"Not Supported by Current Science": The National Forest Management Act and the Lessons of Environmental Monitoring for the Future of Public Resources Management

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I. INTRODUCTION[1]

Environmental monitoring presents a fundamental challenge: how should we measure a complex system with enough specificity to be accurate, but with enough generality to be useful? From this central challenge flow related difficulties; for example, tracking the environmental impacts of particular development or management decisions, or embedding methods of analysis in a regulatory framework. Thirty-plus years of science have yielded enormous insight into the structure and function of the ecosystems in which human activities take place, but higher-resolution views of the system's complexity do not automatically point to the best means of measuring our effects on the state of the environment.

Nevertheless, a wide (and growing) variety of laws and regulations relies on environmental monitoring as a critical tool to assess the impact of particular human activities on the ecosystems on which we depend.[2] As a legal proposition, this makes eminent

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2. *See generally* Eric Biber, *The Problem of Environmental Monitoring*, 83 U. COLO. L. REV. 1 (2011) (describing the rise of ambient monitoring in environmental regulation, and the

sense: how else might we measure the success or failure of laws meant to safeguard environmental public health and safety, or estimate the potential impacts from a proposed change in land use? But as a scientific question, environmental monitoring is far less straightforward than it might seem.

Legal and regulatory regimes routinely assume a level of scientific certainty (or the existence of particular scientific tools) that is unwarranted, leaving the implementing agencies scrambling to fulfill regulatory requirements. In the case of environmental assessment—required in one form or another by NEPA,[3] NFMA,[4] FLPMA,[5] CAA,[6] CWA,[7] CZMA,[8] and other major environmental statutes—a core legal assumption is the existence of metrics of environmental "health" or state.

It isn't that such metrics don't exist. Rather, the problem is that *too many* such metrics exist. There is a nearly infinite number of ways to describe the state of an ecosystem. Further, such methods require data that is often expensive and difficult to collect. And because science tends to change much faster than do statutes or regulations, the scientific challenges compound the longstanding problem of how to enshrine an appropriate level of specificity in environmental regulation. This risks leaving agencies with an onerous top-down mandate (where regulation is too specific, requiring a particular monitoring methodology), an overgenerous amount of regulatory discretion (regulation is too broad, leaving agencies vulnerable to agency capture and/or leading to erratic outcomes), or in some cases, both.

The case of the National Forest Management Act provides a vivid example of these issues: a legal mandate to include biological diversity among Forest management priorities, a regulatory implementation creating an expensive and unproductive mismatch with the science of monitoring, a seemingly clear agency mandate that nevertheless provided broad discretion, and a regulatory scheme without a "best available science" provision that left science frozen in time.

increasing importance of monitoring generally).

3. National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321-4370(h) (2012).
4. National Forest Management Act of 1976, 16 U.S.C. §§ 1600-1687 (2012).
5. Federal Land Policy and Management Act of 1976, 43 U.S.C. §§ 1700-1786 (2012).
6. Clean Air Act of 1963, 42 U.S.C. §§ 7401-7671(q) (2012).
7. Clean Water Act of 1972, 33 U.S.C. §§ 1251-1387 (2012).
8. Coastal Zone Management Act of 1972, 16 U.S.C. §§ 1451-1466 (2012).

A review of the science of monitoring and its legal applications is particularly appropriate now, both as the Forest Service's 2012 NFMA planning rule[9] takes effect and as the federal government considers embarking on an analogous comprehensive public-resource management endeavor: ocean planning. The nation's first-ever National Ocean Policy[10]—which was announced in 2010 and which is just now beginning implementation—contains many elements that move management of the ocean as a natural resource into the 21st century. Among these are ecosystem-based management and coastal and marine spatial planning (CMSP)[11] to unify the disparate regulatory regimes governing the United States' vast territorial waters. These waters are in many ways analogous to the National Forests, being sparsely populated, multiple-use public resources that are difficult to monitor due to their vast sizes, and so the lessons of forest planning are especially salient as we move toward improved management of the nation's ocean resources.

In this Article, after discussing some general properties of indicators, we review the Management Indicator Species (MIS) provision of the 1982 NFMA regulations, one of the statute's relevant environmental monitoring requirements. We then place this requirement in the research context from which it arose, applied ecology, and discuss the subsequent development of the science of environmental monitoring. We go on to evaluate the National Forests' MIS in light of guidelines for good environmental indicators developed in this subsequent literature. Finally, we introduce ocean and coastal management as a context relevant for applying the lessons of NFMA's monitoring provisions, and suggest some concrete steps that the managing agencies might take to avoid the mistakes of past environmental monitoring efforts in public resources management. In particular, these steps require intense focus on the *what*, *why*, and *how* of environmental monitoring.

II. INDICATORS GENERALLY

An environmental indicator is a "measurable surrogate[] for

9. 36 C.F.R. § 219 (2012).

10. Exec. Order No. 13547, 75 Fed. Reg. 43023 (Jul. 22, 2010).

11. NAT'L OCEAN COUNCIL, DRAFT NATIONAL OCEAN POLICY IMPLEMENTATION PLAN 8 (2012), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ceq/ national_ocean_policy_draft_implementation_plan_01-12-12.pdf (National Priority Objectives 1 and 9).

[an] environmental end point[],"[12] or more generally, "a parameter, or a value derived from parameters, which . . . describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value."[13] Thus, as we use the term here, an indicator is not itself the measurement of interest, but rather is an easier-to-measure stand-in for the actual measurement target.

Body temperature is a familiar example that illustrates the concept nicely in the context of human (rather than environmental) health. A person's body temperature is an indicator of her state of health, because a fever is correlated with an infection. Although we are actually interested in the patient's state of health (and not her temperature for its own sake), we take her temperature because it is much more easily measured than viral load or any more direct measure of infection. In order for body temperature to be an effective indicator of health, we must first understand something about the relationship between temperature and infection, and about the background variation of body temperature in healthy individuals.[14]

In the context of environmental monitoring, indicators are measurement tools that allow researchers to track environmental state, structure, or function. These provide critical feedback for public resources management, making it possible to track the managed natural resource as it changes in response to management actions. Indicators may take the forms of direct measures of physical, chemical, or biological parameters. Particularly relevant in the case of the National Forests, discussed at length below, are indicator *species*—biological entities monitored because their presence indicates something about the state of the larger ecosystem.[15]

There is no best way to summarize the state of the environ-

12. Reed F. Noss, *Indicators for Monitoring Biodiversity: A Hierarchical Approach*, 4 CONSERVATION BIOLOGY 355, 357 (1990).

13. ORG. FOR ECON. CO-OPERATION AND DEV., OECD ENVIRONMENTAL INDICATORS: DEVELOPMENT, MEASUREMENT AND USE 5 (2003), *available at* http://www.oecd.org/env/.

14. Note that this is an imperfect metaphor for ecological indicators because human body temperature is an equilibrial value. There is a narrow range of body temperatures that a human body will sustainably maintain; excursions from that range tend to be brief, and body temperature quickly returns to its equilibrial (that is, homeostatic) value. By contrast, environmental variables may have multiple stable states, or none at all.

15. Indicator species have also been used as proxies for other (harder to count) species or communities, although this use is disfavored among ecologists. *See* Gerald F. Niemi & Michael E. McDonald, *Application of Ecological Indicators*, 35 ANN. REV. OF ECOLOGY, EVOLUTION, & SYSTEMATICS 89 (2004); *see also* discussion *infra* p. 120.

ment. The cacophony of interactions among species, nutrients, climate, and geography that occurs within even the smallest forest, grassland, or estuary calls into question the desirability of developing an index of environmental "quality." An index of any kind requires summarizing and simplifying—indeed, that is the point—which loses information in the process. An optimal index strikes a balance between increased comprehension (gained through simplifying a complex system) and the attendant loss of detail. But precisely where the optimal balance lies depends upon at least two things: *what we want to know*, and *why we want to know it*.

Compare, for example, the Dow Jones Industrial Average with the S&P 500. The two indices have similar purposes, measuring the state of the American economy and acting as yardsticks for changes to that state.[16] The Dow represents a weighted average stock price of 30 companies[17] whose stocks are listed on the New York Stock exchange, while the S&P is a weighted index of the stock prices of 500 such companies.[18] The S&P therefore represents a broader swath of the market, but changes to any one stock price are likely to be swamped out in the process of weighting and averaging the values of all 500 companies.[19] The Dow, conversely, is more sensitive to changes in any one of its constituent companies' stock prices. Neither can be said to be the "better" index; they simply have different strengths. If one cares about the prices of blue chip companies to the exclusion of all else, the Dow is probably of more interest, while the S&P is likely to be a better snapshot of market-wide changes. Note, however, that neither provides any information about any individual stock: such resolution is necessarily lost by creating an index.[20]

16. Note, too, that the stock price of a company is itself a kind of index, a summary of the company's worth or future prospects in the eyes of the stock-buying public. We use the analogy to economic indicators with apologies to Jameal Samhouri and coauthors, who seem to have beaten us to the punch on this point. *See* J.F. Samhouri et al., *Using Existing Scientific Capacity to Set Targets for Ecosystem-Based Management: A Puget Sound Case Study*, 35 MARINE POL'Y 508, 509 (2011). At the time of writing, we had not yet become aware of their paper, in which they use the same comparison.

17. *See* *Overview*, S&P DOW JONES INDICES, http://www.djaverages.com/?go=industrial-overview (last visited Jan. 13, 2013).

18. *See* S&P DOW JONES INDICES, http://us.spindices.com/ (last visited Jan. 13, 2013).

19. Note that both the Dow and the S&P are weighted such that changes to the stock price of companies with a higher market capitalization will influence the index to a greater degree. Nevertheless, the broader point remains true.

20. Just as when measuring an index of species diversity, information about the individual constituent species is necessarily lost.

The creation of indices is thus a value-laden and purpose-bound process. Selecting which variables to include and how to weight those variables will determine the index's output, and requires a value judgment regarding which variables are most important. Such judgment, whether implicit or explicit, goes to the critical question: *what do we want to know*? In the case of the stock market, including some stocks in a particular index will necessarily force us to pay less attention changes to others. Put another way, we remain willfully ignorant about some aspects of the market, filtering them out as background "noise" in order to focus on the signal coming from a subset of particularly interesting stocks. Closely related is the fact that the utility of an index's output depends strongly upon the particular study question at hand. Using the economic example again, if one is interested in the health of the steel industry, a tech-heavy index is unlikely to be the most informative barometer.

In an ecosystem context, indices carry the same set of limitations. Like an economy, an ecosystem is a complex of interactions among a vast number of interacting units at different hierarchical levels of organization. Perhaps we are interested in the physical structures of an ecosystem as a way of summarizing such complexity; or maybe quantifying nutrient flows into and out of a circumscribed area would be more helpful for a given purpose. But because tradeoffs are inherent in crafting an indicator of any type, durable and effective sets of indicators may only be selected after an explicit assessment of the purpose and goals of that particular indicator set.[21]

III. THE RISE OF ENVIRONMENTAL MONITORING AND INDICATOR SPECIES

A. *Environmental Monitoring and the Need to Simplify a Complex System*

The late 1960s saw the rise of environmental awareness in the United States leading to the landmark federal environmental statutes of the early 1970s: NEPA,[22] ESA,[23] CWA,[24] CAA.[25] These stat-

21. The lack of explicit goals and purposes for indicators is perhaps the most common criticism in the academic literature regarding the use of indicator species in ecology and conservation biology, and has remained so for decades. NFMA's regulations requiring MIS are a prime example of such an omission.

22. 42 U.S.C. §§ 4321-4370(h) (2012).

23. Endangered Species Act of 1973, 16 U.S.C. §§ 1531-1544 (2012).

utes and their implementing regulations demanded ways of making abstract concepts—such as environmental health and integrity—into concrete and measurable quantities.

This changing legal landscape likely accelerated the growth of applied ecology as a discipline, as researchers began to formalize ways of summarizing nature's complexity, simplifying the dense tangle of organismal interactions in just the same way the Dow Jones Industrial Average provides a window into the workings of the American economy. An analogous yardstick to measure changes in environmental condition was an attractive goal for academics seeking field data, and had immediate policy relevance for agencies newly charged with environmental responsibilities.

We can understand most of the resulting environmental measurement techniques in terms of a black box model: the addition of some input (or *stressor*) results in a change to some environmental outcome. We need not understand the mechanism by which the input results in the outcome, so long as we can predict a given outcome from a particular level of input. All methods of ecosystem assessment focus on inputs, outcomes, or both, with environmental *indicators* being cheap or easy ways of measuring inputs or outcomes.[26] In the wake of the environmental legislation of the 1970s, applied ecologists developed a variety of competing and complementary environmental metrics, a scientific give-and-take that can be seen as a struggle for the appropriate hierarchical level of focus.

The simplest examples of biological monitoring to measure an ecosystem parameter are bioassays, EPA-mandated animal-based tests for acute and ambient toxicity of effluents. The EPA sought to establish dose-response curves, calculating the effect of an input (say, selenium in effluent) on an outcome (the detrimental effect on a particular species of fish, for example). Bioassays are straightforward tests of both input and outcome, and establish a clear relationship between the two.[27] However, they focus on the narrow

24. 33 U.S.C. §§ 1251-1387 (2012).

25. 42 U.S.C. §§ 7401-7671(q) (2012).

26. Note that a danger of selecting such indicators is that it tends to focus attention on the indicator rather than the indicated, losing the larger point of environmental quality/health/function, by instead fixating on particular species or metrics.

27. A more familiar example of the same principle is the canary in a coal mine. *See infra* p. 112. The survival of the canary (the outcome) indicates the absence of toxic levels of methane or carbon monoxide in the mine (the input). As above with the human body temperature example, we must first understand the relationship between toxic gas levels and the canary's survival before we may treat the canary as an indicator of toxic gases. Fur-

questions of determining single-stressor, single-species toxicity levels, rather than more complex ecosystem-level assessments.

Such narrow focus is problematic, as it fails to address many of the underlying motivations for environmental regulation.[28] For example, the Clean Water Act (CWA) defines water quality with respect to particular designated uses of water bodies,[29] measuring individual chemical parameters against national criteria. Hence, water "quality" is defined in large part by the absence of high levels of pollutants.[30] This approach is equivalent to measuring some of the inputs to the system, but not measuring the outcome: we track levels of stressors, but no resulting measure of "quality" or environmental state itself. Many water bodies may be appropriate for a particular designated use—swimming pools are "swimmable," for example—but they are as far from a functioning ecosystem as one might imagine.

Following the passage of the CWA, ecologists therefore criticized its means of water quality assessment as overly reductive and, moreover, ineffective. An ecosystem is the entire set of interactions among species and nonliving components of an environment (such as temperature or sunlight), and therefore merely tracking pollutant levels is no measure of ecosystem integrity because it misses much of what defines an ecosystem. At the same time, however, a catchall measure of the health of a complex ecosystem was (and is) elusive for the same reasons as described above for economic systems: any index is a tradeoff between loss of information and increased simplicity, and there is no all-purpose "best" measure. Moreover, there is no one equilibrial state to an ecosystem (in contrast to the temperature of the human body), such that even if there were a "best" measure of ecosystem state, it would remain unclear what value that measure should take in any given case. The seemingly-simple questions of *what do we want to know?* and *why do*

ther, the canary is not an indicator of "mine safety" more generally until we understand the relationship between the canary's requirements for life and our own.

28. For example, the purpose of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 U.S.C. § 1251(a) (2012). The idea of environmental "integrity" necessarily entails a broad focus on the structure and function of the environment in question.

29. Examples of beneficial uses include recreation, fishing, shellfish culture, and many others.

30. A water body's acceptability for particular beneficial uses is also a measure of water quality, insofar as those uses are quality-dependent. This may be seen as an ecosystem "output," albeit one with only tenuous connections to ecosystem composition, structure, or function.

we want to know it? are surprisingly slippery when applied in a real-world context.

Researchers of the 1970s focused on different hierarchical levels of ecosystem organization to attack this problem: some zoomed in (looking at species or other component parts of an ecosystem), some zoomed out (focusing on system-wide variables, such as the change in species composition over space). Those that zoomed out suggested holistic measures best captured a portion of ecosystem complexity, or sought to measure fundamental processes as indices of ecosystem function. For example, measures of energy or nutrient flow through a lake would provide a view of the "function" of that lake in the context of global energy or nutrient cycles.[31] But quantifying and measuring these properties can be costly and difficult, and the remote sensing data that today makes these measurements easier was not yet widely available in the 1970s and early 1980s, making these holistic measures less useful in practice at the time.

The ecologists that zoomed in used smaller-scale, more field-friendly methods, such as monitoring individual species thought to be surrogates for larger ecosystem processes.[32] A species that is especially sensitive to change in habitat, for example, might be a good stand-in for change to that habitat. This approach had the additional benefit of integrating the effects of stressors over time—a change in the sensitive species would reflect changes to the habitat now or at any time in the recent past, unlike periodic chemical monitoring, which is likely to miss discrete events that impact habitat (such as the sudden release of a pollutant).

But of course, any single-species measure necessarily failed to capture much of what we think of as important about an ecosystem. Single-species indicators are akin to choosing a *single company's* stock to measure the state of the New York Stock Exchange. The ecological solution to this problem mirrored the economic approach: creating indices that combined multiple species' trends into a single, trackable, number. One particular index of note was the Index of Benthic Invertebrates (IBI),[33] which occupied a kind

31. *See, e.g.*, William H. Schlesinger, *Community Structure, Dynamics and Nutrient Cycling in the Okefenokee Cypress Swamp-Forest*, 48 ECOLOGICAL MONOGRAPHS 43 (1978).

32. *See infra* p. 112 and note 83.

33. James R. Karr, *Assessment of Biotic Integrity Using Fish Communities*, 6 FISHERIES 21 (1981) (providing an early and widely-cited example of the biotic community approach to monitoring freshwater environments).

of compromise position between species-focused and ecosystem-focused metrics, combining elements of species diversity and larger ecosystem processes into a single metric. But this and other multimetric indices shared many of the drawbacks of species-based approaches, insofar as they were place-specific and required a high level of expertise in a particular ecosystem to implement.

It was into this area of active ecological research that the NFMA regulations were born, in which monitoring individual indicator species became a mandatory feature of forest management in the United States.

B. *Indicator Species as a Type of Environmental Monitoring*

By the mid-1970s the indicator species concept—that is, the idea of monitoring one or a few species as an indicator of some larger process or state—was appearing in the academic literature as a method of environmental monitoring. This was an attractive monitoring tool because it was cheaper and easier than many of the alternatives, and because monitoring species captured at least some level of information about the larger ecosystem: the occurrence of particular species demonstrates the existence of the ecosystem services necessary to support that species, as well as the ongoing absence of lethal conditions.

But important details of using species as indicators remained fuzzy, details that would be necessary to make the concept of indicator species useful in practice. For example, authors differed widely regarding exactly which ecosystem states indicator species might depict, how the connections between indicators and ecosystem states might be verified, and how to go about selecting indicators. One 1974 paper on the use of indicator species to measure pollution is a helpful illustration of early ideas about the use of indicator species as ecological assessment tools.[34] The author—John Cairns, Jr., a future member of the National Academy of Sciences—begins with a broad conception of what an indicator species is:

> The idea that certain species can be used to indicate certain types of environmental conditions is well established. Trout are usually associated with cold water, game birds are usually associated with a particular kind of habitat, gardeners know that plants have certain preferences regarding soil, amount of sunlight, temperature,

34. John Cairns, Jr., *Indicator Species vs. the Concept of Community Structure as an Index of Pollution*, 10 WATER RESOURCES BULL. 338 (1974).

> and the like . . . their presence indicates something about the nature of the environment in which they are found.[35]

By the next paragraph, though, Cairns has narrowed the indicator concept to one sometimes known as a subtype of indicators called "sentinel" species: "[t]he presence of a species furnishes assurance that certain minimal conditions have been met."[36] The classic sentinel species is the canary in the coal mine.[37] So long as the canary is alive, it is clear that sufficient oxygen is present for the bird's requirements and that, conversely, toxic levels of methane, carbon monoxide, or other gases are *not* present.[38] Cairns's usage emphasizes the presence of necessary environmental conditions, rather than the absence of toxic conditions, but the point remains the same.

Cairns then goes on to warn of the wide range of interpretations for an absence of such species, and ultimately reaches a conclusion that community-level assessments (rather than species-level analyses) might be preferable.[39] This single example of ecological scholarship in the mid-1970s thus struggles with many of the themes that would be seen repeatedly in the ensuing decades: the tension between simpler and more complex environmental indices, the tradeoffs between the desire for holistic measures and the

35. *Id.* at 338.

36. *Id.* at 346. The article goes on to state:

> There are very few data supporting the indicator species assessment of pollution, and the results are difficult if not impossible to quantify . . . and require much information about the responses of organisms to various types of pollutional stress that is not now in the literature. That is, most of the species likely to be found in North America and other areas outside of Europe and even many of the areas in Europe are not adequately characterized in terms of their response to various pollutants. About the only alternative for assessing the biological consequences of pollution is the use of information involving entire communities in the receiving system. Bioassays involving one or more individual species are extremely useful but do not yet furnish sufficient evidence to predict what will happen to a complex community with multiple interlocking cause-effect pathways exposed to the same waste discharges. *Id.*

37. *See, e.g.*, *supra* note 27; *see also* William H. van der Schalie et al., *Animals as Sentinels of Human Health Hazards of Environmental Chemicals*, 107 ENVT'L HEALTH PERSP. 309, 309 (1999).

38. Importantly, canaries are more sensitive to these gases than are humans, such that the bird's continued vitality suggests a safe working environment for human miners, leaving some margin for error.

39. Cairns, *supra* note 34, at 346.

costs of obtaining the information necessary to make those measures robust, ambiguity about the definition and uses of species-as-indicators altogether, a desire for higher quality quantitative data, and a call for more data overall.

The idea of using indicator species was seductive, promising a means of ecosystem-level assessment with simple and field-friendly tools, but in the 1970s the idea was still coalescing. Nevertheless, it was about to be implemented in the NFMA regulations as a tool of environmental management on a grand scale.

IV. NFMA AND "MANAGEMENT INDICATOR SPECIES" (MIS)

A. *The Statutory Planning Scheme*

Congress passed the National Forest Management Act (NFMA) in 1976 to address over-exploitation concerns and to resolve intense conflict about the "correct" balance of industrial use and conservation in the national forests.[40] NFMA requires the U.S. Forest Service (USFS) to develop Land and Resource Management Plans (LRMPs) for each management unit.[41] The USFS must also issue a layer of national regulations to flesh out the statutory requirements and provide further guidance to resource managers as they develop individual LRMPs.[42]

With respect to biodiversity management, the Act specified that USFS regulations for land use management plans must "provide for diversity of plant and animal communities" among other multiple-use objectives.[43] More specifically, NFMA required the Forest Service to specify "guidelines for land management plans . . . which insure consideration of the economic and environmental aspects of various systems of renewable resource management . . . to provide for outdoor recreation (including wilderness), range, timber, watershed, wildlife, and fish." Together, these provisions

40. 16 U.S.C. §§ 1600-1687 (2012); *see also* Oliver Houck, *The Water, the Trees, and the Land: Three Nearly Forgotten Cases That Changed the American Landscape*, 70 TUL. L. REV. 2279, 2291-309 (1996) (discussing the litigation and politics resulting in the Act).

41. 16 U.S.C. § 1604(a) (2012). In theory, these plans are revised at least every fifteen years. *Id.* § 1604(f)(5).

42. The NFMA regulations are currently codified at 36 C.F.R. § 219 (2012).

43. 16 U.S.C. § 1604(g)(3)(B) (2012). *But see* The Lands Council v. Powell, 395 F.3d 1019, 1025 n.2 (9th Cir. 2005) ("The Forest Service is obligated to balance competing demands on national forests, including timber harvesting, recreational use, and environmental preservation . . . . The national forests, unlike national parks, are not wholly dedicated to recreational and environmental values.") (citations and internal quotations omitted).

form the core of the NFMA biodiversity protections; land use plans must make some accommodation for fish and wildlife.

B. *NFMA's Implementing Regulations*

The Forest Service was then left to create the rules by which more than 225 million acres of National Forest[44] would be managed via land use management plans. Fulfilling a statutory requirement, the Service appointed a Committee of Scientists in 1977,[45] to help draft this first set of forestry regulations.

This Committee saw biological diversity as compelled by NFMA's mandate to provide guidelines for management plans that would "provide for diversity of plant and animal communities."[46] However, the Committee regarded diversity *per se* as insufficient for evaluating management effects on the forest, and no practical strategy for measuring ecological outcomes had emerged as a clear winner out of the foment of academic ideas.[47] Management indicator species[48] (MIS) were the Committee's solution, multiple forest species to be selected by individual forest managers, to serve as field-friendly metrics for a variety of interrelated ecological goals.[49]

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44. As of 2011. FS Directive 383, Land Areas of the National Forest System 1 (U.S.D.A. 2012).

45. Congress required the Forest Service to convene a Committee of Scientists (COS) to assist the Forest Service in developing regulations to implement the new law: "[T]he Secretary of Agriculture shall appoint a committee of scientists who are not officers or employees of the Forest Service. The committee shall provide scientific and technical advice and counsel on proposed guidelines and procedures to assure that an effective interdisciplinary approach is proposed and adopted." 16 U.S.C. § 1604(h)(1) (2012). The Carter administration assembled the first COS in 1977, with advice from the National Academy of Sciences. This group of scientists would have a profound impact on the resulting regulations, creating the "Management Indicator Species" nomenclature and establishing the contours of this new regulatory requirement. For a short history of the COS, see Steven E. Daniels & Karren Merrill, *The Committee of Scientists: A Forgotten Link in National Forest Planning History*, 36 FOREST & CONSERVATION HIST. 108 (1992). The Committee consisted of eight scientists (seven at a time, with one substitution), headed by Arthur W. Cooper of the School of Forest Resources at North Carolina State University.

46. 16 U.S.C. § 1604(g)(3)(B) (2012).

47. As evidence of this foment, see James R. Karr, *Biological Monitoring and Environmental Assessment: A Conceptual Framework*, 11 ENVTL. MGMT. 249 (1987) ("Some direct approaches for biological monitoring have been developed but a lack of consensus among biologists, fueled by bureaucratic inertia, tends to favor established procedures.").

48. COMM. OF SCIENTISTS, FINAL REPORT OF THE COMMITTEE OF SCIENTISTS 112-13 (1979); *see also* 36 C.F.R. § 219.12(g)(2)(1979).

49. The Committee's product proved sturdy: despite the Reagan administration's encouragement to cut back the forest planning rules, the COS's Carter-era product remained largely intact when reissued as the 1982 NFMA regulations. *Compare* 44 Fed. Reg. 53928 *et seq.* (Sept. 17, 1979) *with* 47 Fed. Reg. 43026 *et seq.* (Sept. 30, 1982).

The original 1979 NFMA land use planning regulations and the subsequent 1982 revision had largely identical biodiversity provisions. First, land use plans were to ensure that habitat would be managed to maintain "viable populations of existing native and desired non-native vertebrate species" (the "vertebrate viability" requirement).[50] Second, forest units were to select MIS as tools to aid in evaluating alternative management actions:

> In order to estimate the effects of each alternative on fish and wildlife populations, certain vertebrate and/or invertebrate species present in the area shall be identified and selected as management indicator species and the reasons for their selection will be stated. These species shall be selected because their population changes are believed to indicate the effects of management activities.[51]

The regulations went on to enumerate categories of species that "shall be represented, where appropriate," including federally threatened or endangered species, game species, and "plant or animal species selected because their population changes are believed to indicate the effects of management activities on other species of selected major biological communities or on water quality."[52] MIS would be used in evaluating planning alternatives, and their population trends monitored.

A final layer of guidance for forest managers comes from the Forest Service Manual and the Forest Service Handbook,[53] field-

50. 36 C.F.R. § 219.19 (1982). The vertebrate viability requirement largely merges into the MIS requirement, as forest units have tended to select vertebrates as MIS, thus fulfilling both provisions simultaneously.

51. *Id.* at (a)(1), (a). Notably, Forest Service proposals to remove these provisions through "updates" to the 1982 regulations have been the subject of intense litigation for the last decade. For an overview, see Citizens for Better Forestry v. U.S. Dep't of Agric., 632 F. Supp. 2d 968, 982 (N.D. Cal. 2009), discussed *infra* p. 117.

52. 36 C.F.R. § 219.19(a)(1) (1982).

53. For a treatise discussion on the Manual and Handbook, see 1 PUB. NAT. RESOURCES L. § 7:16 (2d ed. 2012), explaining that:

> [M]anual provisions continue to govern many procedural and some substantive matters. Forest Service regulations, for example, indicate that procedures for the conduct of agency activities are issued as directives, which include the Forest Service Manual and related Handbooks . . . . The Forest Service Manual and handbook are published by the Office of the Chief, supplemented as necessary for field office use by Regional Foresters and others, while guidance issued through letters and memoranda must be issued in accordance with signing authorities

level instructions that are more frequently updated than regulations. Since 1982, these guidelines have periodically changed to reflect an evolving view of MIS, and have attempted to increase the scientific rigor with which the MIS provision is carried out.[54] However, neither the Handbook nor the Manual has the "independent force and effect of law," and consequently do not bind the Forest Service.[55] This Article focuses on the regulations themselves, while recognizing the existence of these lower-level guidelines more responsive to dynamic science.[56]

In sum, the 1982 regulations bind forest managers, requiring they select particular species and monitor them as an aspect of evaluating management alternatives under their Land and Resource Management Plans (thus locking managers into *how* they should monitor). The first Plans to incorporate MIS were due in 1985, to be revised at least every 15 years.[57] The regulations do not tie MIS explicitly to action, such that so long as foresters disclose why they selected MIS, they need not use the selected species in any particular way.

The 1982 NFMA regulations were ambiguous on their face, failing to address the *what* and the *why* of environmental monitoring by providing little instruction to forest managers as to how best to identify a suite of MIS and by implying a variety of regulatory purposes for their use. For example, the fact that MIS "shall be selected to indicate the effects of management activities" suggests MIS are a generic outcome variable for environmental health, but the enumerated categories of MIS species suggest multiple purposes, including ESA compliance and maintaining hunting opportuni-

delegated through issuances to the Forest Service Directive System. While the agency makes available for public inspection and copying all unpublished directives, it is obviously more difficult to procure these materials than more formal sources of 'law,' such as agency regulations. Indeed, the Forest Service does not even publish the indices of much of these informal documents.

54. *See, e.g.*, U.S. FOREST SERV., FOREST SERV. HANDBOOK 1909.12 ch. 40 (2006) (updating provisions on science and sustainability).

55. W. Radio Services Co. v. Espy, 79 F.3d 896, 901 (9th Cir. 1996) (noting that neither the Handbook nor the Manual are subject to notice-and-comment periods consistent with the Administrative Procedures Act, that neither is routinely published in the Federal Register or the Code of Federal Regulations, and consequently holding "that the Manual and Handbook do not have the independent force and effect of law").

56. We also discuss the Manual and Handbook briefly *infra* Part 6, in evaluating the MIS provision in light of best practices.

57. 16 U.S.C. § 1604(f)(5)(A) (2012).

ties. At the same time, the original underlying logic for creating the MIS was to ensure compliance with NFMA's mandate to provide for the "diversity of plant and animal communities," seemingly a different goal entirely. This profusion of regulatory goals would enshrine a significant level of agency discretion in fulfilling the national forests' biodiversity requirements.

C. *The 2012 Planning Rule Revision, and the Fate of Previous Revisions*

NFMA has proved highly controversial since 1976. Local, industrial, and conservation interests have fought intense battles over the degree to which NFMA's substantive and procedural requirements should constrain the discretion of regional and unit-level forest managers in the face of evolving science, local economic demands, and competing interests. Within the last decade courts have repeatedly struck down several Forest Service attempts to provide managers with additional flexibility on issues such as biodiversity conservation, public process, and environmental review.[58]

The biodiversity regulations have been a particular administrative battleground over the past decades, as different presidential administrations have fought to ensconce their preferred management policies governing land-use planning in the National Forests. The first complete set of planning regulations under NFMA came into force in 1982 during the Reagan Administration,[59] creating a baseline for both the process and substance of planning documents. The MIS provision focused on single species as indicators of management activities' effect on forest health. Late-Clinton-era regulations[60] then sought a broad philosophical change, rooting USFS decisionmaking in principles of ecosystem-based management and sustainability, but were quickly replaced by a new set of rules early in the George W. Bush administration.[61] The 2005 Bush

58. *See* Citizens for Better Forestry v. U.S. Dep't of Agric. (*Citizens II*), 481 F. Supp. 2d 1059, 1063 (N.D. Cal. 2007) (summarizing this procedural history); *see also* Citizens for Better Forestry v. U.S. Dep't of Agric. (*Citizens III*), 632 F. Supp. 2d 968, 982 (N.D. Cal. 2009); Citizens for Better Forestry v. U.S. Dep't of Agric. (*Citizens I*), 341 F.3d 961 (9th Cir. 2003); George Hoberg, *Science, Politics, and U.S. Forest Service Law: The Battle over the Forest Service Planning Rule*, 44 NAT. RESOURCES J. 1 (2004).

59. National Forest System Land and Resource Management Planning, 47 Fed. Reg. 43037 (Sept. 30, 1982) (codified at 36 C.F.R. pt. 219).

60. National Forest System Land and Resource Management Planning, 65 Fed. Reg. 67568 (Nov. 9, 2000) (codified at 36 C.F.R. pt. 217, 219).

61. National Forest System Land and Resource Management Planning, 67 Fed. Reg. 72770 (Dec. 6, 2002) (codified at 36 C.F.R. pt. 219).

rules,[62] aimed to streamline forest management by weakening environmental review and biodiversity management requirements for LRMPs, but were enjoined for lack of proper environmental assessment.[63] A subsequent similar set, the 2008 Bush regulations,[64] met a nearly identical fate.[65] In *Citizens for Better Forestry v. United States Dept. of Agriculture*,[66] the court vacated the 2008 regulations, giving USFS the option of continuing under either the 1982 or the 2000 regulations because of the Service's view that the 2000 version was unworkable in practice.[67] The Forest Service then promulgated a rule in December 2009 reinstating the 2000 regulations and leaving open the option for forest managers to use the 1982 rule under existing transitional provisions.[68]

The politicization of the NFMA planning regulations and resulting litigation created years of administrative uncertainty. In the end, Forest Service planning has tended to rely on the Reagan-era 1982 regulations, which have remained on firm legal footing and which the 2009 rulemaking explicitly validated.[69] Perhaps as a result of the legal battles, however, forest planning has fallen badly behind schedule; as of 2012, "[o]f the 127 land management plans for National Forest System lands, 68 are now more than fifteen years old and are past due for revision."[70] Given the constant state of change in the nation's forest ecosystems—for example, 5 out of the twenty five largest wildland fires in the past fifteen years have

62. National Forest System Land and Resource Management Planning, 70 Fed. Reg. 1023 (Jan. 5, 2005) (codified at 36 C.F.R. pt. 219).

63. *Citizens II*, 481 F. Supp. 2d at 1100.

64. National Forest System Land and Resource Management Planning, 73 Fed. Reg. 21468 (Apr. 21, 2008) (codified at 36 C.F.R. pt. 219).

65. *Citizens III*, 632 F. Supp. 2d 968, 982-83 (N.D. Cal. 2009).

66. *Id.*

67. *Id.* ("The effect of invalidating an agency rule is to reinstate the rule previously in force. It appears that the 2000 Rule was in force before the 2008 Rule was promulgated. However, the USDA has expressed in the past its view that the 2000 Rule is unworkable in practice. Accordingly, the agency may choose whether to reinstate the 2000 Rule or, instead, to reinstate the 1982 Rule.") (citation, quotation marks, and footnote omitted).

68. *See* National Forest System Land and Resource Management Planning, 74 Fed. Reg. 67059, 67060 (Dec. 18, 2009) (codified at 36 C.F.R. pt. 219) ("[R]esponsible officials may continue to revise or amend land management plans under either the 1982 rule provisions or the 2000 rule provisions.").

69. *Id.* This is especially the case because forest planning can take many years to complete. As such, completing an LRMP under an invalid set of regulations can result in a court invalidating the entire Plan, an extremely expensive prospect.

70. FOREST SERVICE FACT SHEET, HOW IS THE PREFERRED ALTERNATIVE DIFFERENT FROM THE 1982 RULE PROCEDURES? at 1 (2012), *available at* http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5349609.pdf.

been in National Forests[71]—this state of chronic delay hampers effective resource management.

The 2012 revision to the planning rule, which went into effect on May 9, 2012,[72] is the result of a years-long process that aimed to avoid a similar fate.[73] In response to widespread criticism of the 1982 MIS provision, the new rule includes a requirement to monitor "focal species"[74] as "one of many ways to gauge progress toward achieving desired conditions in the plan."[75] The new regulations then define "focal species" broadly:

> A small subset of species whose status permits inference to the integrity of the larger ecological system to which it belongs and provides meaningful information regarding the effectiveness of the plan in maintaining or restoring the ecological conditions to maintain the diversity of plant and animal communities in the plan area. Focal species would be commonly selected on the basis of their functional role in ecosystems.[76]

Because no forest units have yet revised their plans under the 2012 rule, it remains to be seen how this new set of rules will fare by ei-

71. *See* NATIONAL INTERAGENCY FIRE CENTER, http://www.nifc.gov/fireInfo/fireInfo_stats_lgFires.html (last visited: Jul. 2, 2012).

72. National Forest System Land and Resource Management Planning, 77 Fed. Reg. 21162, 21162 (Apr. 9, 2012) (to be codified at 36 C.F.R. pt. 219) (listing effective date as May 9, 2012).

73. For the Forest Service's account of this process, see NATIONAL FOREST MANAGEMENT ACT (NFMA) / PLANNING, http://www.fs.fed.us/emc/nfma/index.htm (follow "USDA Forest Service Launches Collaborative Process for New Planning Rule") (last visited Mar. 23, 2012).

74. 36 C.F.R. § 219.12(a)(5)(iii) (2012); *see also* U.S. DEP'T OF AGRIC., FOREST SERV., FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT 129 ("The Committee of Scientists (1999) advanced the term 'focal species' to allow for a variety of approaches to selecting species whose status and trends provide insights to the integrity of the larger ecological system to which it belongs. Their use of the term focal includes several existing categories of species used to assess ecological integrity, such as indicator species, keystone species, ecological engineers, umbrella species, link species, strong interactors, and species of concern. Focal species would commonly be selected on the basis of their functional role in ecosystems, for example: species that act as ecosystem engineers by modulating the availability of resources to other species through changes in biotic or abiotic materials, thus creating or maintaining habitats; ecological indicators that indicate the action or consequences of key environmental stressors; or strongly interactive species that are disproportionately significant to the survival of other native species and ecosystems, such as plants that provide critical resources, insect pollinators, and carnivores."(citations omitted)).

75. U.S. DEP'T OF AGRIC., FOREST SERV., FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT, APPENDIX A, PROPOSED PLANNING RULE A26-27 (2012).

76. *Id.* at APPENDIX I, MODIFIED ALTERNATIVE A, § 219.19, I29-30 (2012).

ther environmental or legal standards.

Although the proposed 2012 NFMA regulations phase out the 1982 regulations' MIS provision, the older rule contains important lessons about the interaction between science and law that are important for the future of public resources management. The 1982 rule, not quite state-of-the-art when implemented, quickly became outdated as the science of environmental monitoring moved on. The Forest Service remained bound by this aging methodology—frustrating foresters, environmentalists, and courts alike—even as the Service expanded its environmental monitoring and assessment program far beyond what the regulations required. This conflict between dynamic science and static law[77] frequently occurs when statutes or regulations must identify a particular scientific means to a policy end.[78] Below, we review the scientific progress since the 1982 regulations locked the MIS requirement in place, and then evaluate specifically what made the MIS rule a misfire. We then suggest how public resources agencies can do better in the future, and in particular, how federal ocean governance should benefit from the mistakes of NFMA's MIS provision. The fate of the new 2012 NFMA planning rules remains unclear, and will likely be settled only after litigation. As the Forest Service launches this most recent revision, it seems a particularly appropriate time to evaluate the way in which the 1982 regulations set up a conflict between dynamic science and static law.

V. POST-1982 SCIENCE OF ENVIRONMENTAL MONITORING

A. *Problems with the Indicator Species Concept(s)*

The MIS requirement began to appear dated almost immediately, as applied ecological research continued apace following the Forest Service's adoption of the 1982 NFMA regulations. In contrast to the ESA and other major environmental statutes, NFMA has neither a "best available science" mandate[79] nor any analogous

77. We use this phrase with apologies to Holly Doremus, author of *The Endangered Species Act: Static Law Meets Dynamic World*, 32 WASH. U. J.L. & POL'Y 175 (2010).

78. *See* Emily Hammond Meazell, *Super Deference, the Science Obsession, and Judicial Review as Translation of Agency Science*, 109 MICH. L. REV. 733 (2011) (discussing the related issue of courts' deference to agencies regarding scientific issues, ultimately diminishing agency incentives to use the best available science).

79. Note that the 2012 NFMA planning regulations do require the Service to "take into account the best available scientific information throughout the planning process." 36 C.F.R. § 219.3 (2012).

provision for updating its indicator scheme as new techniques came to the fore. The result was a bright-line requirement to use MIS in every national forest, a requirement that remained in place even as ecological researchers began a marked shift away from using individual species as tools of ecosystem assessment.

As academic and agency scientists gained experience with environmental monitoring techniques, a trend towards formalization began to emerge. Between roughly 1970 and 1982, monitoring had gone from ad-hoc to experimental to routine, and routine demanded reliability. It was as if coal miners required not just the canary, but had to determine the canary's precise tolerance for methane, or the distribution of such tolerance among all canaries. With respect to species-as-indicators, this drive for increased rigor led academic authors to make increasingly fine distinctions among categories of indicator species based upon specifically what ecological outcome variables were being measured (that is, based upon just what was indicated.)[80]

By the early 1990s, the result was a proliferation of indicator species sub-types, often with overlapping purposes, among them "focal species, umbrella species, flagship species, [and] guilds,"[81] where

> [t]he term focal species has been used in many ways in the literature. . .[and t]here is not a consistent definition of a focal species, except when they are selected by various means as the "focus of a study." Umbrella species [are] those whose conservation confers a protective umbrella to numerous co-occurring species . . . Flagship species are those that have large public appeal, such as charismatic megafauna like bears and tigers. . . Guilds [are groups] of species that exploit the same class of environmental resources in a similar way.[82]

Review articles proliferated, attempting to wrangle the fragmented

80. BIOSIS Previews, an online database of academic publications in the life sciences, shows an exponential increase in publications with the topic "indicator species" beginning around 1976. This is a very robust trend, with a significant regression (R^2=0.92). The database lists 16 publications in 1980 with the topic "indicator species," compared to 188 in 2010. *See* http://www.webofknowledge.com/ (search last performed Nov 30, 2012). Note, however, that this trend in part reflects a tremendous increase in the overall number of academic articles published since 1980.

81. Niemi & McDonald, *supra* note 15, at 97 (citing various authors as proponents of each sub-concept).

82. *Id.* (citations and quotation marks omitted).

indicator concepts into meaningful categories, each arriving at a different organizational scheme.[83] Given such a diversity of views on the state of the indicator species approach to monitoring, it is hardly surprising that frustration has ensued. There came to be as many types of indicators as there were motivations for measuring environmental state or change, and such specificity came at a cost: the panoply of closely related—but not identical—ideas led to suspicion among some ecologists regarding the indicator species concept altogether.[84] In short, "[t]he term 'indicator' has been defined in many different ways, exacerbating confusion about how to use them."[85]

An authoritative 2004 paper covers the waterfront of indicator critiques, and provides perhaps the most useful organizational framework for the present purposes. Defining "indicator" as "a general term to refer to approaches that use one or a few species to 'indicate' condition or a response to stress that may apply to other species with similar ecological requirements,"[86] the authors cite three categories of indicator species: (a) those that reflect the

83. *See* Erik A. Beever, *Monitoring Biological Diversity: Strategies, Tools, Limitations, and Challenges*, 87 N.W. NATURALIST 66 (2006); Vincent Carignan & Marc-André Villard, *Selecting Indicator Species to Monitor Ecological Integrity: A Review*, 78 ENVTL. MONITORING AND ASSESSMENT 45 (2002); Robert J. Lambeck, *Focal Species: A Multi-Species Umbrella for Nature Conservation*, 11 CONSERVATION BIOLOGY 849 (1997); David B. Lindenmayer, Chris R. Margules & Daniel B. Botkin, *Indicators of Biodiversity for Ecologically Sustainable Forest Management*, 14 CONSERVATION BIOLOGY 941, 943 (2000); Niemi & McDonald, *supra* note 15, at 97-99 (discussing each concept separately); Reed F. Noss, *Assessing and Monitoring Forest Biodiversity: A Suggested Framework and Indicators*, 115 FOREST ECOLOGY AND MGMT. 135 (1999); Daniel Simberloff, *Flagships, Umbrellas, and Keystones: Is Single-Species Management Passé in the Landscape Era?*, 83 BIOLOGICAL CONSERVATION 247 (1998); *see also* T.M. Caro & Gillian O'Dogherty, *On the Use of Surrogate Species in Conservation Biology*, 13 CONSERVATION BIOLOGY 805 (1999) (discussing similar material, though using the term "surrogate species" as a general term for all of the abovementioned applications). Note also that spatial scale plays an important role in selecting and assessing indicator species, such that the usefulness of a particular set of species will vary both for different purposes and over different spatial scales. *See, e.g.*, Jan C. Weaver, *Indicator Species and Scale of Observation*, 9 CONSERVATION BIOLOGY 939, 939 (1995) (noting that species richness varies with spatial scale and focusing attention on the scale dependence of indicator species).

84. For example, Daniel Simberloff was moved to title one well-cited 1998 paper *Flagships, Umbrellas, and Keystones: Is Single-Species Management Passé in the Landscape Era?*, *supra* note 83, and Sandy J. Andelman & William F. Fagan expressed their frustration with the title *Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes?*, 97 PROC. NAT'L ACAD. SCI. 5954 (2000).

85. Andrew A. Whitman & John M. Hagan, FINAL REPORT TO THE NATIONAL COMMISSION ON SCIENCE FOR SUSTAINABLE FORESTRY, A8, BIODIVERSITY INDICATORS FOR SUSTAINABLE FORESTRY 2 (2003).

86. Niemi & McDonald, *supra* note 15, at 96.

state of the environment,[87] (b) those that serve as markers for environmental change, and (c) those that stand in as surrogates for other "species, taxa, or communities within an area."[88] It is this third category, the authors argue, that is the cause of ontological confusion, in part due to a lack of data supporting the use of one species as a surrogate for others, and that this uncertainty has led to the proliferation of narrow subtypes of indicators.

NFMA's MIS requirement pre-dates this mushrooming of specialized indicator designations, seemingly encompassing many or all of the particular goals later given different names. Against this diversifying backdrop, the nonspecific MIS appears ever more vague and dated, reflecting an earlier untested assumption about the strength of links between MIS and environmental outcome variables.[89]

Despite the abundance of ideas and naming schemes for indicator species as a basic tool of conservation, biological or ecological assessment—and regardless of where MIS fit into this universe of ideas—as of the late 1990s there was little in the way of data to substantiate claims that indicator species were effective in the field.[90] One major study evaluated a wide variety of different indicator species schemes across different ecosystems, datasets, and spatial scales.[91] This broad sampling was intended to be a rigorous test of the species-as-indicator concept, and the authors found that *none* of the schemes performed significantly better than a random

87. In the marine context, an example of this kind of "state" indicator is benthic invertebrate species composition. *See* S. CAL. COASTAL WATER RESEARCH PROJECT, SCCWRP, 2012-13 RESEARCH PLAN, *available at* http://www.sccwrp.org/Documents/ResearchPlan.aspx#a._Development_of_Benthic_Macrofauna_as_Indicators_for_Sediment_Quality_Assessment. Conservation International's Ocean Health index encompasses both status and trends monitoring. CONSERVATION INTERNATIONAL, *Ocean Health Index*, *available at* http:// www.conservation.org/global/marine/initiatives/ocean_health_index/pages/ocean_health_index.aspx.

88. Niemi & McDonald, *supra* note 15, at 96-97 (citing JH Lawton & KJ Gaston, *Indicator Species*, *in* Encyclopedia of Biodiversity 437 (S. Levin ed., 3d ed, 2001)). Note that "taxon" (plural = "taxa") is a general term referring to species or coherent groups of species that share an evolutionary history.

89. Conversely, MIS may be seen as a *sui generis* indicator type. Lindenmayer, *supra* note 83, at 943, for example, refers to MIS as a distinct category of indicator.

90. Perhaps the plural "tools'" would be more appropriate here, but as the focus here is on the rise, diversification, and assessment of indicator species generally, we will treat the complex of techniques as a singular entity for simplicity.

91. Andelman & Fagan, *supra* note 84, at 5955. The authors evaluated up to 14 schemes for selecting indicator species, in three ecosystems. Each of these three made use of a different dataset and occurred at a different spatial scale.

selection of species from the relevant database.[92] Another analysis demonstrated that areas of high diversity for one taxonomic group rarely overlap with those for other taxonomic groups, and that rare species (often of conservation interest) often do not occur within the most species-rich geographic areas.[93] Taken together, these data undermine the very concept that one or several species can stand as a measure of many others, or of a larger idea of biodiversity.

B. *Toward Holistic Measures of Ecosystem Structure and Function*

The fragmentation of indicator species concepts and the lack of data supporting their general use contributed to a shift away from indicator species and toward more synthetic methods of environmental monitoring. However, the move away from focusing on individual species (as individual components of a larger ecosystem) and towards more holistic measures of ecosystem structure and function has also reflected a larger conceptual trend in environmental management: from single-species management to ecosystem-based management.[94] In this new light, monitoring individual species seemed to miss the larger point.[95] The shift away from individual-species-based management was apparent even within the Forest Service; the Forest Health Monitoring Program (begun in 1990) used forest crown cover, chemistry, morphology, and species diversity as metrics of forest health.[96]

92. *Id.* at 5954. *See id.* at 5955-56 for a description of the different surrogate (that is, indicator) species schemes the authors evaluated, and for the evaluation criteria for each.

93. *See* J.R. Prendergast et al., *Rare Species, the Coincidence of Diversity Hotspots, and Conservation Strategies*, 365 NATURE 335, 335 (1993).

94. "Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors." KAREN L. MCLEOD ET AL., SCIENTIFIC CONSENSUS STATEMENT ON MARINE ECOSYSTEM-BASED MANAGEMENT, COMMUNICATION PARTNERSHIP FOR SCIENCE AND THE SEA 1 (2005), *available at* http://www.compassonline.org/science/EBM_CMSP/EBMconsensus. This influential statement was signed by hundreds of scientists and policy experts with relevant expertise, among them the now-Administrator of the National Oceanographic and Atmospheric Administration, Jane Lubchenco.

95. Measuring the trees and not the forest, as it were.

96. *See* Samuel A. Alexander & Craig J. Palmer, *Forest Health Monitoring in the United States: First Four Years*, 55 ENVTL. MONITORING AND ASSESSMENT 267 (1997); Dayle D. Bennett & Borys M. Tkacz, *Forest Health Monitoring in the United States: A Program Overview*, 71

In 2000, the National Research Council issued a report entitled "Ecological Indicators for the Nation," in an effort to synthesize the thinking about the use of indicators in environmental monitoring, and to recommend particular indicators of broad applicability.[97] Indicator species were not among the Council's recommendations. Rather, the report centered on a small handful of fundamental ecosystem structures and processes, reflecting the improved status of these metrics in environmental monitoring. Indicators of ecosystem structure included land cover and related variables, as well as species diversity—an index of the biological components of an ecosystem that avoids tracking individual species.[98] The report recommended parameters such as carbon storage, net primary productivity, and nutrient flows as indicators of ecosystem function,[99] and echoed many other efforts to develop similar metrics.[100] It became possible to measure more important variables directly, rather than relying heavily on indicators of those same underlying variables. These and similar measures represent the present state of the art in environmental monitoring.

Further evidence of the trend toward holism comes from emerging efforts to measure and manage coupled social-ecological systems, reflecting a formalization of the basic observation that the sphere of human activities is not somehow distinct from a separate sphere of the "environment."[101] Such integrative monitoring attempts to place environmental data into an appropriate social con-

AUSTL. FORESTRY 223 (2008).

97. NATIONAL RESEARCH COUNCIL, ECOLOGICAL INDICATORS FOR THE NATION (2000). ("[T]he Indicators Committee decided that its main task was to identify and characterize general ecological indicators capable of informing the public and decision makers about the overall state of the nation's ecosystems and how those ecosystems may be changing.").

98. *Id.* at 7.

99. *Id.*

100. For example, the Heinz Center's 2008 State of the Nation's Ecosystems Report included a large number of metrics meant to express ecosystem health in a pluralistic way (including indicators of nutrient cycling, biological productivity, and other metrics). THE HEINZ CENTER, HIGHLIGHTS: THE STATE OF THE NATION'S ECOSYSTEMS 6 (William C. Clark et al. eds., 2008). The focus on fundamental biological and chemical variables underscores the conceptual shift away from monitoring individual ecosystem components (such as particular species) and towards more a more holistic, ecosystem-level view of environmental management. Improved technology probably also played a role in promoting these fundamental indicators, as more widely available remote sensing, GIS, and modeling tools made such measurements more feasible.

101. Note that the lack of separation between these spheres is made clear by the very existence of environmental statutes, all of which mediate the interactions between humans and the natural resources on which we depend.

text, and therefore requires a conceptual model that more fully incorporates human dimensions.[102] For example, some conservation projects have begun to measure social outcome variables rather than solely ecological ones.[103] Although certain social factors are likely to be difficult to quantify, the future of environmental monitoring will likely entail improved means of incorporating social and ecosystem variables—a far broader view of environmental health than the single-species monitoring of the 1970s captured.[104]

C. *Best Practices of Environmental Indicators*

The move toward ecosystem-based monitoring does not alleviate the need for well-designed metrics to reflect ecosystem state. On the contrary, because more holistic measures tend to be composite statistics, ensuring transparency in the values that underlie these statistics is more salient than ever, as the metrics themselves are more removed from everyday experience. The trade-offs between generality and specificity (inherent in any indicator or index, as discussed *supra* in Part 2) remain, and striking a reasonable balance among a metric's assets and liabilities requires significant up-front time investment to determine the purposes and practicalities of a particular monitoring regime. A summary of best practices

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102. One such conceptual framework that integrates social and ecological variables is the five-part Driver-Pressure-State-Impact-Response (DPSIR) model developed by the European Environment Agency. In this case, the two-part ecological system (Pressure and State) occurs within a social context (social and demographic Drivers leading to environmental Pressure, the magnitude of social Impact resulting from a change in ecosystem State, and the social/political Response to that Impact). (This is a more elaborate version of the earlier Pressure-State-Response model). These kinds of models form a framework for developing social indicators of environmental pressures, as well as for identifying the least socially-disruptive paths to changes in environmental management. *See* R.E. Bowen & C. Riley, *Socio-Economic Indicators and Integrated Coastal Management*, 46 OCEAN & COASTAL MGMT 299 (2003); Hanne Svarstad et al., *Discursive Biases of the Environmental Research Framework DPSIR*, 25 LAND USE POL'Y 116, 116 (2008) (arguing that the framework is biased by the "discursive positions the applicant brings to it").

103. *See, e.g.*, Helen E. Fox, *Reexamining the Science Of Marine Protected Areas: Linking Knowledge to Action*, 5 CONSERVATION LETTERS 1 (2011); Patrick Christie, *Marine Protected Areas as Biological Successes and Social Failures in Southeast Asia*, *in* AQUATIC PROTECTED AREAS AS FISHERIES MANAGEMENT TOOLS: DESIGN, USE, AND EVALUATION OF THESE FULLY PROTECTED AREAS 155 (J. B. Shipley, ed., 2004); Patrick B. Christie et al., *Toward Developing a Complete Understanding: A Social Science Research Agenda for Marine Protected Areas*, 28 FISHERIES 22 (2003).

104. Note, too, that the social context of environmental variables blurs the line between what we want to know and why we might want to know it: for example, the incentives leading to increased population density are as relevant to understanding environmental stressors as they are to finding ways of ameliorating those stressors.

for designing and selecting environmental indicators is therefore helpful.

Adequately summarizing thirty years of academic literature on environmental indicators and monitoring is neither within the scope of this article nor particularly desirable for the present purposes. However, a broad consensus has emerged out of this body of work as to the necessary or desirable properties of environmental indicators generally, whether such indicators are narrow and single-species-focused or broad and holistic. We can then use these properties to evaluate the NFMA MIS provision in light of the best practices of the present. Environmental monitoring regimes using indicators should have: [105]

1. Clear purposes for which the indicator is being used
2. Explicit criteria used to select the indicator
3. Known, robust, and reliable relationship between indicator and the indicated environmental or biological variables that informs purposes
4. Appropriate spatial scale of analysis, given purposes
5. Clear baseline or reference condition against which to measure change or state
6. Appropriate statistical power, precision, and accuracy of the indicator set, given purposes
7. Logistical, financial, and social feasibility
8. Explicit monitoring standards
9. Explicitly-evaluated sources of error, including sampling error and intra-annual, inter-annual, and spatial variability in the indicator
10. A clear plan for information management over lifetime of data collection

This is not a trivial list: each of these ten requirements requires substantial analysis and engagement across sectors, and most pre-

105. These suggestions represent a synthesis of the following reviews and reports: U.S. ENVTL. PROT. AGENCY, EPA/620/R-99/005, EVALUATION GUIDELINES FOR ECOLOGICAL INDICATORS 1-1 to 1-5 (2000); NATIONAL RESEARCH COUNCIL REPORT, *supra* note 97; NAT'L ACAD. OF ENGINEERING, MEASURES OF ENVIRONMENTAL PERFORMANCE AND ECOSYSTEM CONDITION (1999); Carignan & Villard, *supra* note 83; Caro & O'Dougherty, *supra* note 83, at 805; Lindenmayer, *supra* note 83; David Niemeijer & Rudolf S. de Groot, *A Conceptual Framework For Selecting Environmental Indicator Sets*, 8 ECOLOGICAL INDICATORS 14 (2008); Niemi & McDonald, *supra* note 15; Simberloff, *supra* note 83.

suppose the existence of datasets relevant to the management question at hand.

Note that the use of individual species-as-environmental-indicators is not necessarily inconsistent with these best practices, so long as that use is supported by sufficient background analysis and information.[106] For example, one relative bright spot for indicator species has been the sustained use of benthic macroinvertebrates—that is, easily-visible species without backbones that live on the bottoms of rivers and lakes, which are generally insect larvae from various taxonomic groups—to determine and monitor the environmental health of freshwater environments.[107] The success of the biomonitoring technique in this context is in large part due to the sheer bulk of relevant data. A review of selection criteria for indicators, published in 2000, found 84% of invertebrates used as indicators had documented tolerance levels to stressors, necessary information for a valid use of indicators. This was in stark contrast to a mere 8% of vertebrates with the same available data.[108] As a result, many benthic macroinvertebrates have a substantial basis supporting their use of indicators, unlike most vertebrates.[109] The common use of explicit reference conditions[110]—nearby rivers against which to measure the condition of the focal river—also makes freshwater indicators more useful and rigorous in practice than most MIS in the National Forests.[111] In fact, monitoring programs using benthic

106. Note especially the use of benthic macroinvertebrates as indicator species that reflect water quality in freshwater streams.

107. For a discussion of this suite of indicators, see FRESHWATER BIOMONITORING AND BENTHIC MACROINVERTEBRATES (D.M. Rosenberg & V.H. Resh eds., 1993).

108. Jodi Hilty & Adina Merenlender, *Faunal Indicator Taxa Selection For Monitoring Ecosystem Health*, 92 BIOLOGICAL CONSERVATION 185, 190 (2000). Note, however, the authors found only 1% (vertebrates) and 3% (invertebrates) of indicator taxa were tied to data "correlating changes in the indicator status with changes to the ecosystem."

109. *See, e.g.*, Thomas F. Cuffney et al., *Responses of Physical, Chemical, and Biological Indicators of Water Quality to a Gradient of Agricultural Land Use in the Yakima River Basin, Washington*, 64 ENVTL. MONITORING & ASSESSMENT 259, 267 (2000) (providing correlation data for agricultural intensity and indicator response).

110. T.B. Reynoldson et al., *The Reference Condition: A Comparison of Multimetric and Multivariate Approaches to Assess Water-Quality Impairment Using Benthic Macroinvertebrates*, 16 J. N. AM. BENTHOLOGICAL SOC'Y 833, 833 (1997). Note that the reference condition provides a critical directionality to indicators that is otherwise lacking from environmental monitoring: given a reference condition, we know what we're aiming at. Without a reference condition, measures of ecosystem states are descriptive, rather than normative.

111. Note that, although most MIS in National Forests are vertebrates, some Forests list benthic macroinvertebrates as MIS—see the Kaibab National Forest discussion *infra* page 142, for an example.

macroinvertebrates often meet nearly all of the Best Practices for indicators, supra.[112]

The NFMA regulations missed all of this, from the wholesale movement of applied ecology toward ecosystem-based management to the development of best practices. The regulations were stuck in 1982, with species-based monitoring and ambiguous monitoring goals that spawned costly litigation, did little to illustrate the state of the National Forests, and included common uses of indicators that are "not supported by current science."[113]

VI. EVALUATING THE MANAGEMENT INDICATOR SPECIES (MIS) PROVISION IN LIGHT OF SUBSEQUENT SCIENCE

Having reviewed some of the science of environmental monitoring and set of best practices for developing environmental indicators, we can evaluate NFMA's MIS provision in light of these subsequent developments in order to distill lessons for future public resources management efforts. Despite having evolved subsequent to the 1982 regulations, present-day scientific standards are the relevant bases for measuring the MIS provisions' effectiveness because most National Forest units continue to use these indicator species under current Land and Resource Management Plans, and because future resources management regimes—such as the newly-enacted 2012 NFMA regulations, or the analogous effort in the coastal oceans that we discuss further below—must meet the best available scientific standards.[114]

112. *See* Hilty & Merenlender, *supra* note 108, at 20(comparing invertebrates to vertebrates); *see also* ANDREW A. WHITMAN & JOHN M. HAGAN, FINAL REPORT TO THE NATIONAL COMMISSION ON SCIENCE FOR SUSTAINABLE FORESTRY, A8: BIODIVERSITY INDICATORS FOR SUSTAINABLE FORESTRY 2 (2003) (listing many more desirable criteria, many of which benthic macroinvertebrates meet).

113. WAYNE OWEN, BEST PRACTICES FOR SELECTING AND USING MANAGEMENT INDICATOR SPECIES, USFS TECHNICAL GUIDANCE MEMO 4 (2010) (describing the use of indicator species as proxies for other species, and citing 36 C.F.R. § 219.19(a)(1) [1982] as motivating this use of MIS). Additionally, an internal Forest Service review of the MIS concept concluded that species may be used as indicators of environmental quality (such as water quality), but are not reliable measures of the effects of management decisions on other (non-MIS) species. CHRISTINA VOJTA, A REVIEW OF THE MANAGEMENT INDICATOR SPECIES CONCEPT AS USED BY THE FOREST SERVICE FOR PLANNING AND MONITORING (Aug. 2009) (graciously provided by Wayne Owen, USFS). Notably, this language made it into the Federal Register to accompany the final planning rule. 77 Fed. Reg. 21162, 21175 (Apr. 9, 2012) (to be codified at 36 C.F.R. pt. 219).

114. The 2012 NFMA planning regulations do require forest managers use the best available scientific information to inform the planning process. 36 C.F.R. § 219.3 (2012). Moreover, a failure to meet modern scientific standards could leave any management re-

A threshold difficulty in evaluating MIS performance in the National Forests is that the 1982 regulations and subsequent guidance documents are nonspecific in establishing purposes for monitoring using MIS. As noted above, the regulations provide a list of candidates for MIS: federally threatened and endangered species, "species with special habitat needs that may be influenced significantly by planned management programs; species commonly hunted, fished, or trapped; non-game species of special interest; and additional plant or animal species selected because their population changes are believed to indicate the effects of management activities on other species of selected major biological communities or on water quality."[115] This mandate implies—but does not state—at least five different goals: 1) safeguarding endangered/threatened species, 2) species sensitive to changes in particular habitats, 3) maximizing game species, 4) maximizing unspecified non-game species of undefined "special interest," 5) and species selected to indicate the effects of logging or other management activities on unmonitored species or on the state of water quality.

As a result of this multiplicity of implied goals, it is impossible to assess the success of the MIS provision as a whole in terms of its particular aims. With neither a clear *what* or *why*, we therefore assess the 1982 MIS requirement using other available criteria: the best practices for environmental indicators listed above, internal evaluations by Forest Service employees themselves, and success in meeting the implicit purposes of MIS in particular forests. The MIS program fares poorly by any metric.

It bears noting that one measure of *in*effectiveness is extensive litigation. Where limited resources are dedicated to defending agency decisions in court, funding for environmental monitoring probably suffers. Uncertainty caused by litigation is also unlikely to result in a robust and continuous dataset of the type most useful in environmental management. The Forest Service's MIS provision has been the subject of repeated and acrimonious litigation over the course of more than two decades, not least because of the ambiguities inherent in the regulation.[116] MIS are bright-line regula-

gime vulnerable to challenge as arbitrary and capricious under the Administrative Procedure Act. 5 U.S.C. § 706 (2)(A) (2012).

115. 36 C.F.R. § 219.19 (2012).

116. *See* discussion of NFMA planning regulations, *supra*; *see also* Utah Envtl. Conference v. Bosworth, 372 F.3d 1219 (10th Cir. 2004) (finding forest service monitoring of MIS

tory requirements; forest managers must designate a number of species as MIS, and such clarity limited litigation on this particular issue. But because the regulations provide broad discretion as to how forest managers might select, use, and monitor MIS, decades of litigation resulted in court-mediated biology and forestry. Future efforts at biodiversity management would do well to avoid such an outcome.

Litigation has ultimately focused on the question of how National Forests must monitor MIS once it has selected them. For example, an important question has been whether a Forest manager must monitor the populations of MIS directly, or if the manager may use models that predict the effects of management actions on the habitats associated with those species. Because an indicator species is already a proxy—it substitutes for a more comprehensive accounting of ecosystem structure and function—monitoring the MIS *habitat* rather than *populations* is a technique that the Ninth Circuit has described as a "proxy on a proxy."[117] The practice of monitoring habitat rather than populations has been controversial perhaps because it distills a number of legal, scientific, and policy questions into a single issue: to what extent must the Forest Service ensure that MIS adequately incorporate available science and account for uncertainty? Because of the lack of specificity in the NFMA diversity regulations, federal courts have reached conflicting decisions on the question.

For instance, despite its somewhat pejorative characterization of the Forest Service's "proxy-on-proxy" monitoring technique, the Ninth Circuit has sporadically approved the practice.[118] In *Idaho Sporting Congress v. Thomas*, the court held that the Forest Service could use habitat as a proxy for MIS population measurements, but only "if it demonstrate[d] no appreciable habitat disturbance"

insufficient); Idaho Sporting Cong., Inc. v. Rittenhouse, 305 F.3d 957 (9th Cir. 2002) (finding Forest Service use of habitat data as proxy for MIS arbitrary and capricious); Sierra Club v. Martin, 168 F.3d 1 (11th Cir. 1999) (finding habitat viability analysis insufficient as monitoring to satisfy MIS requirement); Neighbors of Cuddy Mountain v. U.S. Forest Serv., 137 F.3d 1372 (9th Cir. 1998) (holding environmental impact analysis inadequate due to insufficient treatment of MIS impact); Inland Empire Pub. Lands Council v. U.S. Forest Serv., 88 F.3d 754 (9th Cir. 1996) (finding Forest Service analysis of project alternatives using evaluation of MIS prior to timber sale adequate).

117. *Idaho Sporting Cong.* , 305 F.3d at 962 ; Lands Council v. Powell, 395 F.3d 1019, 1036-37 (9th Cir. 2004).

118. *See Inland Empire Pub. Lands Council*, 88 F.3d at 762-63 (finding no actual population counts required); *Idaho Sporting Cong.*, 305 F.3d at 971-73 (finding habitat availability acceptable as a proxy for population data).

from proposed industrial activities.[119] However, in *Ecology Center v. Austin*, the court later held that the Forest Service had violated the NFMA diversity requirements by failing to use on-the-ground observations verify its assumptions about the effects of timber harvest on dependent MIS.[120]

In a 2008 en banc decision, *The Lands Council v. McNair*,[121] the Ninth Circuit then overruled both *Idaho Sporting Congress v. Thomas*[122] and *Ecology Center v. Austin*,[123] holding that the Forest Service need not empirically verify its estimates of the effects of projects on MIS. Instead, the Service may model the effects of proposed actions on habitat as a proxy for their effects on MIS, even if it knows that a proposed project will subject that habitat to appreciable disturbance.[124]

The Ninth Circuit's waffling on this issue exemplifies the judiciary's inability to impose scientifically-informed checks on the Forest Service's use of MIS. The Seventh Circuit appears to agree with the Ninth in giving the Forest Service broad discretion to choose and monitor MIS.[125] By contrast, the Eleventh Circuit has invalidated project approval decisions because the Service failed to gather population data on indicator species.[126] District Courts in the Tenth Circuit have similarly required the Forest Service to conduct species-specific monitoring and data collection to validate its management models,[127] and some Circuits have failed to settle

119. Idaho Sporting Cong. v. Thomas, 137 F.3d 1146, 1154 (9th Cir. 1996); *accord* Native Ecosystems Council v. U.S. Forest Serv., 428 F.3d 1233, 1250 (9th Cir. 2005).

120. Ecology Ctr., Inc. v. Austin, 430 F.3d 1057, 1063-65 (9th Cir. 2005); *see also* Oregon Natural Res. Council Fund v. Goodman, 505 F.3d 884, 890 (9th Cir. 2007) ("[W]e find that in this instance the Forest Service's use of habitat as a proxy for population violated the NFMA.").

121. Lands Council v. McNair, 537 F.3d 981 (9th Cir. 2008) (en banc).

122. *Id.* at 997.

123. *Id.* at 990.

124. *Id.* at 998. Note, of course, that a court could still find that any particular use of habitat-as-proxy to be arbitrary and capricious where the facts on the ground do not support the use of the technique. ("We will defer to its decision to use habitat as a proxy unless the Forest Service makes a 'clear error of judgment' that renders its decision arbitrary and capricious." *Id.*).

125. *See, e.g.*, Ind. Forest Alliance, Inc. v. U.S. Forest Serv., 325 F.3d 851, 865 (7th Cir. 2003) ("We find that the Forest Service reasonably relied on habitat and survey information about management indicator species to monitor the effects of the forest openings management project on those species. Because this method was reasonable, the Forest Service did not act arbitrarily or capriciously in proceeding with the action.").

126. *See, e.g.*, Sierra Club v. Martin, 168 F.3d 1, 4 -5 (11th Cir. 1999).

127. Utah Envtl. Cong. v. Zieroth, 190 F. Supp. 2d 1265, 1271 (D. Utah 2002).

on any answer whatsoever to this question. The Fifth Circuit, for example, held in *Sierra Club v. Peterson* (1999) that "NFMA requires on-the-ground inventorying and monitoring and is not simply a planning statute."[128] It then vacated its own decision in a rehearing en banc.[129]

A. *Evaluation in Light of Best Practices Developed for Indicators of Environmental State*

The best practices for ecological indicators, developed above, provide a means of assessing the 1982 regulations' MIS requirement, incorporating subsequent work on environmental monitoring. We address these in turn, evaluating the regulations themselves. We note at the outset that because the regulations provided broad authority to individual forest units, those forest units could—and in some cases, did—implement the regulations in a way that more closely aligned with best practices than the federal regulations required. However, our focus remains identifying the regulatory floor, rather than ceiling: what did the 1982 NFMA regulations *require* in their MIS provision? Where applicable, we note Forest Service guidance documents—the Forest Service Manual and Handbook—that inform MIS implementation, but because these documents are not binding on the Service, they do not change NFMA's regulatory floor.

1. Clear purposes for which the indicator is being used

The 1982 NFMA regulations fall well short of this most fundamental practice for environmental monitoring and indicators. As discussed above, the enumerated categories of MIS imply a multiplicity of sometimes-inconsistent goals, and do not explicitly set out any particular purpose as paramount. A lack of clarity about the purposes of the MIS program at the federal level made overall assessment difficult or impossible; it became unclear how to measure the success or failure of this environmental monitoring technique. The Forest Service Manual provided little further guidance on the purposes of MIS, instructing individual foresters only to "[u]se management indicators to address issues, concerns and opportunities for plants, wildlife, fish, and sensitive species habitats through all planning levels."[130] This guidance simply restated the

128. Sierra Club v. Peterson, 185 F. 3d 349, 372 (5th Cir. 1999).

129. Sierra Club v. Peterson, 228 F. 3d 559 (5th Cir. 2000).

130. U.S.D.A. FOREST SERVICE: FOREST SERVICE MANUAL § 2620.3(1) (effective Jul.

instruction to use MIS as a tool, without clarifying why the tool might be helpful. However, another section of the Manual did instruct foresters to identify goals and objectives relating to MIS specifically.[131]

Because the 1982 regulations did not direct foresters to use MIS for any specific purpose, forest unit managers were free to use indicators for any number of permissible aims, leading to confusion and frustration among managers.[132] For example, in amending the list of MIS for three national forests in 2005, Forest Supervisor Charles Richmond encapsulated much of this frustration:

> The concept and application of MIS have come under critical review. . . . Identifying species which are well suited as MIS, and which meet the intent and letter of the 1982 regulation has proven to be a challenge . . . Adjoining National Forests have gone through similar selection processes, applying the best science and reasonable judgment, and have come up with different species lists. **It appears that there, in fact, is no set of species which meet[s] the theoretical intent of the regulations**[133]
>
> . . .
>
> Identifying species which truly meet the intent of MIS, to indicate some change in environment or condition caused by manage-

19, 1991).

131. U.S.D.A. FOREST SERVICE: FOREST SERVICE MANUAL § 2621.4 (1991) ("The forest plan must identify habitat components required by management indicators; determine goals and objectives for management indicators; specify standards, guidelines, and prescriptions needed to meet management requirements, goals, and objectives for management indicators. Prescribe mitigation measures, as appropriate, to ensure that requirements, goals, and objectives for each management indicator will be sufficiently met during plan implementation at the project level."), *available at* http://www.fs.fed.us/im/directives/fsm/2600/2620.txt. We note also that the Forest Service Handbook was revised in 2006 to provide greater guidance surrounding planning, MIS, and monitoring. U.S.D.A. FOREST SERVICE: FOREST SERVICE HANDBOOK § 1909.12 (2006). However, because most Forests have not undergone planning since this update, we focus the analysis below on the NFMA regulations themselves and the 1991 Forest Service Manual guidance that informed the majority of Forests' Land and Resource Management Plans now in effect. U.S. FOREST SERVICE: SCHEDULE OF FOREST SERVICE LAND MANAGEMENT PLAN REVISIONS & NEW PLANS (2010), *available at* http://www.fs.fed.us/emc/nfma/includes/LRMPschedule.pdf.

132. Note that this ambiguity also led to great discretion on the part of forest managers, which was no doubt valuable in shaping the overall thrust of land use planning in different forests.

133. CHARLES S. RICHMOND, U.S.D.A. FOREST SERVICE: DECISION NOTICE & FINDING OF NO SIGNIFICANT IMPACT, MANAGEMENT INDICATOR SPECIES FOREST PLAN AMENDMENT TO THE LAND AND RESOURCE MANAGEMENT PLAN FOR THE GRAND MESA, UNCOMPAHGRE AND GUNNISON NATIONAL FORESTS 3 (May 11, 2005) (emphasis added), *available at* http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev7_003183.pdf.

> ment has proven to be far less straight forward than was thought at the time the regulation was promulgated. Very few species meet all criteria for being a good MIS. . . . [C]ollectively, **the burden of monitoring the large number of species suggested exceeds the usefulness of the information. It becomes instead a barrier to efficient planning and decision-making**."[134]

Data-driven policy requires that testable hypotheses provide the foundation for management decisions.[135] If there is no obvious way of testing the success or failure of a policy, its continued implementation lies in the realm of faith, not science. Although it may be politically desirable to institute policy whose effectiveness cannot be publicly disproved, such a justification for opaque policymaking is normatively undesirable and contravenes the public-participation rationale of both the APA and NFMA.

2. Explicit criteria used to select the indicator; 3. Known relationship between indicator and the indicated environmental or biological variable

The mingled purposes of MIS necessarily obscured the criteria by which those MIS might be selected: one cannot derive meaningful criteria for aspects of any environmental monitoring regime without a clear purpose against which to judge those criteria.

However, one MIS purpose seems clear enough to infer a selection criterion: those species "selected because their population changes are believed to indicate the effects of management activities on other species of selected major biological communities or on water quality."[136] Only species with documented associations between the species' population on the one hand and the effects of some management action, un-monitored species, or water quality on the other hand would fulfill this purpose. Although the NFMA regulations themselves fail to require such a link, the 1991 MIS guidance in the Forest Service Manual remedies this shortfall,

134. *Id.* at 6 (responding to public comment requesting a more extensive list of MIS) (citation removed and emphasis added). Nevertheless, a core scientific concern does seem to have reached forestry decision makers: Richmond removed the mule deer from the three forests' MIS lists because it is an ecological generalist, insensitive to changes in habitat. "I find that mule deer, while of great economic, and public, interest, is such a habitat generalist that it would serve as a poor indicator of management effects on the Forest." *Id.* at 4.

135. *See, e.g.*, KAI N. LEE, COMPASS AND GYROSCOPE 51 (1993) (discussing "adaptive management" as a means of deriving policy through testable hypotheses).

136. National Forest System Land and Resource Management Planning, 47 Fed. Reg. 43048 (Sept. 30, 1982) (to be codified at 36 C.F.R. § 219.19(a)(1)).

instructing managers to "[s]elect ecological indicators (species or groups) only if scientific evidence exists confirming that measurable changes in these species or groups would indicate trends in the abundance of other species or conditions of biological communities they are selected to represent."[137] Thus at least for one particular purpose of MIS, Forest Service guidance provides a baseline criterion for identifying particular candidate MIS species.

In practice, however, the adequacy and performance of MIS often went unassessed. In the words of one study co-authored by Forest Service employees, "[d]espite this increased use [of indicator species], the conceptual bases, assumptions, and published guidelines for using ecological indicators have not been adequately examined."[138]

4. Appropriate spatial scale of analysis, given purposes

The 1982 NFMA regulations do not mention spatial scale explicitly. But because each Forest unit was required to select its own MIS, the provision implicitly required MIS appropriate to the scale of the individual Forests. Where multiple Forests collaborated to

137. U.S.D.A. FOREST SERVICE: FOREST SERVICE MANUAL § 2621.1(3) (1991), *available at* http://www.fs.fed.us/im/directives/fsm/2600/2620.txt. Note, however, that interpreting this guidance is complicated by the fact that the Forest Service Manual defined "management indicators" without mentioning the NFMA regulations' MIS provision specifically: "Management Indicators. Plant and animal species, communities, or special habitats selected for emphasis in planning, and which are monitored during forest plan implementation in order to assess the effects of management activities on their populations and the populations of other species with similar habitat needs which they may represent." *Id.* § 2620.5(1). Note that this type of indicator falls into the problematic third category of Niemi and McDonald, *supra* note 81, at 96-97, but that the problems with the use of such surrogate species are eased if sufficient data exist to demonstrate the link between indicator and indicated.

138. Peter B. Landres et al., *Ecological Uses of Vertebrate Indicator Species: A Critique*, 2 CONSERVATION BIOLOGY 316, 317 (1988) (discussing the use of vertebrates, specifically, as indicators). Both Verner and Thomas were listed as Forest Service affiliates on the paper. In this well-cited critique, the authors suggest best practices including setting explicit assessment goals and criteria for indicators, explicit analysis of sources of subjectivity, peer review, and the incorporation of variability. *See id.* at 316-17. These remain among the most common suggestions for improving the MIS requirement and the use of indicator species generally. The lack of data on indicator effectiveness points out a catch-22: indicators are useful as a management tool insofar as they represent cost-effective and labor-saving means of accurately assessing an environmental state or change. But in order to test the indicators' efficacy and validity, one must have sufficient baseline data describing the indicated environment. Because avoiding such a resource-intensive, comprehensive census is often the very impetus for using indicator species in environmental management, managers are likely to be forced to decide between using unverified indicator species or none at all. Under the 1982 NFMA regulations, foresters had to develop MIS, but without a means or motive to ground-truth the indicators, the requirement became a mere hurdle. *See, e.g.*, RICHMOND, , *supra* note 133.

select MIS, as in the case of the ten Sierra Nevada National Forests, their evaluation of candidate MIS occurred over the scale of the combined Forest units. But because the regulations appear to require (albeit implicitly) congruent spatial scales of MIS selection and MIS function, they tend to satisfy this Best Practice.[139]

5. Clear baseline or reference condition against which to measure change or state

Again, both the regulations and the guidance documents available when most Plans were completed were silent as to establishing a baseline or reference condition, a necessary condition for effective ecosystem management.[140]

6. Appropriate statistical power, precision, and accuracy of the indicator set, given purposes

Although the regulations contain no provision that speak to the statistical adequacy of the selected MIS, the 1991 Forest Service Manual directs Forests to "[i]nvolve Research Stations, universities, and other research entities in monitoring to ensure that appropriate sampling methods are employed and statistically valid results are obtained."[141] It is not clear why external entities—and not the Forest Service itself—were necessary to ensure the statistical validity of sampling results, but nevertheless the guidance document does incorporate a level of statistical awareness into the MIS monitoring process.

7. Logistical, financial, and social feasibility; 8. Explicit monitoring standards

Because Forest units selected their own MIS, the 1982 regulations built in feasibility to some degree. Foresters are presumably more likely to select MIS that are easy to monitor than those that would be pose more substantial time- or resource-burdens.[142]

139. The Forest Service Handbook contains directives from 2006 — well after most of the current forest Plans were completed — that do explicitly reference spatial scale. "Select characteristics for evaluation that are appropriately matched to the scale of planning." U.S.D.A. FOREST SERVICE: FOREST SERVICE HANDBOOK § 1909.12, ch. 43.12 (2006).

140. Again, the later Forest Service Handbook amendments do include guidance on this point, discussing the historical range of variation, which is clearly relevant to establishing a baseline condition. *Id.* at ch. 43.13 ("The range of variation under historic disturbance regimes is an important context to evaluate current and desired conditions."). However, because these guidelines arose only after the most recent Plan revisions for nearly all forest units, it is hard to know how influential the guidelines are.

141. U.S.D.A. FOREST SERVICE: FOREST SERVICE MANUAL § 2621.5 (1991), *available at* http://www.fs.fed.us/im/directives/fsm/2600/2620.txt.

142. Nevertheless, there are many instances of named MIS that are absent or difficult to find within a forest unit, as in the cases of the Chequamegon and Kaibab Forests.

However, the automatic inclusion of federally threatened or endangered species as MIS introduced an additional difficulty; by definition, these species are rare, and therefore likely to be hugely burdensome to monitor. This led the Forest Service to seek new ways of monitoring MIS, and in turn, resulted in extensive litigation over monitoring details.[143] There were good policy reasons to require Forest management take into account federally listed species—among these reasons, ensuring that the Forest Service wasn't working at cross-purposes with the Department of Fish & Wildlife, which had listed the species—but by including these among the MIS, the regulations created a more onerous monitoring burden for the Service.

More specific monitoring requirements in the regulations might have decreased the likelihood of litigation on this particular point, but the text of the regulations is reasonably specific: "[p]opulation trends of the management indicator species will be monitored and relationships to habitat changes determined."[144] Specifying how often monitoring should take place, or by what methods, would have greatly limited the flexibility of individual Forest units to monitor in a way that made sense for their particular species.[145] Finding the appropriate balance between regulations that provide too much and too little of this kind of specificity is a classic problem of administrative law, and we discuss some means of doing so in the scientific monitoring context below in Part 7.

9. Explicitly-evaluated sources of error; 10. Plan for information management

The regulations make no mention of evaluating the sources of error associated with environmental monitoring. This is unsurprising: as with the monitoring details themselves, perhaps guidance documents (being lower-level and more fluid than regulations) are the more logical place for such details. The Forest Service Manual,

U.S.D.A. FOREST SERVICE, LAND AND RESOURCE MANAGEMENT PLAN FOR CHEQUAMEGON NATIONAL FOREST (1986).

143. *See* Idaho Sporting Cong., Inc. v. Rittenhouse, 305 F.3d 957 (9th Cir. 2002).

144. National Forest System Land and Resource Management Planning, 47 Fed. Reg. 43048 (Sept. 30, 1982) (to be codified at 36 C.F.R. § 219.19(a)(6)).

145. The Forest Service Manual, too, references monitoring throughout the relevant sections. For example, it instructs to "monitor management indicators to evaluate compliance of management activities with plan direction, effectiveness of prescribed management, and validity of information used in habitat evaluation and planning." U.S.D.A. FOREST SERVICE: FOREST SERVICE MANUAL § 2620.3(5) (1991). *See also* 53 Fed. Reg. 26807, 26812-13 (Jul. 15, 1988) (describing "implementation," "effectiveness," and "validating" monitoring in Forest Service Manual 1922.7).

however, also neglects the topic.

Information management, too, is mentioned neither in the regulations nor the guidance. This Best Practice is key for developing a robust time-series of data, which in turn is important for making management decisions on ecologically relevant time scales.

In sum, the 1982 NFMA regulations embodied few of the Best Practices for environmental monitoring, which is perhaps not surprising given that it was primarily subsequent research—conducted after 1982, and so after the regulations were in place—that informed the development of the Best Practices. Although the guidance documents available to forest managers (most notably the Forest Service Manual and Handbook) were updated periodically and reflected some substantial improvements over the Reagan-era rules, these generally did not have the force of law and moreover, the improvements came too late to influence the land use planning processes in many forests.

A 2007 revision of MIS for a set of Sierra Nevada forests echoes these sentiments, seeming to lament the existence of the MIS requirement while awaiting a revision of forest planning rules:

> I want to acknowledge the problems with the MIS concept and the associated difficulties with implementing this concept to meet the continued requirement to use MIS until forest plans are revised or new NFMA regulations permit otherwise. Until revision occurs or new planning regulations permit otherwise, each of these National Forests will be required to use MIS.[146]

These are not isolated complaints. Taken together with further statements below, and especially considering that the Forest Service has instituted additional, parallel monitoring schemes over the years that do not include MIS,[147] it seems clear that many forest

146. U.S.D.A. FOREST SERVICE, PACIFIC SOUTHWEST REGION, SIERRA NEVADA FORESTS MANAGEMENT INDICATOR SPECIES AMENDMENT, RECORD OF DECISION 11 (Dec. 14, 2007).

147. Such monitoring efforts include at least the following: (1) Forest Health Monitoring Initiative, *see* Alexander & Palmer, *supra* note 96, at 267; (2) Forest Inventory Analysis, *see* B.K. SCHULZ ET AL., U.S.D.A. FOREST SERVICE, U.S.D.A. GEN. TECH. REPORT, PNW-GTR-781, SAMPLING AND ESTIMATION PROCEDURES FOR THE VEGETATION DIVERSITY AND STRUCTURE INDICATOR (2009); U.S.D.A. FOREST SERVICE, FOREST INVENTORY AND ANALYSIS NATIONAL CORE FIELD GUIDE (2006); SUSAN WILL-WOLF, U.S.D.A. FOREST SERVICE, GEN. TECH. REPORT, PNW-GTR-818, ANALYZING LICHEN INDICATOR DATA IN THE FOREST INVENTORY AND ANALYSIS PROGRAM (2010); and (3) Multiple Species Inventory and Monitoring (an effort within the larger Forest Health Monitoring Initiative that includes repeated baseline monitoring of set plots), *see* P.N. MANLEY ET AL., U.S.D.A. FOREST

managers came to view MIS as a "barrier to efficient planning"[148] rather than a useful management tool.

B. *Evaluation in Light of Implicit Purposes*

In practice, forest units have often used MIS as surrogates for larger species assemblages—as a metric for all species using a particular habitat, for example, or for an index of species diversity in a particular area.[149] These related purposes fall into Niemi & McDonald's[150] problematic third category, indicating neither environmental state nor change to that state, but rather standing in for some number of other species.[151]

As surrogates for larger assemblages of species, MIS have not performed well. One study directly on point examined the avian MIS for the Chequamegon National Forest in detail.[152] There, the USFS had designated twelve bird species as MIS and thirteen others as "sensitive" species[153] important for monitoring. The authors were able to census eighteen species out of this combined group, assessing whether the selected MIS were effective stand-ins for presence and health of other species in the forest.

If the designated MIS were to function effectively as indicators of the presence of other species, the MIS would have to be associ-

SERVICE, U.S.D.A. GEN. TECH. REP. WO-73, MULTIPLE SPECIES INVENTORY AND MONITORING GUIDE (2006), *available at* http://www.treesearch.fs.fed.us/pubs/24985.

148. RICHMOND, *supra* note 133, at 6.

149. *See* case studies, *infra* pp. 139-45. Note also that there is some evidence of Forest Service intent to use MIS as indicators of ecosystem state or change to that state. *See* UNITED STATES GENERAL ACCOUNTING OFFICE, GAO/RCED-91-123, WILDLIFE MANAGEMENT: PROBLEMS BEING EXPERIENCED WITH CURRENT MONITORING APPROACH 2 (1991) ("Population changes in the indicator species being monitored are interpreted as a signal of changes in the health of the ecosystem."). But we have not found examples of this use in practice.

150. Niemi & McDonald, *supra* note 81, at 96-97.

151. In large part, this is due to NFMA's statutory mandate to provide for a "diversity of plant and animal communities," 16 U.S.C. § 1604(g)(3)(B), among the multiple uses of National Forest land. The MIS provision was the way in which the regulations made this requirement concrete, and so it followed that particular indicator species would stand in for some larger suite ("diversity") of species.

152. Gerald J. Niemi et al., *A Critical Analysis on the Use of Indicator Species in Management*, 61 J. WILDLIFE MGMT. 1240, 1240 (1997) ("Here we focus on the overall question on [*sic*] whether the MIS approach can be used to ensure the perpetuation and well-being for many other species in a forest setting."). The authors note that the "scientific basis for selecting MIS in the plan is obscure." *Id.*

153. The authors report a total of sixteen "sensitive" species, but three—the common loon, sharp-tailed grouse, and olive-sided woodpecker—appear on both the MIS and sensitive species lists.

ated with the presence of those others in a statistically significant way. The 1986 Management Plan for the forest reiterated this aim, stating that the MIS would "each represent all other game and non-game species associated with similar habitat needs."[154] The study's authors found a different reality, however: only seven of the eighteen study species were even sufficiently abundant for analysis.[155] Four of the eighteen appear to have been absent from the forest altogether.[156]Of the seven analyzed bird species, only one[157] was consistently and significantly associated with a particular habitat type. Moreover, the authors found only inconsistent associations between the monitored species and other, non-monitored forest species,[158] the very parts of the forest assemblage the MIS were supposed to reflect.

The data therefore showed that most of the USFS's designated species were rare or absent, and of those abundant enough for analysis, most were associated neither with particular habitat types nor with particular species. As a group, the MIS indicated nothing. And the Chequamegon National Forest MIS are not alone, especially insofar as they represent the shortfalls of the first generation of MIS sets designated under the 1982 NFMA regulations.[159] A 1991 Government Accountability Report reported a similar lack of information in an anonymous forest:

> At a national forest, the wildlife biologist said that the forest does not have habitat-monitoring data for the eight management indicator species specified in the forest plan. . . . The forest wildlife biologist said that predicting species population levels from habitat availability is risky because not all species/habitat relationships have been defined. For example, in the case of the sage

154. U.S.D.A. FOREST SERVICE, LAND AND RESOURCE MANAGEMENT PLAN FOR CHEQUAMEGON NATIONAL FOREST (1986) (cited in Niemi et al., *supra* note 15, at 1240-41). Note that this statement is an ecological non-sequitur: on the one hand, each of the various MIS cannot possibly represent all other species with "similar habitat needs" as every species—indicator and indicated—occupies a unique niche described by the intersection of its biotic and abiotic needs. On the other hand, the statement could be read as trivially true: the MIS represent all of the species associated with them.

155. Niemi et al., *supra* note 15, at 1243.

156. *Id.*

157. The yellow-bellied flycatcher (*Empidonax flaviventris*). *Id.* at 1244. A second species, the pine warbler (*Dendroica pinus*), was associated with a particular habitat for a subset of the analyzed data. *Id.* at 1244.

158. *Id.* at 1245.

159. The Chequamegon National Forest Land and Resource Management Plan was completed in 1986.

grouse, more needs to be known about its use of habitat and about the impacts of fire, fencing, water developments, and grazing.[160]

A second GAO report makes the same point: "even when planned data collection efforts are completed using this monitoring approach, the data can have limited usefulness because observed population changes in the species being monitored often cannot be related to overall habitat conditions or the effects of Forest Service management actions."[161] Of course, the lack of monitoring in this particular forest contravenes the NFMA regulations.[162] But the lack of information about species/habitat relationships suggests that even had the monitoring been done, its value as a management tool would have been negligible because of the lack of known relationship between indicator species and indicated environmental change.[163]

160. UNITED STATES GENERAL ACCOUNTING OFFICE, GAO/RCED 91-64, PUBLIC LAND MANAGEMENT: ATTENTION TO WILDLIFE IS LIMITED 30 (1991) (emphasis added). Note that a subsequent GAO report from 2004 encourages the development of "indicator sets" and coordination for their use across agencies, but that this report refers to environmental indicators generally, and not indicator species specifically. UNITED STATES GOVERNMENT ACCOUNTABILITY OFFICE, GAO-05-52, ENVIRONMENTAL INDICATORS: BETTER COORDINATION IS NEEDED TO DEVELOP ENVIRONMENTAL INDICATOR SETS THAT INFORM DECISIONS (2004). Notably, the term "indicator species" and "management indicator species" do not appear in the 2004 document.

161. UNITED STATES GENERAL ACCOUNTING OFFICE, GAO/RCED-91-123, WILDLIFE MANAGEMENT: PROBLEMS BEING EXPERIENCED WITH CURRENT MONITORING APPROACH 1 (1991). The report continues: "First, relationships between indicator species and the habitat characteristics they are supposed to predict are often not known. Without a clear understanding of such relationships, an observed population decline in an indicator species may or may not represent a change in overall habitat conditions or establish whether the change was caused by Forest Service management actions or other reasons. Second, as noted by Forest Service managers, changes in population that are detected could be due to habitat changes beyond management control, or be part of a normal cycle requiring no management action." *Id.* at 3.

162. National Forest System Land and Resource Management Planning, 47 Fed. Reg. 43,048 (Sept. 30, 1982) (to be codified at 36 C.F.R. § 219.19(a)(1)) indicates that MIS should be "selected because their population *changes*," (emphasis added), and are useful to assess the effects of management activities. Without monitoring, it is impossible to measure changes to populations. § 219.19(a)(6) requires more explicitly that "population trends of the management indicator species will be monitored." Note that these citations refer to the 1982 regulations, no longer in force as of this writing. Nevertheless these are the relevant regulations because they were in force at the time of the GAO report, and remain relevant because the vast majority (if not all) of the forest land use plans to date have been completed under the 1982 regulations.

163. Note that even if an MIS is carefully selected and monitored, MIS can lead to perverse consequences as forests manage exclusively in favor of that species. Designating particular species to signal the health of a forest unit, perhaps inevitably, has often led for-

The absence of species/habitat relationships remains a problem even today, with the result that Forests often select indicators without much knowledge about what (if anything) they might indicate. The 2010 evaluation of Kaibab National Forest's MIS,[164] for example, presented data on eighteen species[165] of management importance. Each species was intended to represent a larger suite of species using the same habitat. However, the 256-page report included almost no data supporting the idea that any one of the MIS in fact shared habitat with other, non-MIS species.[166] The absence of such necessary information is striking more than twenty-five years after MIS were first required in Forest Service planning. Moreover, many species on the Kaibab's newly-revised list of MIS

esters to concentrate their attention on those few focal species to the exclusion of the rest of the ecosystem; to lose the forest for the trees, so to speak. Simberloff crystallizes this critique as follows:

> The legal status of the owl as an indicator species under the National Forest Management Act has led to an undue focus on this particular species to the exclusion of all that it is supposed to indicate. For example, logging industry representatives frequently suggest management procedures specifically targeted at owls, like moving or feeding them, artificially enhancing their prey density, or providing added shelter, in order to boost their populations so that logging quotas can be raised. The Forest Service proposed moving owls from site to site. Lost in such suggestions is the recognition that single-species management of an indicator species is a self-contradiction. After all, *if the species' status is artificially improved, it no longer indicates the status of all the species it is supposed to represent.* Would we also add food or shelter for other birds, mammals, amphibians, and insects of the old-growth forest, and move them around?

Simberloff, *supra* note 83, at 249 (emphasis added) (citations omitted). Thus, where MIS become a focus of management rather than a yardstick for that management, much of the logic behind the use of species as indicators disappears. NFMA and its implementing regulations nearly demand this kind of selectively myopic management by lumping in federally-listed threatened and endangered species with other MIS. NFMA requires foresters to track the populations of listed species, presumably to ensure the ongoing existence of those species in the National Forests. The listed species are therefore being managed for their own sake, not as representatives of anything larger than themselves, and they are thus "indicators" only by legal designation, lumped into the MIS term-of-art.

164. Valerie Stein Foster et al., MANAGEMENT INDICATOR SPECIES OF THE KAIBAB NATIONAL FOREST: AN EVALUATION OF POPULATION AND HABITAT TRENDS, VERSION 3.0 (2010), *available at* http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5114494.pdf.

165. The document treats aquatic macroinvertebrates as a unit for analysis, though they are in fact a highly diverse group.

166. One bird species, the juniper titmouse, may forage with chickadee species under some conditions. Foster, *supra* note 164, at 49. This is the only cited example of a MIS significantly associated with another (non-MIS) species.

have the most undesirable traits for indicators: exceedingly rare species or those absent from the National Forest entirely,[167] ubiquitous or ecological generalist species that are unlikely to reflect changes to the Forest habitat,[168] and species that are only rarely monitored.[169] Finally, the Service's analysis of the scant MIS data leaves much to be desired; for example the authors conclude "[t]he data from the [aquatic environment] studies indicate stable conditions," one paragraph after noting that the "[l]ow numbers of individuals sampled suggest an unstable ecosystem."[170] The recent Kaibab evaluation document underscores the many challenges that remain before MIS might be effective management tools in the National Forests.[171]

Necessarily, if some species are to stand in for others, the potential MIS must be vetted to ensure they will fulfill their intended function.[172] Assessing the usefulness of a species of quail as a MIS to represent a particular ecological guild,[173] for example, one study found that the quail's habitat differed significantly from the habi-

167. For example, the Cinnamon Teal, Lincoln's Sparrow, Mexican Spotted Owl, Red-Naped Sapsuckers, and Yellow-breasted Chat occur rarely or not at all in the Kaibab National Forest. These are five of the eighteen species analyzed, or nearly thirty percent of the biological indicators for the Forest. See *id.* at 18-92 for individual species evaluations.

168. Mule deer and red squirrels are common in many habitats; wild turkeys are widespread in North America, but have been observed only once in each of the 2005 and 2006 landbird surveys of the Kaibab National Forest. *Id.* at 244.

169. Benthic macroinvertebrates, for example, have not been assessed since 1998; the Arizona bugbane, an ESA candidate species, likewise was last counted in the Clinton administration. *Id.* at 20, 92.

170. *Id.* at 21, 20.

171. Other Forests have the same problems. The 2007 MIS revision for Sierra Nevada Forests noted that one reason the revision was necessary was that prior MIS were "inadequate" in part because "they [were] not strongly linked to habitats or ecosystem components that are affected by National Forest management activities or have population changes that have no known link to the effects of our management activities (for example, Canada Goose, largemouth bass, Peregrine Falcon, rainbow trout." U.S.D.A. FOREST SERV., SIERRA NEVADA FORESTS MANAGEMENT INDICATOR SPECIES AMENDMENT FEIS 6 (2007).

172. In terms of the Administrative Procedure Act, 5 U.S.C. §§ 701-06, it would seem arbitrary and capricious to declare some species to be "indicators" of others in the absence of data in support of that association. "While the scope of review under the 'arbitrary and capricious' standard is narrow and a court is not to substitute its judgment for that of the agency. Nevertheless, *the agency must examine the relevant data and articulate a satisfactory explanation for its action, including a 'rational connection between the facts found and the choice made.'*" Motor Vehicle Mfrs. Ass'n of the U.S., v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43 (1983) (citation omitted) (emphasis added).

173. The authors use a definition of "guild" that refers to "assemblages of species that use a particular class of resources in a similar way." William M. Block, Leonard A. Brennan & R.J. Gutierrez, *Evaluation of Guild-indicator Species for Use in Resource Management*, 11 J. ENVTL. MGMT. 265, 265 (1987).

tat of other species in its guild in fourteen out of fifteen comparisons.[174] Because of these habitat differences, the presence of quail would not indicate the presence of the others, and it would therefore fail as a surrogate for the other species.[175] But over the quarter-century history of MIS in practice in National Forests, this sort of *a priori* evaluation seems the exception to Forest Service practice, rather than the rule.

A recent revision of the list of MIS for ten California National Forests offers an improved model for such large-scale prospective analysis, ensuring that the selected species would meet a list of suitability and feasibility requirements that parallel many of the best practices discussed *supra*.[176] There, the USFS compiled data on a large number of candidate MIS and evaluated them relative to five explicit selection criteria,[177] rejecting those candidates that

174. *Id.* at 268. Note that such habitat differences are to be expected under standard ecological theory: species are thought to have unique niches, no two of which overlap entirely. *See, e.g.*, Jared Verner, *The Guild Concept Applied to Management of Bird Populations*, 8 J. ENVTL. MGMT. 1, 4 (1984) ("We should not be surprised to find few if any groups of species in a community with patterns of habitat use so alike that one species could be used as an indicator of the others in its group.").

175. Worse, using such a species to indicate the other members of its guild would be actively misleading, akin to depending on a car with a broken fuel gauge. The authors, if anything, understate their case: "[T]here is little assurance that habitat suitability or population status of a guild indicator will parallel those of other species in the guild. Moreover, if the guild includes an uncommon species, the welfare of that species may be jeopardized by indirectly monitoring its status with a guild indicator." Block et al., *supra* note 173, at 268. *See also* Winston P. Smith, Scott M. Gende & Jeffrey V. Nichols, *The Northern Flying Squirrel as an Indicator Species of Temperate Rain Forest: Test of an Hypothesis*, 15 ECOLOGICAL APPLICATIONS 689 (2005) (finding that the focal species was inappropriate as a surrogate for old-growth habitat).

176. U.S.D.A. FOREST SERV., SIERRA NEVADA FORESTS MANAGEMENT INDICATOR SPECIES AMENDMENT RECORD OF DECISION 1-6 (2007). Note, however, that this set of MIS may not be useful to evaluate the impacts of any given management decision because of its massive spatial scale. The Deputy Regional Forester emphasized in the Record of Decision that "all MIS monitoring is at the planning area level, not at the project level. For this Amendment, the planning area is the 10 Sierra Nevada National Forests. The regulations require that 'population trends of the management indicator species will be monitored and relationships to habitat changes determined'; this monitoring, as with all actions identified in 1982: 36 CFR 219.19, are required at the planning area level. There are no MIS monitoring requirements in the project area or at the project level." *Id.* at 11 (citation omitted).

177. U.S.D.A. FOREST SERV., SIERRA NEVADA FORESTS MANAGEMENT INDICATOR SPECIES AMENDMENT FEIS 22-23 (2007) ("I. Suitability Criteria: A. The species is linked to a habitat or ecosystem component that is affected by Forest Service management activities. . . . B. The population changes of the species are thought to primarily indicate the effects of Forest Service land management activities versus indicating the effects of other factors. . . . II. Feasibility Criteria: A. There is an available, tested methodology (either currently being implemented or readily available to implement) to monitor the population or habitat

failed to meet the criteria or had inappropriate geographic ranges. The document is far from perfect. For example, it features a potentially serious drawback in stretching the same set of MIS across a vast geographic range. It also makes some questionable substantive decisions—such as including the mule deer, an ecological generalist, as a MIS linked to seasonal shrublands.[178]

Nevertheless, the California Forests' effort is a step in the right direction towards data-based decisionmaking: the Service set out clear goals for their monitoring program, guidelines for selecting MIS, and made available the data used to evaluate the candidate MIS.[179] By combining the MIS selection across multiple forest units, the individual National Forests were able to use information and resources more efficiently, probably resulting in a more rigorous process than would have otherwise been possible. But the tradeoff is having less location-specific MIS, because the selected species represent a compromise across all ten forest units. However, insofar as these compromise species function as anticipated, continue to be supported by data, and help the individual forest units manage biodiversity, the California Forests' approach to designating MIS is an improvement on past practice.[180]

VII. LESSONS OF MIS FOR FUTURE PUBLIC RESOURCES MANAGEMENT, AND FOR COASTAL AND OCEAN PLANNING IN PARTICULAR

The NFMA regulations faced a problem of how to make a somewhat vague statutory mandate—"provide for the diversity of plant and animal communities"—operational and practical. MIS were the tools that the Forest Service chose to accomplish this aim, in an attempt to balance a variety of overlapping and competing objectives. Faced with the same problem today, the agency might choose a different suite of techniques, but the problem itself is no less daunting now than it was in 1976: in practical terms, just how should an agency measure and manage the living resources under

of the species. . . . B. The methodology, including data analysis, can be implemented within budget constraints. . . . C. The methodology gives information regarding population or habitat status and change of the species that is useful to informing management decisions.")

178. *Id.* at 121.

179. *See generally* Sierra Nevada Forests Management Indicator Species Amendment FEIS, app. B.

180. Note that the FEIS emphasized that the Sierra Nevada National Forests would re-do this analysis under a new planning rule, and so it remains to be seen what the final outcome will be under the 2012 regulations.

its care?

The experience of NFMA's MIS provision helps clarify this challenge somewhat, identifying three distinct questions surrounding biodiversity management: *what*, *why*, and *how*. First, "diversity" is not a single thing, and there is no best way to simplify the continuum of hierarchical components that we think of as constituting biological diversity.[181] This means that natural resources agencies must think more deeply about *what* it is they are managing, and approach the rulemaking process accordingly. Second, "diversity" (however defined) probably is not a fundamental goal of natural resources management; more likely, the core goal is to incorporate some sense of ecosystem "health," stability, performance, or sustainability into management.[182] That is, defining *why* one might want to include some such ecosystem-based measure is a reasonable starting point for any biodiversity-related regulation. Finally, even given clarity on these first two points, there remains the challenge of *how* to encapsulate appropriate ecosystem monitoring techniques into a regulatory framework—that is, how to balance static law with dynamic science, uniform standards vs. requirements flexible enough to be applicable in individual management units, and how to make all of the above financially feasible.

Each of these three aspects of biodiversity management holds lessons for the future of natural resources regulation. Below, we apply these lessons in the concrete context of the next federal major federal public resources challenge, the oceans.

A. *Marine Spatial Planning as Closely Analogous to National Forest Planning*

On July 19, 2010, President Obama issued Executive Order No. 13547,[183] establishing a National Ocean Policy and making comprehensive coastal and marine spatial planning (CMSP)[184] the Federal Government's primary approach for managing ocean,

181. Dale D. Goble, *What Are Slugs Good For? Ecosystem Services and the Conservation of Biodiversity*, 22 J. LAND USE 411, 414-17 (2007); John M. Hagan & Andrew A. Whitman, *Biodiversity Indicators for Sustainable Forestry: Simplifying Complexity,* J. FORESTRY 203 (2006).

182. Although, of course, NFMA's statutory language does not demand this interpretation, and neither is it necessarily what the Forest Service or other agencies might see as their institutional mission.

183. Proclamation No. 13,547 75 Fed. Reg. 43,023 (July 22, 2010).

184. Note that the federal acronym is CMSP (Coastal and Marine Spatial Planning). Where we discuss the use of marine spatial planning approaches generally, we use the more common acronym "MSP" or else the more general "ocean planning."

coastal, and Great Lakes waters.[185] The Policy also enshrines a suite of other important features for natural resources management, including science-based decisionmaking,[186] ecosystem-based management,[187] and a precautionary approach to environmental stewardship.[188] As a result, it offers an important opportunity for improved stewardship of our national public resources.

The history of biodiversity management in the national forests is a chance to derive concrete lessons that give meaning to these new environmental policy goals. Ocean governance is closely analogous to forestry and public lands management, in which vast, sparsely-populated areas contain valuable public resources subject to overexploitation in the absence of responsible management.[189]

185. The Obama Administration has defined CMSP as "a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. Coastal and marine spatial planning identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives. In practical terms, coastal and marine spatial planning provides a public policy process for society to better determine how the ocean, our coasts, and Great Lakes are sustainably used and protected—now and for future generations." Proclamation No. 13,547 75 Fed. Reg. 43,023 (July 22, 2010). The Executive Order adopted the *Final Recommendations of the Interagency Ocean Policy Task Force*, which provides a blueprint for the future of ocean and coastal management in the United States. WHITE HOUSE COUNCIL ON ENVTL. QUALITY, FINAL RECOMMENDATIONS OF THE INTERAGENCY OCEAN POLICY TASK FORCE (2010), *available at* http://www.whitehouse.gov/files/documents/ OPTF_FinalRecs.pdf. The Intergovernmental Oceanographic Commission, which has analyzed MSP approaches in a number of countries, defines MSP more generically as "a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process." UNESCO, MANUAL AND GUIDES NO. 53, ICAM DOSSIER NO. 6, INTERGOVERNMENTAL OCEANOGRAPHIC COMM'N, MSP: A STEP-BY-STEP APPROACH TOWARD ECOSYSTEM-BASED MANAGEMENT 18 (2009), *available at* http://www.unesco-ioc-marinesp.be/msp_guide.

186. Proclamation No. 13,547 75 Fed. Reg. 43,023 (July 22, 2010).

187. *Id.*

188. NAT'L OCEAN COUNCIL, DRAFT NATIONAL OCEAN POLICY IMPLEMENTATION PLAN 97 (2012) ("One of the Policy's guiding stewardship principles provides that decision-making will be guided by a precautionary approach as reflected in the Rio Declaration of 1992.").

189. Both terrestrial and marine systems generate ecosystem goods and services and support local economies through their support of tourism and recreation; both sets of ecosystems also support "extractive" economic activities and sectors that, when governed responsibly, can serve as valuable sources of jobs and raw materials for the indefinite future. At the same time, like the timber industry in the National Forests, ocean-based industries such as commercial fishing have suffered from overexploitation as users' extractive activity has degraded the underlying ecosystems and surpassed managers' abilities to control extractive use.

The large spatial scales of both terrestrial and ocean ecosystems encompass a complex mix of habitats. This complexity poses similar challenges of management and monitoring in the terrestrial public lands and in the federal jurisdictional oceans.

Pursuant to the Executive Order federal agencies will enlist state and tribal partners to develop spatially-specific use and resource management plans on a regional basis,[190] similar to Land and Resource Management Planning process in the National Forests under NFMA. For the last decade, scholars and policy experts have advocated to make multi-resource, multi-sector spatial planning and management approaches more central to ocean governance. With the Executive Order, this approach is now at the forefront of U.S. ocean policy.[191]

As with the origin of NFMA in the 1970s, ocean planning comes to the fore amidst a growing recognition that our oceans and inland seas and the resources they contain are finite assets. A long list of stressors – including widespread habitat loss, pollution, over-exploitation, invasive species, and the effects of climate change and ocean acidification[192] – threatens the viability of our marine ecosystems, in turn jeopardizing the billions of dollars and millions of jobs that the ocean's goods and services provide.[193]

Some states have already taken action on marine spatial planning, independent of the emerging federal initiative. The state of Massachusetts has been the leader with respect to adopting and implementing an MSP framework. The Massachusetts legislature passed the Massachusetts Oceans Act in 2008[194]; the state published its first Ocean Plan in December 2009.[195] Other states are

190. Proclamation No. 13,547, 75 Fed. Reg. 43,023.

191. Though the Executive Order and the Final Recommendations apply to the Great Lakes as well, this article focuses on ocean management specifically.

192. *See, e.g.*, CTR. FOR OCEAN SOLUTIONS, PACIFIC OCEAN SYNTHESIS, SCIENTIFIC LITERATURE REVIEW OF COASTAL AND OCEAN THREATS, IMPACTS, AND SOLUTIONS (2009), *available at* http://centerforoceansolutions.org/sites/default/files/pdf/PacificSynthesis.pdf; Melissa M. Foley et al., *Guiding Ecological Principles for Marine Spatial Planning*, 34 MARINE POL'Y 955 (2010).

193. *See generally* Boris Worm et al., *Impacts of Biodiversity Loss on Ocean Ecosystem Services*, 314 SCIENCE 787 (2006); Gretchen Daily et al., *Ecosystem Services*: *Benefits Supplied to Human Societies by Natural Ecosystems*, 2 ISSUES IN ECOLOGY 1 (1997).

194. Massachusetts Oceans Act of 2008 (codified at MASS. GEN. LAWS CH. 114, § 35HH).

195. *See* MASS. OFFICE OF ENERGY AND ENVTL. AFFAIRS, MASSACHUSETTS OCEAN MANAGEMENT PLAN (2009), *available at* http://www.env.state.ma.us/eea/mop/final-v1/v1-complete.pdf. The Plan designates two areas for commercial-scale renewable energy de-

poised to follow suit: Washington passed marine spatial planning legislation in early 2010[196]; Rhode Island and Oregon are conducting MSP under existing legal mandates; and New York has initiated MSP as part of its coastal management program.[197] Meanwhile, California has nearly completed a network of marine protected areas that could function as a starting point for more comprehensive planning, and both the California Legislature and the California Ocean Protection Council have expressed interest in MSP.[198] These ocean governance initiatives—along with other initiatives, such as monitoring in marine protected areas—can benefit significantly from the lessons of prior large-scale public resource management efforts such as NFMA (and its public lands equivalent, the Federal Land Policy and Management Act.)[199]

Maintaining sustainable ecosystems is a key aspect of natural resources management, in part because these ecosystems and their constituent parts form the basis for generating the goods and services on which we depend. As such, the lessons of NFMA's MIS biodiversity provisions—and the lessons of decades of experience

velopment and retains a "prohibited area" in which development is forbidden pursuant to prior legislation. The majority of Massachusetts waters remain designated for general use, although new siting maps and performance standards identify "special, sensitive, or unique resources" and establish a mechanism for resolving use-ecosystem and use-use conflicts. *Id.* at 2-1 to 2-23.

196. Marine Waters Planning and Management, Substitute S.B. 6350, ch. 145 (Wash. 2010), *available at* http://www.ecy.wa.gov/programs/sea/msp/pdf/SB6350.pdf.

197. *See* N.Y. DEP'T OF STATE, N.Y. STATE COASTAL MGMT. PROGRAM, ATLANTIC OCEAN AMENDMENT (2010), *available at* http://www.nyswaterfronts.com/downloads/pdfs/NYS_CMP_Amendment.pdf; OR. DEP'T OF LAND CONSERVATION AND DEV., OR. COASTAL MGMT PROGRAM, OREGON TERRITORIAL SEA PLAN, PART FIVE: USE OF THE TERRITORIAL SEA FOR THE DEVELOPMENT OF RENEWABLE ENERGY FACILITIES OR OTHER RELATED STRUCTURES, EQUIPMENT, OR FACILITIES (2009), *available at* http://www.oregon.gov/LCD/OCMP/docs/Ocean/otsp_5.pdf; OR. DEP'T OF LAND CONSERVATION AND DEV., OR. COASTAL MGMT PROGRAM, REQUEST FOR ROUTINE PROGRAM CHANGE TO THE OREGON COASTAL MANAGEMENT PROGRAM, RPC.OR-2010-001, ITEM 4 (2010), *available at* http://www.oregon.gov/LCD/OCMP/docs/Public_Notice/RPC.OR-2010-01_Combined.pdf; R.I. COASTAL RES. MGMT. COUNCIL, OCEAN SPECIAL AREA MANAGEMENT PLAN, DRAFT CH. 1 (2009), *available at* http://seagrant.gso.uri.edu/oceansamp/samp.html.

198. *See* Cal. A.B. No. 2125 (as amended by Senate, July 15, 2010), *available at* http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2101-2150/ab_2125_bill_20100715_amended_sen_v96.pdf; CAL. OCEAN PROTECTION COUNCIL, OPC SUPPORT FOR COLLABORATION ON MARINE SPATIAL PLANNING, (resolution amended, Sept. 17, 2009), *available at* http://www.opc.ca.gov/2009/11/opc-support-for-collaboration-on-marine-spatial-planning/; *see also* CAL. OCEAN PROT. COUNCIL, STAFF MEMO RE: COORDINATING GEOSPATIAL DATA TO MAP HUMAN USES AND CONDITIONS IN THE OCEAN ENVIRONMENT (2009), *available at* http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20090917/0909COPC_03_MSP.pdf.

199. 43 U.S.C. § 1701 (2012).

with environmental monitoring generally—are especially salient for the emerging ocean planning effort.

B. *Lessons from the Experience of NFMA's Management Indicator Species*

1) What to measure: Diversity is not just one thing

As many authors have noted, and as we discuss briefly above in Parts 2 and 3, biological diversity is a slippery concept with nested hierarchical levels. Accordingly NFMA's mandate that Forest management provide for a "diversity of plant and animal communities" proved to be difficult for the Forest Service to translate into practical terms. In the context of ocean policy, any large-scale marine spatial planning effort will have to balance a host of often-competing uses for nearshore waters—from shipping lanes to commercial fishing to marine protected areas—while maintaining a level of biological complexity sufficient to ensure the ongoing viability of our marine ecosystems. Ocean planning regulations (or statutes) therefore will very likely feature some language that explicitly addresses the conservation of biological diversity, with conservation listed among many other desirable uses of federal ocean waters—just as NFMA did in the case of the National Forests.

One clear lesson from the NFMA experience is that such language will have to be more specific in order to effectively guide implementation. Rather than espousing the value of "diversity" or "biodiversity," a more effective mandate would include preserving the particular *elements* and hierarchical levels of biological diversity that together contribute to ecological complexity. For example, one such hypothetical regulation might require that:

> resource use plans for each identified habitat type within a management unit must use the best available science to ensure and maintain sufficient genetic, population, species, and community biological complexity to ensure 1) the continuing composition, structure, and function of the ecosystem relative to an identified reference condition, and 2) the continued viability, sustainability, and evolution of the ecosystem's constituent species.

Although perhaps less elegant than preserving "diversity," this more specific mandate would both better protect what we think of as biological diversity,[200] and provide clear guidance for the man-

200. That is, the proposed language would address the various hierarchical levels of biological complexity, would link that complexity to measureable ecosystem characteris-

agement agency[201] to avoid the expense and uncertainty of litigation. It is also a tenable goal: as the cost of biological assessment and monitoring decreases, the intensity of monitoring can and should increase concomitantly. Genetic sampling of seawater, for example, could provide a wealth of information about community composition (such as which species are present, and in what proportion) while simultaneously speaking to the existing level of genetic diversity within each species.[202] As the cost of genetic techniques continues to plummet, environmental monitoring using these methods becomes increasingly cost-effective, and in many cases may be cheaper than traditional monitoring.[203]

The language above punts on a critical scientific question: what is "sufficient" complexity to meet the goal of the hypothetical regulation? Defining sufficiency is a key entry point for scientific data, and this might usefully be made explicit rather than implicit. Any natural resources statute or regulation requires scientific data to give meaning to its terms—for example, "maximum sustainable yield" is meaningless in the abstract, and requires field measurements and ecological models to approach a credible estimate of MSY for any particular species. Here, the implementing agency would use primary scientific data to make the regulatory language operational in the same way.[204] This interaction between science and law provides the important secondary benefit, discussed further below, of allowing scientific methods and norms to change while remaining informative for the same point of law.

2) Why to measure it: Diversity is not the goal in and of itself

The shift from species management to ecosystem management

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tics, and would seek to protect the *processes* (evolution and the raw genetic diversity that it requires) resulting in the variety of biological entities we observe in the world.

201. Presumably NOAA would be the relevant agency, in the case of CMSP, although in principle other public resources agencies could adopt similar requirements.

202. *See, e.g.*, Philip Francis et al., *Monitoring Endangered Freshwater Biodiversity Using Environmental DNA*, 21 MOLECULAR ECOLOGY 2565 (2011) (implementing similar technique in freshwater lakes and streams to sample imperiled species, which are by nature difficult to census by traditional, hand-counting methods).

203. *Id.*

204. Of course, no one definitive scientific answer would be forthcoming, but existing science allows us to estimate a "sufficient" population size to ensure ongoing viability and to avoid the loss of genetic diversity that results from very small population sizes. Population viability analysis—familiar in the context of the Endangered Species Act—performs a similar role. Note, too, that although the implementing agency would be due deference in selecting the "identified reference condition," the agency would be limited by the regulatory purpose of ensuring and maintaining sustainably viable ecosystem composition, structure, and function.

illustrates a larger point: diversity *per se* probably should not be a core goal of natural resources management. Rather, preserving the composition, structure, and function of the ecosystems under management is the more fundamental mission.

Oceans—like the Forests—are multiple-use public resources, and so both politics and practicality demand balancing these uses in some rational way. But regardless of the particular balance of uses one might wish to strike, maintaining a functioning ecosystem is a necessary underlying precondition to any natural resources management. Neither commercial nor recreational fishing, for example, has a future in the absence of an intact trophic web supporting the targeted fishery species. Tourism, the primary contributor to the ocean economy, depends in significant part on the existence of intact coastal ecosystems—for instance, diving on coral reefs requires the existence of coral reefs as well as the entire set of ecological interactions that support them. Building ecosystem-level monitoring into marine spatial planning is therefore necessary to bring ocean management into the 21st century and to ensure its ongoing effectiveness.

Quantifying the composition, structure, and function of ecosystems (and the baseline levels of temporal variability in these parameters) remains challenging, but some well-accepted measures have existed for many years, and the experience of NFMA underscores the fact that identifying the real goals of a management program is one key to its continued relevance in the face of evolving science.

A set of critical ecosystem measures, such as mean trophic level and the ratio of net primary productivity to biomass, would provide agencies with relevant management feedback when paired with explicit baseline or reference conditions. In the context of the oceans, community-wide genetic sampling (described above) offers a high-resolution means of assessing the membership of species assemblages, and therefore of determining ecosystem measures like mean trophic level. Net primary productivity can be measured routinely by satellite, and much of this data is already publicly available.[205] Incorporating these kinds of measurements would be a substantial step toward ecosystem-based ocean management, avoiding some of the pitfalls of single-species-based biodiversity regulations in the National Forests by speaking to the more fundamental goals

205. NOAA and NASA satellites, for example, provide such data.

of natural resource management. As further measures of ecosystem composition, structure, and function become commonly accepted in the scientific community,[206] the implementing agency could employ such measures to fulfill the existing regulatory requirement, allowing science to evolve within federal ocean policy.

California's Marine Protected Areas Monitoring Enterprise[207] offers one example of the process by which agencies or public-private partnerships might work towards implementing ecosystem measures within a regulatory scheme in the marine environment. The Monitoring Enterprise builds upon baseline environmental data to develop monitoring plans that capture a core set of ecosystem attributes within California's network of marine protected areas. It does so by engaging a broad cross-section of stakeholders—including scientists with significant expertise in the specific geographic area—evolve region-specific plans.[208]

3) How to incorporate dynamic science into regulation

Perhaps the clearest lesson of the NFMA MIS experience is that science will continue to evolve, and therefore regulation that requires a particular monitoring technique risks becoming quickly anachronistic.[209] The case of MIS is analogous to requiring the

206. As the scientific process generates new methods of measurement, the question of how to distinguish between legitimate/useful advances and pseudo-science arises. The implementing agency can establish quality control for evolving scientific standards by wielding its "best available science" mandate (coupled with a court's deference to the agency in reasonably defining that science). Where this is insufficient, environmental and administrative law could borrow from evidence law, applying the *Daubert* or similar standard familiar for expert witnesses.

207. MARINE PROTECTED AREAS MONITORING ENTER., http://monitoringenterprise.org (last visited Jan. 26, 2013).

208. *See* MARINE PROTECTED AREAS MONITORING ENTER., NORTH CENTRAL COAST MARINE PROTECTED AREAS MONITORING PLAN 4 (2010), *available at* http://monitoringenterprise.org/pdf/NCC_MPA_Monitoring_Plan.pdf.

209. Requiring such a particular monitoring technique would be an example of what Prof. Seidenfeld calls an *ex ante* constraint on agency action. Mark Seidenfeld, *Bending the Rules: Flexible Regulation and Constraints on Agency Discretion*, 51 ADMIN. L. REV. 429, 433 (1999) ("Broad statutory delegations of power to an agency to regulate a general area of the economy, characteristic of much legislation adopted under the New Deal belief in agency expertise, impose few ex ante constraints on the agency. In contrast, statutes that provide rigorous formulae may preclude reasonable regulation that balances social costs against benefits.") The present discussion of how to balance dynamism with stasis in law is closely related to the larger and older body of work on the proper degree of agency discretion, and regulations' generality vs. specificity, in administrative law generally. *See generally* Richard J. Pierce, Jr., *Political Accountability and Delegated Power: A Response to Professor Lowi*, 36 AM. U. L. REV. 391, 404 (1987); Edward L. Rubin, *Law and Legislation in the Administrative State*, 89 COLUM. L. REV. 369 (1989); Peter L. Strauss, *Legislative Theory and the Rule of Law: Some Comments on Rubin*, 89 COLUM. L. REV. 427 (1989). Richard Stewart adds:

Forest Service to conduct all land-use planning using an Apple II computer: arguably the best of several options at the time the regulations were written, but very quickly surpassed as technology improved over time. To better integrate science into a regulatory framework, it therefore makes sense to focus on the process-based (rather than product-based) lessons of NFMA, seeking to define enforceable standards of management while also incorporating constantly-advancing science.

An important structural starting point is ensuring that the management agency has appropriate institutional incentives; the agency has to *want* to change, or at least must have an institutional structure that can adapt in the face of new information.[210] In the case of the National Forests, the Forest Service had long been geared toward timber and game production rather than toward maintaining a healthy balance of uses. Moreover, timber sales helped to finance the Service, adding a financial incentive to err on the side of timber production in land use planning.[211] Game animals were important to a vocal subset of the Forest's public, further politicizing MIS selection and management decisions.[212]

> In many government endeavors it may be impossible in the nature of the subject matter to specify with particularity the course to be followed. This is most obvious when a new field of regulation is undertaken. Administration is an exercise in experiment. If the subject is politically and economically volatile — such as wage and price regulation — constant changes in the basic parameters of the problem may preclude the development of a detailed policy that can consistently be pursued for any length of time. These limitations are likely to be encountered with increasing frequency as the federal government assumes greater responsibility for managing the economy.

Richard B. Stewart, *The Reformation of American Administrative Law*, 88 HARV. L. REV. 1669, 1695 (1975). Note that if one reads "environment" in place of "economy" in Stewart's piece, his point retains at least equal force.

210. *See, e.g.*, Biber, *supra* note 2, at 76 (discussing the evolution of the U.S. Geological Survey as a monitoring agency).

211. *See, e.g.*, Austin D. Saylor, *The Quick and the Dead: Earth Island v. Forest Service and the Risk of Forest Service Financial Bias in Post-Fire Logging Adjudications*, 37 ENVTL. L. 847 (2007) (discussing a particular case of financial conflict-of-interest, post-fire timber sales, in the context of Earth Island v. U.S. Forest Service, 442 F.3d 1147 (9th Cir. 2006)). Note that timber sales apparently represent net financial losses to the USFS, and that accounting within the Service (at least as of 2001) left the Forest Service's "cost information totally unreliable." U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-01-1101R, FINANCIAL MANAGEMENT: ANNUAL COST OF FOREST SERVICE'S TIMBER SALES PROGRAM ARE NOT DETERMINABLE (2001).

212. Telephone interview with anonymous Forest Service employee integrally involved with implementing biodiversity provisions in a suite of National Forests (Feb. 21,

It is critical that the agency implementing marine spatial planning on a national scale be financed independently of the resource-extraction rights they may confer. This was made clear, for example, by the reorganization of the former Minerals Management Service in the wake of BP's Deepwater Horizon oil spill.[213] Moreover, ocean planning would benefit from an agency culture accustomed to balancing uses for long-term sustainability—perhaps looking more to the Federal Reserve Board or OIRA rather than to the Forest Service or Bureau of Land Management as a model for agency culture. This structural setting would improve the odds of implementing testable, economically sustainable, and data-based resource management policies.

Ocean planning statutes or regulations could help ensure structural adaptability by defining the relationship of the implementing agency to the managed marine resources as that of a trustee to a beneficiary. This would formalize the agency's attendant duty to act in the best interests of the beneficiary, the American public, presumably including present and future generations. Because a trustee must act as a reasonably prudent person in managing trust property, it seems likely the agency would then be bound to consider the best available information in making management decisions regarding the public resources under its control.[214] Moreover, the trust relationship would impose the duties to inventory and maintain the trust property, to account for actions regarding the trust property, to be impartial with respect to beneficiaries of the trust, and not to profit from trust property.[215]

2012) (notes on file with the author).

213. MMS became the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), which was then split to separate revenue-generating from safety-regulation and enforcement activities. *See Reorganization of the Bureau of Ocean Energy Management, Regulation, and Enforcement*, http://www.boem.gov/About-BOEM/Reorganization/Reorganization.aspx (last visited Jul. 3, 2012) ("In the place of the former MMS – and to replace BOEMRE – we are creating three strong, independent agencies with clearly defined roles and missions. MMS – with its conflicting missions of promoting resource development, enforcing safety regulations, and maximizing revenues from offshore operations and lack of resources – could not keep pace with the challenges of overseeing industry operating in U.S. waters. The reorganization of the former MMS is designed to remove those conflicts by clarifying and separating missions across three agencies and providing each of the new agencies with clear missions and additional resources necessary to fulfill those missions.").

214. This fiduciary duty would of course be in addition to (and probably stronger than) the APA's baseline "arbitrary and capricious" standard for agency action.

215. As an example of these commonly-held duties see, for example, Cal. Prob. Code § 16000 (1990) (providing general fiduciary duties of trustee under California probate

Requiring the responsible agency to employ best practices (such as those discussed above for environmental indicators) when developing an environmental monitoring program would be a more targeted means of embedding a dynamic element into public resources regulation. Such a "best practices" mandate would be akin to a best-available-science requirement,[216] or to the technology-based standards of other environmental laws. The Clean Water Act and Clean Air Act, for example, have provisions that require polluters use the Best Available Control Technology or the Best Practicable Technology (or some similar standard) to reduce their pollution levels. Technology-based standards both institute an enforceable regulatory provision and allow that standard to become more stringent over time. Moreover, they are particularly appropriate where some heterogeneity in the regulatory landscape—in the case of environmental monitoring, this is literal habitat heterogeneity—makes implementing uniform requirements difficult or impossible. Applying the same logic, best practices for environmental monitoring form an evolvable, "technology"-based standard for future public resources management; identified reference conditions could ensure each geographic area meets core goals in a quantifiable way. Critically, these best practices should be constrained by, and guided by, a clear statement of the purpose of the monitoring regime and a requirement the agency use the best available science in implementing it.

Technology-based standards are a special case of a general strategy that separates detailed, technical specifications (which may change comparatively rapidly) from the slower-moving process of notice-and-comment rulemaking under the Administrative Procedures Act. Guidance documents play a similar role, albeit one that is less enforceable. Just as regulations (found in the Code of Federal Regulations) implement sections of statutes (the U.S. Code), sub-regulatory guidance often contains ground-level details useful for carrying out regulatory mandates. For example, as noted above, the Forest Service Manual and Handbook contain guidance relevant to the NFMA regulations. These documents do not have

law). *See also* Mary Turnipseed et al., *The Silver Anniversary of the United States' Exclusive Economic Zone: Twenty-Five Years of Ocean Use and Abuse, and the Possibility of A Blue Water Public Trust Doctrine*, 36 ECOLOGY L. Q. 1, 10 (2009) (discussing public trust applied to oceans).

216. For a discussion of possible improvements to the Forest Service planning regulations, including a best-available-science mandate, see Nell Green Nylen, *To Achieve Biodiversity Goals, the New Forest Service Planning Rule Needs Effective Mandates for Best Available Science and Adaptive Management*, 38 ECOLOGY L. Q. 241 (2011).

the force of law,[217] consistent with the larger principle of administrative law that more enforceable or coercive rules require greater procedural safeguards, such as notice-and-comment periods in administrative rulemaking.[218] By embedding malleable details—such as scientific techniques subject to change—into sub-regulatory documents, the implementing agency can update them regularly,[219] although the price of such flexibility is decreased enforceability because the regulations were not promulgated through the APA rulemaking process.[220]

Another way to encourage agency accountability and responsive policymaking is to establish an external scientific advisory committee, with its role defined by regulation. In the case of NFMA, the statute itself instructed the Forest Service to convene a Committee of Scientists, limiting its membership to people not "officers or employees of the Forest Service."[221] The Committee was a positive step to review and incorporate ideas from outside the Service. However, it was not a permanent institutional component: NFMA provided that "the Committee shall terminate upon promulgation of the regulations."[222] A standing external committee might have provided ongoing and valuable technical input, especially insofar as its members were unaffiliated with the regulators or the regulated parties.[223] In the case of ocean planning, such a committee could be charged with deriving or honing best monitor-

217. W. Radio Serv. Co. v. Espy, 79 F. 3d 896 (9th Cir. 1996) (holding that the Forest Service Manual and Forest Service Handbook do not have independent force of law).

218. *See, e.g.*, City of Williams v. Dombeck, 151 F. Supp. 2d 9, 22 (D.D.C. 2001) ("[T]he law in this circuit expressly rejects publication in the Federal Register as the hallmark of a regulation. Rather . . . the real dividing point between regulations and general statements of policy is publication in the Code of Federal Regulations, which the statute authorizes to contain only documents having general applicability and legal effect.") (citing Brock v. Cathedral Bluffs Shale Oil Co., 796 F.2d 533, 539 (D.C. Cir. 1986) (quotations and emphases omitted)).

219. Better yet, the agency could empower an external committee of scientists to update the scientific details in guidance documents, which would likely be a cost-effective means of identifying and maintaining the best available science.

220. The limits of this internal guidance are then presumably set by a statutory or regulatory "best available science" mandate.

221. 16 U.S.C.A. § 1604(h)(1) (2012). The Service went beyond this mandate, excluding timber company employees as well.

222. *Id.* Another committee was formed in 1997, which influenced the 2000 regulations. *See* U.S.D.A. FOREST SERV., COMMITTEE OF SCIENTISTS REPORT, *available at* http://www.fs.fed.us/news/news_archived/science/.

223. Other agencies have similar scientific advisory committees. *See, e.g.*, 16 U.S.C.A. § 1852 (2012). The National Academy of Sciences also plays an analogous role in shaping national-scale policy, albeit from a more removed standpoint.

ing practices and renewing them on a regular basis—say, every five to ten years, consistent with an adaptive regulatory regime. This periodic review could evaluate the techniques and performance of the monitoring scheme as well as its purposes.

A necessary precondition to data-based (as opposed to faith-based) natural resources management is the use of ecosystem outcome data to inform future decisions that will inevitably affect that ecosystem. Ideally, regulations would function as working hypotheses, to be tested by outcomes on the ground; regardless of whether the hypothesis is supported or refuted, new information (the outcome resulting from the regulation) would animate the decision to change or maintain the existing rule.[224] This is *adaptive management*, a much-discussed philosophy of governance, but one that is difficult to implement in part as a result of the agency incentive to avoid explicit and public tests of decisions.[225] Because adaptive management requires a consistent flow of information from which to assess the results of past actions, ambient monitoring is critical to adaptive natural resources management.[226] However, just as critical as re-evaluation and improvement of regulatory decisions is re-evaluation of the methods used to collect the underlying monitoring data. One means of embedding dynamic science in static regulation, then, is ensuring that the regulation provides not just for "adaptive management" in the abstract, but in concrete terms that include the frequency and thoroughness with which the implementing agency should re-evaluate monitoring methods.[227]

224. *See* Lee, *supra* note 135; *see also* J.B. Ruhl, *Regulation by Adaptive Management—Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 27 (2006) (arguing that adaptive management is necessarily implicated in second-generation environmental law tools for dealing with diffuse, complex problems); A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1139 (1994) (discussing adaptive management as part of a larger shift in academic ecology and natural resources management, in which there is no such thing as a "final" management decision).

225. Lee, *supra* note 135. Note also that adaptive management is easily confused with ad hoc management—each requires dynamic decisionmaking, but while the former is a structured, scientific approach to learning from the results of one's actions, the latter is the opposite: unstructured decisions that evince a *lack* of learning from existing information. The seminal work on adaptive management in natural resources is CARL J. WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES (1986), and many authors trace the origin of modern scholarship surrounding adaptive management to ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (C.S. Holling ed., 1978).

226. *See generally* Biber, *supra* note 2.

227. For an insightful discussion of adaptive management in the context of law and natural resource management, see Holly Doremus, *Precaution, Science, and Learning While Doing in Natural Resource Management*, 82 WASH. L. REV. 547 (2007). One may also see adaptive management as providing iterative feedback. One aspect of complex systems is that

Finally, it bears mentioning that an ideal law, regulation, or policy would be neither over-inclusive nor under-inclusive. It would limit the behavior of all of its target population and only its target population. Because no such ideal regulation exists, a key policy question is whether the emerging marine spatial planning effort (or any other natural resources management regime) should err on the side of under-constraining or over-constraining agency action. Too much agency deference leads to heterogeneous application of law and variable outcomes; too little agency deference leads to inefficiency, frustration, and a sclerotic bureaucracy.

Rational natural resources regulation should be tied to the spatial and temporal scales of the processes that generate the resources themselves. Given this, and applying baseline risk management in which both the risk of error and the severity of the potential harm due to that error are factored into decisionmaking, it seems reasonable to err on the side of over-constraining an agency's power to allocate resources more rapidly than those resources are generated. Such a policy tilted toward avoiding the harms of over-exploitation should sound familiar: it is essentially the precautionary principle, well-established in international law following the Rio Declaration of 1992, and now formally part of the Implementation Plan for the National Ocean Policy.[228]

This is analogous to maintaining a personal bank account: because it is far easier to spend money than it is to accrue money, sustainable fiscal policy errs on the side of over-constraining expenditures. In the case of biological diversity, reductions in diversity (however measured) are essentially irreversible on human time-

they can evolve over time. In this context, administrative law functions as a complex, adaptive system whose properties may be understood with reference to complexity theory in physics and biology. *See* Donald T. Hornstein, *Complexity Theory, Adaptation, and Administrative Law*, 54 DUKE L.J. 913 (2005).

228. NAT'L OCEAN COUNCIL, DRAFT NATIONAL OCEAN POLICY IMPLEMENTATION PLAN 97 (2012) ("One of the Policy's guiding stewardship principles provides that decision-making will be guided by a precautionary approach as reflected in the Rio Declaration of 1992, which states in pertinent part, '[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'"). It is worth noting that one of the nation's key laws protecting marine biodiversity, the Marine Mammal Protection Act, 16 U.S.C. §§ 1361-1423(h) (2012), implements an essentially precautionary regulatory regime by creating a presumption against activities that might negatively impact marine mammals. *See* Cara Horowitz & Michael Jasny, *Precautionary Management of Noise: Lessons from the U.S. Marine Mammal Protection Act*, 10 J. INT'L WILDLIFE L. & POL'Y 225, 228 (2007) (discussing the precautionary principle embedded within the Act).

scales: even genetic diversity, which accrues most rapidly, takes millennia to develop in the species we tend to exploit most heavily.

For marine spatial planning and other future public resources management regimes—which themselves depend upon the existence of intact ecosystems for the goods and services they are charged with managing—sustainability turns on limiting the resource agency's ability to erode ecosystem function faster than it builds up. Thus, even as a future ocean planning regime should provide the implementing agency with the procedural flexibility to select techniques that evolve along with best available science, it should constrain the agency's substantive ability to unsustainably allocate natural resources.[229]

VIII. CONCLUSION

Public resources management requires *management*; that is, it requires responsible agencies to make decisions about whether and how to use natural resources that are public or public trust property. As with any ongoing management—be it in the financial sector, forestry, or ocean resources—making responsible decisions requires some kind of feedback by which to gauge the impact of those decisions. Environmental monitoring is thus an integral aspect of public resources management, providing the feedback necessary for managers and for the public to evaluate the state and the trajectory of our shared resources.

The insidious challenge of environmental monitoring is that it seems simple, but its ground-level details are maddeningly complex. In the case of National Forest management, a small statutory element and brief interpretive regulation spurred years of litigation, failed regulatory reforms, and frustrations on the part of foresters attempting to implement the MIS regulation. The story of

229. One means of implementing such asymmetrical discretion is to focus on the uncertainty surrounding any given data point. CMSP's animating law could require that the agency allow a margin of error (for example, 2 SE) in making allocation decisions. If, for example, a management plan called for permitting shipping lanes in a given area of ocean, and the agency estimated it could sustainably use 100 +/- 10 mi^2 for this purpose, the 2 SE margin of error would allow it to lease only 80 mi^2. As uncertainty decreased, the margin of error would decrease accordingly. Such a precautionary limiting principle would minimize risk to ecosystem composition, structure, and function, while providing an agency incentive to improve its statistical methods (which would, in turn, lower the required margin of error and maximize agency discretion within allowable bounds). Of course, the efficacy of such a system depends on the transparency and validity of the method used to generate the margin of error.

NFMA's MIS regulation is an object lesson in the interaction of dynamic science and static law, and in the struggle within administrative law to balance flexibility and discretion in implementation against a need to ensure the statute's purposes are uniformly met. Future natural resources management, and in particular the emerging federal CMSP initiative, must improve upon the experience of federal biodiversity management in the National Forests.

Sustainable, data-based policy is a normatively desirable goal—indeed, one might argue it is the only rational means of managing public resources. But of course, raw data do not generate automatic answers to core ethical questions about resources management: what is sustainable use, over what timescales? What are acceptable environmental tradeoffs for economic development? Such value-laden questions are always embedded in resource management, unaddressed by even the most thorough environmental indicator data.[230] Environmental monitoring requires both *a priori* value-based decisions (for example, which variables are important to track?) and *a posteriori* value-based decisions (given the data in hand, what is an appropriate use of public natural resources?).[231] Despite considerable agency incentives to avoid addressing these questions directly in regulation, transparent and responsive governance requires that value-based questions not be buried in technical standards. Rather, the lessons of NFMA and its MIS provision for managing biodiversity suggest that future large-scale public resource management regimes—such as the emerging federal coastal and ocean planning effort—must face difficult, value-based decisions head-on or else risk substantial ecological and legal uncertainty if they fail to do so.

230. *See* Holly Doremus & A. Dan Tarlock, *Science, Judgment, and Controversy in Natural Resource Regulation*, 26 PUB. LAND & RESOURCES L. REV. 1 (2005).

231. *See* M.L. Morrison & B.G. Marcot, *An Evaluation of Resource Inventory and Monitoring Program Used in National Forest Planning*, 19 ENVTL. MGMT. 147, 153-54 (1995) (noting that "[t]he [Forest Service] would be better served by developing a system to answer specific, key questions about the environment by selecting ecosystem element indicators that will answer those questions, rather than forcing environmental questions a posteriori into the MIS or other systems").