Prepared for the Proceedings of 2002 California World Oceans Conference, Santa Barbara, CA

Calculating Compensatory Restoration in Natural Resource Damage Assessments: Recent Experience in California

Steve Hampton and Matthew Zafonte[1]

Abstract

Natural resource damage assessment (NRDA) is the process of quantifying monetary damages for injuries to wildlife, habitat, and the services they provide, in the event of an oil spill or other pollution event. One economic method, Resource Equivalency Analysis (REA), has become the predominant tool used for calculating these damages. It may be employed to calculate damages to both habitat and/or individual animal species. It has been used nationwide in a wide range of cases involving a wide array of habitat types and animal species. This paper provides a conceptual overview of REA, a review of the use of this method in California, and a discussion of some of the practical and theoretical issues facing the application of REA.

Introduction

In the aftermath of an oil spill or other pollution event, various federal and state statutes, such as the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the Oil Pollution Act of 1990 (OPA), and California's Lempert-Keene-Seastrand Oil Spill Prevention and Response Act (Government Code §§ 8670 et seq.), authorize trustee agencies to seek monetary compensation for injured natural resources. The process of quantifying injuries and damages from a pollution event is called natural resource damage assessment (NRDA). These assessments determine the compensation that parties responsible for pollution incidents owe to the public. The Department of the Interior, responsible for promulgating NRDA regulations pursuant to CERCLA, has suggested that "compensable value" due to the public should "encompass all of the public economic values associated with an injured resource, including use values and passive-use values such as option, existence, and bequest values" (56 Federal Register 19760 (1991))[2]. California Fish and Game Code § 2014 specifies that "the state may recover damages in a civil action against any person or local agency which unlawfully or negligently takes or destroys any bird, mammal, fish, reptile, or

[1] Resource Economists, Office of Spill Prevention and Response, California Department of Fish and Game, 1700 K Street, Suite 250, Sacramento, CA 94244-2090

[2] This citation is from the Department of the Interior's Notice of Proposed Rulemaking, "Natural Resource Damage Assessments" on Apr. 29, 1991.

amphibian..." and that "the measure of damages is the amount which will compensate for all the detriment..."

Since the Exxon Valdez oil spill in 1989, NRDA has evolved into a well-defined discipline, with its own case history, legal precedents, and economic literature. Use of contingent valuation (CV) as a means to derive passive use values was upheld by the Court in *Ohio et al. v Department of the Interior,* 880 F. 2d 432 (D.C. Cir. 1989). Thereafter, in the early 1990s CV was employed to derive compensable value in a number of instances. In 1997, the National Oceanic and Atmospheric Administration (NOAA) issued a guidance document for conducting NRDAs under OPA (NOAA 1997). NOAA recommended the calculation of compensation should be based upon restoration projects, where compensable restoration is determined using Habitat Equivalency Analysis (HEA) and the cost of the restoration project(s) becomes the measure of damages (NOAA 1995). At the same time this guidance document was issued, natural resource agencies were suffering negative experiences using CV (Thompson 2002). Since then, HEA has evolved into the more generic Resource Equivalency Analysis (REA) and has become the primary method for calculating damages from pollution events nationwide. Flores and Thacher (2002) have accurately described this as a "paradigm shift". Indeed, nearly every pollution damages case in the nation over the past five years has employed REA as the primary method to quantify damages to wildlife and habitat. Furthermore, two courts have recently upheld the method as an appropriate measure to determine the scale of compensatory restoration projects (United States vs. Fisher, 1997 and United States v. Great Lakes Dredge & Dock Co., 1999).

This paper focuses on experiences of practitioners using REA for NRDA in California. It starts by providing a conceptual introduction to the REA method, describes the breadth of its application in California to date, and then concludes with a discussion of some of the practical issues associated with implementing REA in a "real world" setting.

Resource Equivalency Analysis: The Method

Concept. There are two basic approaches to measuring the compensation for natural resources injuries. One is to focus on the demand side, the "consumer valuation" approach; the other is to focus on the supply side, the "replacement cost" approach. In the former, we seek to measure the monetary value that the public puts on the natural resources (i.e., how much the public demands the services of natural resources); in the latter, we seek to measure how much it costs to replace the natural resource services that the public loses as a result of the injury (i.e., how much it costs to supply natural resource services).

Figure 1 illustrates the difference between these two approaches. In both graphs, the supply of natural resources shifts from S^0 to S^1 as a result of an incident (e.g., oil spill, sediment discharge into a stream, illegal removal of vegetation). In the top graph, the area under the aggregate demand curve between S^0 to S^1 illustrates the dollar value of the resource loss as measured by the monetary payment that would make the public indifferent to the incident. For example, if each individual in a 30

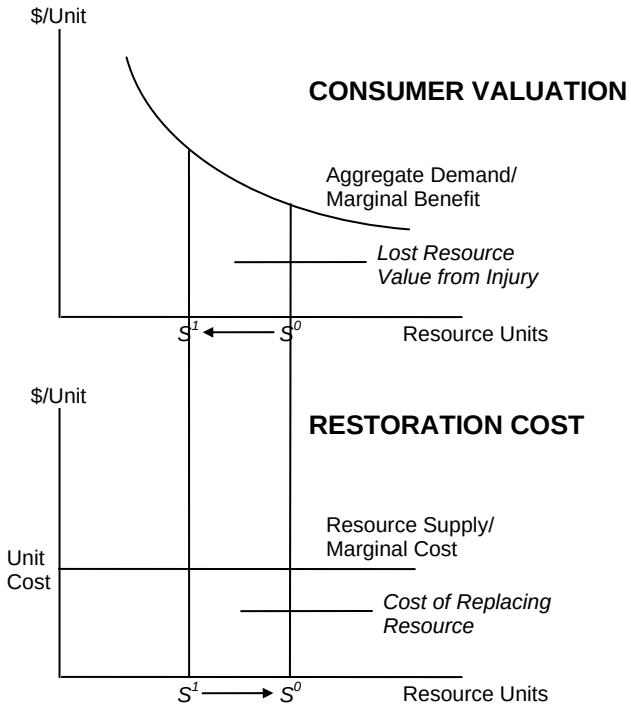

Figure 1. Consumer Valuation versus Replacement Cost approaches for Natural Resource Damage calculation

million person society would need a $.05 payment (on average) to make them indifferent to the resource loss, the area identified in the top graph would equal $1.5 million. Because of the difficulty in observing market prices that reveal the level of cash payment that would compensate individuals for resource losses, the quantitative characteristics of the demand curve(s), and consequently the size of the identified area in the upper graph, are difficult to measure. Contingent Valuation (CV) and other types of analyses are designed to estimate this dollar value. These methodologies typically involve large surveys and can be expensive to implement.

The lower graph illustrates a replacement cost approach. Beyond noting that the injured resource has value, the actual extent to which the public values it is not directly considered. Instead, the determination of adequate compensation depends on the level of natural resource provision (versus monetary payments) that compensates society for what it has lost as a result of the incident. The cost of providing this compensation becomes the estimate of damages. Resource Equivalency Analysis (REA) is the primary methodology for conducting this type of measurement in natural resource damage assessment. Conceptually, it estimates the size (or "scale") of a given restoration project necessary to induce the resource supply shift in the lower graph from S^1 back to S^0. The area under the resource supply curve (between S^1 and S^0) is the total monetary cost of funding that shift.

It is clear from Figure 1 that the public's valuation of the resource (the area identified in the top graph) is not necessarily equal to the total replacement cost (the area identified in the bottom graph). This is especially true when unique resources or

rare species are involved, as the slope of the aggregate demand curve (top figure) may be much steeper due to resource scarcity. This would result in a much larger monetary payment being necessary to compensate the public. In such a case, the replacement cost approach of REA may result in damages far less than the losses as valued by the public. However, because it is easier and less costly to measure the total replacement cost than the total public value, REA has an advantage over other methods, especially for small to medium-sized incidents with minimal impact on rare species.

REA involves three steps: (1) the debit calculation, (2) the credit calculation, and (3) the computation of the restoration project costs. The first step involves determining the amount of "natural resource services" that the affected resources would have provided had it not been injured. The unit of measure may be acre-years, stream feet-years, or some other metric (such as animal-years). The second step is to equate the quantity of lost services with those created by proposed compensatory restoration project. The final step is to cost out the project. Thus, the size of the restoration project is "scaled" to the injury first; the cost of restoration is then calculated after the scaling has been done. In this sense, REA calculates the *replacement cost* of the lost years of natural resource services.

In California, calculations discount future years at 3% per year, consistent with NOAA recommendations for NRDA (NOAA 1999). This discounting is done based on the assumption that present services are more valuable than future services, and that some uncertainty exists when estimating future restoration benefits.

Habitat Example. Suppose a 10-acre area is degraded due to an oil spill such that it supplies only 30% of its previous habitat services during the year following the incident. In the second year after the incident, the habitat begins to recover, supplying 90% of its baseline services. By the third year it is fully recovered. In this case, the lost acre years of habitat services would be 70% x 10 acres x 1 year + 10% x 10 acres x 1 year = 8 acre-years of habitat services. Figure 2 (left) illustrates this example by showing the recovery path of the habitat over time (sold line).

As stated above, future years are discounted at a 3% rate, thus the injuries in the second year count a little less. Incorporating this, 7.97 acre-years of habitat services were lost. This difference appears minimal here, but becomes significant (due to compounding) if injuries persist many years into the future.

The credit calculation focuses on the gain in habitat services that result from a restoration project. Creating acre-years of habitat services is a function of both area and time. If we remove discounting from the equation, compensation could involve taking 7.97 acres of land with no habitat value (e.g., a parking lot) and turning it into productive habitat for 1 year. Alternatively, we could achieve compensation by creating 1 acre for 7.97 years. In reality, most restoration projects involve taking previously degraded habitat (at another nearby location) and restoring it over a number of years, and maintaining it into the future.

Suppose the restoration project improves the quality of a nearby degraded area, so that, if it previously provided only 30% of potential services, it would provide 80% of potential habitat services after restoration. Also suppose the project

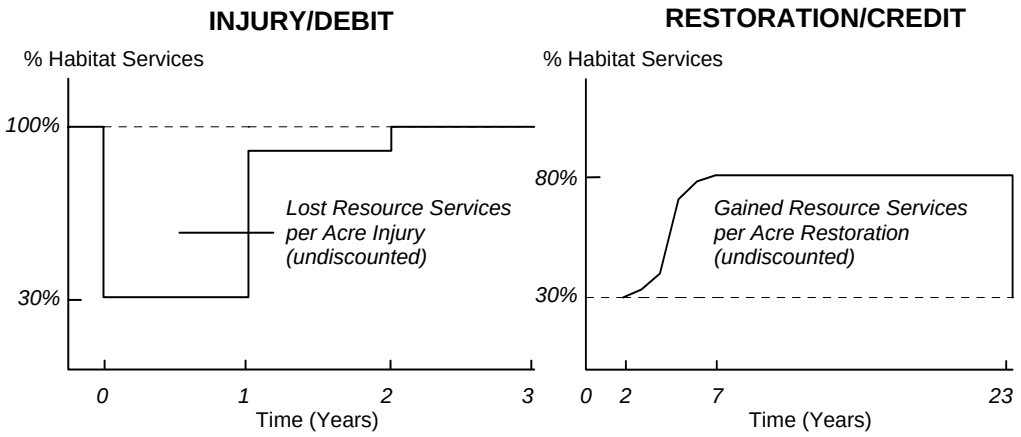

Figure 2. Example biological injury and restoration trajectories in a habitat-based Resource Equivalency Analysis

begins two years after the incident and it takes an additional 5 years for the 80% level to be achieved. Figure 2 (right) provides an illustration of this restoration trajectory (solid line). In our hypothetical example, the project is expected to have a lifespan of 20 years. With future years discounted, the 20th year of the project (22-23 years after the incident) counts much less than the 5th year of the project; for this example, we assume that years after that are effectively completely discounted due to uncertainty regarding the future. The total value of this project is approximately 6.31 acre-years per acre of restoration.[3]

Mathematically, we seek to restore an area that will provide 7.97 acre-years of services over the discounted 20-year life of the restoration project. In this example, that would be an area of approximately 7.97/6.31 = 1.26 acres. That is to say, restoration of 1.26 acres for 20 years would compensate the public for the 7.97 lost acre-years of habitat services due to the spill. Visually, the area identified by the left graph in Figure 2 (multiplied by the affected acres and calculated to measure the present discounted value) should equal the area identified by the right graph in Figure 2 (again, multiplied by the acres targeted for restoration and calculated to measure the present discounted value, thus discounting future years).

The percentage of habitat services lost (or gained, in the case of the restoration project) may be measured in a variety of ways. For our hypothetical oil spill case, three examples might include (1) the use of a habitat-wide evaluation index, (2) the use of one or more surrogate species, or (3) the use of an estimate based on the degree of oiling. Care must be taken when using a surrogate species to represent the entire affected habitat. Ideally, this surrogate is the population of one or more species that is immobile (that is, the animals do not move easily in and out of

[3] Service Value per Acre Restoration in Figure 2 (right)

$$= (0.03)(1.03^{-2}) + (0.1)(1.03^{-3}) + (0.4)(1.03^{-4}) + (0.48)(1.03^{-5}) + \sum_{t=6}^{21}(0.5)(1.03^{-t})$$

$$= 6.31\,\text{acre - years per acre}$$

the affected area) and that has significant forward and/or backward ecological links to other species in the affected ecosystem. For example, the population of red crossbills (*loxia curvirostra*), a bird that feeds primarily on pinecone seeds and migrates erratically from year to year, would be a poor surrogate for measuring injuries to a streambed. The aquatic macroinvertebrate community within the stream, however, provides an ideal surrogate, as they play a key role in the streambed food chain. Likewise, on the restoration side, care must be taken when the project targets one or a few species rather than the entire habitat. Ideally, a project that seeks to restore the population of a key indicator species will also benefit the entire habitat and, thus, other species as well. Indeed, such projects typically focus directly on habitat improvements. However, it is important to verify that such a species-centered project is indeed benefiting the entire habitat.

Application to Animals. When the injury is primarily to individual animals rather than to a complete habitat, the REA may focus on lost animal-years. For example, suppose an oil spill causes negligible injury to a body of water, but results in the death of 100 ducks. Using information about the life history of the ducks (e.g., annual survival rate, average life expectancy, average fledging rate, etc.), it is possible to mathematically model/estimate the lost "duck-years" due to the spill. On the credit side, we can examine restoration projects designed to create duck nesting habitat and scale the size of the project such that it creates as many "duck-years" as were lost in the incident.

The Use of Resource Equivalency Analysis in California

Mazzotta et al. (1994) and Unsworth and Bishop (1994) provide the first formal presentations of the REA framework that we have outlined above.[4] The label "Habitat Equivalency Analysis" quickly followed, as the REA approach was initially employed only for injuries to habitat, such as wetlands. Because the costs and benefits for wetland restoration projects are relatively well documented, this application of REA was simple and attractive. The method soon evolved into the more generic "Resource Equivalency Analysis" when it was applied to animals. The first complete "bird REA" was done in Rhode Island, for the 1996 *North Cape* Oil Spill (Sperduto et al. 1999). This REA counted *lost* "loon-years" and estimated the restoration project size that would provide an equal number of *gained* "loon-years". During the same NRDA, REA was employed to calculate restoration for other birds, as well as lobsters and oysters.

Even before the method was formalized, logic consistent with REA was used in California to quantify injuries to common murres (*Uria aalge*, a seabird) resulting from the 1986 *Apex Houston* oil spill (Swartzman 1996). A REA "debit" calculation was later conducted in California's assessment of the 1996 *Cape Mohican* oil spill to quantify injury to shoreline habitat, but "credit" calculations were not used to assess compensatory restoration.

[4] For a more thorough economic and legal treatment in the context of OPA and CECLA, see Jones and Pease (1997).

The Torch/Platform Irene oil spill in 1997 was the first time REA was used in California to both quantify natural resource injuries *and* equate them to benefits from compensatory restoration projects. In the same year, the California Department of Fish and Game's Office of Spill Prevention and Response (OSPR), the primary state agency conducting NRDAs for fish and wildlife resources, began using REA in smaller cases.[5]

Since the 1997 Torch/Platform Irene oil spill, OSPR has employed REA for assessing wildlife and habitat injuries in virtually every NRDA case in the state.[6] This equates to eight large cases and 47 small cases. With regard to habitats, REA has been used to measure injuries to freshwater and saltwater wetlands, riparian zones, coastal dunes, uplands, instream habitat for a variety of stream types, rocky intertidal habitat (including pier pilings and rip-rap), and oak woodlands. Species-specific REAs in California have been limited to birds, including loons, grebes, cormorants, ducks, common murres, marbled murrelets (*Brachyramphus marmoratus*), and western bluebirds (*Sialia mexicana*). Each application requires feasible restoration options, plus estimates of project costs and benefits. Many of these analyses are involved in ongoing NRDA settlement discussions.

Even though California has not used REA to assess specific injuries to non-bird species, there is no theoretical reason why such calculations cannot be performed. REA has been used outside California to scale restoration projects for a wide variety of non-bird species, including lobsters and oysters (mentioned above), Chinook salmon (*Oncorhynchus tshawytscha*) (Chapman *et al.* 1998), and loggerhead and green sea turtles (*Caretta caretta* and *Chelonia mydas*) (NOAA and FDEP 2002). Thus, REA has proved useful in a wide range of applications.

Issues in the Application of Resource Equivalency Analysis

There are a number of practical and theoretical issues associated with applying REA in specific cases. These include dealing with cases that have a wide array of injuries to different species and habitat types and the lack of known restoration options for many species. This section will briefly explore these areas.

Lumping and the Use of Surrogates. REA is intended to be used to scale the size of a restoration project that will provide ecological services that are "of the same type and quality, and of comparable value" as those that were lost due to the pollution event (NOAA 1997). This criterion is most likely to be met when the restoration project focuses on the same species or type of habitat that was injured. This can be called in-kind restoration.

---

[5] Other state agencies, such as the State Lands Commission, the Department of Parks and Recreation, and the State Water Resources Control Board, are also trustees for natural resources and have been involved in several of California's larger NRDA cases.

[6] In cases where damages are claimed for losses of human recreational activities, the Benefits Transfer Method is typically used, drawing upon previous studies that employed the Travel Cost Method or some other approached designed to estimate the public's willingness-to-pay for non-market recreational activities. See Ofiara and Brown (1999) for an example application of the Benefits Transfer Method to NRDA.

In many of the larger oil spills, a wide variety of bird species are affected, such that often no one species accounts for even the majority of the birds killed. In this situation, replicating a bird REA for each and every impacted species would be both time-consuming and expensive, and undoubtedly limited by a lack of data regarding potential restoration benefits. The dilemma is the fact that restoration project data (regarding both the benefits and costs) exists for only a handful of the 650 or more bird species that regularly occur in the United States. It is thus impractical to develop a REA for all of these species. Additionally, responsible parties desire to minimize assessment costs and avoid lengthy and expensive studies, which they are ultimately called upon to fund. In California and nation-wide, species injured in a pollution event are typically lumped into categories (e.g. seabirds, waterfowl, shorebirds, etc.). Lost bird-years are calculated for all of the impacted species, while the restoration project, and thus the gained bird-years, focus on one or more species that are the primary beneficiaries of the project. In this way, the beneficiary species become surrogates for the other impacted species.

In general, this practice of lumping species has been well received. Responsible parties are able to take advantage of economies of scale in assessment and restoration planning/implementation. The public has the opportunity to comment on projects that are more detailed and significant in size. From a theoretical perspective, such simplifications work best when the surrogate specie is a dominant part of the species grouping being assessed (which occurs frequently) or the species grouping shares similar habitats and life histories (so that the restoration project provides some benefits to each member).

Extrapolation for Species-Specific Injuries without Known Restoration Costs. If one can plausibly assume a relationship between restoration costs and species characteristics, it is possible to approximate restoration costs for species-specific injuries based upon restoration information from non-target species. This provides an alternative to "lumping similar species" when no specific restoration options have been identified. It is designed for expedited "cash-out" resolutions to small cases when: (1) the likely compensatory project size will be insufficient to support an economically viable restoration action (e.g., due to relatively high fixed design and permitting costs); and (2) the cost of collecting data relevant to estimating unknown parameters is excessive compared to the dollar damages associated with the species to be extrapolated. It is the intention that the monetary damages recovered using this method be combined with settlement dollars from other cases (or other species from the same case) to fund the most appropriate feasible project.

In California, this approach has been used in a few instances to estimate compensatory restoration costs for smaller scale bird kills resulting from oil spills. The application has focused on a hypothesized relationship between cost and species scarcity (i.e., compensatory restoration cost per bird killed is higher for rare species than for common species; see Figure 3). Costs per bird are derived from REAs of the lost bird-years due to specific bird kills and the gained bird-years from an identified restoration project. The cost of the REA-scaled project is then divided by the original bird kill, giving us the true cost per bird killed in the incident. Given enough data points, a relationship between restoration cost per bird and some measure of species

abundance can be evaluated. For this reason, birds are especially amenable to the approach because: (1) there can be many different species without known restoration costs affected by a spill; and (2) there are multiple bird species with restoration data that can be used as the basis of extrapolation.

The relationship between scarcity and restoration costs is supported by basic economic intuition as well as our case experience. By virtue of their specific habitat requirements, rare species are often at odds with valuable human economic activities (thus making them more expensive to restore). Extreme conceptual examples would be restoration for house sparrows (*Passer domesticus*), which would require nothing but simple bird houses in urban settings, compared to restoration for spotted owls (*Strix occidentalis*) or California condors (*Gymnogyps californianus*), which would require protection of old growth forests or millions of dollars in research. In addition, many rare species have life history characteristics that are "slow growing" (e.g., low reproductive rate, high adult survivorship). This may lend itself to longer recovery times as a result of a mortality incident (i.e., more "lost bird-years" per bird killed), and slower production of restoration benefits (i.e., fewer "gained bird-years" per restoration unit of effort). Combining these two factors results in the need for more compensatory restoration projects per individual bird lost as a result of an incident.[7]

Two limitations of this approach are important to note. First, creating and choosing an "index of abundance" is not a trivial task. There are undoubtedly many different possibilities, each of which has advantages and disadvantages for a specific inference. Second, if one follows the basic shape of the curve in Figure 3, it is clear that the slope of the cost curve is much steeper for rare species than for common species. Since small changes in abundance at low levels can produce large changes in estimated restoration cost, there is a risk that errors in cost extrapolation will be magnified for the rarer species. Combining these two observations leads us to conclude that this method should only be used with the most extreme caution for injuries to rare species. However, for relatively abundant species, this approach can offer the opportunity to compensate the public (on average) for a broader range of small incident bird mortalities (thus providing more complete compensation), while reducing assessment costs and saving responsible parties unnecessary expenditures.

Trophic Level Scaling and Substitutability. Out-of-kind restoration projects (i.e., those that do not provide in-kind services) complicate the use of REA in NRDA. As noted above for oil spills, trustee agencies are provided legal guidance to compensate the public with resources that are of the same type and quality. From an economic perspective, when the resource services provided by the restoration project are not equivalent to that of the injury, there is a problem of "substitutability" (see Flores and Thacher 2002).

[7] In this way, even though REA does not explicitly consider special legal status of a species (e.g. threatened or endangered), it does take into account the greater recovery times and restoration costs that may be associated with those species.

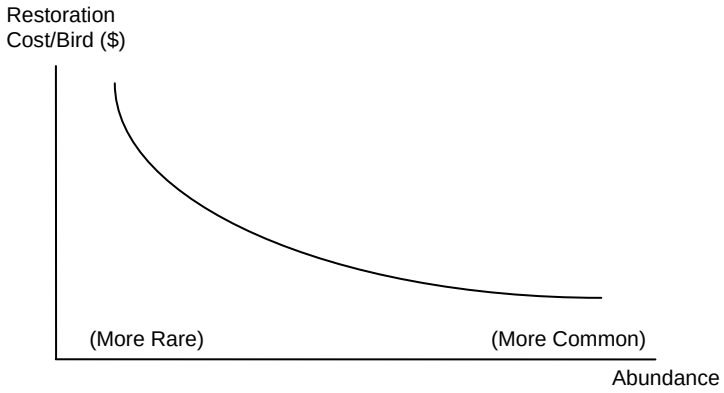

Figure 3. Restoration Cost as a Function of Species Abundance

In application, REA practitioners have found ways to scale seemingly out-of-kind restoration projects. In these cases, the scaling exercise utilizes a metric common to both the injury and the restoration in order to compare and equate the two. The common metric, a kind of lowest common denominator, is typically some measure of either biomass or primary productivity. For example, in the Chalk Point oil spill, injured birds were tallied in terms of their biomass and food consumption and compared to an oyster reef project that would increase benthic biomass and, stepping through several trophic layers in the food chain, benefit birds (NOAA *et al.* 2002). It was determined that the loss of 134 birds could be compensated for by the creation of a 1.9 acre oyster reef. In another similar example, the East Timbalier Island Restoration Project in Louisiana associated with the Lake Barre oil spill, injured aquatic fauna and birds were measured in terms of lost biomass. Then, through the amount of primary production generated by a marsh in one year to produce such biomass, the aquatic fauna and birds were measured in terms of lost hectare-years (Penn and Tomasi 2002).

While these biological conversion metrics are intended to maintain the requirement that the restored resource be "of the same type and quality, and of comparable value" as the injured resource, this may not be the case. For example, enhanced primary productivity is not necessarily going to "create birds." Any one unit of energy is potentially diverted in many different directions throughout the ecosystem. Furthermore, even a sufficient amount to "create a bird" may not result in the public receiving a bird in return, as other factors (e.g., predation) may play dominant roles in regulating bird numbers. Unfortunately, for some types of natural resources, few other viable options have been developed for resource valuation.

Conclusion

In sum, REA has proven a useful tool for calculating natural resource damages in California. Its flexibility allows application to a wide range of cases in a manner that links resource losses suffered by the public to actions that can be taken to compensate

for those losses. As with any method that evaluates complex systems, complications can arise when putting the methodology into practice. In the case of REA, analysts have developed approaches for addressing some of the challenges that have emerged. As a result, REA should be a ripe topic for future applied valuation research.

References

Chapman, D., N. Iadanza, and T. Penn. (1998). "Calculating resource compensation: An application of the service-to-service approach to the Blackbird Mine hazardous waste site." NOAA Damage Assessment and Restoration Program, Technical Paper 97-1.

Flores, N. E., and J. Thacher. (2002). "Money, who needs it? Natural resource damage assessment." *Contemporary Economic Policy* 20(2), 171-178.

Jones, C. A. and K. A. Pease. (1997). "Restoration-based compensation measures in natural resource liability statutes." *Contemporary Economic Policy* 15, 111-122.

Mazzotta, M. J., J. J. Opaluch, and T. A. Grigalunas. (1994). "Natural resource damage assessment: The role of resource restoration." *Natural Resources Journal* 34, 153-178.

NOAA. (1995). "Habitat Equivalency Analysis: An Overview." NOAA Damage Assessment and Restoration Program, Policy and Technical Paper Series, No. 95-1, (Revised 2000).

NOAA. (1997). "Natural Resource Damage Assessment Guidance Document: Scaling Compensatory Restoration Actions (Oil Pollution Act of 1990)." NOAA Damage Assessment and Restoration Program, Washington, D.C., December, 1997.

NOAA. (1999). "Discounting and the Treatment of Uncertainty in Natural Resource Damage Assessment." NOAA Damage Assessment and Restoration Program, Washington, D.C., February, 1999.

NOAA and Florida Department of Environmental Protection. (2002). "Final damage assessment and restoration plan/environmental assessment for the Fort Lauderdale mystery oil spill, Fort Lauderdale, Florida and vicinity." http://www.darp.noaa.gov/pdf/flfdarp.pdf (Aug. 26, 2002).

NOAA, Maryland Department of Natural Resources, Maryland Department of the Environment, and US Fish and Wildlife Service. (2002). "Final restoration plan and environmental assessment for the April 7, 2000, oil spill at Chalk Point on the Patuxent River, Maryland." http://www.darp.noaa.gov/neregion/chalkpdf/cp2107.pdf (Nov. 2002).

Ofiara, D. D., and B. Brown. (1999). "Assessment of Economic Losses to Recreational Activities from 1988 Marine Pollution Events and Assessment of Economic Losses from Long-Term Contamination of Fish within the New York Bight to New Jersey" *Marine Pollution Bulletin* 38(11), 990-1004.

Penn, T., and T. Tomasi. (2002). "Calculating resource restoration for an oil discharge in Lake Barre, Louisiana, USA." *Environmental Management* 29(5), 691-702.

Sperduto, M., C. Hebert, M. Donlan, S. Thompson. (1999). "Injury Quantification and Restoration Scaling for Marine Birds Killed as a Result of the North Cape Oil Spill." United States Fish and Wildlife Service.

Swartzman, G. (1996). "Resource modeling moves into the courtroom." *Ecological Modeling* 92, 277-288.

Thompson, D.B. (2002). "Valuing the environment: Courts' stuggles with natural resource damages." *Environmental Law* 32(1), 57-89.

United States v. Fisher, 977 F. Supp 1193 (D.D. Fla 1997).

United States v. Great Lakes Dredge & Dock Co., 97-2510, No. 97-10075, 1999 U.S. Dist. LEXIS 17612 (S.D. Fla. Sept 27, 1999).

Unsworth, R. E., and R. C. Bishop. (1994). "Assessing natural resource damages using environmental annuities." *Ecological Economics* 11, 35-41.