Prescribing "Due Process,"* 49 CALIF. L. REV. 215, 221 (1961). Reliability is ensured by procedures such as cross-examination. It is generally assumed but seldom discussed that such procedures are necessary because a sanction can only be imposed if there is a causal connection between the person against whom the sanction will be imposed and the harm. *See* Bountiful Brick Co. v. Giles, 276 U.S. 154 (1928). In affirming a workman's compensation award for an employee who was injured as he crossed railroad tracks away from a public crossing to get to the employers' premises, Justice Sutherland observed:

> Liability was constitutionally imposed under the Utah compensation law if there was a causal connection between the injury and the employment in which Giles was then engaged substantially contributing to the injury.

Id. at 158.

8. *See* H.L.A. HART & A. HONORE, CAUSATION IN THE LAW 58-64 (1959) [hereinafter cited as HART & HONORE]. In recent years it has been argued that liability should be imposed on individuals without regard to established concepts of cause, as well as concepts of fault, if it can be shown that liability would be consistent with the efficient allocation of resources. G. CALABRESI, THE COSTS OF ACCIDENTS (1970); Coase, *The Problem of Social Cost,* 3 J. LAW & ECON. 1 (1960). Basing liability on principles of resource allocation does not, of course, avoid fairness questions. This point is further discussed notes 18-24 *infra.* For a defense of causation as a basis for the imposition of liability, see Epstein, *A Theory of Strict Liability,* 2 J. LEGAL STUDIES 151 (1973).

tablished a possibility rather than a probability of such impact. In short, an essential element of responsibility—cause-in-fact—may not have been established.

It is often difficult to establish cause-in-fact in such a context because embedded within existing concepts of cause are temporal limitations and limitations of the range of permissible inferences. For example, injunctive relief cannot be obtained without a demonstration of imminent irreparable injury; this requires a showing that the anticipated harm is immediate and practically certain to occur.[9] Science is not concerned with the moral questions of whether an actor should be held liable for the consequences of his activity, but with the logical problem of defining the conditions under which it is valid to infer the existence of "unobserved matters of fact on the basis of evidence concerning observed matters of fact."[10] It is appropriate that law and science treat prediction differently. Fairness demands that in many situations the law should require a high level of proof of cause-in-fact, *e.g.*, preventive detention or the suppression of pornography. In other situations, however, *e.g.*, protection of human health, lower standards of proof may be consistent with principles of fairness. No such constraints operate to limit scientific inference, although the accepted rules of proof may restrict the scientist's flexibility. However, there is a basic tension between legal concepts of cause and the conditions for valid scientific predictive inferences which has become increasingly important as regulators turn to scientists, especially ecologists, for the basic information on which regulations and other sanctions aimed at minimizing potential risks of adverse environmental impact are based.

9. Note, *Imminent Irreparable Injury: A Need for Reform*, 45 S. CAL. L. REV. 1025, 1030-37 (1972). To date, courts have held that the National Environmental Policy Act of 1969 does not modify traditional equity doctrines. To obtain a preliminary injunction the plaintiff still carries the burden of persuasion that imminent irreparable injury will result if the injunction is not granted. *See* Canal Authority v. Callaway, 489 F.2d 567 (5th Cir. 1974). The case is interesting because the traditional doctrine was invoked in favor of environmental interests and is illustrative of the continuing reluctance of the court to prevent activities when the benefits of prohibition are speculative. Plaintiff obtained a preliminary injunction to prevent the Secretary of the Army from drawing down a lake to save a large number of hardwood trees described as the cornerstone of the area's ecology. The trial judge issued the preliminary injunction and refused to modify it unless the Secretary proved to a "probable and ecological certainty" that the trees would suffer irreparable harm if the injunction were not modified. The Fifth Circuit remanded for reconsideration on the grounds that the trial judge failed to apply the traditional standards in deciding whether to grant a preliminary injunction and instead shifted the burden of proof to the defendants.

10. W. SALMON, THE FOUNDATIONS OF SCIENTIFIC INFERENCE 76 (1966) [hereinafter cited as SALMON].

The same principles[11] of fairness that have been applied to the determination of civil and criminal liability also apply to choices made by legislatures and administrative agencies. A finding by a legislature or administrative agency that a circumscribed activity may cause adverse social impacts need not be made with the same degree of specificity as a court's finding that a defendant committed a criminal act, or as a plaintiff's proof of cause-in-fact in a civil action. Processes of collective choice exist to allow society to decide what activities are and are not consistent with its preservation. Of necessity these decisions rest on probability judgments. Activities may be prohibited which threaten harm to individuals or resources. Society may also prohibit activities which threaten no specific harm but contravene values deemed important. The Anglo-American legal tradition has, however, always been concerned with the tension between duly constituted authority and individual discretion, and at some point the government must establish that the statute or administrative regulation which is the basis for a sanction rests on a rational relationship between the challenged activity and the prevention of harm to society. This familiar constitutional standard requires a court to determine if there is a "factual linkage between means and end—whether the regulation promotes (or could reasonably be believed to promote) permissible legitimate objectives."[12] A sanction imposed in the absence of a causal relationship between the prohibited activity and posited adverse consequences would be arbitrary and hence unconstitutional.

It might be argued that we have overstressed the analogy between the role of cause in civil and criminal trials and the role it plays in constraining legislative and administrative choice in protecting and enhancing environmental quality. Legislative enactments represent collective judgments about the level of environmental quality that society should have; fairness is established, not by showing that the inference drawn by the legislature is rational, but by showing that the proc-

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11. Legal rules can be justified by either policies or principles. Rules justified by policies are instrumental in the sense that the result they dictate contributes to the achievement of a socially desired objective. Rules justified by principles are rules derived from conventional morality. The major difference between the two justifications is that rules justified by policies are more unstable than those justified by principles, for conceptions of what is socially desirable change much faster than societal conceptions of morality. See Wellington, *Common Law Rules and Constitutional Double Standards: Some Notes on Adjudication*, 83 YALE L.J. 221, 222-49 (1973) for an excellent discussion of the interplay between these two components of rules.

12. P. BREST, PROCESS OF CONSTITUTIONAL ADJUDICATION: CASES AND MATERIALS ch. 5, at 2 (Preliminary Draft, 1973).

ess of decision conforms to relevant constitutional rules. For example, an early student of technology assessment has argued that "[i]t is more important in a democracy that the public have the decisions it wants, rationally or irrationally, right or wrong, than that 'correct' decisions be made."[13] This argument rests on the principle that an important function of the presumption that legislative and administrative decisions are constitutional is that

> most governmental decisions are based on empirical assumptions, the probable validity is considerably less than certainty. An important, but highly intuitive and non-objectifiable, aspect of the decisionmaking process is the assertion of what probabilities justify particular actions. It may be perfectly rational for a legislature to make decisions based on facts it recognizes are not likely to exist.[14]

The presumption therefore protects the value judgments we expect from collective decisionmaking institutions. Shifting the forum of decision will not, however, eliminate the necessity for concern with the validity of causal inferences. The legislature often, as a matter of discretion, adopts the requirement that conclusions be supported by valid inferences based on available scientific information.[15] This is often done when the authority is delegated to administrative agencies to make regulations and undertake adjudications, and the legislature specifies that the regulations and decisions must be supported by substantial evidence[16] or a lesser evidentiary standard. The importance of this

13. Green, *Limitations on the Implementation of Technology Assessment*, 14 ATOMIC ENERGY L.J. 59, 82 (1972). *See also* Green, *The Adversary Process in Technology Assessment*, in TECHNOLOGY ASSESSMENT: UNDERSTANDING THE SOCIAL CONSEQUENCES OF TECHNOLOGICAL APPLICATIONS 49 (R. Kasper ed. 1972); Green, *The Resolution of Uncertainty*, 12 NAT. RES. J. 182 (1972).

14. P. BREST, PROCESS OF CONSTITUTIONAL ADJUDICATION: CASES AND MATERIALS ch. 5, at 23-24 (Preliminary Draft, 1973). The case for application of the presumption to administrative action is made in Alfange, *The Relevance of Legislative Facts in Constitutional Law*, 114 U. PA. L. REV. 637, 662 (1966).

15. Although economic considerations were an important factor in the congressional decision not to fund the SST program, members of Congress were concerned with environmental risks and relied on existing scientific studies to support the case for a denial of funding. Members supporting the project attempted to refute the evidence of risk. *E.g.*, 116 CONG. REC. 17307 (1970) (pollution by exhaust) (remarks of Rep. Vanik); 116 CONG. REC. 27122-23 (1970) (stratospheric effects) (remarks of Rep. Yates).

16. *E.g.*, Environmental Defense Fund, Inc. v. EPA, 489 F.2d 1247 (D.C. Cir. 1973) (DDT ban found supported by substantial evidence). The standard of review for rulemaking "may differ little, if at all, from the standard normally used in substantial evidence review." Bunny Bear, Inc. v. Peterson, 473 F.2d 1002, 1006 (1st Cir. 1973); *accord*, Chrysler v. Department of Transp., 472 F.2d 659 (6th Cir. 1972). The

constraint is illustrated by the current controversy over sulphur dioxide air quality standards where it is alleged that the standards are not supported by scientific evidence.[17]

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case for the use of rulemaking to deal with issues adapted to generic resolution but where the scientific assumptions need a public airing is made in Murphy, *The National Environmental Policy Act and The Licensing Process: Environmentalist Magna Carta or Agency Coup De Grace?*, 72 COLUM. L.J. 963 (1972). The standards used by agencies and courts to make risk-benefit decisions are discussed in Section III *infra.*

17. *See, e.g.*, Kennecott Copper Corp. v. EPA, 462 F.2d 846 (D.C. Cir. 1972), which involved a challenge to the EPA's secondary sulphur dioxide standards. Primary and secondary air pollution standards must be based on published air quality criteria, 42 U.S.C. § 1857c-3 to c-4 (1970), which reflect for each pollutant

> the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air, in varying quantities.

Id. § 1857c-3(a)(2). The court characterized the regulatory process as informal rulemaking since no public hearings and evidentiary submissions are required to be held on proposed national ambient air quality standards but held that although the minimum requirement of section 4 of the Administrative Procedure Act that a "concise general statement" of the basis for the regulation was satisfied this was not sufficient as "in a particular case fairness may require more than the APA minimum." 462 F.2d at 850 n.18. The case was remanded for an implementing statement that would enlighten the court as to the basis on which "the standard was derived from the criteria." *Id.* The court stressed, however, that it did not consider that more than the written submissions specified by Congress was required.

Both the Environmental Protection Agency and the electric power industry concede that the magnitude of the risks to health from prolonged exposure to sulphur dioxide have not been established with certainty. The EPA, however, supports the present high standards on the ground that a margin of safety should be preserved pending further research while the electric power industry argues for relaxation of the standard. *See Current Developments,* 4 ENVIRON. RPTR. 1063, 1239 (Oct. 26, 1973; Nov. 23, 1973).

However, the District of Columbia Circuit Court of Appeals retreated from its activist role in supervising the administrative process in its most recent statement on the relationship between scientific knowledge and environmental rulemaking. In AMOCO Oil v. EPA, — F.2d —, 6 ERC 1481 (D.C. Cir. 1974) Judge Wright returned to the traditional distinction between adjudicative and legislative functions to give administrators the discretion to make the kind of risk-benefit analyses we advocate in Section III of this article. In sustaining the EPA's unleaded fuel regulations, which must be based on findings, Judge Wright wrote:

> When—as is the usual case—findings are required in the context of an administrative adjudication, there is no need to ask what the requirement means. An adjudication typically involves a single, ultimate determination, the agency's sole task being to reason from raw evidence to a final conclusion of a mixed legal-factual character, usually framed in statutory language. For instance, an agency will be asked to determine whether the evidence available on a public utility's rate practices shows behavior that is "unreasonable" or "unduly discriminatory." The agency's "findings" are simply those "basic" or "intermediate" conclusions of fact by which it resolves evidentiary disputes aud from which it moves, in a final step, to the ultimate statutory decision. *See generally* 2 K. DAVIS, ADMINISTRATIVE LAW TREATISE § 16.06 (1958).
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> In rule-making, however, an agency's task is not to test raw evidence against a single, pre-established standard; rather the agency is to fashion a host of new legal standards—regulations—having prospective effect. A rule-making agency makes not one but dozens of "ultimate" decisions—not ouly because a

The constraints imposed by current concepts of cause are illustrated by the opinion of a Minnesota trial court in *Reserve Mining v. Minnesota*[18] and in later federal litigation involving Reserve. Minnesota attempted to enforce a stringent effluent standard against a mining and beneficiating company which was discharging taconite tailings into Lake Superior.[19] After a lengthy trial which featured a clash of

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set of regulations has many provisions, but also because adoption of any one provision constitutes a simultaneous rejection of many possible alternatives. Few if any of these "ultimate" decisions will depend on factual conclusions of the sort conventional in adjudication. Looking to the future, and commanded by Congress to make policy, a rule-making agency necessarily deals less with "evidentiary" disputes than with normative conflicts, projections from imperfect data, experiments and simulations, educated predictions, differing assessments of possible risks, and the like. The process is *quasi*-legislative in character, and one will search it in vain for those intermediate "findings" of fact which mark the midway point in an adjudicator's linear march from raw evidence to single, ultimate conclusion. *See generally Industrial Union Department, AFL-CIO v. Hodgson,* — U.S. App. D.C. —, ——, —, — F.2d —, ——, — (No. 72-1713, decided April 15, 1974) (slip op. 8-16, 41); *Automotive Parts & Accessories Assn v. Boyd,* 132 U.S. App. D.C. 200, 205-207, 407 F.2d 330, 335-337 (1968).

. . .

The "basis and purpose" statement required by Section 4(c) of the APA must be sufficiently detailed and informative to allow a searching judicial scrutiny of how and why the regulations were actually adopted. *Automotive Parts & Accessories Assn v. Boyd, supra.* In particular, the statement must advert to administrative determinations of a factual sort to the extent required for a reviewing court to satisfy itself that none of the regulatory provisions were framed in an "arbitrary" or "capricious" manner. *Portland Cement Assn v. Ruckelshaus, supra,* — U.S. App. D.C. at — —, 486 F.2d at 390-401; *International Harvester Co. v. Ruckelshaus, supra,* 155 U.S. App. D.C. at 425-443, 478 F.2d at 629-647; *Kennecott Copper Corp. v. EPA,* 149 U.S. App. D.C. 231, 234-236, 462 F.2d 846, 849-851 (1972); *City of Chicago v. FPC,* 147 U.S. App. D.C. 312, 322-326, 458 F.2d 731, 741-745 (1971), *cert. denied,* 405 U.S. 1074 (1972). In light of this jurisprudence, which has developed without the aid of a statutory requirement for "findings," we cannot perceive what would be added to the responsibilities of the Administrator, or of this court, by reading into Section 211(c)(2)(B) a diffuse and ambiguous congressional preference for fact-finding.

We read Section 211(c)(2)(B) as incorporating the common-sense approach which the courts have developed in applying Section 4(c) of the APA. Where EPA's regulations turn crucially on factual issues, we will demand sufficient attention to these in the statement to allow the fundamental rationality of the regulations to be ascertained. Where, by contrast, the regulations turn on choices of policy, on an assessment of risks, or on predictions dealing with matters on the frontiers of scientific knowledge, we will demand adequate reasons and explanations, but not "findings" of the sort familiar from the world of adjudication. (6 ERC at 1488, 1492-93).

The formulation leaves some room for a court to inquire into the scientific judgments behind regulations designed to minimize the risk of future impacts but indicates a judicial unwillingness to incorporate common law concepts of cause in fact and imminent irreparable injury into judicial review of rulemaking.

18. 2 Environ. R. Cas. 1135 (1970), *rev'd on other grounds,* 294 Minn. 300, 200 N.W.2d 142 (1972). *See* D. ZWICK AND M. BENSTOCK, WATER WASTELAND 140-66 (1971), for the Nader Study Group's view of the case.

19. The Minnesota water pollution standards contained an anti-degradation clause which was unenforceable because it applied to discharges instituted after Reserve began dumping; but the effluent limitation the state was attempting to enforce would have

scientific experts the judge found that the discharges had only two adverse impacts on the quality of the lake. The aesthetic enjoyment of the lake was impaired by an increase in the green water phenomenon, and there was a decrease in the quantity of a small fish food used by smelt. The trial court found that enforcement of the standard against the company would be unreasonable and held that the discharges did not constitute pollution:

> The word "pollution" is subject to varied definitions, depending upon the intent and position of the definer. Under the dictionary definition—"An act of making or rendering unclean"—any human contact at all could be considered pollution. Robert S. Burd, Respondent's witness and Deputy Assistant Commissioner for Operations of Federal Water Quality Administration, defined pollution as follows: "Anything that lowers the natural or existing quality of water." These definitions, being of such a general nature, were of no assistance. Dr. Charles Murry, Appellant's witness, Professor of Biology at La Salle College and former member of the Academy of Natural Sciences, defined pollution as a "product of legislation." It was, therefore, necessary to resort to the statute for its definition. M.S. 115.01, Subd. 5, defines pollution as follows: "Pollution means the contamination of any waters of the state so as to create a nuisance or render such waters unclean, or noxions, or impure so as to be actually or potentially harmful or detrimental or injurious to public health, safety or welfare, to domestic, commercial, industrial or recreational use, or to livestock, wild animals, birds, fish or other aquatic life." In applying this statutory definition to the voluminous evidence, both oral and documentary, the court concludes that there was lacking the required substantial evidence by Respondent to convince this court that the discharge of tailings by Appellant, after 15 years of operation, had "rendered the waters unclean or noxious or impure thereby."
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> The only exception of convincing quality was the increased display of the "green water phenomenon" and the disappearance of a proportion of the scud, a small shell creature which serves as a food for smelt and small trout. Although measurable, these conditions were of minimal significance or materiality.
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> The question of potential harm to the lake water then became the greatest concern of the court. This facet also became

achieved the same result, because Reserve could comply only by the dilution of the effluent with millions of gallons of water or by the complete cessation of discharge into the lake. *Id.* at 1143.

> the main thrust of Respondent's attack. Respondent's experts, while admitting there had been no measurable deterioration of water quality to date, maintained that the chemical and bacterial content of the tailings were of such significance that they would result in eutrophication by nutrient feeding of algae, and paradoxically, the reduction of algae in the zone of discharge as a limiting factor. They opined, therefore, that the tailings had or would have a pollutant effect on the lake. These findings and opinions were denied by Appellant's experts. And so the court, completely lacking in personal expertise, found itself in the impossible position of being required to analyze, weigh, and choose between these controversial points of view. There was scant consolation to the court in the remark of Dr. Donald Mount who, evidently recognizing the court's dilemma, stated while testifying, "The court has my sympathy."
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> In view of the absence of definitive measurements of pollution in quantity or time, with consideration to the assimilative capacity of Lake Superior, the court would be indulging in speculation to make a determination that the discharge was or was not a potential source of pollution to Lake Superior.[20]

The court retained continuing jurisdiction over the discharges and the state litigation has now been superseded by a federal suit. The federal government introduced evidence that asbestos in the discharges constitutes a public health hazard. A district court judge enjoined the operation of the plant on this ground.[21] The Court of Appeals for the Eighth Circuit recently granted Reserve a stay of injunction pending appeal on grounds that no public health hazard had been shown and, absent such a showing, an injunction was improper due to the substantial economic harm the injunction would cause to the companies and communities affected.[21a] Judge Bright reasoned that the

20. *Id.* at 1144.

21. The federal government filed suit alleging that the discharges violated the Rivers and Harbors Act of 1899, 33 U.S.C. § 407 (1970), and constituted a federal public nuisance under Illinois v. Milwaukee, 406 U.S. 91 (1972). After a nine-month trial, on April 20, 1974, the United States District Court ordered an immediate cessation of Reserve's activities. On the basis of conflicting scientific testimony the judge concluded that the large amounts of minute anthibloe fibers discharged into the air and waters of the lake can, after prolonged exposure, "produce asbestosis, meothelioma, and cancer of the lung, gastrointestinal tract and larynx." Thus the continued discharges of the taconite "substantially endangers the health of the people" in the area. 6 ERC 1449 (D. Minn. 1974).

21a. Reserve Mining Co. v. U.S.A., No. 74-1291 (8th Cir., June 4, 1974). The stay was for 70 days and was "conditioned upon assurances that there will be a speedy termination of Reserve's discharges into Lake Superior and control of its emission into the air." *Id.* at 25-26.

rules of proof governing a court prohibited the issuance of an injunction to eliminate a health hazard unless the existence of, not just the potential for, such a hazard is proven. He posed the issue:

> [A]lthough Reserve's discharges represent a possible medical danger, they have not in this case been proven to amount to a health hazard. The discharges may or may not result in detrimental health effects, but, for the present, that is simply unknown. The relevant legal question is thus, what manner of judicial cognizance may be taken of the unknown.
>
> We do not think that a bare risk of the unknown can amount to proof in this case. Plaintiffs have failed to prove that a demonstrable health hazard exists. This failure, we hasten to add, is not reflective of any weakness which it is within their power to cure, but rather, given the current state of medical and scientific knowledge, plaintiffs' case is based only on medical hypothesis and is simply beyond proof.[21b]

The merits may never be litigated as the government and Reserve are negotiating an abatement plan spurred by the court's indication that the government might prevail on the air and water pollution issues. The opinion is procedurally unobjectionable, but the court's rejection of the use of a risk-benefit analysis as a basis for prohibiting a potentially environmentally detrimental activity is disturbing. In answer to the issue it posed the court wrote:

> If we are correct in our conclusion that evidence does not exist in the record on which to find Reserve's discharges to be unsafe, the district court's determination to resolve all doubts in favor of health safety represents a legislative policy judgment, not a judicial one . . . Although we are sympathetic to uncertainties . . . we are a court of law, governed by rules of proof, and unknowns may not be substituted for proof of a demonstrable hazard to the public health.[21c]

21b. *Id.* at 23-24.

21c. *Id.* at 24-25. The court's conclusion that only a legislature can protect society from the risk of future harm oversimplifies an extremely complex problem. Certainly, as we suggest, it is proper for a court to consider itself more constrained than a legislature in prohibiting activities where only a risk of future harm is established. However, we argue that potential but unknown harm is not so qualitatively different from proven harm so as to relegate the former completely to the political process while the latter remains within the scrutiny of the judicial process. Concepts of probability underlie both. Restraint on the part of courts is proper because courts are not subject to direct political checks while legislatures are. The political process thus operates as a check against the arbitrary exercise of legislative discretion. But the judicial process is also checked through reliance on factual findings and rigorous procedures. These same checks ou the ordinary exercise of judicial discretion operate equally in the area

The state court opinion in *Reserve Mining* is disturbing because many activities which threaten ecosystem stability and may in the long run produce effects society does not desire cannot be classified as public health hazards. We do however recognize that powerful principles of fairness underlie the court's analysis. The state's attempt to enforce a nondegradation standard represents a decision that preservation of the lake in its natural state is a more efficient use than allowing the lake to become a sink for mining wastes. Our legal system has long been distrustful of the cost-benefit ratios calculated by the legislatures in situations where it is claimed that a use should be shifted from the private to the public sector to improve the efficient allocation of resources. Information necessary to calculate the opportunity cost of the choice is often not obtained because the interest of the public is often merely the minimization of the costs of carrying out an activity rather than the improvement of the efficient allocation of resources.

To promote better information about the opportunity costs of public choices, constitutional guarantees of due process require that individuals receive compensation when the impact of a public choice is focused and substantial.[22] Compensation is denied only if the individual was on notice that a resource use claim would not be protected or if the resource user caused harm to other resource users by interfering with the beneficial enjoyment of their property.[23] When Reserve

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on unknown effects. The same judicial procedures applicable to the establishment of past events must be followed and the *fact* that the information is unknown by anyone must be proven. Moreover, the point of having checks on decisionmaking bodies is not only to diminish arbitrariness but also to avoid erroneous decisions. We argue that greater error is likely to be introduced by judicial refusal to consider unknown effects than by consideration in the face of an admittedly frustrating insufficiency of information. For further discussion of this problem see Part III *infra*.

22. R. Posner, Economic Analysis of Law 22 (1972).

23. *See* Michelman, *Property, Utility, and Fairness: Comments on the Ethical Foundations of "Just Compensation" Law*, 80 Harv. L. Rev. 1165 (1967). Professor Sax also accepts the principle that efficiency is the guiding objective in a case such as *Reserve Mining* but would disagree with this analysis. He argues for the expanded use of public nuisance concepts based on the principle that property is an interdependent network of competing uses, and that the prohibition of most activities which uses commons as sinks does not require the payment of compensation. Were the state to restrict a use that does not impose spillovers on neighboring or common property then the property owner would be entitled to compensation. Sax, *Takings, Private Property and Public Rights*, 81 Yale L.J. 149, 161 (1971). Courts should defer to legislative cost-benefit decisions unless

> the court is satisfied that the legislative determination is sufficiently distorted as to constitute an abuse of the police power; that the legislature has subordinated a judgment about maximization of social benefits to advancement of private gain.

Id. at 176. His argument fails to appreciate the problems of information distortion

Mining commenced its dumping activities, it was not on notice that society would not recognize its right to use the lake as a sink although future similar users now have such notice. It is difficult to classify the use as a public nuisance since there was no evidence that Reserve's use would foreclose any uses the public might want to make of the resource or pose a threat to public health. In effect, the state decided that preservation of Lake Superior in its natural state is a "merit good" and thus ought to be undertaken for its own sake. The risk of arbitrariness in merit good decisions, especially those designed to promote aesthetic objectives,[24] is so high that society has traditionally thought it fair to make the public purchase the good just as a private individual would have to do to vindicate his preferences.

This analysis of *Reserve Mining* suggests only that there are fundamental reasons for limiting society's right to prohibit an activity to cases where there is a showing of a causal relationship between the activity and harm. These reasons apply whether the issue posed is locking up people whom the social scientists predict may commit crimes or restricting the discharge of residuals into a lake. We are not, however, arguing that the standards for establishing cause should be the same in each case.[25] Fairness is only one of the principles

that arise when a legislature is allowed to make cost-benefit decisions freed from the burden of proving its assertion that a resource use shift will improve efficiency.

24. Equity has traditionally refused to enjoin an activity alleged to be a nuisance solely because it interferes with aesthetic interests on the ground that the lack of standards to determine what is and is not aesthetically acceptable increases the potential for arbitrariness. For an analysis and criticism of this rule see Ellickson, *Alternatives to Zoning: Covenants, Nuisance Rules, and Fines as Land Use Controls*, 40 U. CHI. L. REV. 681, 733-35 (1973). Courts have increasingly recognized the power of legislative bodies to protect aesthetic interests. Courts initially resorted to the fiction that the purpose was to protect property values not to promote aesthetic interests but increasingly aesthetic regulations are permitted where the benefits run to the public generally rather than to specific property owners. The cases and citations to the literature are collected in Note, *Beyond the Eye of the Beholder: Aesthetics and Objectivity*, 71 MICH. L. REV. 1438 (1973). *But see* Mayor & City Council v. Mano Schwartz, Inc., 268 Md. 79, 299 A.2d 828 (1973). However, the necessity to show a relationship between the prohibition and the protection of property values, in short to show that the activity does in fact cause injury, can be justified on fairness grounds. The requirement of a quantifiable injury is "a kind of socially computerized, objective evidence that the regulated activity is by social consensus deemed intrinsically ugly, negatively suggestive, or destructive of prior existing beauty." Michelman, *Toward A Practical Standard for Aesthetic Regulation*, 15 PRAC. LAW No. 2, 1969, at 37. For a case illustrating the need for compensation to prevent arbitrary decisions, see State *ex rel.* Stoyanoff v. Berkeley, 458 S.W.2d 305 (Mo. 1970).

25. Professor Morton Horowitz has shown how 19th-century American courts modified the doctrine of riparian rights to accommodate development. The natural flow theory which prohibits all uses of the stream except those consistent with the

recognized in definitions of cause. Existing concepts of cause are also premised on attitudes about the role of the law in encouraging or discouraging certain types of resource use. Many of these assumptions need to be re-evaluated because they are no longer valid. In the 18th century theories of property use were often static and rules such as the natural flow theory of riparian rights operated to preserve a state of limited development.[26] Nineteenth century property rules often encouraged the development of industry by positing exploitation of property and use of new technologies as desirable objectives. An interesting recent Note in this law review argues that the necessity of showing that harm will be "practically certain" to result before an injunction will issue is a function of 19th century attitudes toward the relationship between technology use and social welfare. The risk of future injury was often found to be outweighed by the benefits of present exploitation because some new technology might eliminate the problem and thus the risk was in fact minimal.[27] Nineteenth century resource exploitation policies also placed little incentive on resource users to acquire information before undertaking an activity to determine if injury might result. The concept of foreseeability was used to limit liability when it was assumed that information about future impacts would be costly and perhaps impossible to obtain. The application of these policies is illustrated by the famous ground water case of *Wheatly v. Baugh*.[28] Plaintiff sued for damages incurred as a result

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maintenance of the natural flow was first replaced with the principle of priority of use. Priority was in turn replaced with the reasonable use theory which allowed the courts to balance the necessity to provide security to prior investment with the benefits to society which could accrue from new uses which, although they interfered with prior uses, were thought to represent a more efficient use of the resource. Horowitz, *The Transformation in the Conception of Property in American Law*, 1780-1860, 40 U. CHI. L. REV. 248 (1973). On the basis of J. HURST LAW AND ECONOMIC GROWTH (1964), Professor James Krier has similarly argued that "burden of proof rules at present have an inevitable bias against protection of the environment and preservation of natural resources," as those seeking to prevent exploitive uses carry the burden of proof as most of the basic issues in a lawsuit. Krier, *Environmental Litigation and the Burden of Proof*, in LAW AND THE ENVIRONMENT 105, 107 (M. Baldwin & J. Page eds. 1970). The limits of burden of proof manipulation as a means of resolving uncertainty problems is discussed in notes 119-23 *infra*.

26. For example, it has been persuasively argued that the constitutional preference for personal autonomy requires that inferences that a person is mentally incapable of making an informed consent to treatment be subjected "to the closest scrutiny." M. H. Shapiro, *Legislating the Control of Behavior Control: Autonomy and the Coercive Use of Organic Therapies*, 47 S. CAL. L. REV. 237, 309 (1974).

27. *See* Note, *Imminent Irreparable Injury: A Need for Reform*, 45 S. CAL. L. REV. 1025, 1030-37 (1972).

28. 25 Pa. 528 (1855).

of defendant's pumping large amounts of ground water which dried up plaintiffs spring. In denying recovery the Pennsylvania Supreme Court reasoned that if the defendant was held liable:

> Such a claim, if sustained, would amount to a total abrogation of the right of property. No man could dig a cellar, or a well, or build a house on his own land, because these operations necessarily interrupt the filtrations through the earth. Nor could he cut down the forest and clear his land for the purpose of husbandry, because the evaporation which would be caused by exposing the soil to the sun and air would inevitably diminish, to some extent, the supply of water which would otherwise filter through it. He could not even turn a furrow for agricultural purposes, because this would, partially, produce the same result. Even if this right [to a continued flow of water] were admitted to exist, the difficulty in ascertaining the fact of its violation, as well as the extent of it, would be insurmountable. The Roman law, founded upon an enlightened consideration of the rights of property, declared that 'he who, in making a new work upon his own estate uses his right without trespassing either against any law, custom, title, or possession, which may subject him to any service towards his neighbors, is not answerable for the damages which they may chance to sustain thereby, unless it be that he made that change merely with a view to hurt others without any advantage to himself.' 'He may raise his house as high as he pleases, although by the elevation, he should darken the lights of his neighbor's house.' Domat § 1047 . . . . the owner of the land is not bound to resort to an action for redress of which he cannot by any possibility have notice.[29]

This Article has argued that the principal difference between legal and scientific concepts of cause stems from the different functions each performs. We now turn to a more precise analysis of the different approaches to problems of cause. Science is concerned with describing physical relationships and thus with drawing inferences from observed to unobserved behavior. Because the law must assign responsibility for events which have occurred and less frequently for events which may occur within a relatively short time,[30] cause has not been seen as being as difficult an analytical problem for the lawyer as it is for the scientist. Scientists must always be concerned with the limitations in predicting the future from the present.

29. HART & HONORE, *supra* note 8 at 532, 534.

30. The leading analysis of cause is confined, as are others, to questions of what has happened, not what may occur. HART & HONORE, *supra* note 8.

This was not always so in the case of lawyers. Seventeenth century English legal thinkers considered themselves part of the community of scholars developing new modes of analysis, and incorporated the concept of relative certainty into the law of evidence by emphasizing that conclusions as to what occurred were probability statements based on the credibility of witnesses and the ability to accept their statements of fact beyond "any more reason to be doubted than if ourselves had heard and seen it."[31] Subsequently the standards for establishing cause such as the "but for" test[32] assumed that it is possible in most cases to describe what did in fact occur. Uncertainty was, of course, recognized but it was seen as a variation from the norm. Professor Prosser told generations of lawyers that the problem of cause was simple: "Causation is a fact. It is a matter of what has in fact occurred."[33] The analytical problems of inference drawing have been de-emphasized.[34] Lawyers are not much concerned with what actually did happen or might occur but instead are interested in the circumstances in which it is legitimate to treat an event as having happened or likely to occur regardless of what did in fact happen or may occur. American scholarship has concentrated instead on the process of conflict resolution; juries and other fact finders have been free to draw somewhat strained inferences not because the inference is logically valid, but because causation has been characterized as a policy problem.[35] This seems to mean that which permissible causal inferences are permissible should vary according to whether a court should encourage or discourage the activity alleged to cause the injury.[36]

Lawyers do not find scientific concepts of cause relevant to the determination of responsibility for two principal reasons. First, scientific principles of cause relate to the conditions under which predictive inferences can be justified and the conditions are too rigid for the law, which must assign responsibility to specific individuals for specific

31. B. Shapiro, *Law and Science in Seventeenth-Century England*, 21 STAN. L. REV. 727, 755 (1969), *quoting* G. GILBERT, THE LAW OF EVIDENCE 4 (1756).

32. 2 HARPER & JAMES, THE LAW OF TORTS § 20.2 (1956).

33. W. PROSSER, THE LAW OF TORTS § 41, at 237 (4th ed. 1971).

34. *Cf. id.* at 242. Prosser argues that "[t]he fact of causation is incapable of mathematical proof, since no man can say with absolute certainty what would have occurred if the defendant had acted otherwise," supports the material element and substantial factor test for cause in fact.

35. The leading article is Malone, *Ruminations on Cause-In-Fact*, 9 STAN. L. REV. 60 (1956).

36. For example, Professor Malone suggests that high standards of proof should be required in medical malpractice cases to encourage the practice of medicine. *Id.* at 85-88.

events. In addition, prediction of future events historically has been of little interest to the law. The foundations of scientific inference were developed by Hume, who identified three relationships between an effect and its antecedent events relevant to determination of whether a causal relationship exists. The first two are contiguity and succession; the third is "a necessary connection . . . and that relation is of much greater importance than any of the other two."[37] For Hume the only acceptable definition of cause is an instance of an *invariable* relationship between two or more processes. All other instances of observed uniformities must be classified as correlations, not causes. Having established a definition of cause, Hume went on to pose a paradox which continues to concern philosophers of science. Hume posited that no ampliative inference (a conclusion with content not present either implicitly or explicitly in the premises) could be justified by induction since the uniformity of nature cannot be taken as a synthetic a priori principle.[38] In short, according to Hume's paradox "there is no way in which we can extend our knowledge of the unobserved."[39] The paradox has been operationally resolved by treating scientific knowledge as hypotheses which have been verified by evidence which justifies a probability statement.

When problems of uncertainty have arisen, the law has in some instances followed science and denied relief when a causal relationship could not be established. However, in cases such as *Summers v. Tice*[40] recovery has been allowed when an inference could not be logically justified. In *Summers* one of two defendants shot the plaintiff in the eye and the court held that since it was clear one of them caused the injury and was negligent the burden of proof of apportioning the injury shifted to the defendants, on the grounds that "[t]o hold otherwise would be to exonerate both from liability."[41] In effect, the court shifted the burden of persuasion on the issue of cause-in-fact and held lack of causation would not be a defense when two or more persons

37. D. HUME, *A Treatise of Human Nature*, in THE ESSENTIAL DAVID HUME 59 (R. Wolff ed. 1969).

38. SALMON, *supra* note 10, at 10.

39. *Id.* at 11.

40. 33 Cal. 2d 80, 199 P.2d 1 (1948). In *Summers*, only one defendant caused the injury. Multiple polluters have also been held jointly and severably liable where "an injury which from its nature cannot be apportioned with reasonable certainty to the individual wrongdoers." Landers v. East Texas Salt Water Disposal Co., 151 Tex. 251, 256, 248 S.W.2d 731, 734 (1952). *See also* Hall v. E.I. Du Pont de Nemours & Co., 345 F. Supp. 353, 378-80 (E.D.N.Y. 1972).

41. 33 Cal. 2d at 85, 199 P.2d at 3, *quoting* Oliver v. Miles, 144 Miss. 852, 860, 110 So. 666, 668 (1926) [emphasis omitted].

contemporaneously and negligently injure someone.[42]

The second and somewhat inconsistent reason that lawyers do not find scientific concepts of cause relevant to the determination of responsibility is that the law cannot afford the tentativeness science permits in the process of hypothesis verification, for the law is interested in simple rather than complex relationships. Scientific knowledge is cumulative; legal decisionmaking to assign responsibility is not. Scientists recognize that it may take many years to develop acceptable theories of causal relationships when complex systems are being described. Scientists seeking to describe complex sets of interrelationships build on Mill's criticism and extension of Hume. Mill criticized Hume for viewing cause as a relationship between a consequent and single antecedent. Mill presented a more complex conception of cause which he defined as the sum total of all conditions, "the concurrence of all of them being requisite to produce . . . the consequent."[43] Where as Hume defined cause as an occurrence necessary for the occurrence of an event, Mill defined cause in terms of sufficient conditions. The law must radically simplify the conditions which concurred to produce an event because only a few of them are relevant to the issue of responsibility, whereas scientists such as ecologists describe ever more complex webs of interrelationships.[44] For these reasons it is not surprising that when attempts are made to establish causal relationships with evidence that is tentative and emphasizes the limitations of our ability to draw causal inferences (because of the complexity of the situation) judges become impatient and classify the inferences as speculative,[45] setting all questions of fairness aside.

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42. Dworkin, *Easy Cases, Bad Law, and Burdens of Proof*, 25 VAND. L. REV. 1151, 1169-74 (1972).

43. III J.S. MILL, SYSTEM OF LOGIC, ch. 5, § 3; HART & HONORE, *supra* note 8, at 15.

44. Referring to philosophic concepts of cause which search for uniform generalizations about invariable sequences of events, Hart and Honore argue:

> Yet such searches for explanation are not the source of the lawyer's main perplexities: they arise when, after it is clearly understood how some harm happened, the courts have, because of the form of legal rules, to determine whether such harm can be attributed to the defendant's action as its consequence, or whether he can properly be said to have caused it.

HART & HONORE, *supra* note 8, at 22-23. *See also id.* at 30-36.

45. This problem arises frequently in environmental impact analysis. NEPA requires federal agencies to disclose scientific information about the impact of an activity and then to decide if, on balance, the environmental costs exceed or are less than the benefits of undertaking the activity. Increasingly, the impact statement must justify the activity with at least the internal consistency of an appellate opinion. Natural Resources Defense Council, Inc. v. Morton, 458 F.2d 827 (D.C. Cir. 1972) and Monroe County Conservation Council, Inc. v. Volpe, 472 F.2d 693 (2d Cir. 1972). NEPA

II. THE NATURE OF INFORMATION ABOUT ECOLOGICAL SYSTEMS

The problem of deciding how much of an activity to allow or if a project should be prohibited or modified is one aspect of the broader problem of technology assessment. The object of technology assessment is to predict on the basis of available information—subject always to the constraint of cost—the secondary and tertiary impacts of an activity

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seems premised on two assumptions. First, it assumes that the impact statement process can generate sufficient information about the risks posed by major federal activities. It is, however, more accurate to say that NEPA finessed the difficult problems of making such decisions without adequate information. Background documents focused on the limitations of available information but this problem was subsequently ignored as the Act was drafted. *See Hearing Before the Senate Comm. on Interior and Insular Affairs and the House Comm. on Science and Astronautics, Joint House-Senate Colloquium to Discuss a National Policy for the Environment*, 90th Cong., 2d Sess. (1968). The second assumption is that decisionmakers will modify their resource use priorities in response to the new information and values exposed by the impact statement proccss. *See generally* Note, *Recent Changes in the Scope of Judicial Control Over Administrative Methods of Decisionmaking*, 49 IND. L.J. 118 (1973). The basic problem with the Act is that any balancing will be biased in favor of undertaking the activity if the information is not available and the agency has no duty to generate the information. This bias is illustrated by the AEC's response to Calvert Cliffs' Coordinating Committee v. AEC, 449 F.2d 1109 (D.C. Cir. 1971). The court held NEPA mandated a systematic and finely tuned cost-benefit analysis of each nuclear plant the AEC licenses. Detailed guidelines were issued, 10 C.F.R. § 11.55 (1973), and the AEC has made a good faith effort to follow them. However, the unavailability of hard ecological information has left the Commission with little choice but to continue licensing plants. *See, e.g., In re* Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), Nos. 50-369, 50-370, 3 CCH ATOMIC ENERGY L. RPTR. ¶ 11, 707.03 (Initial Decision Atomic Safety & Licensing Bd., June 13, 1973) (conclusion of the Board that since all existing environmental data was exhausted at the evidentiary hearing and other information would only be available after further studies there were no facts in dispute and thus

> there is nothing in the record before us which suggests that a further hearing at the construction permit stage would produce additional evidence that might change the conclusions reached in the initial decision.

Id. at 17,813-50); *In re* Long Island Lighting Co. (Shoreham Nuclear Power Station), No. 50-322, 3 CCH ATOMIC ENERGY L. RPTR. ¶ 11,705.04 (Initial Decision Atomic Safety & Licensing Bd., Apr. 12, 1973) (refusal to postpone decision on location of intake to determine if environmental survey could resolve uncertainty as to environmental impact because delay would impair the reliability of service and be costly to customers). In most cases the applicant is, however, required to implement a monitoring program and must be in a position to eliminate or significantly reduce any irreversible effects the program detects. *In re* Commonwealth Edison Co. (La Salle County Nuclear Power Station, Units 1 and 2), No. 50-373, 50-374, 3 CCH ATOMIC ENERGY L. RPTR. ¶ 11,706.05 (Initial Decision Atomic Safety & Licensing Bd., Sept. 5, 1973).

Courts have imposed some duties on agencies to generate information under NEPA, but following common law analogies have limited the duty when future adverse impacts are speculative. In Environmental Defense Fund, Inc. v. Corps of Engineers, 348 F. Supp. 916 (N.D. Miss. 1972), *aff'd* 492 F.2d 1123, 6 ERC 1513 (5th Cir. 1974) it was held that although an environmental impact statement must or project to decide whether an activity or project should be undertaken. There is considerable debate over the nature of the technology assessment process. Some have argued that it should be a purely adversary process while others have characterized it "as a neutral application of scientific analysis to future outcomes and alternatives."[46] Our own view is that technology assessment is ultimately a policy choice but that questions of scientific inference are intertwined throughout the process. To appreciate the strengths and limitations of scientific information it is useful to divide technology assessment into three stages.

The first stage is *information assembly and display.* Existing technology assessment legislation is designed primarily to achieve a greater information base for subsequent decisionmaking. The amount of information produced is, of course, subject to the constraint of cost, but we assume that substantial public and private resources will continue to be allocated to information assembly and display. The second stage is *inference drawing* based on the available information to determine what predictions of secondary and tertiary impacts are possible. This process is solely one of scientific judgment. No judgment is made as to whether the impacts should be considered adverse or beneficial. The third and final stage is *the evaluation of the scientific judgment* in light of the criteria the decisionmaker considers relevant. The evaluation may continue to be largely scientific for the

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> thoroughly discuss the *significant* aspects of *probable* environmental impact . . . [by] definition, this excludes the necessity for discussing either insignificant matters, such as those without import, or remote effects, such as mere possibilities unlikely to occur as a result of the proposed activity. This criterion not only adheres to the CEQ guidelines but comports with a rule of reason; it does not, however, encompass the necessity for disclosing "all known possible environmental consequences."

Id. at 933. *Compare* Environmental Defense Fund, Inc. v. Corps of Engineers, 325 F. Supp. 749, 759 (E.D. Ark. 1971), *aff'd*, 470 F.2d 289 (8th Cir. 1972) ("all known *possible* environmental consequences" must be disclosed). The leading case on the contents of the impact statement synthesized these two standards and adopted, based on U.S. Army Corps of Engineers Regulations, the standard that "an impact statement should contain 'all possible significant effects on the environment.'" Sierra Club v. Froehlke, 359 F. Supp. 1289, 1342 (S.D. Tex. 1973). Courts have generally approved the incorporation of existing scientific literature into the impact statement but it has been suggested that new research may be required if existing knowledge raises the possibility of potential adverse environmental effects. Environmental Defense Fund, Inc. v. Hardin, 325 F. Supp. 1401 (D.D.C. 1971). *See* F. ANDERSON, NEPA IN THE COURTS: A LEGAL ANALYSIS OF THE NATIONAL ENVIRONMENTAL POLICY ACT 214-17 (1973); D'Mato & Baxter, *The Impact of Impact Statements Upon Agency Responsibility: A Prescriptive Analysis*, 59 IOWA L. REV. 227, 239 (1973).

46. Coates, *Technology Assessment: The Benefits . . . the Costs . . . the Consequences*, THE FUTURIST, Dec., 1971, at 225, 228.

questions can be framed as technical ones: What are the risks of the activity? What are the monetary costs and benefits of the activity?[47] The question may also be framed to permit technical criteria to be supplanted. For example, the issue can be framed in terms of the kind of society to be desired in the future.[48] What options for present and future generations should be preserved? The proper relationship between scientific judgment and final value choice is complex and not clear. Despite a growing skepticism toward science, based largely on the realization of the destructive potential of nuclear fission, many advocate or assume that principles of environmental management can be derived from ecology. The political scientist and student of ecology L. K. Caldwell has argued:

> The primary contribution of ecology to the practical task of environmental protection would be to establish ecological baselines, parameters, ranges and gradients for sustaining life at various conditions of stability and diversity. A rational approach to public policy would seek, therefore, to establish ecological baselines to meet the known needs and values of society.[49]

We have earlier referred to others who argue that risk-benefit decisions can and should ignore scientific evidence.

In this Section of the Article we explore the relationship between the problems studied by the science of ecology and the difficult problems of value choice faced by decisionmakers forced to choose between alternative uses of our natural resources. Our objective is to refine the role of scientific information in risk-benefit analysis by analyzing its strengths and limitations. We first develop a model of ecology to explore the questions ecologists ask in studying change in natural ecosystems and compare the questions to those which lawyers and decisionmakers ask when the change must be evaluated for the pur-

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47. Current theories of technology evaluation are generally based on the principle that resource use should be maximized. Use of a resource is considered maximized if the benefits from its use exceed its costs. The selection of the proper policy is thus a calculation based on the underlying statistical base. This theory of policy choice has been powerfully criticized on the grounds that it reduces complex structures to an unstructured set of components rendered comparable by simple exchange rates or indifference functions but it is fallacious because individual preferences are more complex and discoutinuous. Tribe, *Policy Science: Analysis or Ideology*, 1972 PHILOSOPHY & PUB. AFFAIRS 66, 87. *See also* B. COMMONER, SCIENCE & SURVIVAL (1963).

48. *See* Tribe, *Technology Assessment and the Fourth Discontinuity: The Limits of Instrumental Rationality*, 46 S. CAL. L. REV. 617 (1973).

49. L. CALDWELL, ENVIRONMENT: A CHALLENGE TO MODERN SOCIETY 99-100 (1970).

poses of regulation and assignment of responsibility. In the final Section we analyze the current use of the concept of risk-benefit analysis to determine if existing concepts of cause are appropriate for risk-benefit analysis in light of the constraint of uncertainty, and whether modification of burden of proof allocations can aid risk-benefit analysis.

A. Four Categories of Ecological Information

It is possible to distinguish four different states that may exist when scientific information is sought about ecological systems.[50] First, the information sought may be both available and definite. Second, the information may be available but inherently indefinite or uncertain. Third, the information may not be available but still be obtainable, at least theoretically. Fourth, the information may be unavailable and unobtainable. These four states represent four categories of ecological information.

The difference between the first two categories depends on the fact that the information in the first category is based on phenomena that have been completely described and are not random, while information in the second category is based on completely described phenomena that are random or on phenomena that appear to be completely described and random but that are actually so complex that they can neither be described completely nor be distinguished functionally from random phenomena at the present level of technology. Information about inherently random systems may be complete, accurate and fully descriptive, yet provide only an uncertain prediction of what will happen in a specific case.[51] The knowledge is expressed in statistical terms; *i.e.*, in terms of probabilities. A statement about the sex of a child about to be born can only be given in statistical terms. For any given birth, assuming there has been no prior sex selection by amniocentosis and selective abortion or any other method, there is a 48.5 percent probability that the child will be female.[52] This statement is uncertain in that it does not provide precise informa-

50. Marcia Gelpe would like to express her appreciation to David F. Parkhurst, Assistant Professor of Public and Environmental Affairs, Indiana University, Bloomington, for reading over the material in this section and offering helpful and constructive comments. Errors that remain are the authors'.

51. The same is true for all practical purposes for information about systems which are functionally indistinguishable from inherently random systems.

52. This figure is an average for all live births. On the average, 100 females are born to each 106 males. I. Herskowitz, Genetics 105 (1962). The ratio varies somewhat for groups that differ in parental age, with the percentage of girls being higher (although still less than 50 percent) for older parents. *Id.* at 106.

tion on what will happen in a specific case. One is left ignorant of whether a given child will be a boy or a girl. But the statement is not uncertain in terms of whether it is completely accurate. There is a 48.5 percent probability that a given child about to be born will be female. If the statement is taken as descriptive of a system rather than an individual event, there is no uncertainty in any meaning of the term. But despite the accuracy in describing the system, the outcome of individual events is not precisely predictable.

The third category of ecological information involves three subcategories which differ in the ease and practicality of obtaining the necessary information. In subcategory (A), the information can be easily obtained by the time a decision must be made and requires no significant commitment of resources. For our purposes, such information may be treated as that in either the first or second category, depending on the nature of the information involved. In cases within subcategory (B) the information is not readily obtainable due to time or cost, but the inability to obtain the information could in fact be cured by a greater commitment of resources to the problem. Subcategory (C) is composed of those cases in which the inability is theoretically but not practically curable. The situation in (C) may arise from one of two sources. First, obtaining the required information may be so extremely impractical that any foreseeable commitment of resources to the study of the problem could at best provide information which would reduce the uncertainty in the present state of knowledge, but which could not remove that uncertainty. For example, a modification of a watercourse may have a significant impact at a great distance from the place where it occurs.[53] Theoretically, all natural species and physical phenomena within 100, 1,000, or 10,000 miles of the site of the change could be studied to determine whether there were any impact on them. In fact, such extensive studies would never be done. All major marine species within 10 miles might be studied and this would provide more information than if there had been no study at all, but it would not provide all relevant information. Uncertainty would have been reduced but not eliminated. Second, the situation in subcategory (C) may arise where there is a time set for making a decision and it is impossible to acquire the necessary information by that time; *i.e.*, studies involving longer periods of time are necessarily involved.[54] For example, one could theoretically determine the

53. *See* note 94 and accompanying text *infra*.

54. It may also be impossible at a given point in time to obtain information in one field because necessary information in other fields is not yet available. Break-

effects of long term exposure to a new pesticide on human reproductive potential. To gain the data a study extending over many years would be necessary. The issue of whether the pesticide should be allowed to be registered may be presented long before the study could be completed. Moreover, unless the pesticide were registered and its use permitted, it is highly unlikely that data on the effects of long term exposure could ever be gathered. To the extent that the information in subcategory (C) cases will not be provided; *i.e.*, to the extent that any uncertainty involved will not be removed, situations in this subcategory are like those in the fourth category. It is possible, however, that if the nature of the information in subcategory (C) is recognized, steps will be taken or reasonably can be taken to reduce the uncertainty involved. To this extent, the information is like that in subcategory (A) or (B).

The fourth category, involving information that is unknown and unobtainable, can be illustrated by the question of what the effects on all the components of an ecosystem would be if a gross irreversible change were introduced into the system. The only way to fully determine the effects would be to introduce the change, and since the change would be irreversible, one would get information which would then be useless since the system would already have been changed.

To recapitulate, the categories and subcategories of ecological information may be outlined as follows:

1. Available and definite
2. Available and indefinite
3. Unavailable but theoretically obtainable
   A. Practically obtainable without significant commitment of resources
   B. Practically obtainable with significant commitment of resources
   C. Practically unobtainable
      (1) Necessary resource commitment too great
      (2) Necessary time too long
4. Unavailable and theoretically unobtainable

These four categories of information differ in their significance for the decisionmaker. No special problems arise in dealing with information

throughs in understanding in one area may depend on development of knowledge in another area and on advances in instrumentation. Gates, *Toward Understanding Ecosystems*, 5 ADVANCES IN ECOLOGICAL RESEARCH 1 (1968).

in the first category. Information in the second category states the dimension of a risk. The decisionmaker must then decide whether to take the risk. It is important, however, that he understand that none of the risk is attributable to an insufficiency of information, so that allocation of information-gathering roles cannot properly play any part in the decision. In dealing with information in the third category, where there is an insufficiency of information, the decisionmaker will need to consider the cost of obtaining the necessary information and allocation of that cost as well as the difficulties of dealing with the issue at hand if the information is not obtained. This latter difficulty is the central problem presented by information (or the lack of information) in the fourth category. Category four cases are in some respects like category two cases but there is the added problem that the number of different risks involved and the dimensions of these risks may not be susceptible to accurate determination or even reasonable estimation.

It is maintained that the limitations expressed here on the information about ecological systems stem at least in significant part from the nature of those systems.[55] To support this assertion, we shall examine some pertinent features of ecological systems and identify how such features place limitations on what may be known about the systems.[56] The inherent nature of ecosystems[57] places fundamental limits on the information that may be obtained about them in four ways. First, it leads to difficulties in describing the systems. Second, it inhibits the identification of causal relationships between new factors intro-

55. *Cf.* Murdoch, *Ecological Systems*, in ENVIRONMENT, RESOURCES, POLLUTION & SOCIETY 1, 16 (W. Murdoch ed. 1971) [hereinafter cited as Murdoch]. Murdoch maintains that much of what is said here on the nature of information about ecological systems and the effects of environmental disturbances on such systems also applies to information about the effects of environmental disturbances on human social and psychological phenomena. *See generally* Interview with Dr. Stanley M. Greenfield, Assistant Administrator for Research and Monitoring, U.S. Environmental Protection Ageucy, Apr. 8, 1971, in M. GORDEN & M. GORDEN, ENVIRONMENTAL MANAGEMENT; SCIENCE AND POLITICS 4, 11 (1972) [hereinafter cited as Greenfield Interview].

56. This paper does not include consideration of limitatious on scientific or ecological information that derive from sources other than the inherent nature of the systems studied, although the problems presented in dealing with such information may be similar to the problems identified here. A limitation beyond the scope of this paper that immediately comes to mind is that found in studying effects of environmental alterations on man. Humanistic and political notions may limit the amount and type of experimentation involving hnman beings. Such limitations are treated here as having an origin other than the inherent biological nature of the human species.

57. An ecosystem is "the total sum of organisms, the environment, and the processes of interaction between and within all parts of the system." Gates, *Toward Understanding Ecosystems*, 5 ADVANCES IN ECOLOGICAL RESEARCH 1 (1968).

duced to the systems and changes within the systems. Third, it leads to difficulties in making predictions about how systems will react if novel factors are introduced. Fourth, it dictates that much information about ecosystems must be stated in statistical terms.

One generally begins a study of anything by describing the subject of the study. Yet the ecologist can never fully describe an ecosystem and invariably must work with a subject the characteristics of which he is more or less ignorant. Furthermore, causal relations may be difficult to establish even for a system whose components are fully described. Even where presently operating cause-effect relationships are described, it may not be possible to predict the effects of similar factors acting on another ecosystem. Moreover, while difficulties in prediction may depend on the inability to completely describe the system, they may also be of independent origin.[58] Finally, to the extent that the system under study behaves randomly, that system can be described only by statements of the probability that some phenomenon exists or will occur.

B. Description of Ecosystems

Difficulties in describing ecosystems stem primarily from the large number of components in such systems, the fact that many species in any system occur only rarely, and the multiplicity and complexity of interactions between system components.[59] Of course, these factors also contribute to the difficulties in establishing causal relationships and in making predictions.

Even the simplest natural ecosystems have huge numbers of components. Evans Old Field, a 12-acre plot owned by the University of Michigan, is an abandoned farm that is now grazed by wild deer, and is a relatively simple system.[60] According to a 1971 report, 2,190 species of higher plants and animals have been identified on the plot.[61]

58. Mayr, *Cause and Effect in Biology*, in CAUSE AND EFFECT 33, 46-48 (D. Lerner ed. 1965) [hereinafter cited as Mayr].

59. The individual populations of the various species that make up an ecosystem often are also structurally complex. Population complexity, of course, contributes to ecosystem complexity. For a brief discussion of sources of population complexity, many of which are similar to the sources of ecosystem complexity, see Pimentel, *Complexity of Ecological Systems and the Problems in Their Study and Management*, in SYSTEMS ANALYSIS IN ECOLOGY 15, 17-23 (K. Watt ed. 1966) [hereinafter cited as Pimentel].

60. Murdoch, *supra* note 55, at 1.

61. *Id.* The 2,190 species include 1,800 species of insects, 250 species of birds, mammals and other animals, and 140 species of herbs and grasses. Protozoa, bacteria

By contrast, a very complex tropical rain forest has been found to support 200 different species per hectare of trees alone (there are no grown trees in the Old Field) and 667 species of breeding birds (compared with 250 species of *all* animals except insects in the Old Field).[62] These figures represent data for intensely studied areas, and yet are still not complete species lists for either environment.

The large number of species found in most natural ecosystems leads to a difficulty in identifying all the components of such systems, which is compounded by the tendency of most species to be rare at any given time and place.[63] Living communities are characteristically made up of comparatively few species that are each represented by a large number or mass of individuals and a comparatively large number of species that are each represented by few individuals or a small mass of material.[64] Thus, in one analysis of the vegetation in a grassland area, of 29 species present, there were 20 which were found to be rare; each of these accounted for 1% or less of the community, as measured by percent of the soil surface coverage they composed.[65] It is at best difficult to find all of the rare species in a system. In fact, while the identification of species components of an ecosystem is theoretically possible, it is, in practice, impossible due to the problems of large numbers, rarity, and to practical limitations on time and funds available for study. One prominent ecologist reported in 1969 that no one had catalogued all the species in any sizable area.[66] Yet identifying all species may be important in making certain predictions about natural systems. For example, rare species may play an important role by providing increased variety in the community and hence giving it a greater chance to survive environmental disturbances.

and fungi are not included. Identification has been made over a 20-year period of study. *Id.*

62. *Id.*

63. H. ANDREWARTHA & L. BIRCH, THE DISTRIBUTION AND ABUNDANCE OF ANIMALS 663 (1954). *Cf.* Preston, *Diversity and Stability in the Biological World,* 22 BROOKHAVEN SYMPOSIA IN BIOLOGY 1, 4 (1969), in which the author hypothesizes that commonness is distribnted lognormally among species. *See generally* Preston, *The Commonness, and Rarity, of Species,* 29 ECOLOGY 254 (1948). Preston's work involves the relative frequency of rarity. However, as long as the frequency of rarity is substantial, the problem discussed in the text remains.

64. E. ODUM, FUNDAMENTALS OF ECOLOGY 148 (3d. ed. 1971) [hereinafter cited as ODUM].

65. Rice, *Phytosociological Analysis of a Tall-Grass Prairie in Marshall County, Oklahoma,* 33 ECOLOGY 112 (1952). Ten species, or one-third of those found, each accounted for 0.1 percent (1/1000) or less of the soil coverage. *Id.*

66. Odum, *The Strategy of Ecosystem Development,* 164 SCIENCE 262, 265 (1969).

When a sudden change occurs in the environment of a community, the continued existence of that community may depend on the presence of individuals already able to survive in the new environment. While a formerly well-represented species may have been adapted or well-suited to surviving in the old environment, it may be unable to survive under the changed conditions. If there is a rare species with the present capacity to survive in the new environment due to a different genetic constitution, it may take over part of the role of the predominant species in the community. Where this role is crucial to the community, the capacity of the rare species to step in assures community survival, or community adaptation to the new environment. To the extent that the former rare species differs in its role from the old dominant, the character of the community is changed.

Such an essential rare species role is illustrated by the change which occurred in some Long Island Sound aquatic communities when duck farming was begun in the area.[67] Aquatic communities are generally dependent on phytoplankton[68] as "producers," or manufacturers of food from inorganic materials for other living things. In some areas of Long Island Sound, "blue-point" oysters, which fed on the phytoplankton, were economically important members of the offshore aquatic communities. When large-scale duck farming began on the shore, large amounts of organic manure were introduced into the waters. The species of phytoplankton that had been dominant were unable to tolerate the enriched water. There were several rare phytoplankton species that could exploit the changed conditions and they became the new producers for the community. Oysters, however, could not utilize the new phytoplankton as food and died out. Thus the presence of the rare phytoplankton species insured survival of the community but also led to a change in at least one of its components. The ascendance of the rare species had not only ecological but also economic importance.

In this case a study of only the predominant species would produce an incomplete description which would then contribute to an inability to predict the effects of a change on the system. Yet most studies are practically limited to consideration of only the most common or dominant species. The necessity for concentrating on the dominants in a system where there are many rare species with potentially important roles therefore limits what we can know about the systems.

67. This account is taken from ODUM, *supra* note 64, at 112.

68. Phytoplankton are very small floating plants, mainly algae.

Even where the biological and physical components of an ecosystem are identified, it is difficult to describe the interactions between these components due to the large number of such interactions and their complexity. A forest system described by Watt is illustrative:

> [A] highly abstract forest is assumed, in which only the following factors are considered: weather, trees, man, insect defoliators, birds (warblers), spiders, [insect] parasites, and insect diseases.
>
> Now suppose that in a particular year the spring season is unusually hot for the time of year. This will have the following results. The trees will grow fast and flower early. Because of this, insect defoliators that eat the flowers will gain two advantages: food will be available earlier, which is an indirect benefit of the good weather, and their own metabolic rates will be speeded up so that they can utilize the earlier-available food to grow faster, a direct benefit of the weather. On the other hand, good weather will have an effect on each of the types of organisms that attack the pests: [some] have their metabolic rates speeded up so that they will attack faster, but diseases which are most effective in cool, damp weather will be less effective than usual. The various weapons which man can use against a pest have their effectiveness in turn governed by weather; this is true for parasites, predators, disease and insecticides.
>
> Consider the [insect-eating] birds. They eat the insect defoliators, and hence are in competition with insect parasites and spiders. The more pests the birds eat, the less are available for the other [insect-eating] organisms. Further, if a bird eats a defoliator larva containing a parasite larva, the bird is a predator of the parasite larva, in a very real sense.
>
> Finally, consider the defoliators. They regulate the probability of tree survival, and hence the economic life of the human community which earns a living cutting down the trees and transporting them to mills. Hence, they also affect the probability that trees will be cut down here in the future. The defoliators govern the density of all their enemies because as the pest larvae build up in density from year to year, the birds, spiders, and parasites will show various degrees of numerical response to this, in order to exploit the increased availability of food.[69]

Watt's description illustrates that large numbers of related interactions may exist in a system.[70]

69. Watt, *The Nature of Systems Analysis*, in SYSTEMS ANALYSIS IN ECOLOGY, 1, 1-2 (K. Watt ed. 1966) [hereinafter cited as Watt].

70. *See also* Pimentel, *supra* note 59, at 23-25, where the complexity of food

Even between just two components, there may be more than one mode of interaction. Take, for example, feedback mechanisms. These are interactions in which the effect of one component (*A*) or another (*B*) influences the future effect of *A* on *B*. A common feedback mechanism is that in which an increase in the number of prey organisms leads to an increase in the predator population, which then eat more prey organisms and by stabilizing or decreasing the size of the prey population shut off the prey's effect of increasing the predators. Thus, in Watt's simple forest, an increase in the number of insects and insect larvae, providing more food for spiders, should at first tend to cause an increase in the number of spiders. As the spider population increases, there is added pressure on the insect population—more insects are eaten—and the number of insects would tend to decline. The original effect of the insects, that of increasing the number of spiders, would be cut off. Another way of stating this phenomenon is to say that there is feedback by which the *B* factor, spider population size, could influence the effect of the *A* factor, insect population size, on *B*.[71]

One factor may also have multiple and opposite effects on another factor in an ecosystem. Thus, while warm weather may increase tree growth, it can also cause an increase in the size of the population of insect defoliators, which, in turn, tend to cause a decrease in tree growth by eating tree leaves. Here, the warm weather tends to have one direct effect on the trees and a different indirect effect.

These are only examples of the large number of interactions that may appear in an ecosystem and give it the character of " '[a]n interlocking complex of processes characterized by many reciprocal cause-effect pathways.' "[72] Beyond the interactions within a system, the investigator must often be concerned with interactions between systems. Ecosystems are all open to some extent[73] and may interact with each other in a variety of ways. The causative agent of an occurrence in one system might be a change in another system. For instance, migration may cause events in one ecosystem to influence the state of another system. Thus, salmon, important ocean predators which migrate to fresh water to spawn, link two ecosystems and are a medium by which events in their ocean habitat can be influenced by the conditions

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chains and webs, or "who eats whom" interactions, is discussed briefly.

71. Predator-prey feedback mechanisms have been described for other organisms, *see, e.g.*, T. Lewis & L. Taylor, Introduction to Experimental Ecology 21 (1967).

72. Watt, *supra* note 69, at 2.

73. Murdoch, *supra* note 55, at 18.

of their fresh water river spawning grounds.[74] For such intersystemic interactions, as for multiple intrasystemic interactions, complete identification may be theoretically possible, but in some cases it is impossible in practice.

The complexity of the interactions in ecosystems, as well as their multiplicity, contributes to the difficulty of describing biological systems. Threshold phenomena are one type of complex relationship. The presence of a threshold relationship between two factors occurs when a change in one factor does not produce an apparent change in the other until a certain level of the first is reached. This level is considered the threshold level. If *X* and *Y* are the two factors, *X* may vary over a range of values without producing any apparent change in *Y*, but when *X* excedes the threshold, there is a change in *Y*.[75] That change may be quantitative or qualitative. If such a system is examined when *X* is at a sub-threshold level, it would not be possible to identify the relationship between *X* and *Y*. They appear to be independent. Yet the action of *X* on *Y* may be an important part of a full description of the system. Moreover, it is sometimes the case that as *X* varies there is only a quantitative change in *Y* until *X* reaches a certain level, at which point *Y* undergoes a qualitative change or a very different dimension of quantitative change.[76] In these systems, some relation between *X* and *Y* may be identified. Full description of the relationship through observation of the natural system may be impossible, however, if under normally occurring conditions *X* ranges only through values below that at which the qualitative change occurs.

The appearance of threshold relationships may depend on what feature of the affected factor is considered. The affected factor may change in response to variations in the first factor, but that change may not be perceived at certain levels and, therefore, no interaction identified. Take again *X* and *Y* as the two factors. Con-

74. *Id.* at 20.

75. *E.g.*, flight in gnats exhibits a threshold relationship to temperature. As maximum temperature varies from 3°C to 6°C, no flight is observed in a certain species of gnats. When the maximum temperature is at or above 6°C, flight occurs; thus, the temperature threshold for flight is 6°C. T. LEWIS & L. TAYLOR, INTRODUCTION TO EXPERIMENTAL ECOLOGY 141-44 (1967).

76. *E.g.*, in brook trout, as the temperature increases from 40° to 48°F, the fish become more active and swimming speed increases. At 49°F the effect of temperature increase changes and the fish become less active and swimming speed decreases from 49° to 60°F. At about 77°F there is another point of change and the fish die. A. TURK, J. TURK, & J. WITTES, ECOLOGY, POLLUTION, ENVIRONMENT 182-83 (1972).

sider, for example, that *X* is an environmental factor such as the amount of a toxic agent in the environment and *Y* is man. The question is asked what interaction exists between *X* and *Y*, or, more specifically, what effect factor *X* has on factor *Y*. How this question is answered depends on what feature of *Y* we consider when we look for an effect. If we consider the presence of detectable disease in *Y*, *X* may have no apparent effect for a wide range of values. In the same case, if we take the physiological state[77] of the body as the relevant feature of *Y*, there may be changes perceived in *Y* at levels of *X* which were sub-threshold when detcctable disease was considered. While such physiological changes may not lead to detectable disease, they may be important because they produce other ill effects, such as decreased longevity.[78] This illustrates that even when an apparent threshold relationship is identified, it is not safe to assume that nothing happens until the threshold is reached. There may be real but unrecognized changes occurring within the system, even at "sub-threshold" levels. A scientist studying the system may not be able to identify sub-threshold changes due to the practical infeasibility of checking all of the features of the *Y* factor that could conceivably be affected by *X*, or due to the technical impossibility of monitoring the changes that are occurring in *Y*. Still, the changes are there, and may be relevant to the problem under consideration.

The complexity of phenomena and systems discussed here is a common feature of biological systems.[79] While such complexity is generally thought to be important in maintaining the stability of natural systems,[80] it does make them difficult to analyze. Furthermore, there

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77. The physiological state may be all or some of the reactions occurring within the cells, intercellular media, and organs.

78. In summarizing the findings of the various contributors to the book ENVIRONMENTAL FACTORS IN RESPIRATORY DISEASE, editor Douglas Lee states:

> Acute responses to relatively high doses of a toxic agent are often dramatic or even lethal. But the lesser effects of lower doses, particularly where repeated over long periods of time, may in the long run be of greater significance for the productivity and welfare of an exposed population, or even of the individual. Acting imperceptibly, producing only small immediate changes in function, or eliminating only small segments of the lung at any one time, they do not draw attention to their operation until a considerable amount of damage has occurred.

Lee, *Conclusions and Reservations*, in ENVIRONMENTAL FACTORS IN RESPIRATORY DISEASE ch. 17, at 247, 251 (D. Lee ed. 1972).

79. Mayr, *supra* note 58, at 47; Murdoch, *supra* note 55, at 16.

80. Murdoch, *supra* note 55, at 20-21. If this is true, complexity is widespread because it occurs as the result of evolutionary selection. Simply stated, this means that if complex communities are stable and therefore have the best chance to survive, most surviving communities will be complex.

are methodological problems in analyzing ecosystems which restrict the information that may be obtained. The methodological problems are themselves related to the characteristics of the systems. Most biological problems are subjected to close analysis through laboratory studies. In the lab, variables one wishes to eliminate from consideration are controlled. One or more other variables are altered, and the effects on the system measured. Laboratory work is particularly difficult in studying whole ecosystems, however. It is impossible to take a whole natural system into a lab or to reproduce a system of great size or complexity in the laboratory. It may be possible to remove a portion of a system to a lab, but this simplifies the system and such simplification may eliminate the elements of the system that are necessary to understand its functioning. Field studies, on the other hand, may not only be difficult but also are subject to severe constraints on the investigator's ability to control all of the potentially significant variables. Furthermore, any investigatory disruption of the system may change the feature which the investigator seeks to study.[81]

To meet some of the problems, systems analysis is being used in studying ecosystems.[82] The processes involved have been described as follows:

> Basically, the system is analyzed in terms of simple components. The variables and processes affecting each component are analyzed and described so that changes through time can be described and predicted. The way the various components fit together is also analyzed, and finally these units are then reassembled in a model of the whole system. Almost invariably this involves the use of a computer to simulate the consequences of changes in the variables controlling the system.[83]

However, even with the use of such techniques, initial description of the system is crucial,[84] yet system description is still subject to the difficulties discussed above. Systems analysis may help in identifying in-

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81. *See* Mayr, *supra* note 58, at 47.

82. *See generally*, K. WATT, ECOLOGY AND RESOURCE MANAGEMENT [hereinafter cited as ECOLOGY] (1968); Dale, *Systems Analysis and Ecology*, 51 ECOLOGY 2 (1970); Watt, *supra* note 69. Recently it has been suggested that there will be a revolution in the study of ecosystems in the next 15 years due to the use of theoretical ecology, including computer models. *Theoretical Ecology: Beginnings of a Predictive Science* 183 SCIENCE 400 (1974).

83. Murdoch, *supra* note 55, at 17.

84. *See* Watt, *Ecology in the Future*, in SYSTEMS ANALYSIS IN ECOLOGY 253, 255 (K. Watt ed. 1966). Watt calls the step of describing the components of the system "systems measurement".

teractions within an ecosystem but cannot guarantee that the system description is complete.[85]

C. Identification of Causal Relationships

The scientific information required for environmental decisionmaking often turns on the identification of causal relationships.[86] While this is sometimes part of system description, it more often presents a separate problem involving an external influence on an ecosystem. The scientist may be asked to identify the effect of some environmental disruption or to determine what feature of the environment caused an observed change in an ecosystem. His ability to answer these questions is limited by features of ecosystems that make identification of causal relationships difficult, features such as time lag effects, broad spacial effects and buffering.

The first of these, time lags,[87] arise when effects are remote in time from their causative agents. For example, many pathological effects of the environment on man are slow in developing.[88] Radiation levels that are not immediately lethal may cause damage that does not become apparent for one or two decades.[89] Some lung disease caused by exposure to occupational conditions may not appear until a lapse of more than 40 years.[90] The full effect of an environmental change may even be separated from its cause by generations. Where the causal agent leads to a change in the hereditary material, this change may be undetectable until it is expressed as an abnormal characteristic in a future generation. Moreover, sometimes the immediate effect of an environmental change differs significantly from the long-term ef-

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85. *See* Murdoch, *supra* note 55, at 17.

86. In a different but analogous context, J. H. Dales has identified four levels of knowledge of causal relationships.

> No knowledge is ignorance; *Level One* knowledge is capable of *identifying* a cause-effect relationship; *Level Two* knowledge is capable of *measuring* the total "receptor damage" resulting from any given amount of "emitter activity"; and *Level Three* knowledge can measure how much damage *each* receptor experiences as the result of a given level of activity by *each* emitter.

J. Dales, Private Damage and Public Harm (unpublished paper) on file with the Authors.

87. Lag phenomena, are those "in which an effect resulting from a cause is only completely revealed a considerable period after the operation of the cause." Ecology, *supra* note 82, at 64.

88. Dubos, *Adaptation to the Environment and Man's Future*, in The Control of the Environment, A Discussion at the Nobel Conference 59, 64 (J. Roslansky ed. 1967).

89. *Id.*

90. Selikoff, *Occupational Lung Diseases*, in Environmental Factors in Respiratory Disease ch. 13, at 199, 208 (D. Lee ed. 1972).

fect. The application of a pesticide may cause an immediate and severe decline in the size of a pest population, but that population may return to its original size after a generation or two.[91] Such time delays create significant problems in identifying causal relationships in two ways. First, it is difficult to detect effects that are temporarily remote from their causes. Sometimes studies spanning years or even generations are required.[92] Even then, the effect may not be readily associated with the cause, and the causal relationship may be overlooked by investigators.[93] Second, when an effect is temporally remote from its cause, there is an increased chance that other factors operating in the interim will change or mask the effect. Even if intervening events have no effect, proof of the fact that there is none may be difficult or impossible.

Similar problems arise when the effect of an environmental disruption is geographically remote from the site of the disruption, or when the effect occurs over a broad spacial area. The building of the Aswan High Dam was an environmental disruption which is thought to have had significant spacially remote effects. After the dam was built, a drop in the sardine catch in the eastern Mediterranean was

91. This is caused by homeostatic mechanisms for maintaining population size stability that have evolved in the pest population. ECOLOGY, *supra* note 82, at 64.

92. In a comment on the effect on man of long-term exposure to low doses of many substances such as air pollution, radiation and hazardous materials, Dr. Stanley M. Greenfield, then Assistant Administrator for Research and Monitoring of the U.S. Environmental Protection Agency, stated:

> This is a very difficult type of effect to sort out because normally such effects require a host of statistics extending over long periods of time—probably many lifetimes, maybe generations of animal experiments.

Greenfield Interview, *supra* note 55, at 8.

93. A related problem is that of identifying causal relationships where either a possible causal factor or an effect is cyclical. Study of such problems generally depends on data gathered over a number of cycles. If each cycle is several years, such studies necessarily take a long time. *See* Murdoch, *supra* note 55, at 16.

The complexities of ecosystems often also mandate lengthy periods of study to gain even partial explanations of observed phenomena. Murdoch discusses this problem in the context of studying population dynamics, or population characteristics such as structure, size, growth and dispersal, and the causes of fluctuations in these characteristics:

> An illustration of the difficulties is the very large scale and intensive work which was carried out on the spruce budworm (caterpillar) which is a pest of balsam fir forests in New Brunswick, and breaks out periodically after several years of good weather. After 15 years' study the major causes of mortality had been found for most of the life stages in the insect, but after this enormous effort, it is still not known what normally limits their numbers . . . . Other 15-20 year studies of animal populations have been made which do not provide a complete answer, and an important lesson is that field studies are difficult and require a long time. This is something which decisionmakers have to learn about ecosystems.

Id. (footnote omitted).

observed. The catch decreased from 18,000 tons per year to 500 tons.[94] The basis of this correlation is unclear. It has been suggested that the dam caused a change in salinity which led to a decrease in the sardine population, which was reflected in the smaller catch.[95] Alternatively, a reduction in nutrients feeding into the sea may have been the cause. Before the dam was built, annual floodwaters of the Nile carried large amounts of nutrients into the sea. This supported phytoplankton which may have supported the large sardine populations. The dam stopped the flooding and the rich nutrient supply, possibly reducing the phytoplankton population and, therefore, the population of the fish feeding on the phytoplankton.[96]

In such cases, spacially extensive studies may be necessary to observe all relevant effects. Moreover, as with temporally remote effects, there is a large chance for intervening factors to occur, altering or masking the causal relationship. Therefore, it is very difficult to identify an association of two distant events or to prove a causal relationship once an association is identified. Moreover, what has been said here about the difficulty of identifying effects that are temporally or spacial remote from their cause applies in the reverse situation; that is, when an effect is identified, it is also difficult or impossible to identify the cause if that cause was remote.

The presence of alternative pathways and buffering mechanisms within natural systems also produces problems in finding cause-effect relationships. Natural ecosystems generally include potential alternate pathways for performing one function.[97] The alternative pathways create a buffering effect. When a system is buffered, there can be some degree of change in one part of the system without seriously affecting the other parts. For example, one animal species may have many alternative sources of food within an ecosystem. It may be possible to remove one food source of that animal and have no effect on the size of its population because it has sufficient alternative food sources.[98] Moreover, if the system is really well buffered, the added pressure on each alternative food source will not be large enough to substantially change the population sizes of the prey species. A disturbance introduced into such a complex well-buffered ecosystem does

94. Murdoch, *supra* note 55, at 20.
95. *Id.*
96. *Id. See also* McCaull, *Conference on the Ecological Aspects of International Development*, 2 NATURE AND RESOURCES 5, 7 (1969).
97. Mayr, *supra* note 58, at 47.
98. *See* Murdoch, *supra* note 55, at 21.

not seriously disrupt the system; looking at our hypothetical system in general, one might say that the removal of one food source has no effect. In reality, however, there is some adjustment in the internal mechanisms of the system. The system has lost one alternative pathway and may have become more susceptible to future disruption.[99] Yet it would be difficult to perceive the effect because it would not result in any immediate change in the readily observed external features of the ecosystem. Whether the change would even be possible to identify would depend, first, on whether the alternative pathways had been identified and, second, on whether methods were available which were sufficiently sensitive to measure the degree of change occurring in alternative pathways as a result of suppression of one of the pathways.

The difficulties explored above in identifying causal relationships are immediately relevant to the legal system in some cases, such as when the issue is presented whether the effluent from the defendant's plant caused a fish kill observed downstream. Moreover, the problem may be relevant to the more general issue discussed next, namely, that of predicting the effects on an ecosystem of environmental disturbances. To the extent that information about what has happened in one ecosystem informs us about what will happen in another,[100] the difficulty in establishing a causal relationship in one system contributes to the difficulty in making predictions about another.

D. Prediction of Effects

In many cases of environmental decisionmaking the central scientific question is one of prediction; *i.e.*, if a project entailing certain disturbances of the environment is undertaken, what effect will there be on natural systems? We turn then to an examination of the features of natural systems that make accurate predictions of environmental impacts difficult or impossible.[101]

99. This also suggests the legal problem involved in dealing with additive effects. What is to be done about liability for a disruption that does not harm an ecosystem but increases the chance that the next disruption will cause harm?

100. *But see* discussion of uniqueness, notes 102-05 and accompanying text *infra*.

101. It is conceptually very difficult to draw a clear line between the characteristics of natural systems which make it impossible to describe those systems, or to identify causal relationships in them, and those characteristics which make it difficult to predict the effects of environmental disruptions. In one sense it could be said that a complete description of a system includes a description of those elements which will react to an environmental disruption and of how they will react. However, it seems that understanding is aided by separating questions of present state from those of future

The difficulties in describing the systems are, of course, relevant to this inquiry. One can hardly predict how unidentified features will react to change, or how they will affect the reactions of identified features. Independent of this there are problems in predicting the reactions of the identified features. These problems are attributable to the uniqueness of each system, thresholds, and interactions that are synergistic.

Each ecological system is unique.[102] This means that it is difficult to predict the characteristics of one system based solely on the characteristics of another. To some extent each system requires individual study. One can say that Spot Pond resembles Mill Pond and predict that what we know about the ecology of Spot Pond also applies to Mill Pond, but there is sure to be some difference between the two pond systems and, therefore, some uncertainty to the prediction. Predictions are not impossible,[103] but they always entail some degree of uncertainty. Furthermore, in the absence of a complete study of Mill Pond, it is impossible to precisely determine the magnitude of the uncertainty. If the necessary commitment of time and resources to the study of Mill Pond is made, the uncertainty may be reduced, but never eliminated.[104]

Even if two systems appear identical at any point in time, they may differ due to differences in their histories. Ecological systems are often non-Markovian: future states cannot be predicted on the

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reaction. It is also true that some factors which affect description or identification of causal relationships also independently affect predictions. Threshold interactions, for example, are important in both description and prediction. However, an effort has been made to minimize repetition in discussing such factors.

102. Mayr, *supra* note 58, at 46-47; Murdoch, *supra* note 55, at 16.

103. In fact, some information about one community may be useful even in studying another distant community with different species if the environmental conditions and community structures of the two are similar. Different species may perform similar roles in such communities. Lollock, *Temperature-Biological Aspects Related to Nuclear Power Plant Siting, Operation, and Other Considerations*, 8 THE FORUM 381, 389 (1972).

104. The fact that differences between two similar systems may be crucial when dealing with environmental problems is illustrated by a comparison of the mosquito control programs at two artificial lakes, one in the Tennessee Valley and the other the Volta Lake in Ghana. At both sites malaria outbreaks were caused by malaria-transmitting mosquitos associated with aquatic environments. In the Tennessee Valley, the mosquitos were successfully controlled by raising and lowering the water level about one foot every seven to 10 days. Tests at Volta Lake, where a different species of mosquito was the malaria vector, showed that similar treatment would increase the number of mosquitos. Kassis, *Ecological Consequences of Water Development Projects*, in THE ENVIRONMENTAL FUTURE, PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON THE ENVIRONMENTAL FUTURE 216 (1972).

basis of present states alone.[105] This is attributable to the fact that the future states of individuals, populations, and ecosystems depend on their hereditary, or genetic, composition. The genetic components and potential of the populations in a system are products of the populations' and system's histories and are not necessarily fully revealed in their actual or observable present state. Thus, two populations of the same species may show the same structural and functional traits in the present but have different genetic compositions which can produce different future populations or different responses to new environmental factors. Similarly, two ecosystems that appear to be alike may have very different future potentials due to differences in the genetic compositions of the represented species. The future of each ecosystem thus is not completely predictable from its present state alone. Since it is not possible to obtain a complete hereditary history of a natural system, predictions of future states are to some degree impossible. Moreover, evidence of the effects of a factor of change on one experimental system are not transferable even to an apparently identical system with complete certainty, since the second system may have historical and genetic differences from the experimental one. Genetic differences between ecosystems are an important source of uniqueness.

The role of thresholds in hindering identification of the interactions within an ecosystem has already been discussed.[106] Thresholds also complicate the process of predicting the effects of novel changes. Because of thresholds, responses to rate changes may not be linear. A change in quantity of input of some variable may even lead to a qualitative change in the biological system. Thus, if the effect of 1-, 2-, 3-, 4- and 5-degree changes in stream temperature due to the introduction of heated effluent is known, it may still be impossible to predict accurately the effect of a 10-degree change by extrapolation.

The presence of synergistic, or nonadditive, effects further contributes to the difficulty in making predictions about natural systems. The findings at one level of biological integration do not completely

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105. Murdoch, *supra* note 55, at 16.

> A Markov chain is a chance process having the special property that one can predict its future just as accurately from a knowledge of the present state of affairs as from a knowledge of the present together with the entire past history.

Billingsley, *Markov Chains*, in 9 INTERNATIONAL ENCYCLOPEDIA OF THE SOCIAL SCIENCES 581 (D. Sills ed. 1968).

106. *See* notes 75-76 and accompanying text *supra*.

explain the phenomena occurring at a different level.[107] Thus, the properties of a higher level are not all necessarily " 'a logical or predictable consequence of the properties of the [lower-level] components.' "[108] The characteristics of a forest are different than the additive sum of the characteristics of all the trees, shrubs, etc. Therefore, even if one knew all about trees and shrubs, one could not fully predict what a forest would be like. Separate descriptive studies at each level are necessary.[109] This does not mean that description of the higher level is impossible, but rather that accurate description of the higher level depends to some extent on empirical, rather than predictive, study.

Similarly, there may be synergistic interactions between factors: the effect of two factors acting together in an ecosystem may be greater or less than the sum of the effects of the factors operating separately. Such an interaction has been hypothesized for the production of lung cancer by asbestos exposure and smoking[110] and also for the effects of air pollutants and cigarette smoke on man.[111] In each case, the incidence of disease in groups of individuals who have been exposed to both factors is greater than the sum of the incidences in groups exposed to each factor alone.

Synergisms hamper predictions by making it impossible to predict with confidence the effect of two factors operating together from a knowledge of the effects of those factors operating separately. Thus,

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107. ODUM, *supra* note 64, at 5.

108. Mayr, *supra* note 58, at 47.

109. *See* ODUM, *supra* note 64, at 5-6.

110. McMahon, *Introduction: Concepts of Multiple Factors*, in MULTIPLE FACTORS IN THE CAUSATION OF ENVIRONMENTALLY INDUCED DISEASE 1, 10 (D. Lee & P. Kotin, eds. 1972). Synergistic effects of uranium exposure in mining and cigarette smoking in the production of human lung cancer have also been suggested. *Id.* McMahon also notes that when disease induction is considered, a synergism can be identified if the risk of disease from the two factors operating together is greater than the sum of the risks attributable to each factor operating separately discounted to compensate for the possibility of competing risks. *See id.* at 8.

111. Schaefer, *Some Effects of Air Pollution on Our Environment*, 19 BIOSCIENCE 896 (1969). Schaefer also suggests the mechanism which accounts for this synergism. Air pollutants are normally in the form of airborne particles to which the human body has highly resistant mechanisms. According to Schaefer's theory, when the cigarette smoker inhales, he draws these particles through the burning tobacco and the particles are vaporized by the heat. The chemicals in the pollutants are highly reactive in the vaporized condition. As they reach the lung, reactions may occur producing new chemicals which are deposited on or absorbed by the lung surfaces. *Id.* The chemicals can then have more of an effect on the body than they would if just inhaled in particulate form. Thus the damage caused by air pollutants is increased by combining air pollution and cigarette smoking.

when a novel factor is introduced into an ecosystem, there is the risk that its effect in combination with some factor already in the system will be quite different than the effect anticipated through study of the novel factor alone.

E. DESCRIPTION IN STATISTICAL TERMS

Some phenomena that may influence ecosystems or their component populations occur in random ways. Certain genetic events are random, as is weather, a feature of the physical environment that is part of ecosystems. Other events appear to be random, although it is possible that there are specific operative factors which account for observed variations but which cannot be perceived due to the complexity of the systems or the state of the art of monitoring techniques. In either case, at the best available level of detection the occurrence of some phenomena appears not only to be random, but also to be unrelated to the biological effects or desirability of their occurrence.[112] The best information that can be obtained about features of an ecosystem which involve real or apparent randomness is statistical in nature. Through observation, it may be possible to determine the frequency of association of two features in the system or the frequency of a certain change being associated with a certain result. The most general form of statement of such information is in a probability statement: "If *A*, there is *X*% chance that *B*." This statement means that there is a correlation between the occurrence of *A* and *B*, but that the correlation is such that *B* occurs only a certain percentage of the times that *A* occurs.[113]

Moreover, the statement about the presence of the correlation does not itself indicate the presence of a causative relation between the two events. "If *A*, there is *X*% chance that *B*" does not necessarily mean that *X*% of the time *A* causes *B*. *A* may cause *B*, but

112. Mayr, *supra* note 58, at 46. Thus, whether such a random event occurs is unrelated "to the evolutionary needs of the particular organism or of the population to which it belongs." *Id.* Simply stated, this means that an environmental condition which mandates that a change must occur in order for an organism, population, or ecosystem to survive has no influence on whether a random change does occur. It is also true, however, that once a random change does occur, environmental conditions may influence the effect of the change on the population or, in the case of a genetic change, its retention in the population.

113. This type of probability statement is to be distinguished on the basis of accuracy from a statement of estimated risk which also takes the form of a probability statement. Estimations of risk have inherent inaccuracy that is not present in statements of probability based on randomness.

it is also possible that *B* causes *A* or that another event, *C*, causes both *A* and *B*. The statement "If *A*, there is *X%* chance that *B*" may be accurate and valuable as a descriptive or predictive statement but leave open the question of causation.

In summary, statements of probability present two problems. First, they may state relations with complete accuracy without determining the outcome of individual cases. Second, they may state correlations that indicate real risks without stating a causal relationship or identifying the mechanism that creates the risk or the reason for the correlation.

III. FACTORS RELEVANT TO RISK-BENEFIT ANALYSIS

In order for the legal system to respond to the need to limit activities where the risk of future adverse impact is uncertain, three fundamental modifications of existing legal concepts are necessary. The reforms proposed are applicable primarily to adjudication and standard setting. Legislatures have sufficient discretion to base prohibitions on *risks* rather than *proof of injury* even if they do so relatively rarely. First, concepts of harm and injury must be redefined to include the risk of future adverse impact. Second, the factors relevant to a cost-benefit analysis must be defined to include risks of uncertain harm as a cost, and courts and agencies must be given the discretion to undertake a risk-benefit analysis as a justification for preventing or limiting an activity which poses only a risk of future adverse impact.[114] Third, the burden of risk identification must in some instances be shifted to those whose activities threaten ecosystem stability. This section focuses on the problems of cost and risk rather than benefit identification because under existing laws and cost-benefit procedures there is little chance that the economic and other benefits of an activity will be underestimated.

Under existing concepts of damage and injury applied by the courts, an activity causes injury and thus exposes the actor to sanction when human health is impaired or some recognized human use of a

114. The question of how much risk a society is willing to tolerate is ultimately a political one and depends in part on how much that society values the objectives for which the risk is undertaken. We urge that risk analysis be incorporated directly into judicial and administrative decisionmaking at the same time that it is put forth for political discussion. *But cf.* Green, *The Resolution of Uncertainty*, 12 NAT. RES. J. 182 (1972). This will not only help correct present errors in identification of injury and in cost-benefit analysis, but will also provide a scheme and balancing standard around which political discussion may center.

resource is foreclosed.[115] The National Water Commission, for example, has criticized the no discharge policy of the 1972 Federal Water Pollution Control Act because it deviates from this principle and urges instead that water be considered polluted only

> if it is not of sufficiently high quality to be suitable for the highest uses people wish to make of it at present or in the future . . . . Under this approach, maintenance of natural water quality is necessary only where some use of resources requires it.[116]

Even if one accepts the argument that the protection and enhancement of environmental quality is only one—albeit important—objective that society must pursue, we question whether present definitions of what constitutes a harmful activity allow decisionmakers a sufficient margin of safety to avoid the risks of future adverse impacts.[117] In many

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115. Courts may be somewhat more willing to enjoin anticipated harm, but concepts of injury remain the same. *See* Opal Lake Ass'n v. Michaywe' Limited Partnership, 47 Mich. App. 354, 209 N.W.2d 478 (1973). The court approved an injunction limiting use of a small lake by residents of a projected resort complex to prevent pollution. Cases refusing to grant relief for anticipatory injury were distinguished on the grounds that most "are dated at a time when there was little organized or successful opposition to air or water pollution;" and, with respect to private as opposed to public nuisances, courts are more willing to anticipate harm because "there is no threat to the doctrine of separation of powers." *Id.* at 363, 209 N.W.2d at 483. Injunctions based on anticipated harm were, however, limited to instances where the potential harm was discernible from evidence taken in an adversary hearing. Previously the Michigan Supreme Court in dictum rejected the principle that a nuisance exists if a lake has reached a "tipping" point so that further development will result in pollntion. Thompson v. Enz, 385 Mich. 103, 188 N.W.2d 559 (1971). *But cf.* Irish v. Green, 2 ENVIRON. L. RPTR. 20,206 (Emmet County Cir. Ct. 1972) decided under the Michigan Environmental Protection Act of 1970, MICH. COMP. LAWS ANN. §§ 691.1201 to 691.1207 (Supp. 1972). *See generally* Sax & Conner, *The Michigan Environmental Protection Act of 1970: A Progress Report,* 70 MICH. L. REV. 1004 (1972). For a typical case refusing to enjoin an activity because the evidence of future environmental damage was classified as speculative, see Green v. Castle Concrete Co., 509 P.2d 588 (Colo. 1973).

116. NATIONAL WATER COMM'N, FINAL REPORT TO THE PRESIDENT AND TO THE CONGRESS OF THE UNITED STATES, WATER POLICIES FOR THE FUTURE 70 (1973) [emphasis omitted].

117. Note, *Imminent Irreparable Injury: A Need for Reform,* 45 S. CAL. L. REV. 1025, 1057 (1972), suggests that the following factors are relevant in establishing a margin-of-safety in deciding whether a court should grant an injunction and, we believe, in risk-benefit analysis generally:

> (1) the availability of definitive knowledge as to the effects, especially long-term, of the proposed action; (2) the magnitude and nature of the anticipated harm; (3) the cumulative effect of many users; and, (4) the potential synergistic effects. Although the magnitude and nature of the harm were also included as factors in determining the appropriateness of the injunction, their inclusion as factors in setting the margin-of-safety is justified because of the different purpose served in each case. In determining the appropriateness of injunctive relief, the magnitude and nature of the harm are used to determine the weight of the injury the plaintiff will suffer if the injunction

cases evidence of risk under this standard might be dismissed as speculative even when the evidence demonstrates the existence of a danger that should be considered.[118]

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is denied, whereas in setting the margin-of-safety they are used to determine the desired degree of safety or confidence that the harm will be avoided.

In a statement entitled *Reasons Underlying the Registration Decisions Concerning Products Containing DDT, 2, 4, & 5-T, Aldrin and Dieldrin, Before the Environmental Protection Agency*, ENVIRON. L. RPTR. 30,028, 30,031 (EPA Mar. 18, 1971), the EPA concluded "in the short term, extrapolation from small scale laboratory analysis must err on the side of safety." The concept is recognized in the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. § 1313(d)(1)(C) (1970), which provides:

> Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load, for those pollutants which the Administrator identifies under section 304(a)(2) as suitable for such calculation. Such load shall be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

118. The case for recognizing the concept of damages to a resource *qua* resource rather than to human uses of the resource is made in Stone, *Should Trees Have Standing—Toward Legal Rights for Natural Objects*, 45 S. CAL. L. REV. 450 (1972).

In recent years some powerful analyses of environmental problems have been developed using the welfare economics concept of external effects, *see* A. KNEESE, R. AYERS & R. D'ARGE, ECONOMICS AND THE ENVIRONMENT: A MATERIALS BALANCE APPROACH (1970), but the definitions of cost which underlie this analysis do not adequately take into account the risk of future harm. Welfare economics seeks to describe alternative resource allocations by the criterion of efficiency. The cost of an activity is thus measured by the highest valued opportunity (alternative use) that the decisionmaker must forego. Initially opportunities foregone by parties other than the decisionmaker were ignored although technically they must be counted before it can be determined that an allocation is efficient. Otherwise an allocation may be inefficient because there is a divergence between private and social cost. *See* Mishan, *Reflections On Recent Developments in the Concept of External Effects*, 31 CANADIAN J. ECON. & POL. SCI. 3 (1965). In the case of the use of common property resources as sinks for the discharge of residuals it is now recognized that external effects are pervasive, but welfare economics is still primarily concerned with those effects on third parties which can be measured by monetary damages; more diffuse effects not immediately incurred or by humans are excluded from the definition of cost. This is, in part, because costs are partially a function of previously recognized property rights.

> Therefore, inferences made with respect to rights or to policies affecting rights, which are based on market costs, give effect to the rights on which the costs are themselves based. . . . To evaluate costs and benefits in terms of the maximized value of production is to reason circularly to give effect to already extant costs and rights reflected or given therein.

Samuels, *The Coase Theorem and the Study of Law and Economics*, 14 NAT. RES. J. 1, 16-17 (1974).

Much attention has been devoted to the calculation of proxies for market values as guides to public investment and regulatory decisions (which are the same since they both involve decisions as to how much environmental quality is to be produced) where no organized markets exist. However, benefit cost-analysis techniques which have been developed historically have ignored the problem of risks of future adverse impact because considerations such as the future value of an undisturbed natural environment is

In recent years it has been argued that the law can minimize the long-term risks of environmental degradation by reallocating the burden of proof to those whose activities threaten natural ecosystem stability.[119] A common theme underlying these arguments is that we are now a stable rather than developing society and ecosystem stability must be the norm if we are to endure.[120] Unfortunately, traditional burden of proof doctrines are of limited utility in analyzing the problem. The law of evidence distinguishes between the burden of persuasion, which is said never to shift, and the burden of producing evidence or going forward. These concepts are irrelevant to the problem under discussion; the burden of proof issue should be addressed to how the costs of displaying impact and risk information should be allocated and not to who must prove what. The modern function of the burden of persuasion is to make it possible for the trier of fact to decide issues that could not otherwise be decided. When the issue is treated as whether an activity will cause *injury* to human health or to man's ability to use a resource and there is only evidence of a *risk of future injury*, it is likely that the activity will be allowed regardless of where the burden of going forward lies, so shifting that burden does not solve the problem.[121] On the other hand, if the burden of persua-

considered an intangible incapable of quantification. We have no way of measuring the preferences of future generations and developing a weighing system to yield welfare tradeoffs between existing and future generations. *See generally* J. RAWLS, A THEORY OF JUSTICE, 284-93 (1971). Such soft values tend to be submerged by the harder evidence of the value of the benefits of present development. Increasingly, cost-benefit analyses based on the principle of consumer sovereignty are only one type of information sought by decisionmakers. *See* note 137 *infra*. *See also* Note, *Benefit Cost-Analysis and the National Environmental Policy Act of 1969*, 24 STAN. L. REV. 1092 (1972) for a discussion of methods used to display non-quantifiable environmental impacts in water resource management. For a discussion of the problem of quantification and a strong defense of cost-benefit analysis in many situations, see Ackerman, Ackerman & Henderson, *The Uncertain Search for Environmental Policy: The Costs and Benefits of Controlling Pollution Along the Delaware River*, 121 U. PA. L. REV. 1225 (1973).

119. The ecological case is made in G. HARDIN, EXPLORING NEW ETHICS FOR SURVIVAL: THE VOYAGE OF THE SPACESHIP *Beagle* 57-65 (1972). For legal arguments based on ecological imperatives see Hanks & Hanks, *An Environmental Bill of Rights: The Citizen Suit and the National Environmental Policy Act of 1969*, 24 RUTGERS L. REV. 230, 265-68 (1970); Krier, *Environmental Litigation and the Burden of Proof*, in LAW AND THE ENVIRONMENT 105 (M. Baldwin and J. Page, Jr. eds. 1970) and J. KRIER, ENVIRONMENTAL LAW AND POLICY: READINGS, MATERIALS AND NOTES ON AIR POLLUTION AND RELATED PROBLEMS 218-21 (1970). *See also* J. SAX, DEFENDING THE ENVIRONMENT: A STRATEGY FOR CITIZEN ACTION 136-57 (1971).

120. *See* B. COMMONER, THE CLOSING CIRCLE (1971); Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

121. A pesticide manufacturer has "the burden of proving the safety of his product." Environmental Defense Fund, Inc. v. Ruckelshaus, 439 F.2d 584, 593 (D.C. Cir.

sion were shifted and those undertaking an activity had to establish as part of their prima facie case that there will be no injury; *i.e.*, that there is no risk, the result would be an irrational curtailment of resource use. We have earlier referred to *Summers v. Tice* as an example of the use of burden shifting to mask substantive changes.[122] The consequences of using reallocation of the burden of persuasion in the environmental context for this purpose would be to establish a nondegradation principle for all resources. As had been observed,

> Anxieties are often expressed about the subtle long-term effects of toxic substances present in very low concentrations. That these substances could be injurious is not the same as a positive finding to that effect. The connection between 'could' and 'action' is complex; to avoid all perceptible danger as a matter of policy is either costly or likely to lead to worse danger of asceptic inactivity.[123]

Society may well wish to establish non-degradation policies with respect to specific resources, as has been done, but this is a collective decision that should be taken openly and not under the cover of reallocation of the burden of proof. We seek the more modest objective of insuring that decisions be based on a thorough consideration of future risks, and perhaps incorporate a margin of safety. It is unreasonable to expect that those desiring to undertake an activity or those objecting to it prove or disprove the consequences of the activity. It is necessary, however, that decisionmakers have discretion to make a risk-benefit analysis before deciding if an activity can proceed.

1971). The burden could be characterized as one of ultimate persuasion. However, "[i]t is scientifically impossible to prove that a chemical is without hazard." REPORT OF THE ADVISORY COMMITTEE ON 2, 4-5-T TO THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY 9 (May 7, 1971). The burden cannot therefore be a presumption against registration requiring the registrant to produce a preponderance of evidence to disprove all evidence of risk. It is more accurate to say that the decision will be against the manufacturer when the risk is deemed unacceptable and, as we have argued, shifting the burden of proof is not useful in a situation where the final decision must be an exercise in informed discretion.

The inappropriateness of traditional burden of proof requirements is also illustrated by the AEC's traditional allocation of the burden of proof. The Commission has always required an applicant to prove that the proposed nuclear plant is in the public interest but as a member of the Commission testified before Congress "it just turns out in real life that nothing happens in these contested cases until the staff has testified." *Hearings on AEC Licensing Procedure and Related Legislation Before the Subcommittee on Legislation of the Joint Committee on Atomic Energy*, 92d Cong., 1st Sess., pt. 1, at 11 (1971).

122. *See* text accompanying notes 40-42 *supra.*

123. Langbein, *Water*, in PUBLIC POLICY TOWARD ENVIRONMENT 1973: A REVIEW AND APPRAISAL 42, 48 (N.Y. Academy of Sciences 1973).

The "partnership" between the District of Columbia Circuit Court of Appeals and the Environmental Protection Agency (EPA) has contributed a useful although ultimately limited model of risk-benefit analysis. In 1970 the Administrator of EPA began a study to determine if DDT registrations should be cancelled. When it became clear that EPA was committed to a gradual phase-out policy, the Environmental Defense Fund brought suit to compel the Administrator to suspend as well as cancel the registrations, which would have resulted in the immediate prohibition of DDT. After a loose risk-benefit analysis the Administrator refused to suspend the registrations on the grounds that the benefits of continued use exceeded the costs and continued to study the question of cancellation. In *Environmental Defense Fund, Inc. v. Ruckelshaus*,[124] Judge Bazelon, aided by the EPA's construction of the Federal Insecticide, Fungicide and Rodenticide Act,[125] transformed a statute, which seemed to contemplate that pesticide usage would only be prohibited where there was a "public health situation that must be corrected immediately," into one which mandated a comprehensive risk-benefit analysis. Specifically the court held that (1) the refusal to suspend was a final action subject to judicial review;[126] (2) because the Administrator had found that "DDT in large doses has produced cancer in test animals and various injuries in man, but in small doses its effect on man in unknown," FIFRA requires the Administrator to initiate the cancellation process as "there is substantial question about the safety of the registered pesticide";[127] and (3) the Administrator had greater discretion to decide if suspension was warranted and it was "appropriate" to defer his findings, but to determine if the correct standard was applied to the decision it was necessary to remand the decision as the record failed to disclose the standard applied and the criteria used in applying the standard to the facts.

Judge Bazelon recognized the desirability of developing standards on a case by case basis but did suggest some general guidelines for the Administrator to follow. First, the court agreed with the Administrator that cancellation "does not turn on a scientific assessment of haz-

124. 439 F.2d 584 (D.C. Cir. 1971); *see also* Environmental Defense Fund v. EPA, 465 F.2d 528 (D.C. Cir. 1972).

125. 7 U.S.C. § 135 *et seq.* (1970).

126. The court relied on Environmental Defense Fund v. Hardin, 428 F.2d 1093 (D.C. Cir. 1970). *But see* Nor-Am Agricultural Products v. Hardin, 435 F.2d 1151 (7th Cir. 1970) (en banc).

127. 439 F.2d at 594.

ard alone. The statute leaves room to balance the benefits of a pesticide against its risks."[128] Second, the Administrator had conceded

> that a hazard may be 'imminent' even if its impact will not be apparent for many years, and that the 'public' protected by the suspension provision includes fish and wildlife.[129]

The court enthusiastically indicated that this should be the starting point for the formulation of risk-benefit standards.[130] *Environmental Defense Fund, Inc. v. Ruckelshaus* is a classic example of the use of a familiar legal technique—remand for a more complete statement of reasons so a court can determine if a decision was arbitrary—to implement a substantive change. Standards and factors to determine environmental risks are only relevant if the statute requires them, which was the issue the court assumed. The EPA correctly interpreted the decision to require a full risk-benefit analysis in situations where there is evidence of long-term environmental damage and the standards developed by the Agency were incorporated into the Federal Environmental Pesticide Act of 1972.

On remand the Environmental Protection Agency issued cancellation notices for all DDT registrations but refused to suspend them. The Agency found itself unable to develop general criteria and instead identified two general considerations: (1) the nature and magnitude of the foreseeable risks associated with the use of a particular product, and (2) the nature of the benefit conferred by use of a given product.[131]

The role of increased scientific knowledge was accorded considerable weight, as the opinion noted: "The concept of the safety of a product is an evolving one which is constantly being refined in light

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128. *Id.*

129. *Id.* at 597.

130. Wellford v. Ruckelshaus, 439 F.2d 598, 601 (D.C. Cir. 1971). The court gave as authority for the standard:

> Statement of the Reasons Underlying the Decision of the Secretary with respect to the Registrations of Products Containing 2,4,5-T, Aug. 31, 1970, at 4 (J.A. 54). The Statement adopts the definition of "imminent hazard" formulated in the original panel opinion in Nor-Am Agricultural Products, Inc. v. Hardin, 435 F.2d 1133 at 1142-1143 (7th Cir. decided July 15, 1970) vacated and decided *en banc* on other grounds, 435 F.2d 1151 (Nov. 9, 1970). That definition was drawn in turn from the legislative history of an analogous provision of the Federal Food, Drug, and Cosmetic Act (FDCA), 21 U.S.C. § 355(e), on which the FIFRA provision was apparently modeled. *Id.* at n.12.

131. Reasons Underlying the Registration Decisions Concerning DDT, 2, 4, 5-T. Aldrin and Dieldrin, Before the Environmental Protection Agency, 1 ENVIRON. L. RPTR. 30028 (Mar. 18, 1971). The decision was upheld on appeal on the ground that it was supported by substantial evidence. Environmental Defense Fund, Inc. v. EPA, 489 F.2d 1244 (D.C. Cir. 1973).

of our increasing knowledge."[132] The problem of uncertainty was recognized by expanding and clarifying the definition of imminent hazard developed in the cases and adopted by the Agency.

> An 'imminent hazard' may be declared at any point in a chain of events which may ultimately result in harm to the public. It is not necessary that the final anticipated injury actually have occurred prior to the determination that an 'imminent hazard' exists. In this connection, significant injury or potential injury to plants or animals alone could justify a finding of imminent hazard to the public from the use of an economic poison.[133]

The EPA thus clearly dispensed with notions of only proven harms being relevant and mandated the Agency to consider risks of future harm as well. However, this expanded definition was somewhat undercut by the EPA's insistence that health "narrowly defined" should be distinguished from "the broader concern of environmental quality."[134]

To determine how courts and agencies should handle the problem of risk identification and consideration, the problem should be analyzed in terms of the four categories of ecological information set out in Section II.A of this Article. Information that is available and definite presents no new analytical problems. As has been suggested elsewhere,[135] the decisionmaker may require greater scientific exper-

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132. 1 ENVIRON. L. RPTR. at 30,029.

133. *Id.* at 30,030.

134. *Id.* The Federal Environmental Pesticide Control Act of 1972 defines imminent hazard as "a situation which exists when the continued use of a pesticide during the time required for cancellation proceeding would be likely to result in unreasonable adverse effects on the environment or will involve an unreasonable hazard to the survival of a species declared endangered by the Secretary of the Interior under Endangered Species Act of 1973." 7 U.S.C. § 136(1) (Supp. II, 1972). The definition does not appear to constrain significantly the EPA in defining imminent hazard as it did during the DDT proceedings.

135. *E.g.* Caponera, *Towards a New Methodological Approach in Environmental Law*, 12 NAT. RES. J. 133, 138 (1972); Leventhal, *Environmental Decisionmaking and the Role of the Courts*, 122 U. PA. L. REV. 509 (1974).

> What an appellate court needs, in my view, is an aid who is not a witness so much as a kind of hybrid between a master and a scientific law clerk, a scientific expert who might be available, at the call of the appellate court, not to give evidence or resolve factnal or technical issues, but to advise a court so that it could better understand the record. . . . [T]he expert could aid the court in the difficult task of establishing the relative significance of petitioners' scientific contentions. He could also provide assistance in understanding problems of scientific methodology aud in assessing the reliability of tests conducted by the agency in light of specific criticisms.

Id. at 550. *Cf.* Whitney, *The Case for Creating a Special Environmental Court System*—WM. & MARY L. REV. 33, 41 (1973), arguing that a separate environmental tise or aid from scientific experts to understand the information, but the problems of properly using and applying the information are substantively no different than the problems of using and applying other types of definite information. In fact, information of this type will generally identify future harms with certainty, and not only the risks of future harms. However, since there can be scientific conflict over the interpretation of data, there may be cases where seemingly definite information will not necessarily be conclusive as to whether there will be future harm. To the extent that the conflicts are unresolvable, the information should be treated as unavailable.[136]

Information that is available and indefinite does present substantively new problems. The proper use of such information requires both an understanding of the nature of probability information and a consideration of the chance of harm or change. Treatment of such information by rules requiring a showing of certainty of harm evades the underlying issue of whether the activity in question should be foreclosed because of the risk itself. To change the present treatment of such problems it must be recognized that: (1) the basic issue faced by decisionmakers is the weight that should be attached to harm that may be produced by the activity as opposed to the weight to be attached to the costs of precluding it; (2) rules requiring proof of certainty of harm from an activity function as an irrebuttable presumption that the harm of preclusion outweighs any indefinite future harm; and (3) this presumption is presently neither justified on available scientific evidence nor desirable as a matter of policy. At a minimum, it is now widely recognized that requiring information before proceeding with resource alteration will not necessarily unduly prohibit resource development. Moreover, resource development is no longer seen as an overriding or even desirable goal in all cases. Faith in the ability of future technological developments to solve whatever problems we create is at least diminished. Questions have been raised as to whether the necessary technology will be developed in time to meet the problems and as to whether certain problems are solvable through any kind of technology. In light of present perceptions, then, the presumption that indefinite future harm cannot outweigh present harm is invalid and must not be used as a basis for decisionmaking.

court system would improve the consideration of matters requiring expertise.

136. If no better information can be obtained, the disparity between conflicting interpretations will be relevant to estimation of the risk and confidence in the estimation.

Courts and agencies should be free to consider risks of future harm without the pressure of such a presumption.

For information in the third category; *i.e.*, that which is obtainable but ouly at a substantial cost, the first role of the decisionmaker is to maximize the amount of known information to the extent consistent with the utility of information improvement.[137] This poses a problem of allocating the duty to obtain the information necessary to identify the harm and the risks entailed in the activity in question. We realize that shifting the burden of risk identification may be seen as shifting the burden of persuasion to those desiring to undertake an activity, but the two concepts should not be confused. The policy we are advocating is a flexible one for it will allow (but not require) a decisionmaker to permit an activity in the face of uncertainty on the grounds that the costs of obtaining additional information exceed the benefits whereas a shift of the burden of persuasion would require that an activity be prohibited because the absence of risk had not been proven. As we have said, we are not manipulating burdens to mask a substantive change.

Principles of resource allocation suggest that the burden should be shifted to the party who can obtain the information at the least cost. However satisfactory this standard is in theory, the basic problem with using the least cost standard to determine who has the duty of risk identification is that in many cases the information will be unavailable to both parties and will have to be obtained by third parties, so it will be impossible to allocate the duty on the ground that resource efficiency has been improved. In these cases we suggest the following factors are relevant to the assignment of the duty: (1) the comparative ability of each party to obtain access to information on the specific nature and dimensions of the disrupting activity; (2) the comparative ability of each party to obtain access to the necessary expertise;[138] (3) the quality of research likely to be produced by each party; and (4) the comparative freedom from bias of each party.

137. *See* Note, 87 HARV. L. REV. 1050, 1058 (1974). Information is increased when it is shifted from the third to the first or second category, or when the confidence in the risk estimations for information in the fourth category is increased.

138. Bronstein maintains that in the AEC proceedings on the Calvert Cliffs' nuclear power plant, the financial inability of the Chesapeake Environmental Protection Association to hire experts contributed to CEPA's failure to raise certain issues relevant to the safety of the proposed plant before the Atomic Safety and Licensing Board. Bronstein, *The AEC Decision-Making Process and the Environment: a Case Study of the Calvert Cliffs' Nuclear Power Plant*, 1 ECOL. L.Q. 689, 713 n.160, 720 (1971).

The most important issue that will arise when the burden of risk identification is shifted is how the burden can be discharged. The decisionmaker must make two determinations. First, he must determine whether the information is available, that is, whether it falls into one of the first two categories rather than into the third. Information should be considered available if it can readily be obtained from the existing scientific literature or by undertaking relatively simple research. The party with the burden of risk identification should be required to show that the information displayed represents the full extent of available information. Information should be considered unavailable if substantial research will be necessary. In this second situation the decisionmaker must determine if the costs of the research are likely to outweigh the benefits of obtaining it. Factors such as whether an adequate methodology to obtain the information exists and an informed judgment about the marginal gains to the decision that will result from the information are relevant here.[139] Because the same factors that would result in assignment of the information-gathering role to a party would make that party the one best able to present evidence on the cost of obtaining the information and the dimension of the difficulties and risks resulting from not obtaining it, we suggest that the party with the burden of obtaining unknown information should also bear the burden of showing that the information should be treated as unobtainable; *i.e.*, that it is probably unobtainable or that the cost of obtaining the information outweighs the difficulties of proceeding without it.[140]

139. In determining whether information is available and whether it is obtainable, decisionmakers may have to consider conflicting evidence on issues such as the state of the literature, available methodology and the experimental design required to investigate the problem. This may involve judgments on rather sophisticated scientific issues, but should not be impossible for either courts or agencies. *See* note 135 and accompanying text *supra*.

140. The recently issued Proposed EPA Procedures for the Imposition of Alternative Effluent Limitations, 39 Fed. Reg. 11434 (1974), follows an appropriate scheme of allocation of the duty of obtaining information. These procedures implement section 316(a) of the Federal Water Pollution Control Act, 33 U.S.C. §§ 1251, 1326(a) (Supp. II, 1972), which provides that if an applicant for a point discharge permit

> can demonstrate to the satisfaction of the [EPA Regional] Administrator . . . that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator . . . may impose an effluent limitation . . . for such plant, with respect to the thermal component of such discharge . . . that will assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on that body of water.

The regulations address the procedure to be followed by an applicant seeking an alter-

If a party assigned the burden of showing that information is unobtainable discharges that burden, the information is treated as that within the fourth category. If it is determined that the information is obtainable, the party with the burden of obtaining the information must present sufficient data to discharge the burden. The decisionmaker may then treat the information as that in category one or two, depending on whether the information is definite or indefinite. However, in many cases, even after the burden of obtaining information is discharged, there will be unresolvable conflicts as to the dimensions of the risk in a certain activity. To this extent, the information will still have to be treated as that in the fourth category.

For information that is unknown and unobtainable,[141] the proper treatment is in many ways like that which should be afforded informa-

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native effluent limitation, and indicate that an applicant is not required to *prove* that alternative effluent limitations will assure the protection and propagation of the population. Rather, the applicant must produce a certain amount of information that tends to show that the population will not be harmed. In general, this amount of information is supplied by a showing that discharges consistent with the alternative limitations either (1) have caused no harm to the population in the past or (2) will ensure the protection of "representative important species" in the future. Proposed EPA Procedures § 122.8, 39 Fed. Reg. 11437-38 (1974). This requirement applies to those applicants who can make such a showing within 60 days of the application for an alternative effluent limitation. Proposed EPA Procedures § 122.5, *id.* at 11437. The Regional Administrator may then grant the alternative effluent limitations. Proposed EPA Procedures § 122.9, *id.* at 11438. This is appropriate, as long as the Regional Administrator is free to refuse the alternative limitations in cases where the showings are unrebutted, but there is other evidence that the protection and propagation of a balanced, indigenous population will not be assured under the alternative limitations.

A similar scheme of requiring an initial showing and then leaving discretion whether to grant the alternative limitation to the Regional Administrator probably applies to those applicants presenting their cases solely through the hearing process, although the amount of information initially required is not specified. Proposed EPA Procedures § 122.10, *id.* at 11438-39.

If a discharger seeks to show that "representative important species" will not be harmed by future effluent, the question arises as to what species are representative. The species to be taken as "representative important species" are to be selected by the Regional Administrator. Proposed EPA Procedures § 122.8(a)(2)(ii)(A), *id.* at 11438. However, if there is insufficient information to enable the Regional Administrator to make such a choice, the applicant may make the choice, but then bears the burden of proving the appropriateness of the choice of species. Proposed EPA Procedures § 122.8(a)(2)(ii)(B), *id.* This is a correct handling of the issue of availability and sufficiency of information.

A similar scheme is provided for alternative effluent limitations to be granted by the director of a state water pollution control agency or interstate agency issuing permits under the National Pollution Discharge Elimination System. Proposed EPA Procedures, Subpart C, *id.* at 11439-41.

141. Information to be treated in this way includes that which is theoretically obtainable but cannot be obtained by the time a decision must be made. *See* discussion

tion which is known and indefinite. In both cases, the central problem is that of weighing a risk of future harm against known benefits.[142] Here, however, the decisionmaker must consider not only the dimensions of the risk but also the accuracy of the estimate of those dimensions. The risk may in fact be larger or smaller than estimated. Yet

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of category 3(*C*) in text accompanying note 53 *supra*. The prevalence of problems involving such information was discussed in COUNCIL ON ENVIRONMENTAL QUALITY, FOURTH ANNUAL REPORT:

> [T]he most serious problem is the lack of knowledge about the magnitude of the various costs, particularly damage costs. We have some estimates of the magnitude of the more easily measured damages but only the most limited data on others such as psychic costs. We have some idea about short-term toxic effects but very little about long-term chronic impacts.
>
> Yet we must formulate and implement policies while faced by such uncertainty. Often the abatement costs of alternative policies can be estimated but the reduced damages cannot. To delay until better damage data are available may lead to more accurate decisions but may also risk increased damage during the period of inactiou.

Id. at 110-11.

When dealing with information that could in time be obtained by further study without prohibitive cost, the argument for ongoing review is particularly strong. *Sec* p. 426-27 *infra*.

142. In the hearings on the Calvert Cliffs' nuclear power plant the Maryland Public Service Commission (PSC) apparently failed to understand this problem despite the fact that it was clearly set out in the testimony before that body. The PSC was charged by statute with considering evidence on water pollution. MD. CODE ANN. art. 78, § 54A (Supp. 1973). In testimony before the PSC there were contradictory statements as to whether there would be any effect on biological populations in the Chesapeake Bay from the thermal discharge. One scientist testified that it is the *evidence* in this case that:

> If the plant is placed in operation without such studies [on the possible effects of the plant], the public is in my opinion undertaking a degree of risk. Whether that risk is in the opinion of the Commission an acceptable risk against the need for electric power is seriously your question and not mine.

Bronstein, *State Regulation of Powerplant Siting*, 3 ENVIRON. L. RPTR. 273, 299 (1973) [hereinafter cited as Bronstein] *citing* Transcript at 889, *In re* Application of Baltimore Gas & Elec. Co. for a Certificate of Public Convenience & Necessity for the Construction of a Nuclear Power Plant, No. 6394 (Md. Pub. Serv. Comm'n, Nov. 25, 30, Dec. 1, 2, 7, 9, 1970). Despite this clear statement of the problem, the PSC declined to take up the role of risk consideration. The contradictory testimony on the effects on life in the Bay was not discussed in the PSC's opinion other than a statement that:

> It is our belief that the evidence in this case that bears on the effect of the operation of the Calvert Cliffs' nuclear power plant on . . . pollution supports the conclusion that there will be no significant adverse effect in this regard.

Bronstein, *supra* at 299, *citing In re* Application of Baltimore Gas & Elec. Co. for a Certificate of Public Convenience & Necessity for the Construction of a Nuclear Power Plant, No. 6394, at 38 (Md. Pub. Serv. Comm'n, Ian. 19, 1971). While it is possible that the PSC found on the evidence that there would be no significant pollution, the absence of discussion of problems raised suggests a failure to consider the risk and a view that harm must be proven to be considered.

See also the discussion of the recent court of appeals decision in the *Reserve Mining* case, notes 21a-c *supra* and accompanying text.

the estimation cannot be refined or knowledge improved by allocation of the burden of persuasion.

Under the guidelines suggested above, a court or agency should be able to obtain the information necessary to conduct a thorough risk-benefit analysis. We now suggest the substantive factors relevant to such analyses. In addressing a risk, the decisionmaker must consider both the probability of the occurrence of an adverse impact and the magnitude of the impact. Both factors contribute to the weight to be given to a certain risk. There is a special problem of proper weighting with risks of large scale or severe harms that have only small probabilities of occurring.[143] Legal decisionmakers, unaccustomed to dealing with remote "what-ifs," must develop sensitivity to such problems if decisionmaking is to proceed on a rational basis.

Moreover, in adopting risk-benefit analysis as the model for decisionmaking in the environmental area, it is essential to dispense with not only the formal effects of notions of proof and certainty but also the more subtle influence of such notions on deliberations. The necessary change in decisionmaking will not be fully accomplished if old notions of proof of injury are discarded only to be replaced by parallel notions of proof of risk.[144] Information in the fourth category, in

143. This point was made rather nicely by the sociologist, Amitai Etzioni, in a recent letter to the editor commenting on an article by Ralph E. Lapp in the New York *Times* Magazine about nuclear power:

> To say that reactors have a 1 out of 10,000 chance to blow, each year (or 1 out of 1,000,000 per community), which makes them about as safe as flying, does not take into account the number of persons to be killed in a nuclear disaster.
>
> As the size of the disutility is often overlooked in the discussion of risk possibilities, the point deserves illustration. Most persons who would accept a $10 bet at odds of 99 to 1 in their favor, would hesitate if the bet was $1,000 at the *same* odds, and refuse a $100,000 bet at *identical* odds. Why? Only because the disutility changed.
>
> Similarly, in the case of nuclear reactors. If the loss is one person's life, 1 out of 1,000 might be quite tolerable. The same odds to lay waste a city seem qnite unacceptable. Perhaps for an individual the difference is theoretical; he will be just as dead, but for public policy the difference between losing some lives on a flight and—a city, are monnmental.

Letter from Amitai Etzioni to the Editor, N.Y. Times, Mar. 24, 1974, § 6 (Magazine), at 70. (Lapp replied that unpublished data may reveal that nuclear risks are comparable to airplane crash risks. *Id.*).

144. Inadequate consideration of risks is especially likely to occur if the risk is quantified in monetary terms at too early a stage in the process of analysis of environmental impacts. The central question in risk-benefit analysis should be the cost of taking the risk; *i.e.*, what value does society place on not taking it. Where an administrative agency conducts a NEPA review of a grant or license applicant's proposal, the evaluation of the risk should be done by the agency. This function is improperly allocated to the applicant if the applicant is encouraged to put monetary valnes on risks engendered in the proposed activities. Even if agency review is mandated, there is a

which the dimensions or perhaps even the existence of a risk cannot be proven scientifically, must still be considered in the risk-benefit analysis. The decisionmaker must take on the difficult task of drawing a line between the valid refusal to consider spurious claims of risk and the invalid refusal to consider real risks that are of low probability or impossible to prove. The need to insure a margin of safety in decisionmaking suggests that close cases, however, should be resolved in favor of consideration of the risk and minimization of it.

Finally, for the administrative, as opposed to judicial, decisionmakers an affirmative duty to engage in a continuous study and planning process must be recognized. Alternative methods of achieving the societal objective for which the technology is employed are to be

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danger that once a risk is evaluated monetarily the basis of the evaluation will not be closely reexamined.

The present AEC procedure for reviewing environmental costs of proposed nuclear power plants apparently is designed to avoid such difficulties. In the guide for preparation of environmental reports by applicants for AEC construction permits and operating licenses, applicants are given instructions on quantifying environmental impacts in setting out the environmental cost of the plant. Table 6, *Cost Description of Proposed Facility and Transmission Hook-Up*, referring to Table 3, *Environmental Factors to Be Used in Comparing Alternative Plant Systems*, USAEC REGULATORY GUIDE 4.2, PREPARATION OF ENVIRONMENTAL REPORTS FOR NUCLEAR POWER PLANTS, 4.2-64 (March, 1973). However, such quantification is in non-monetary terms; *e.g.*, pounds per year of fish affected by thermal discharge or acres of plants experiencing toxic effects of chemical contamination of ground water. Table 3, *Id.* It is expressly recognized that monetization of all such costs by applicants is inappropriate.

> While the benefit-cost analysis approach discussed in this Guide is conceptually similar to the benefit-cost approach classically employed in a purely economic context, the method recommended differs from it procedurally. This is because the benefits and costs to be evaluated will not all be monetized by the applicant. The incommensurable nature of the benefits and costs makes it virtually impossible to provide a concise assessment of benefits vs. costs in classical quantitative terms.

Id. at 4.2-42. Still, a cost benefit analysis by the applicant is mandated.

> However, although a simple numerical weighing of benefits against costs is clearly not feasible here, nevertheless the applicant can evaluate the factors on a judgmental basis which is consistent with the underlying concept of benefit-cost analysis . . . As indicated above, it is incumbent on the applicant to demonstrate that the benefits of the proposed facility are considered to outweigh the aggregate costs.

Id. The data supplied by the applicant is then to be used by the agency for a reanalysis of the environmental costs during preparation of the draft environmental statement pursuant to 10 C.F.R. § 50, app. D, at A.6 (1973). It would be unrealistic to expect uniformity in agency practice in an agency as large as the AEC. However, according to an ecologist who has worked on the preparation of AEC draft environmental statements, in many cases there is a substantive re-evaluation of the environmental costs at this stage. Dr. J.C. Randolph, formerly Staff Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Teunessee, presently Assistant Professor, School of Public and Environmental Affairs, Indiana University, Bloomington, on Apr. 21, 1973, at Bloomington.

considered in a risk-benefit analysis. As new alternative methods, especially those which do not necessitate reliance on risk-producing technology, are developed, the possibility of utilizing them should be considered. Moreover, continuous monitoring will give improved information on the risks involved in the technology being used, while experience may provide revised assessments on the desirability of achieving the objective for which the technology is employed. Both types of new information should be used in re-evaluating the activity or program through new risk-benefit analyses.

CONCLUSION

Principles of fairness require that some evidence of a causal relationship between an activity and harmful effects be demonstrated before a sanction can be considered valid. We have, on the whole, agreed with Mill's dictum that

> with regard to the merely contingent, or, as it may be called constructive injury which a person causes to society, by conduct which neither violates specific duty to the public, nor occasions perceptible hurt to any assignable individual except himself; the inconvenience is one which society can afford to bear, for the sake of the greater good of human freedom.

We do not advocate an abandonment of this principle, but merely suggest that concepts of cause and injury be refined so they are consistent with real threats to our existence; that is, so that a risk of future harm is considered to be a "perceptible hurt" to society. Risk-benefit analysis is both a powerful method of protecting society's interest in survival and an invitation for arbitrary decisionmaking.[145] We have confidence in the ability of our legal system to insure that risk-benefit analysis is used consistently with principles of fairness by circumscribing its use by following the scheme suggested for the delineation of relevant factors and by procedures which allow all interested parties a fair hearing. What is important is that risk-benefit analysis be recognized as an alternative justification for prohibiting or limiting an activity.

145. For a discussion of the concept of protection of societal interest as a basis for regulation see Pound, *A Survey of Social Interests*, 57 HARV. L. REV. 1 (1943).