

Welcome to the Data-Poor Real World: Incorporating Benefit-Cost Principles into Environmental Policymaking

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Benefit-cost analysis is as natural to economists as breathing - which sometimes gets us into trouble when we try to ply our trade in a data vacuum. Elegant multi-market models and intricate discounting methods are difficult, at times impossible to utilize in the real world because the necessary data just aren't available. When this is the case, the benefit-cost analyst often proceeds by quantifying as many of the benefits and costs as feasible; describing the non-monetized or even non-quantified impacts as precisely as possible; and then using "professional judgment" to compare the total benefits and costs.²

As the non-monetized and non-quantified impacts grow in proportion to the overall impacts, however, the analysis eventually reaches a point where the substitution of "professional judgment" for data becomes untenable, or at least awkward. Benefit-cost analysis becomes less useful as a means for assisting policy makers in choosing the "best" among a set of alternatives. At times, it can even become a game of divining benefits to be large enough to justify the chosen alternative. In the data-poor real world, then, the practice of benefit-cost often becomes a process of substituting analysts for analysis.

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2. "It will not always be possible to express in monetary units all of the important benefits and costs. . . . In such cases, you should exercise professional judgment in determining how important the non-quantified benefits or costs may be in the context of the overall analysis" (OMB 2003). This document is the "best management practices" guidance for regulatory analyses prepared under Executive Order 12866, which requires federal government agencies to conduct a benefit-cost analysis or other form of regulatory analysis for certain major regulatory actions.

While there is no perfect substitute for adequate data, there are good ones other than professional judgment, or at least ones that are capable of making policy decisions *better* if short of best. In this paper, I describe one such substitute by way of an example. The substitute is what one might call a hybrid of benefit-cost analysis and cost-effectiveness analysis, with a dash of a hypothetical valuation experiment thrown in for good measure. The example is drawn from my experience as an economist with the National Marine Fisheries Service, conducting economic analyses of regulatory actions taken under, of all statutes, the Endangered Species Act. While I make no claims that the framework outlined below is the solution to all the benefit-cost analyst's data problems (it certainly is not), I offer it as an example of how benefit-cost analysis in the real world strives to make lemonade out of the data lemons with which we are often forced to work.

The paper begins with a brief overview of the Endangered Species Act (ESA) and the opportunities (or lack thereof) for conducting economic analyses of regulatory actions taken under that law. I then focus on a part of the ESA – critical habitat designation – that in fact allows such analyses. The final section covers in detail an example drawn from the ESA of how data problems can be overcome (to some extent) to improve (but not optimize) regulatory action.

Economics and the Endangered Species Act

Under the ESA, the federal government is responsible for the listing of species that are found to be “endangered” or “threatened.” Once listed, a species is protected by a host of prohibitions and other conservation duties, affecting both private and public parties. By statute, the agencies responsible for these actions are the Departments of the Interior (terrestrial and freshwater species) and Commerce (anadromous and marine species). In practice, the Departments relegate the implementation of the ESA to the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS), respectively. Because the example covered in this paper is drawn from the experience of NMFS, I cast the remainder of this general discussion mostly in terms of that agency.

Much of the ESA is not exactly friendly territory for economic analysis. The listing determination, for example, does not allow for the consideration of economic factors, Congress itself having declared that “economic considerations have no relevance to determinations regarding the

status of species.”³ Other sections of the ESA are less hostile but only because they are silent. This doesn’t preclude economic analysis in areas such as recovery planning, for example, but neither does it give policy makers any compelling reason to use benefit-cost or other forms of economic analysis.

It comes as something of a surprise, then, to find within the ESA a section that not only allows economic analysis but *requires* it. Once a species is listed, NMFS must designate “critical habitat” for the species.⁴ The designation process consists of two steps. First, NMFS identifies specific areas of habitat that have physical or biological features essential to conservation and that require special management or protection to ensure their conservation.⁵ The first part of this step is guided by the biological habitat needs of the listed species, while the second ensures that it is possible to “manage” those features – that is, those features are subject to human influence and will respond positively if harmful (human) actions are avoided.

Second, the agency considers each area identified in the first step and determines whether or not to designate it as critical habitat. It is in this second step that economics plays a role, as outlined in section 4(b)(2) of the ESA:

The Secretary [of the Interior or Commerce] shall designate critical habitat, and make revisions thereto,... on the basis of the best scientific data available and after taking into consideration the economic impact, the impact on national security, and any other relevant impact, of specifying any particular area as critical habitat. The Secretary may exclude any area from critical habitat if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless he determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned.⁶

3. 16 U.S.C. §1533(b)(1)(A), which gives the basis for making listing decisions, states that listing determinations be made “solely on the basis of the best scientific and commercial data available.” The word “solely” was added in 1982, at which time the quoted passage was made in the House report on the 1982 amendments (H.R. Rep. No. 97-567, 1982).

4. There is an exception when the designation of critical habitat is “not prudent.” This can be the case if: (1) the species is threatened by taking or other human activity and identification of critical habitat can be expected to increase the degree of threat to the species; or (2) designation of critical habitat would not be beneficial to the species. 16 U.S.C. § 1533(b)(6)(C).

5. 16 U.S.C. §1532(5)(A).

6. 16 U.S.C. §1533(b)(2) (emphasis added).

This section requires NMFS to take economic impacts “into consideration,” which necessitates some form of economic analysis. It then gives NMFS the option to exclude individual areas from designation if the benefits of excluding it (the costs of designation) outweigh the benefits of designating the area (the benefits of designation).

It is important to note that this process applies to individual areas, not to the overall question of whether critical habitat should be designated at all.⁷ It is also important to note that while the consideration of economic impacts is required, an area for which the costs of designation outweigh the benefits need not be excluded (the Secretary *may* exclude, not *shall* exclude). Nevertheless, despite the awkward language of weighing the benefits of an action against the benefits of the opposite action, this section of the ESA outlines a framework that is essentially that of a benefit-cost analysis.⁸ What is so unusual is that section 4(b)(2) requires not just an analysis of benefits and costs, but a framework for “weighing” those factors to support a decision. Rather than be imposed from without,⁹ the ESA actually embraces benefit-cost analysis from within – that is, it is part of the statute itself.

The core of the 4(b)(2) analysis, as I shall call it, consists of assessing the impacts generated by critical habitat designation. These impacts stem from section 7 of the ESA, which requires all federal agencies to ensure that any actions they take, fund, or authorize are not likely to destroy or

7. Nevertheless, Congress intended to allow for the possibility that, by applying this section and “weighing” the benefits of specifying an area against the benefits of excluding it, no critical habitat might in fact be designated: “The committee expects that in some situations, the resultant critical habitat will be different from that which would have been the established using solely biological criteria. *In some cases, no critical habitat would be specified.*” H.R. Report No. 95-1625, at 16, 17 (1978) (emphasis added).

8. Section 4(b)(2) allows for other types of impacts to enter the “weighing” process. National security is one that is explicitly mentioned, but others include impacts on relations with Indian tribes and with private landowners that have existing conservation agreements. While these types of impacts could be monetized in theory, they are routinely considered separately.

9. Executive Order 12866 requires that federal agencies conduct an economic analysis of proposed regulations. The economic analysis is intended to provide information that, among other things, allows policy makers to determine that “the potential benefits to society justify the potential costs.” This order is imposed from without, so to speak.

adversely modify that habitat.¹⁰ If a federal agency's own activity occurs within an area designated as critical habitat, the impact is relatively easy to discern. The U.S. Forest Service, for example, may alter its timber sales in northern spotted owl critical habitat by reducing the volume of sales or eliminating them all together. The same agency may change its road building activities in bull trout critical habitat by changing the manner in which it constructs or rehabilitates roads, or by changing the location or timing of its work.

Other impacts are less direct and may be harder to measure, particularly if the federal agency's action is to issue a permit or fund another party's activity. For example, under section 404 of the Clean Water Act, the Army Corps of Engineers issues permits for the discharge of material into the waters of the United States. The recipients of these permits are usually private parties engaged in activities such as building a dock or filling a wetlands. Under section 7 of the ESA, the Army Corps must ensure that its action – the issuance of the permit – does not violate the ESA, and so the permit may require that the private party modify its activity.

At first glance, then, the economic analysis associated with section 4(b)(2) appears to be one amenable to a textbook benefit-cost approach. As always, the analysis must contend with all the conceptual and practical difficulties encountered in the real world. As noted later, these problems tend to afflict the benefit side to a greater degree than the cost side, but this is common for environmental regulations and analyses.

What is *uncommon* about critical habitat designation is its spatial dimension, which gives it the distinction of being a rare example of the federal government effectively regulating land use. Moreover, the central question addressed by the 4(b)(2) analysis is not how much to regulate land, but how much land to regulate. Both of these distinctions make the designation of critical habitat

10. The full text of section 7 of the ESA reads as follows:

Each Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency (hereinafter in this section referred to as an “agency action”) is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical... (16 U.S.C. §1536(a)(2))

An important part of this section is the other duty it imposes on federal agencies, namely, to insure that their actions do not “jeopardize” listed species. This has important implications for the economic analysis of critical habitat, as discussed below in note 19.

a more complex task than at first glance. As such, the economic analysis of critical habitat is something that deserves a closer look.

The Economic Analysis of Critical Habitat Designation

Stepping back from the specific requirements of section 4(b)(2) (that is, making a decision about individual areas), consider the general problem of designating “optimal” critical habitat. An immediate need is to define its dimensions: What is it, exactly, that we are optimizing?

Because critical habitat consists of a spatial area, it is tempting to think of it in terms of area alone. One would then simply posit benefit and cost functions that vary – continuously, twice-differentiably, of course – with area, A : $B(A)$ and $C(A)$, both measured in dollar terms, of course. Maximizing the net economic benefits of critical habitat would involve the simple maximization of $B(A) - C(A)$ – hardly a difficult problem.

This simplistic view of the 4(b)(2) process is a caricature, of course, in addition to being misguided. Optimizing with respect to habitat quantity alone necessarily assumes that the landscape is homogeneous in terms of habitat quality, so that one acre or habitat area is fungible with any other. Habitat quality varies spatially, however, as most features that qualify an area as potential critical habitat can vary continuously and so could be judged “better” or “worse” in terms of quality. It also assumes that areas have uniform densities and compositions of the federal activities that are affected by designation, which is also unlikely. Because costs and benefits flow through the modifications to these activities, variability in these will produce variation in the benefits and costs of designation, on top of those introduced by variability in habitat quality. Finally, another necessary assumption is that the habitat will be protected with critical habitat designation but will effectively be destroyed without that action. Enforcement of critical habitat is certainly protective, but the absence of its designation rarely leads to habitat destruction.

What should be obvious, then, is that the benefits and costs of this regulatory action are quite specific to the individual area under consideration. This suggests a different framework for considering the problem of “optimal” critical habitat, one that leads us back into the fold of section 4(b)(2). Let A be the set of N possible critical habitat areas (identified in the first part of the designation process), with A_i the i^{th} area. Let B_i and C_i be the conservation benefit and economic cost, respectively, of designating A_i as critical habitat, both measurable with a monetary metric.

Finally, let \mathbf{D} be a set that represents the designation status of \mathbf{A} , where $D_i = 1$ if A_i is designated as critical habitat, 0 if it is not.

What can be said about B_i and C_i ? At the level of a single area, B_i and C_i present classic problems for the benefit-cost analyst. Ideally, one would start by tallying the federal activities present in A_i , and assessing how these activities would be undertaken with and without critical habitat designation. The difference between these two assessments would then form the basis for estimating changes in consumer and producer surplus; the opportunity cost of resources used or of the actions not taken in response to the designation; and so forth, all of which would go into the estimation of B_i and C_i .

The critical habitat designation process presents one with a second level to consider. As the 4(b)(2) process unfolds, some areas will be included, some will possibly be excluded. If B_i and C_i are contingent on \mathbf{D} , their comparison becomes something of an intractable problem, at least if one wants to adhere strictly to the requirements of section 4(b)(2). This is because $(B_i - C_i)$ will be a function of how many and even which areas have been previously designated or not designated. The net benefit of designating A_i may even change sign depending on “when” it is considered, so to speak. Unless there is a pre-ordained order in which to evaluate areas, the 4(b)(2) process produces an ambiguous results if it evaluates one area in isolation of the others.

Under these circumstances, it is still possible in theory to find the optimal critical habitat designation using combinatorial methods, but even the brute force of this approach may not be able to do it in finite time.¹¹ And so it is admittedly more convenient to assume that B_i and C_i are both independent of the status of any other unit. In this case, total benefits and costs are simple sums of B_i and C_i , respectively. Under these restrictive conditions, the problem of finding the “optimal”

11. For past critical habitat designations, the number of individual areas (which determines the number of combinations to be considered) has varied significantly. For example, in the case of the delta smelt, the FWS designated a single area roughly encompassing the one million acre San Francisco Bay/Delta estuary. In contrast, coastal California gnatcatcher critical habitat involved 13 units within 513 thousand acres (which produces over 8,000 combinations), and the California red-legged frog critical habitat involved 31 units within 4.1 million acres (which gives over 2.1 billion combinations). For the example described in the next section (West Coast salmon and steelhead), the critical habitat designations undertaken by NMFS eclipsed these: the Puget Sound Chinook salmon designation involved 80 individual areas within 7.1 million acres (1.2×10^{24} possible combinations) while the Snake River Basin steelhead designation had 287 areas within 19 million acres (2.5×10^{86} possible combinations).

configuration of critical habitat is then solved simply by including all areas for which $B_i > C_i$ – which is precisely the analysis called for in section 4(b)(2).

Whether we impose these restrictions or not, there is the matter of the initial assumption that both benefits and costs can be expressed with a monetary metric. Measuring costs in dollar terms is rarely a problem, although accounting for *all* the costs of a regulatory action often can be a challenge. Using a monetary metric for benefits, however, is more problematic for critical habitat designation.

The reason for this disparity lies in the complexity of the pathway along which benefits flow, which in turns creates greater demands for data. The initial link between critical habitat designation and the changes in habitat quality is one that is difficult to quantify. Even more difficult are the links between changes in habitat quality and the resulting changes in the species local and global populations. If adequate data on these links existed, a biological metric or set of metrics (if other species or habitat conditions responded to critical habitat designation) could be used to quantify the beneficial effects of critical habitat designation. But data on the economic value of these changes, tied to the set of metrics being used, would then also be needed, and these data are rarer still.

None of this diminishes the complexity, difficulty, and data demands of estimating costs, of course. The estimation of the benefits of critical habitat designation is simply more complex and difficult, and demands data that are far more scarce. As a result, data on the benefits of critical habitat designation are rarely quantified and have never been monetized.

Although the Office of Management and Budget insists that federal agencies adopt a benefit-cost framework as the first choice for a regulatory analysis, it does recognize that a cost-effectiveness analysis is preferable when it is difficult to measure benefits with a dollar metric.¹² By itself, such an approach cannot judge whether the costs of designation “outweigh” the benefits of designation, as the two cannot be directly compared. But an approach drawn from the cost-effectiveness framework can at least get us farther along the path toward optimality. And with a

12. OMB has noted that if it is “difficult to monetize benefits, [the analyst] may consider using ‘cost-effectiveness’ rather than ‘net benefits’ analyses. . . . As a general matter, cost-effectiveness measures that account for all benefits and costs of the [regulatory] rule are preferable to those that omit substantial portions of either benefits or costs” (OMB, 2000).

deus ex machina thrown in for good measure, the approach outline below can get us in the neighborhood of what charitably can be called the optimal critical habitat.

Consider the following cost-effectiveness framework. Suppose “conservation” can be achieved by undertaking an action, A , that produces a conservation benefit, $B(A)$. B is measured in biological terms (*e.g.*, the abundance of a species or its risk of extinction). The action, A , can be undertaken at some cost, $C(A)$, and there is a conservation budget, C_0 . The problem of producing conservation in a cost-effective manner can then be expressed as a simple, constrained maximization problem:

$$\begin{aligned} \max_A & B(A) \\ \text{s.t.} & C(A) = C_0 \end{aligned}$$

Let the cost-effective solution to this problem be $A^{\text{CE}}(C_0) = A^{\text{CE}}(C)$ for notational simplicity. Substituting $A^{\text{CE}}(C)$ into $B(A)$ and varying the conservation budget, we then obtain what can be called the conservation efficiency frontier, $B^{\text{CE}}(C)$. The slope of this frontier, $\partial B^{\text{CE}}/\partial C$, can be expressed as $\partial B/\partial A/\partial C/\partial A$ —that is, the ratio of the marginal benefit of A and its marginal cost.

Any point along the frontier is efficient, but which one is optimal? That question can be answered by hauling out a *deus ex machina*: a social welfare function, $W(B,C)$, for which the conservation budget, C , now represents the resources *not* devoted to all other goods (so that $W_C < 0$). This welfare function can be used to find the optimal level of conservation, (B^*, C^*) , in the usual way (Figure 1). Note that at the optimal point, we have the following condition:

$$\left. \frac{\partial B/\partial A}{\partial C/\partial A} \right|_{A_i} \geq \left. \frac{\partial B/\partial A}{\partial C/\partial A} \right|_{A^*} = T^*$$

where A^* is the level of A that produces both B^* and C^* , and $A_i < A^*$.

In the context of critical habitat designation, this framework can be applied in the following way. The action under consideration is the designation of individual areas as critical habitat, and so what was a one-dimensional, continuous variable, A , is now a set of dichotomous variables, \mathbf{D} . If the assumption is made that B_i and C_i are independent of the status of other areas, then the benefit and cost of designation become $B = \sum B_i D_i$ and $C = \sum C_i D_i$, respectively. A discrete version of

$B^{CE}(C)$ can then be constructed with a simple rule: Designate areas, highest to lowest, in order of B_i/C_i (which is equivalent to $\partial B/\partial A/\partial C/\partial A$).¹³

If one could somehow invoke the *deus ex machina* of a social welfare function, optimal critical habitat could magically emerge (under the restrictions assumed above) from this framework. What would we need to know about that function? Actually, very little. If we somehow knew the slope of the tangency, T^* , in Figure 1, the “optimal” 4(b)(2) analysis would become a simple threshold rule: Designate all areas for which $B_i/C_i \geq T^*$. The threshold benefit-cost ratio, T^* , would divide the set of all potential critical habitat areas into two sets: those to be designated, and those to be excluded (Figure 2).

In the real world, of course, federal government budgets for economic analyses have never been large enough to afford *deus ex machina*. Nevertheless, this framework was the inspiration for a recent critical habitat designation undertaken by NMFS. The designation faced all the problems classically encountered for 4(b)(2) analyses, particularly lacking data sufficient to estimate the benefits of designation in monetary terms. Eschewing the standard benefit-cost approach for this reason, NMFS decided to utilize a cost-effectiveness framework instead. That decision in turn led to some interesting choices, for the data available fell short of supporting a classic analysis in that vein.

Critical habitat designation for West Coast salmon and steelhead

In 2002, NMFS faced the task of designating critical habitat for West Coast salmon and steelhead listed under the ESA.¹⁴ For the purposes of the ESA, salmon and steelhead fall into a

13. Strictly speaking, this method produces not a continuous efficiency frontier but a set of “efficiency points.” This is because the areas are considered not as a continuous stream of acres but as a sequence of discrete areas. If these discrete areas can be subdivided, and if B_i/C_i is uniform throughout A_i , this method can produce a continuous efficiency frontier. If the areas cannot be subdivided, the problem as outlined in the text is in fact the well known knapsack problem, and the simple rule is, to be kind, a very greedy algorithm with all the attendant limitations on its ability to approach an optimal solution.

14. This was actually the second time NMFS had designated critical habitat for these species. In 2000, NMFS Fisheries published final critical habitat designations for the West Coast salmon and steelhead discussed in the text, but the designations were challenged in court by the National Association of Homebuilders and ultimately vacated. The challenge was based in part on NMFS’s inadequate consideration of the economic impacts of the critical habitat designations (National Ass’n

category known as a “distinct population segment.” At the full species level, salmon (Chinook, coho, chum, pink, and sockeye) and steelhead (an anadromous form of rainbow trout) are not in danger of extinction. The ESA, however, allows for the listing and protection of “species” below the full species level, including individual populations. West Coast salmon and steelhead are divided into groups of stocks (that is, a population that spawns in a particular river) known as “evolutionarily significant units,” or ESUs. NMFS has identified fifty-two ESUs along the West Coast, five of which are listed as endangered and twenty-one of which are threatened. The critical habitat designation discussed below covered twelve of these ESUs.¹⁵

As noted above, the process of designating critical habitat broadly involves two steps: Identify areas that meet the definition of critical habitat, and then estimate and weigh the benefits and costs of designating each area. To identify specific areas for the 4(b)(2) process, NMFS used standard watershed units, as mapped by the U.S. Geological Survey, designated by fifth field hydrologic unit codes, or HUC5s (referred to below as “watersheds”).¹⁶

This decision produced a daunting task: Conduct 12 ESU-level analyses of the benefits and costs of designating individual watersheds as critical habitat. The number of watersheds in an ESU ranged between 1 and 289; their size ranged between 4 and 850 square miles across all ESUs, while

of Homebuilders v. Evans, 2002 WL 1205743 No. 00-CV-2799 (D.D.C.).

15. The twelve ESUs are Puget Sound Chinook salmon; Lower Columbia River Chinook salmon; Upper Willamette River Chinook salmon; Upper Columbia River spring-run Chinook salmon; Hood Canal summer-run chum salmon; Columbia River chum salmon; Ozette Lake sockeye salmon; Upper Columbia River steelhead; Snake River Basin steelhead; Middle Columbia River steelhead; Lower Columbia River steelhead; and Upper Willamette River steelhead. A similar effort was undertaken in California covering seven ESUs.

16. The USGS maps watersheds as a drainage area from ridge-top to ridge-top, encompassing streams, riparian areas and uplands. NMFS used the watershed boundaries as a basis for the 4(b)(2) analysis, but actually designated only the stream reaches within the watershed that were occupied by the particular species under consideration. While this might seem to limit the scope of critical habitat’s impacts, the effects of many activities literally travel downstream, which means they would still have the potential to harm the stream reaches designated as critical habitat even if they were physically located outside the designation’s boundaries.

the average size ranged between 96 and 264 square miles for an individual ESU. Overall, there were 609 watersheds under consideration (Figure 3).¹⁷

The 4(b)(2) process was divided into three parts: an economic analysis of the costs of critical habitat designation, a biological analysis of the benefits of designation, and what was called the 4(b)(2) report, which utilized the information from these two analyses to conduct the 4(b)(2) inclusion/exclusion process. All of the restrictive assumptions encountered above, in particular that the benefits and costs of designating an individual area are independent of the status of other areas, were incorporated into these analyses and report.¹⁸

Cost estimation

The economic analysis considered the costs of modifying ten different types of projects, each of which had some connection to a federal agency's action: Hydropower dams; non-hydropower dams and other water supply structures; federal lands management; transportation projects; utility line projects; instream activities; EPA-permitted activities under the National Pollutant Discharge Elimination System; sand and gravel mining; residential and commercial development; and agricultural pesticide applications. In almost all cases (effects on water supply projects was a major

17. A complete accounting of critical habitat designation for West Coast salmon and steelhead is beyond the scope of this paper, but can be found in NMFS (2005a) (the report on the 4(b)(2) decision framework and its results), NMFS (2005b) (the assessment of biological benefits), and NMFS (2005c) (the assessment of economic costs). These documents are available at <http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/Redesignations/Index.cfm>.

18. From the perspective of the economic analysis, an equally important assumption was one that assumed restrictions never rose to the market-level. Where a federal agency's own project was potentially restricted by critical habitat designation, the analysis assumed sufficient expenditures would be made to make the necessary modifications. Similarly, if the activity was one that was permitted or funded by a federal agency, the assumption was made that the non-federal party would do the same. These assumptions are very strong, in that there are alternatives to modifying the project and incurring those costs, even short of market-level effects. The party responsible could pursue the activity in a location that does not potentially harm the species or choose not to pursue the activity at all. These assumptions were necessary (from a practical point of view) because data to support the alternatives were not available.

exception), NMFS developed estimates of the likely costs of modifying these projects to comply with critical habitat designation.¹⁹

The nature of the cost of modifying an activity depended on the nature of the activity. Some activities take the form of a flow, in that a certain level of the activity takes place every year.²⁰ The analysis assumed in most cases that the costs of modifying these types of activities would be borne in one year. Other activities are generated by a “stock” of activity sites that exist in a particular

19. This statement glosses over a huge complexity that I have chosen to ignore in the name of artistic license. Section 7 of the ESA imposes two distinct duties on Federal agencies: avoid jeopardizing listed species and avoid adversely modifying their critical habitat (see note 10). Because the designation of critical habitat is usually subsequent to listing (which triggers the first section 7 duty), the benefits and costs of designation stem from the *additional* section 7 restrictions, if any, that occur when a particular geographic area is designated as critical habitat. Distinguishing these two section 7 duties, then, is the beginning point for any economic analysis of critical habitat designation.

Unfortunately, both FWS and NMFS have a long history of conflating the two duties, making it almost impossible (based on the historical record) to identify a specific set of impacts attributable solely to designation. In addition to making life hard for the economic analyst, this has produced two court decisions that complicate the economic analysis of critical habitat designation. The first is *New Mexico Cattle Growers Association v. United States Fish and Wildlife Service* (248 F.3d 1277, 10th Cir., May 11, 2001). In this case, the plaintiffs challenged the designation of critical habitat for the southwestern willow flycatcher, asserting that FWS had assumed there was no impact from critical habitat designation because that action imposed no restrictions not found by applying the duty not to jeopardize the species. The Tenth Circuit Court of Appeals rejected this assumption, ordering FWS (and by extension, NMFS) to conduct "a full analysis of all of the economic impacts of a critical habitat designation, regardless of whether those impacts are attributable co-extensively to other causes." The result is that economic analyses conducted since *New Mexico Cattle Growers Association* have included *both* the impacts of critical habitat designation alone and those that are "co-extensive impacts," or impacts that are associated with habitat-modifying actions covered by both the jeopardy and adverse modification duties.

Adding to this distortion of the economic analysis is a huge source of uncertainty introduced by another court case, *Gifford Pinchot Task Force v. U.S. Fish and Wildlife Service* (378 F.3d 1059, 9th Cir., Aug. 6, 2004). In this case, the Ninth Circuit Court of Appeals invalidated the regulations both FWS and NMFS used to interpret the meaning of section 7, based on their tendency to conflate the two duties. This meant that these regulations needed to be re-examined and revised – a task the two agencies have not yet accomplished (as of this writing). As a result, an analysis that seeks to predict the *future* impacts attributable to critical habitat designation does so when the legal standard that generates the impacts is itself uncertain.

20. The activities that fell into this category were hydropower dam operations, non-hydropower dam and water supply structure operations, federal lands management, transportation projects, utility line projects, instream projects, and agricultural pesticide applications.

watershed.²¹ Modifications to these activities were then viewed as a capital improvement to the site. Capital expenditures were either amortized over an appropriate period or staged over a number of years, and other costs such as maintenance were included where appropriate. For these activities, the estimated modification cost involved a present value calculation. Using guidance from OMB (2003), the analysis used both a 7% and a 3% discount rate. For the purposes of conducting the 4(b)(2) process, NMFS used a 7% discount rate.

NMFS chose a simple “unit cost” approach to estimate the economic impacts of critical habitat designation. For some types of activities, costs specific to a particular project were estimated (*e.g.*, costs to modify particular hydropower dams); for most types, NMFS estimated costs on a per-project basis, varying the unit-cost for some activity types depending on the scale or location of the activity. Because the unit of analysis was an individual watershed, an accounting had to be made of the annual volume of an activity (if it was a “flow”) or its location (if it was a “stock”) for each watershed. This was done with a variety of spatial data sources, which enabled NMFS to estimate these volumes and discern these locations (Figure 4).

Calculating the total estimated annual cost of critical habitat designation for a particular watershed then took a simple form:

$$\text{Aggregate Annual Impact for Watershed (\$/yr)} = \sum_{\text{(Activity Types)}} \left[\text{Volume of Activity Type} \times \text{Annual Expected Modification Cost per-unit} \right]$$

Table 1 presents a sample of these estimates drawn from the Puget Sound Chinook ESU, giving the estimates for individual activities for one watershed, and aggregate cost estimates for a sample of other watersheds; Figure 5 illustrates the variation in costs at the watershed level for that ESU.; and Table 2 presents total cost estimates for all twelve ESUs as well as statistics for individual watersheds within each ESU.

21. These activities included hydropower dam capital and programmatic modifications, non-hydropower dam and water supply structure capital and programmatic modifications, grazing, NPDES-permitted activities, and mining.

Benefit estimation

To assess the benefits of critical habitat designation, NMFS had insufficient data to support a true benefit-cost approach or even a classic cost-effectiveness analysis. While some studies exist on the willingness-to-pay for improved salmon populations (see, for example, Alkire 1994; Bell *et al.* 2003; ECONorthwest 1999; Layton *et al.* 1999; Loomis 1996; Olsen *et al.* 1991; and Radtke *et al.* 1999), applying these results at the level of an individual watershed was not feasible. Moreover, while there is strong biological support for a positive relation between habitat protection and improved salmon and steelhead populations, the ability to quantify that relation does not yet exist (Beechie *et al.* 2003). Still, NMFS was committed to conducting a 4(b)(2) process that assessed biological benefits in some manner, and so the agency created a framework for estimating these benefits with a categorical measure.

NMFS organized teams of biologists to determine the relative conservation value of each specific area for the species being considered (NMFS 2005a). The teams first scored each watershed for six factors related to the quantity and quality of the physical and biological features identified as the underpinnings of critical habitat. Aggregating these scores (with or without weights) could have produced a cardinal biological metric, which would then have enabled a formal cost-effectiveness analysis. The six factors chosen for quantification, however, represented only part of the full set of biological factors that determine the conservation value of a particular watershed. For example, individual watersheds support particular salmon or steelhead stocks within the ESU (recall that a ESU is a group of individual stocks), and different stocks can have more or less value (in evolutionary terms) to the ESU as a whole. By considering this and other non-quantifiable factors in addition to the six factors scores, the biological teams rated each watershed as having a “High,” “Medium” or “Low” conservation value, as illustrated in Table 3.²²

22. There were some complications with the use of a watershed as the area evaluated for the benefits of designation. A large stream or river can serve as a connectivity corridor to and from many watersheds, yet be imbedded itself in a watershed. Watersheds with major connectivity corridors were therefore broken into two components. For the connectivity corridor portion, NMFS assigned the rating of the highest-rated watershed upstream. For the remaining portion (usually consisting of few or several tributaries), NMFS asked the teams of biologists to rate the conservation value of the watershed based on the tributary habitat alone. This system resulted in some connectivity corridors being assigned a High rating embedded in a tributary habitat area with a Low or Medium rating. Both portions were then considered separately in the 4(b)(2) analysis, with the

The benefit of designating an area as critical habitat is more than just the *potential* conservation value, however. The benefit achievable with designation needed to take into account the likelihood that designation would actually protect the watershed’s conservation value for the species. To address this concern, NMFS developed a profile for a watershed that would have “low leverage” in the context of the ESA.²³ This “low leverage” profile was treated as diminishing the benefit of designation somewhat but not completely: a “High” rating would become a “Medium,” a “Medium” would become a “Low” and a “Low” would become “Very Low” (NMFS 2005a). This process produced ratings with over a majority of the watersheds having a High biological rating, although this wasn’t the case for each ESU (Table 4). Watersheds with a Medium rating were about twice as prevalent as those with a Low rating, but this also varied across ESUs. Only seven watersheds were rated Very Low. An illustration of the results is given for the Puget Sound Chinook salmon ESU (Figure 6).

4(b)(2) decision process

The final task for the designation of West Coast salmon and steelhead was to undertake the heart of the 4(b)(2) analysis: For each watershed being considered for an ESU, does the cost of designation outweigh the benefit of designation? If so, the watershed could then be considered for exclusion.

Lacking data on the monetary benefit of designating each watershed, a straightforward benefit-costs analysis was not possible. Neither was a standard cost-effectiveness analysis as the effectiveness rating was ordinal, not cardinal. Nevertheless, there was sufficient information in the ordinal ratings to seek a *better* critical habitat designation, if falling short of an *optimal* one. To this end, NMFS developed the following decision rule:

economic costs being apportioned using the spatial data used in the economic analysis.

23. The “low leverage” profile included watersheds with less than 25 percent of the land area in federal ownership, no hydropower dams, and no restrictions likely to occur on instream work. NMFS chose these attributes because federal lands, dams and instream work all have a high likelihood of consultation and a potential to significantly affect the physical and biological features of salmon and steelhead habitat.

For each area, A_i , with a given biological rating, R , if the cost of designation, C_i , is greater than the threshold, C^R , A_i is eligible for exclusion.²⁴

A separate threshold was then established for each of the lowest three biological ratings: \$1000 in annual costs for a Very Low watershed, \$85,000 for a Low watershed, and \$300,000 for a Medium watershed.²⁵ The exclusion of a watershed with a High biological rating was deemed to significantly impede conservation, and so a judgment of whether the costs of designation outweighed the benefits was essentially avoided.

The set of thresholds was *not* within the purview of the economic or biological analysis, and certainly not a matter of “professional judgment” for either the economists or the biologists. Both analyses gave additional information to create a context for choosing the thresholds, but ultimately the choice was that of the policy maker’s. As such, it clearly was the key policy choice for the regulatory proceeding, for it divided the set of *potential* critical habitat areas into those areas automatically designated and those that were then eligible for exclusion (Figure 7).

24. The threshold rule uses only cost information, C_i , for two reasons: The true benefit, B_i , is unknown, and the measured benefit, the biological rating, is identical for all areas with the same rating. This raises the possibility that using C_i alone could produce a critical habitat designation that is “worse” than using no information at all (*i.e.*, a random selection of watersheds). This could happen if C_i and $(B_i - C_i)$, the true net benefit of designating A_i , are positively correlated. If that is the case, a rule that excludes areas with relatively high costs will also exclude areas with relatively high net benefits. For this to be the case, however, B_i must increase at a faster rate than C_i , as C_i increases. (If variation in C_i was driven by a scale variable, for example, B_i would be exhibiting “increasing returns to scale,” so to speak.) Without knowing the sources of variation across watersheds for B_i and C_i , it is impossible to rule this out, but neither does it seem like a strong possibility. Across the main three biological rating categories (High, Medium, Low), the average estimated economic cost does not show a strong correlation (average cost for High is \$363,203; for Medium, \$552,307; and for Low, \$381,115).

25. Because watersheds in the Snake River steelhead ESU were significantly smaller in size than the ones in the other ESUs, a separate set of thresholds was established for that ESU. The policy maker also used an additional set of thresholds, which measured the estimated economic costs on a per capita basis for each watershed. Some watersheds have relatively low populations (estimated using spatial census data), and so a relatively low economic cost may nevertheless impose high costs per capita. To account for this equity concern, the policy maker established a set of per capita impact thresholds, which would make a watershed eligible for exclusion if the per capita threshold was exceeded but the total cost threshold was not. This second threshold test resulted in four watersheds being excluded that would not have been excluded otherwise.

Once this division was determined, the watersheds eligible for exclusion on economic grounds (and not excluded for other grounds such as national security) were presented to the biological team. They addressed the following question: Would the exclusion of this area significantly impede conservation for reasons not captured in the original assessment? As a result of this second round of review, 27 of the 133 watersheds eligible for exclusion under the threshold rule set were retained in the critical habitat designation for this reason. Table 5 presents the final results of this process for each ESU.

Is there any reason to believe the set of thresholds chosen were the “optimal” set? In theory, even with the constraint of an ordinal measure of conservation value, an optimal set of thresholds could be derived from a social welfare function – if one could just be found. In this real world exercise, the social welfare function, like Athena, sprung fully formed from the brow of the Zeus-like policy maker. This admission may leave the classic benefit-cost analyst uncomfortable, but the alternative – exercising “professional judgment” – is simply an appeal to an alternate form of *deus ex machina*.

Although not pursued in this regulatory proceeding, the method above could be used to conduct a hypothetical valuation experiment at the policy maker level.²⁶ Using the threshold decision rule but varying the threshold levels, the analyst could present distinct configurations of critical habitat areas to the policy maker (Figure 8). Each configuration could, in principle, be considered biologically at the higher, ESU level. Although it is not yet possible to quantify the “amount of conservation” in each of these figures, it can give the policy maker insights into “how much” conservation is in the first designation, and “how much more” conservation is in the second and third. The policy maker then could weigh the additional conservation against the incremental costs of achieving different configurations. Varying the thresholds and measuring the “preference” for various configurations could thus be used to search for the configuration where the incremental cost just outweighs the incremental benefit – at least in the eyes of the policy maker.

26. I thank David Layton for making this point.

Conclusion

Economists spend much of their time worrying about what is optimal, but sometimes the optimal can be the enemy of the good. Faced with a policymaking exercise for which key data and the resources to gather them are both in short supply, benefit-cost analysts face their own choice. They can use their judgment to divine the optimal alternative, or they can seek ways to use the data at hand to make that policymaking “good,” or at least better.

The example given above was one such attempt. As is often the case for other forms of environmental policy making, data on the monetary benefits of critical habitat designation for West Coast salmon and steelhead were insufficient to pursue a standard benefit-cost approach. While somewhat stronger, data on the biological benefits were still insufficient even to pursue a standard cost-effectiveness approach. One option would have been to present the policy maker with “context”: valuation studies for other species, bits and pieces of biological data that showed quantitative links between habitat protection and population viability, and so forth. With such data in hand, the policy maker could have designated critical habitat in a way that – well, in whatever way policy makers make choices when all they’ve got is “context.” Instead, NMFS chose a somewhat bolder, much messier path of taking cost-effectiveness as far as it could go, and then bringing benefit-cost principles into play to make choices, even when there was insufficient information to be assured those choices were “optimal.” It all may leave some gasping for air, but that’s better than trying to talk one’s way out of a vacuum.

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Table 1
Economic Impacts of Critical Habitat Designation
Puget Sound Chinook Salmon ESU Watersheds

Watershed	Estimated Annual Total Impact
Lower Skagit River/Nookachamps Creek	\$803,494
Hydropower dams	\$10,603
Non-hydropower dams and other water supply structures	\$53,013
Federal lands management	\$0
Transportation projects	\$31,805
Utility line projects	\$50,500
Instream activities	\$491,375
NPDES-permitted activities	\$37,998
Sand and gravel mining	\$45,070
Residential and commercial development	\$18,440
Agricultural pesticide applications	\$64,690
Nooksack River	\$710,060
Skagit River/Gorge Lake	\$2,004,813
Cascade River	\$192,029
Skagit River/Illabot Creek	\$327,016

Table 2
Aggregate and Watershed-level Annual Total Impacts
12 West Coast Salmon and Steelhead ESUs

ESU	Aggregate Impact*	Individual Watersheds			
		Average	Median	Maximum	Minimum
Lower Columbia River Chinook salmon	\$35,146,118	\$783,966	\$549,208	\$3,932,625	\$34,162
Puget Sound Chinook salmon	\$75,924,775	\$1,165,357	\$584,677	\$15,308,987	\$1,445
Upper Columbia River spring-run Chinook salmon	\$9,312,386	\$660,220	\$487,740	\$2,948,332	\$24,454
Upper Willamette River Chinook salmon	\$24,413,253	\$558,312	\$320,406	\$4,236,484	\$1,454
Columbia River chum salmon	\$14,619,190	\$853,130	\$405,922	\$3,931,381	\$49,791
Hood Canal summer-run chum salmon	\$6,755,415	\$419,029	\$255,018	\$1,452,160	\$54,104
Ozette Lake sockeye salmon	\$2,723	\$2,723	\$2,723	\$2,723	\$2,723
Lower Columbia River steelhead	\$34,162,795	\$872,549	\$600,919	\$3,941,426	\$49,953
Middle Columbia River steelhead	\$39,490,612	\$384,859	\$201,580	\$2,402,363	\$1,408
SNAKE RIVER BASIN steelhead	\$24,462,942	\$111,849	\$58,467	\$2,402,363	\$88
Upper Columbia River steelhead	\$19,968,541	\$704,460	\$496,921	\$4,735,387	\$24,454
Upper Willamette steelhead	\$7,899,653	\$433,728	\$185,430	\$3,529,270	\$1,454

*This is the aggregate impact if all watersheds considered in the 4(b)(2) analysis were in fact designated as critical habitat.

Table 3
Biological Ratings for Individual Watersheds
Puget Sound Chinook Salmon ESU

Watershed	Scoring Factors						Total Watershed Score (0-18)	Comments/Other Considerations	Biological Rating
	1	2	3	4	5	6			
Upper Green River	1	1	2	0	1	2	7	Moderate HUC5 score; PCEs support fish that are trapped and hauled into this HUC5; PCEs in downstream (and naturally accessible) HUC5s likely to be of higher conservation value for the Green/Duwamish River population	Medium
Middle Green River	1	2	1	2	2	2	10	Moderate HUC5 score; PCEs support one of six populations in the South Sound region for this ESU; this HUC5 likely to be emphasized for access above Howard Hanson Dam supporting a historically independent population	High
Bellingham Bay	0	1	1	1	1	0	4	Low HUC5 score; not identified as supporting a historically independent population	Low
Samish River	1	1	2	1	1	1	7	Moderate HUC5 score; not identified as supporting a historically independent population; lost connectivity to Skagit River system a key CHART concern for this HUC5	Low

Table 4
Watershed Biological Ratings
12 West Coast Salmon and Steelhead ESUs

ESU	Benefit of Designation			Very Low	Grand Total
	High	Medium	Low		
Lower Columbia River Chinook salmon	30	13	4		47
Puget Sound Chinook salmon	59	9	12		80
Upper Columbia River spring-run Chinook salmon	9	5			14
Upper Willamette River Chinook salmon	19	17	20		56
Columbia River chum salmon	16	2	1		19
Hood Canal summer-run chum salmon	14	3			17
Ozette Lake sockeye salmon	1				1
Lower Columbia River steelhead	28	11	2		41
Middle Columbia River steelhead	76	24	6	3	109
Snake River Basin steelhead	216	44	11	3	274
Upper Columbia River steelhead	20	7	2	1	30
Upper Willamette River steelhead	11	6	16	1	34

Table 5
Watersheds Excluded from Critical Habitat Designation
12 West Coast Salmon and Steelhead ESUs

ESU	% watersheds excluded				
	High	Medium	Low	Very Low	All Ratings
Lower Columbia River Chinook salmon	0%	46%	100%		21%
Puget Sound Chinook salmon	0%	56%	100%		21%
Upper Columbia River spring-run Chinook salmon	0%	80%			29%
Upper Willamette River Chinook salmon	0%	18%	100%		41%
Columbia River chum salmon	0%	50%	100%		11%
Hood Canal summer-run chum salmon	0%	0%			0%
Ozette Lake sockeye salmon	0%				0%
Lower Columbia River steelhead	0%	27%	100%		12%
Middle Columbia River steelhead	0%	13%	83%	100%	10%
Snake River Basin steelhead	0%	9%	55%	100%	5%
Upper Columbia River steelhead	0%	29%	50%	100%	13%
Upper Willamette River steelhead	0%	0%	100%	100%	50%