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ANALYSIS

Clean water, ecological benefits, and benefits transfer: A work in progress at the U.S. EPA

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ABSTRACT

Economists at the U.S. Environmental Protection Agency (EPA) are regularly called upon to assess the anticipated benefits and costs of rules proposed to implement environmental legislation. These laws reflect a concern for both human and ecological health, and the increased flow of ecosystem services is a significant source of benefit. This is particularly true for the Clean Water Act (CWA), one goal of which is to safeguard aquatic habitat. Because the benefit–cost analyses must be completed within mandated deadlines, the approaches taken to assess benefits are often expedient ones that have already survived the gauntlet of review both within and outside the agency. This engenders a strong bias toward the benefits transfer approach and particular variants of it. In this paper, we review how ecological benefits have been assessed for and benefits transfer applied to seven EPA rules issued under the CWA. We highlight common themes and point out recurring concerns. Some concerns relate to agency decisions regarding the treatment of a particular benefit category and could be dealt with relatively easily. Other concerns will require the support of an engaged research community to improve the fit of valuation studies to policy contexts and to ensure that the changes in ecological response to which benefit estimates are being transferred are accurately measured.

1. Introduction

Economists at the U.S. Environmental Protection Agency (EPA) are regularly called upon to assess the anticipated benefits of regulations proposed to implement environmental legislation. The Clean Water Act, for example, stipulates that consideration be paid in effluent limitation guidelines to "the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application" (CWA 33USC1314). This responsibility was clarified in Executive Order 12866, which requires that any federal rule or regulation with an expected annual economic impact exceeding $100 million undergo a

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formal economic analysis and an Office of Management and Budget (OMB) review (President, 1993, 2002).[3]

The economic analysis of proposed EPA rules must meet the agency's peer-review standards (EPA, 2000c; OMB, 2004) and federal and specific EPA rule-making requirements (EPA, 2003b, 2004c,d; APA 5USC511). The analyses must be completed within judicially and legislatively mandated deadlines, thus adding a need for speed and pragmatism to the imperative of academic rigor in the approaches used to carry out the analysis. Because assessment of benefits is the most formidable aspect of the economic analysis, agency analysts frequently employ the techniques of benefits transfer, which applies results from existing (ordinarily peer reviewed) studies to a policy scenario under consideration (Desvousges et al., 1998).

The pressure to use benefits transfer is most acute when estimating a rule's expected ecological benefits. Along with time, funding, and administrative hurdles, the conceptual and operational aspects of estimating these benefits can sorely challenge EPA analysts. The absence of a market for most kinds of ecological benefits often calls for finding or creating appropriate shadow prices, and the linkages among environmental stressors (e.g., excessive nutrients in the waterways), ecosystem impacts (e.g., eutrophication), and ecosystem services (e.g., recreational fisheries) are complex and site-specific.

Researchers working to improve estimation techniques and benefits transfer methods may learn much from past experience in handling benefits transfer. Water rules, which are especially likely to bring ecological benefits, present fruitful examples for study. In this paper we examine the use of benefits transfer methods to estimate ecological benefits as part of the total benefits assessment analysis for seven EPA rules issued under the Clean Water Act (CWA).

Section 2 describes the institutional context of the CWA. Section 3 reviews ecological benefits and their relation to ecosystem services and Section 4 briefly describes how they have been addressed. Section 5 provides a short description of how these benefits have been estimated in the seven CWA-related cases, and Section 6 identifies themes that recur in many of these cases and presents some of our concerns regarding benefits transfer. Section 7 offers our thoughts on how future research can improve regulatory economic analysis.

2. The institutional context

The Federal Water Pollution Control Act was passed in 1972 (Public Law 92-500); when it was amended in 1977 it became the Clean Water Act (Public Law 95-217). While EPA's regulatory authority is provided by more than a dozen federal statutes, a large majority of its surface water-related rules have been issued under CWA authority.

Of the several goals set by Congress in the CWA, three pertain to water quality: "that the discharge of pollutants into the navigable waters be eliminated…, that the discharge of toxic pollutants in toxic amounts be prohibited, [and CWA should ensure the attainment of] water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water…." This last water-quality goal—the "fishable and swimmable" goal—is reflected in the "designated use" and "level of designated use" categories and associated permitted levels of pollutant concentrations for the protection of aquatic life and human health that the CWA requires states to assign to bodies of water.

While the CWA provides EPA with several mechanisms to determine the appropriate criteria for bodies of water, most of the agency's rules are implemented through effluent permits under the National Pollutant Discharge Elimination System (NPDES). Each point-based pollution source must have a permit that specifies which pollutants the source must control, sets numerical or narrative limits for those pollutants, establishes how often the source must monitor each pollutant, and in some cases limits the maximum allowable daily and/or average monthly emissions.

The NPDES permits can be based on either technology or water quality. Technology-based permits can make use of either national effluent guidelines or on the best professional judgment of the permit writer. For specific pollutants not covered by effluent guidelines and for situations in which a technology-based permit proves insufficiently protective of surface waters, more stringent permit limits may be imposed to meet relevant water-quality criteria.

Finally, the CWA requires the states to periodically assess all bodies of water and to prepare, for any water body not meeting the assigned water-quality standards, a TMDL specifying the maximum quantity of given pollutants that may be discharged into the water body in order to meet the standard. The TMDL quantifies pollutant sources and load allocations for both point and non-point sources. Once the state sets a load allocation for a point source, it may include the limits reflecting that allocation in NPDES permits.

3. Ecological benefits and ecosystem services

At the most general level, EPA actions contribute to reducing risks to human health and to property and to increasing the flow of ecosystem services. The benefits of reduced health and property risks are obvious to most people, but the same cannot be said for those conferred by ecosystem service flows, which are termed *ecological benefits*.

Ecosystem services are those ecosystem processes that contribute to human well-being. In hewing to this definition, EPA adopts a somewhat narrower stance than that of the UN's Millennium Ecosystem Assessment (2003). Launched in 2001, that assessment distinguishes between "provisioning services" (that support, say, timber production or fisheries), "regulating services" (that maintain environmental conditions within bearable limits by moderating climate and disease), "cultural services" (less tangible but very real contributions like aesthetic conditions and cultural heritage), and "supporting services" (that are necessary for all of the previous three

[3] OMB may also require economic analysis of certain rules that do not exceed the $100 million threshold.

Table 1 – Some relationships among ecological services and benefits

Benefits / Services	Marketed products	Recreation	Non-use value	Maintaining health and property
Timber provision	✓	✓	✓	
Wildlife provision		✓	✓	
Fisheries provision	✓	✓	✓	
Wild pollinators	✓			
Storm and flood damage attenuation				✓
Climate regulation				✓
Disease regulation				✓

ecosystem services, such as nutrient cycling and soil formation). To minimize the potential for double counting of benefits in assessments, EPA finds it useful to clearly distinguish ecosystem services from both the broader set of processes of which they are part and the benefits that the services confer. Not all of the Assessment's categories are considered to be services as defined by this continuum: The Agency tends to view provisioning and regulating services as services, supporting services as more fundamental upstream processes, and cultural services as among the downstream benefits.

Ecological benefits refer to how flows of ecosystem services contribute to human well-being and the things to which humans explicitly value. For example, the provision of fish is a critical service of aquatic ecosystems and one that often provides the benefit of recreational fishing. The ecosystem may provide fish, but humans value those fish for their recreational value in sport fishing. A finer, yet critical, distinction can be made between the intrinsic value of fish, which the Agency does not consider, and the degree to which humans value the existence of fish, which the Agency does.

EPA categorizes ecological benefits into four categories: the production of marketed products, recreation and aesthetics, protection of health and property, and non- or passive-use (e.g., existence) values (EPA, 2000b). Table 1 shows some of the larger, first-order relationships typical of the many-to-many nature of the links between ecosystem services and ecological benefits.[4]

Unsurprisingly, the distinction between ecological and other benefits is a somewhat blurred one. On one hand, there are instances in which human health and property damage risk reductions are better conceived as an ecological benefit. For example, ecosystems satisfy the basic needs for human life to exist. When these life support services are bolstered, ecological benefits are conferred by buffering humans and their property from harm. Climate and disease regulation are among the ecosystem services that confer such ecological benefits. These benefits contrast with the more obvious human health risk and property damage reductions that are the direct consequence of reductions in pollutant concentrations (e.g., the impact of reducing ambient concentrations of mercury and sulfur dioxide on morbidity and corrosion of building facades, respectively). On the other hand, some impacts that are closely tied to ecosystems can actually fall outside of our definition for ecological benefits. The impact on commercial and recreational fishing that results from fewer contaminants in fish tissue, assuming the life history parameters of the fish are unaffected, is better seen as a human health benefit. Similarly, while the ability to use a waterway to transport cargo obviously relates to an aquatic ecosystem, it is often by virtue of significant modification to the ecosystem, rather than of its services. Thus, while maintenance of barge traffic may be a benefit of an action, it is unlikely to be an ecological one by our conception.

Assessments of rules issued under the CWA have often found the monetary value of ecological benefits to exceed that of the non-ecological benefits.[5] While rules affecting the quality of surface water certainly lead to human health benefits, considerable recreational and aesthetic benefits stem from improved ecosystem services.

4. The transfer of ecological benefits

The agency's benefits assessments must successfully navigate legal, financial, and institutional constraints, and also anticipate possible policy changes midstream in the process. Expediency has thus understandably become a powerful consideration: regardless of the services and benefits being valued or the valuation technique being employed, EPA rarely conducts original valuation studies to support a proposed rule. As a practical matter, such reluctance is unsurprising, if not always defensible. Not only do original studies useful to EPA require significant resources, but survey development and data collection can seem to proceed at a glacial pace as a result of process requirements, rendering them an impractical solution for rules

[4] Table 1 does not include such second-order considerations as the effect of climate regulation on the status of fisheries that people value for recreation purposes, and or the effect of wildlife in providing certain market products.

[5] This is despite the tendency for important ecological benefits to fall off the table before assessment occurs simply because the economic values for ecological improvements tend to be less well accepted as economic values for human health improvements. Furthermore, while EPA assessment guidelines (EPA, 2000b) and the OMB guidelines (OMB, 2004) explicitly require comparing options for achieving a desired environmental protection goal, these options tend to vary by degree of regulatory stringency. The guidelines do not insist that options considered differ in the kind of regulatory approach taken, which could produce greater ecological gains. For example, Agency analyses usually emphasize limiting effluent emissions, typically calling for specific end-of-pipe capital investments. Rules that encourage best management practices, such as riparian and wetlands restoration, could potentially generate the greatest ecological benefits, but their efficiency, costs, and benefits are almost always less certain and more difficult to assess. Trading and other best-practice options also generally have weaker or untested legal underpinnings, but could produce other ecological improvements.

with short judicial or legislative deadlines. Under the Paperwork Reduction Act of 1995, an agency must acquire OMB approval if it collects the same information from ten or more non-Federal respondents. This "Information Collection Request" (ICR) must justify the need for the data, estimate the time and cost burden placed on the public, and must be published in the Federal Register twice, with an appropriate public comment period. The undertaking is a particular challenge when the benefits of dealing with a stressor are mediated by subtle and complex ecological processes. Original assessment studies will undoubtedly remain rare exceptions. One EPA water-quality valuation study, for example, has consumed over $1.4 million since 1999 and is still not ready for use.

Given the difficulties of undertaking original studies, EPA has made frequent use of the *benefits transfer* approach: applying appropriately tailored results of previous studies to a current rule and context (Boyle and Bergstrom, 1992; Desvousges et al., 1998). The level of sophistication ranges from crude unit-value or point-estimate transfers to meta-analytical approaches that synthesize the results of multiple studies that bear at least partial relation to the context of the proposed rule.

As straightforward as benefits transfer may sound, selecting applicable previous studies and adjusting and applying their results present formidable challenges to agency analysts. EPA can do little with an existing study that is unclear about which services and benefits are being valued. This is important because valuation studies often cover multiple services and benefits. Valuation exercises typically focus on either a particular ecosystem service and the package of benefits it confers (e.g., a stated-preference survey may estimate the recreational benefits and non-use values arising from population increase of a fish species) or on a particular ecological benefit determined by a set of services (e.g., a hedonic price study may estimate the aesthetic benefit conferred by a relevant bundle of ecosystem services).

Benefits transfer, however, is not always an available option. Benefits estimates must withstand legal scrutiny, so EPA tends to err on the conservative side when considering whether to use an existing assessment that employed a novel methodology or that yielded results don't appear to comport with intuition or with previous efforts. Experts outside the agency have little incentive to produce valuation studies that tightly fit EPA needs, often leaving EPA analysts no suitable existing studies. When even the benefits transfer approach is not possible, the remaining option is to express those pieces of the ecological benefits pie in quantitative or even qualitative terms.

5. Illustrative cases

In this section we describe benefits assessments carried out at EPA for seven rules issued under authority of the CWA. These rules were chosen because they were all national in scope, and were economically significant enough to have a comprehensive benefit–cost analysis that was reviewed by OMB, and explicitly addressed some ecological benefits. While the selection of these rules was slightly subjective, we feel that these seven rules are representative of the ecological benefits and benefits transfer work at the EPA. For each rule, we note the categories of ecological benefits considered. We emphasize the factors that we believe may be relevant to analysts undertaking valuation and benefits transfer studies and for researchers seeking to learn from and improve upon past benefits transfer efforts.

5.1. *Pulp and paper*

The effluent guidelines for the pulp, paper, and paperboard industry (pulp and paper), finalized in August 1998, limits the emissions of hazardous chemicals to both air and water. This rule sets baseline limits for the release of pollutants, which were expected to cut toxic air pollutant emissions by almost 60% and to virtually eliminate discharged dioxin from this sector into surface waters. The rule also provides individual mills with incentives to adopt advanced pollution control technologies that lead to further reductions in toxic pollutant discharges.

The majority of the benefits discussed in the economic analysis for this rule (EPA, 1997a) were associated with human health impacts, even though significant ecological improvements were anticipated. One of the two quantitative analyses associated with the proposed and final rules that provided some sense of ecological benefits advanced all the way to monetization.

The first water-related ecological benefit estimated for the pulp and paper rule was the recreation benefit from contaminant-free fishing. The number of recreational anglers at sites with fish consumption advisories for dioxin (and no other advisories) was multiplied by the average number of fishing days per angler in each state, the average consumer surplus per day of fishing (Walsh et al., 1990), and the results reported by Lyke (1993), who estimated the percentage increase in consumer surplus that would occur if Wisconsin's Great Lakes trout and salmon fishery were completely free of contaminants. Assuming that there are, in fact, recreation benefits associated with the rule's impact on provisioning services, a study that focuses exclusively on consumption advisories may not have been a suitable choice for transfer. Moreover, whether it was reasonable to extrapolate from this study of Wisconsin anglers to the nation is debatable.

The second measure stopped short of monetization and estimated the number of streams in which water quality criteria for aquatic life was exceeded, both with and without the regulation.[6] This rather coarse approach offered some insight into the spatial extent of the ecological benefits that would be achieved, but did not provide much information on the magnitude of those benefits since the degree of improvement was not measured. No consideration was paid to either impaired streams that improved–though not to the point at which numeric criteria were met–or to streams that improved but had already met the criteria. Streams in exceedence were treated equally, regardless of whether they are just over the criterion limit or were vastly in exceedence. By the same token, among streams newly in attainment, no distinction was made for how far they had been below or how far they would be above the

[6] In addition to human health benefits, the air portion of this rule estimated the benefits of increased yields in commodity crops (e.g., wheat, corn), fruits and vegetables (e.g., citrus, tomatoes), and commercial forests, which are ecological benefits. Since this paper is focused on water-related ecological benefits, we do not describe those benefits here.

threshold. Finally, this indicator-based approach to assessing ecological benefits failed to reflect differences among water bodies of the services conferred under pristine conditions.

5.2. *Stormwater phase 2*

The stormwater phase 2 (SW2) rule, issued in December 1999, pertains to stormwater discharges, generated by runoff from impervious areas, which contain pollutants adversely affecting water quality. The rule requires permits for stormwater discharges from small municipal storm sewer systems and from construction activities that disturb between one and five acres of land.

The benefits assessment for the proposed rule (EPA, 1997b) took considerable effort to characterize the adverse effects of runoff on ecosystems, but data limitations precluded any quantification of changes expected from the rule. Instead, the assessment detailed how pollutants of the kind associated with urban runoff can affect aquatic and riparian ecosystems.

While the bulk of monetized benefits in the assessment pertained to human health and materials damage (e.g., damage to building facades), the ecological benefit portion centered on water-based recreation. For fresh water, EPA relied on the transfer of unit values from Carson and Mitchell (1993). The portion of the Carson–Mitchell willingness-to-pay (WTP) estimate the survey found to relate to in-state, "local" values was used to estimate recreational benefits. Non-use values were associated with the remaining, "non-local" portion. Thus, individuals were considered to have obtained their recreational benefits from any in-state stream that attained its designated use (e.g., fishable) and they obtained their non-use benefit from any out-of-state stream doing so. This however produced a problem similar to that in pulp and paper rule assessment: a stream's contribution to the benefits estimate depended solely upon the attainment or non-attainment of designated uses; the extent of improvements were disregarded. A similar approach was used for marine recreational fishing (Freeman, 1993).

For commercial marine fishery benefits, the SW2 assessment relied on an exceedingly simple approach. Assuming no change in fishing effort or the prevailing price, the dockside value of the change in harvest attributable to the rule was estimated.[7] To this was applied a range of total-revenue-to-total-surplus ratios culled from existing market studies. However, it may have been unwarranted to equate marginal changes as a result of the rule with relationships at the aggregate level: EPA's own guidance indicates the unadjusted dockside value at current prices to be the appropriate proxy for surplus change when the effect on supply is modest (EPA, 2000b).

As SW2 became final, EPA opted not to monetize any benefit associated with marine fisheries. Carson and Mitchell (1993) was still employed for the sake of fresh water benefits, though in a slightly revised form. Use attainment information was estimated using a deterministic water quality model, rather than from lists of which water bodies were impaired and by whom (EPA, 1999).

5.3. *Concentrated animal feeding operations*

The effluent guidelines on concentrated animal feeding operations (CAFOs), issued in January 2003, were designed to eliminate the discharge of animal waste into surface waters. Effluents of animal waste raise the ambient level of nitrogen and phosphorous and can lead to eutrophication, algae blooms, fish kills, and diminished recreational experiences. This discharge was to be eliminated by changing the design of waste lagoons and shelters in animal confinement areas, and by limiting the amount of animal waste spread on cropland as fertilizer.

By far the largest part of the monetized benefits came from ecological benefits, and most of these were associated with recreation. For the proposal, Carson and Mitchell (1993) was used in the same manner as it had been for SW2 (EPA, 2001). Streams were only counted as having been improved if they achieved a new, higher designated use, regardless of how much or how little they improved. As the rule became final, however, a significant innovation was to develop a continuous valuation function that allowed credit to be taken for partial improvements in a stream (EPA, 2002d).

A second ecological benefit valued in this rule was the benefit from reduced kills of non-charismatic fish species.[8] The proposed rule valued this using the average cost of replacing the type of fish killed. Because of the weak link between replacement costs and ecological benefits, the final rule assessment instead used a unit value for a generic fish.

The discussion of non-monetized ecological benefits improved between the proposed and final rule. Among the benefits qualitatively discussed in the final rule were reduced pathogen contamination of underground sources of drinking water; reduced human and ecological risks from antibiotics, hormones, metals, and salts; and improved soil properties.

5.4. *Metal products and machinery*

The effluent guidelines for the metal products and machinery (MP&M) sector limits the water discharges of a variety of harmful pollutants from this industry. The rule establishes technology-based guidelines for the discharge of oil and grease and of total suspended solids. These guidelines were finalized in May of 2003.

As with many EPA rules, the focus of the benefits assessment for the MP&M rule centered on valuing cancer related and other health effects. However, a concerted effort was made, in both the proposal (EPA, 2000a) and the final rule (EPA, 2003a), to at least list the ecological benefits. These benefits included reduced risk to aquatic life, enhanced water-based recreation, increased aesthetic benefits, non-use values

[7] The harvest change was crudely estimated by, first, assuming a change in the spatial extent of estuarine waters results in a proportional change in harvest and, second, by prorating the resulting amount by 8.9%, the fraction of estuarine waters for which storm water was identified as a source of impairment (EPA, 2001).

[8] Another benefit was an increase in shellfish harvest areas that previously had been closed due to fecal coliform contamination. While it may at first seem otherwise, this is not, strictly speaking, an ecological benefit since the shellfish are not adversely affected by this stressor. See Section 3 for additional discussion on how ecological benefits are distinguished from others.

(i.e., existence, option, and bequest value), and reduced non-point source nitrogen contamination of water. The fraction of ecological benefits that was monetized consisted of improvements to water-based recreation and non-use values. The reduced risk to aquatic life was used as a relative measure of the rule's impact on provisioning services.

Recreational benefits were estimated by considering three recreational activities: fishing, wildlife viewing, and boating. For each of these activities, an average per-day value was obtained from two studies (Bergstrom and Cordell, 1991; Walsh et al., 1992). The number of participants partaking in these activities and the number of days of activity undertaken was then estimated for the streams affected by the rule. A range of benefit estimates was obtained for each activity by selecting the appropriate results from eight studies that reported the relative effect of pollutant concentrations on WTP. Non-use values were crudely estimated as a proportion of recreational value (Fisher and Raucher, 1984). Finally, the approach to quantify risk reductions to aquatic life followed exactly the pulp and paper assessments (i.e., the change in the number of streams in which water quality criteria for aquatic life was exceeded) and the same concerns apply.

5.5. *Meat and poultry*

The meat and poultry products effluent guidelines, issued February 2004, establish limits for the discharge of wastewater from slaughtering, rendering, and other processes and are expected to reduce discharges of conventional pollutants to surface waters.

While recreation benefits were the only monetized benefits category in the proposed rule assessment (EPA, 2002c), consideration expanded to other ecological benefits as the rule was finalized (EPA, 2004b). Approaches used for the final rule closely tracked previous efforts. Following the CAFO rule, recreation and non-use benefits were estimated using the Carson and Mitchell (1993) survey results. Following the pulp and paper and MP and M assessments, reduced risk to aquatic life was quantified by counting up the number of streams for which water quality criteria were exceeded with and without the rule.

5.6. *Cooling water intake structures*

As trillions of gallons of water are withdrawn every year to cool the turbines of power plants, aquatic organisms are entrained into the turbines or impinged against the trash grates of the cooling water intake structure, usually dying in the process. EPA issued the cooling water intake structure rule 316b[9] in February 2004 requiring that the location, design, construction, and capacity of the nation's largest cooling water intake structures (those drawing in over 50 mgd) minimize adverse environmental impacts (EPA, 2004a). Thus, the assessment focused solely on ecological benefits, all of which result from the change in provisioning service flows, i.e., fresh water and marine fisheries, as well as population-level effects up and down aquatic ecosystem food chains.

[9] The name commonly used for this rule is a reference to section 316(b) the Clean Water Act under which this action is being taken.

For the proposed benefits assessment (EPA, 2002a), several overlapping approaches were attempted in order to paint a complete picture of ecological benefits, some of which were unconventional. The same ratio-based approach used for SW2 provided an estimate of the change in surplus associated with impacts on commercial fisheries. For recreational fishery benefits, the mean of the unit values—dollars per individual fish—from several studies was used to estimate recreational fishery benefits. Estimates for commercial and recreational fisheries were then adjusted to reflect the impact on forage fish upon which higher trophic levels depend. A "trophic efficiency factor" converted the forage fish losses to losses at valued higher trophic levels. Finally, for non-use benefits, a mean unit value was used for threatened and endangered (T&E) species, while other species were valued via a ratio-based approach that assumed a systematic relationship between use and non-use values (Fisher and Raucher, 1984).

An alternative value for forage fish was estimated by equating benefits with replacement costs (i.e., the cost of replacing losses with hatchery-reared fish) similar to that used for the proposed CAFO rule. Replacement costs were also availed to provide an alternative overall estimate of benefits. Finally, T&E species also received an alternative, cost-based treatment. In this case, the replacement costs were those used to restore a habitat for T&E species not unlike those impacted by impingement and entrainment were estimated. Unlike the other replacement cost estimates, this one was said to be a revealed preference value for California voters who approved a referendum to fund this restoration. The California restoration costs were not extrapolated to the national level in the assessment.

As the rule became final, EPA made dramatic changes to the assessment: Recreation benefits were considerably refined: original random utility models were estimated for all but two regions (EPA, 2004a). Benefits transfer was used for the last two regions, the transfer of point estimates in one case and an estimated function in the other (Hicks et al., 1999). Elsewhere, there was reconsideration of what had been tried: all of the cost-based estimates of value were jettisoned. Regarding T&E species, EPA pulled back from monetization to simply express the number of individuals killed. Last, a meta-regression of over thirty studies to estimate non-use values for non-T&E species was estimated for benefits transfer but ultimately not included in the final assessment (despite the relative sophistication of the approach) (EPA, 2004a).

5.7. *Construction and development*

Absent appropriate measures, construction and the land it disturbs leads to runoff with a significant sediment load. Receiving waters suffer from suspended solids and sedimentation. Although EPA elected in March 2004 to rely on existing programs, rather than a construction and development (C&D) effluent guideline, the proposed and final assessments associated with the rule remain instructive.

For the proposed rule, no ecological benefit was monetized or quantified (EPA, 2002b). On one hand, the assessment did note that "sediment can play havoc with natural stream ecosystems." On the other, it was considered too "difficult to quantify … the value society places on… species preservation." Elsewhere in the proposed assessment, the magnitude

Table 2 – Benefits considered by proposed (P) and final (F) rules

Benefits	Non-ecological, monetized		Ecological				
			Monetized				Quantified
Rule	Human health	Property damage	Marketed products	Recreation	Non-use value	Maintaining health and property	"Big-picture" measures
SW2	P, F	P	P, F	P, F	P, F		P
Pulp and paper	P, F			P, F	P, F		P, F
CAFOs	P, F		P, F	P, F	P, F		
MP&M	P, F			P, F	P, F		P, F
Meat and poultry				P, F	P, F		F
316b			P, F	P, F			P, F
C&D		P		F	F		

of these benefits were said to be too small to justify effort to monetize them. The final rule, however, did see effort to monetize recreation benefits using the same approach as the final SW2 rule (EPA, 2004e). While the assessment's text alluded to a hedonic price study and associated shadow prices, it was not obvious whether or how it manifested in the monetized benefits.

6. Discussion

6.1. *Common themes*

Several common themes are evident in the manner and degree to which the seven assessments treat various categories of ecosystem service and ecological benefits. Table 2 indicates which ecological benefit areas are covered by the assessments for each proposed and final rule, as well as whether some sort of holistic attempt was made to convey overall ecological benefits. The treatment of non-ecological benefits is also provided for comparison.

6.1.1. *Marketed products*

Assessments did not pay adequate attention to commercial fisheries. Among marketed products, commercial fisheries are probably affected by all the rules, yet are regularly ignored, perhaps because of the modeling effort that such analysis would require. For the stormwater rule, the literature provided total revenue and surplus estimates for select fish species. A ratio of the two estimates was calculated and applied to the change in revenue expected from the rule. Greater availability of price elasticities of demand for fish species could be used to assess ecological benefits. This preferred approach would be similar to that taken in the CAFO rule to estimate surplus changes from shellfish bed openings, save the constant production per acre assumption. Ideally, elasticities at multiple scales would be readily available (e.g., for wild salmon, all salmon, all salmonids, and all coldwater fish) since EPA actions are unlikely to affect a single species.

6.1.2. *Recreation*

Monetized aquatic recreation benefits and non-use benefits figured prominently in nearly all assessments. Most assessments estimated recreation benefits by identifying changes in the designated use of surface waters and applying point estimates exclusively from Carson and Mitchell's (1993) stated preference study, rather than using revealed preference approaches such as random utility (RUM) and hedonic price modeling. Because the Carson–Mitchell survey focused on particular types of water-based recreation, the estimates generated do not necessarily encompass benefits associated with less active, yet popular, forms of outdoor recreation, i.e., the aesthetic value of viewing wildlife and the natural settings.

6.1.3. *Non-use values*

The study by Carson–Mitchell also tended to be the basis for non-use values, which it estimated by asking respondents to divide their total WTP into amounts for in- and out-of-state water quality. Rules not using Carson–Mitchell applied two alternative approaches: either equating replacement costs with non-use and possibly other benefits (with one assessment asserting that this approach was based on revealed preferences), or assuming that non-use values vary in proportion to recreation values, with the constant of proportionality derived from the recreation and non-use values reported in the literature.

6.1.4. *Maintaining health and property*

None of the assessments recognized the human health and property maintenance benefits of regulating/life-support services. Despite the recognized significance of the services that buffer our health and property from hazards, natural and otherwise, there have been vanishingly few studies to value them outside of natural scientists' controversial attempts to tally up replacement costs were all such services lost (Pimentel et al., 1997; Daily, 1997).[10]

6.1.5. *Non-monetized ecological benefits*

Finally, those ecosystem services and ecological benefits that fall through the monetization cracks must still be made apparent to the decision maker. Assessments did not provide

[10] The environmental economist Charles Perrings did recently call for greater effort to value these services at the Diversitas Open Science Conference, an international symposium. co-hosted by the Mexican government and held on November 9–12, 2005. The press release for the event is found at http://www.diversitas-osc1.org/.

sufficient sense of the broader picture of which the monetized estimates are only part. This is unfortunate because, in the context of ecological benefits, instances abound where not even benefits transfer is feasible. Some of the assessments attempted to convey a comprehensive sense of ecological benefits with relatively detailed descriptions of services and of adverse effects beyond the monetized benefits. Pulp and paper, meat and poultry, and MP and M also reported on the change in the number of water bodies in attainment, essentially an indicator of total ecosystem value, albeit a problematic one.

In any case, benefits expressed qualitatively or quantitatively were overshadowed by those that were monetized when benefits were compared to cost. This presentational challenge is obvious in the assessment of the C&D final rule, for example. A comparison table in the report illustrated how costs stacked up to a dollar figure for benefits (EPA, 2004e). Although some non-monetized benefits categories were mentioned in the accompanying text, the absence of non-monetized benefits on the table encourages some measure of disregard. The column heading for benefits makes matters worse by listing the monetized benefits as "total social benefits" (EPA, 2004e). In contrast, the final 316b rule assessment did attempt to address this issue, utilizing cost-effectiveness and break-even analyses to fill out the benefits story.

6.2. *Issues*

In addition to any concerns about how specific benefit categories were treated across the seven rules, several subtle issues exist that compromise the accuracy of ecological benefits estimates, generally. The first four issues pertain to the immense challenge for benefits transfer of locating and using studies that adequately reflect the relevant baseline conditions and the change expected to arise from implementation of a rule.[11] They relate in large part to the tendency of studies to estimate values for dramatic local changes, which sharply contrasts with the incremental and dispersed improvements anticipated from rules. The final two issues take a step back to consider how the policy-induced changes are being quantified in the prelude to benefits transfer.

First, many of the rules considered require benefits transfer to a magnitude of change not considered by the valuation study being used for the transfer. This is troublesome because extrapolation that relies on point estimates, expressed in either discrete or marginal terms, means that convexity assumptions regarding utility are not operative. The same problem hinders even function transfer and meta-analytical approaches to benefits transfer as the policy context is typically far afield of the domain defined by the data used in the study. In such cases, the reported values and the study data that underlie them will provide little insight into the policy context and whatever is estimated for the assessment will be due to model specification, which is typically an arbitrary exercise (King and Zeng, in press). For example, meta-regressions developed (though not ultimately used) for the 316b rule closely fit the reported study values used to estimate them, regardless of how they were specified. However, the policy implications of the suite of models developed differed greatly and there was little theoretical justification for choosing among them (Johnston et al., 2005).

Second, transfer is hampered by spartan or incomplete descriptions of the policy-induced change. In the context of angling recreation, for example, a policy effect is likely to be expressed in terms of the change in the number of individual fish killed or in ambient concentrations of some stressor. The connection of such measures to the change in catch rates (mediated by the population-level effect), the metric of particular relevance to angling, is seldom known. An ad-hoc ratio-based approach is instead employed to provide a cross-walk between them. This issue is more serious in the context of non-use values. Both the available measures of the policy-induced change and the candidate study for transfer are unlikely to fully reflect the change along all the dimensions the beneficiary might apprehend and appreciate. What likely resonates to a beneficiary in the context of the aforementioned fish kill, for example, may not so much be the change in mortality, but rather the degree to which species populations are affected in absolute, relative, and viability terms, as well as changes in biodiversity and total biomass. Be that as it may, studies, such as Carson et al. (1994), value the recovery of fish species without quantitatively describing either the absolute or relative impacts on the population, let alone that on species' richness and abundance. Moreover, the foregoing begs the question of whether adequate measures even exist. Despite the potential for non-use values to be associated with species assemblages and overall ecosystems, development of holistic measures has met with little success. At best, efforts fall back on measures pertaining to a species or two, with fingers crossed that the correlation is considerable.

Third, the larger landscape context is a critical aspect of the baseline. Policy impacts occur within a larger matrix of ecosystems and the services they provide, and what is not affected by the rule is as relevant as what is. For a rule affecting a narrow set of services flowing from a limited set of sites, the magnitude of benefits depends largely on the beneficiary's proximity to the affected sites, as well as the proximity and abundance of alternative sites. Few stated preference studies, however, explicitly account this spatial complexity. Studies tend to be local enough that the landscape context is held constant across observations. Individuals are asked about their willingness to pay for a local change, without regard to what other sites may or may not change. Even RUM may exhibit similar shortcomings: Although they are based on a choice set of alternative sites, the choice set, itself, may not vary sufficiently across respondents to support benefits transfer. In any case, whatever degree of baseline variability that does exist in a study is lost when point estimates are transferred, rather than functions.[12]

[11] We do not spend time on topics that have already been accorded considerable attention, such as intergenerational discounting.

[12] Were spatially explicit valuation studies of a scope amenable to benefits transfer readily available, they would be applied to spatially explicit data of similar sophistication associated with the policy context. Since this is almost never possible, EPA has often transferred point estimates by drawing somewhat arbitrary boundaries around affected waters or population centers to identify beneficiaries. Generally, no adjustment is made for the distance or choice set differences among the beneficiaries within that boundary.

This is not to say that these studies have no value in rulemaking. Faced with an otherwise useful study that did not support extrapolation to the national level, the agency has sometimes limited its application of the study results to locations where they overlap with policy contexts. The SW2 rule took this tack in the case of an estimated value for best management practices in North Carolina, as did the 316b rule with a value for threatened and endangered species in California, and the CAFO rule for the eutrophication of estuaries in North Carolina. Beyond providing some anecdotal evidence, however, it is unclear what impact this "case study" approach has in policy-related benefits transfer.

The fourth issue concerning the relevance of existing literature arises from the need to determine whether a study may be a candidate for benefits transfer in a particular policy context. Some of the assessments we examined relied on studies that provide scant reference to what underlying ecosystem services and ecological benefits were presumably being valued. Instead, values are associated with changes in pollutant concentrations or even the adoption of technological or management fixes to problems (Paterson et al., 1993). In light of the highly context dependent and place-based nature of ecological benefits, such studies are problematic for benefits transfer even when the stressor or remedy is apparently similar to those on which the rule focuses. While the effect on service flows and associated benefits from the same stressor and intervention is likely to differ dramatically from one context to another, the analyst has no means by which to make necessary adjustments.

Conceiving the broad outlines of a practical study that effectively addresses these four issues of scale and scope is not impossible: A sample of respondents nationally representative of ecological reference (rather than of demographic) conditions would be surveyed about their preferences, after thoroughly informing each respondent of their local conditions and what service and benefit categories are under consideration. The valuation questions deal, in turn, with 1) the effect on WTP of expanding the perimeter that encompasses the water bodies under consideration, 2) the elasticity of WTP with respect to the fraction of water bodies (among an arbitrary set) that are ecologically healthy, and 3) the change in WTP as ecological health (of a single arbitrary body of water) improves from the worst possible state.[13] The responses to these queries could be combined to form a simple yet defensible model easily adapted to a variety of ecological baselines and policy-related changes.

The fifth issue is how assessments do not deal with the reality that multiple stressors are at play in most, if not all, compromised ecosystems. Non-target stressors may be limiting factors that conceal a rule's impact on an ecosystem's prospect for recovery. The 316b rule assessment was a case in point: The relatively modest estimated impacts in some bodies of water of rules can be attributed to the severely compromised state that fisheries are in (as a result of other stressors). This issue also undercuts the use of the fraction of U.S. waters attaining water quality criteria as a result of a rule (e.g., meat and poultry) as an indicator of service flow changes and relative value. Generally, whereas the ecological benefit at the margin of a narrowly focused rule may compare unfavorably to cost, the total benefit of dealing with all the impediments to ecosystem health may vastly outweigh total cost. Since the marginal analysis is what effectively determines whether the total benefit is realized, care should be taken when the initial intervention step does not appear to sufficiently pay off.

The final issue also relates to a lack of attention to the broader context and the dependence of a single rule's ecological benefits on the overall degree ecosystems are stressed. While lags and discontinuities characterize ecosystem response to stress, these nuances are wholly overlooked by conventional assessments. Instead, the baseline stream of services is typically held constant from the point in time at which monitoring occurred. The assessment fails to reflect the potential for the rule in question to forestall an imperceptible slide toward a threshold that, when surpassed, flips the system to a dramatically lower level of productivity at some point in the future.

7. Conclusion

Despite EPA's relatively close relationship with the community of environmental economists, rule-generated ecological benefits estimation have often followed the path of least resistance, at some distance from the research vanguard. Time and resource constraints faced by agency analysts have led them to repeat "tried and true" approaches that have withstood past scrutiny. In the high-pressure atmosphere of agency rule making, there is scant consideration for the proactive effort needed to fashion a solid basis for ecological benefits assessment. As a consequence, the agency too often churns out bowdlerized versions of the solid analyses that the state-of-art could provide.

Some current EPA efforts may help it to change some long-established habits: the agency is developing a strategic plan for ecological benefits assessment; it is updating its economic guidelines; and it is boosting grant funding for developing benefits transfer methods. These initiatives could provide a springboard for frank and productive dialogue with the research community, identifying ecological benefits assessment issues relevant to EPA and fostering research efforts to resolve them. Such a dialogue could lead to valuation studies that can be applied to policy contexts with minimal effort, cover the broad spectrum of ecosystem services and ecological benefits, and effectively inform agency decision making to protect our natural environment.

[13] Further, we feel that a coarse, ordinal scale of ecological health used in this instance may actually lead to more precise estimates because respondents will have a more intuitive feel for all that a shift from, say, "fair" to "good" implies. Conversely, a suite of continuous measures may outstrip respondent patience and cognitive resources, providing a false sense of precision. Moreover, application of the model to policy contexts is less likely to be constrained by input data requirements.

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