Lost Use-Value from Environmental Injury When Visitation Drops at Undamaged Sites

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ABSTRACT *We describe welfare calculations when an environmental injury reduces trips to undamaged sites as well as those that were damaged. The welfare loss is (1) underestimated when standard welfare formulas are applied only to damaged sites but (2) overestimated when these formulas are applied to all sites with lost trips. We provide a formula that appropriately accounts for the lost trips to undamaged sites. Differences among the procedures are illustrated through hypothetical scenarios that differ in lost trips to undamaged sites. We apply the method under linear demand to aggregate estimates of shoreline-use losses from the Deepwater Horizon oil spill.* (JEL D61, D81)

1. Introduction

An interesting and important issue for welfare analysis of environmental injury arises when the propagating event causes people to avoid not only the damaged sites but also sites that were not damaged. This phenomenon is not uncommon. During and immediately after the Deepwater Horizon oil spill, for example, many households decided not to take trips to areas along the southern Florida Gulf coast, such as St. Petersburg, where the oil never made landfall. These people's decisions were not irrational: no one knew for sure where the oil would land, and the forecasts that were provided to the public held open the possibility of oiling in many areas (NOAA 2010). Similarly, the 2013 Rim Fire in California's Sierra Nevada Mountains induced visitors to cancel trips to Yosemite Valley even during periods when the fire had no effect there.

The question arises of how to value these lost trips to nondamaged sites. Two procedures can be applied with traditional welfare measures, but neither appropriately handles the issue. The first is to identify the injured sites and calculate the loss in welfare for these sites, using standard formulas for the change in consumer surplus. By this method, no loss is included for sites that were not damaged. However, from an economic perspective, there are clearly welfare losses at undamaged sites insofar as people visited these sites less because they anticipated that the sites would or might be degraded. For example, the people who decided not to go to Yosemite Valley because of the Rim Fire lost the enjoyment of a trip that they would have taken if the fire had not occurred. Similarly, the people who did not take a vacation to St. Petersburg because of the Deepwater Horizon spill lost the welfare that they would have obtained from the trip in the absence of the spill.[1]

The other approach is to apply the standard welfare formulas to all sites that experienced a loss in visitation, rather than just the damaged sites. That is: identify the sites with lost trips due to the event and then calculate the loss in welfare for these sites using standard formulas. This approach has the advantage of including all sites at which some form of welfare loss occurred. However, the standard formulas for loss of use-value (described in more detail below) assume that the people who visited an identified site experienced a loss, in addition to those who decided not to visit the site. This assumption is inappropriate for sites that were not actually damaged: the people who went to these uninjured sites did not incur a loss of welfare. In the context of the Rim Fire, the people who went to Yosemite Val-

[1] Responsibility for this loss might depend on whether the decision not to take the trip was based on reasonable expectations versus unfounded fears. But welfare is lost in either case.

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ley on days when the fire had no effect there did not experience a loss—the valley was as wonderful as ever. The same occurred for the beaches around St. Petersburg after the Deepwater Horizon spill: the number of visitors dropped, but the people who went there anyway enjoyed undamaged beaches. The distinction can be stated more directly as follows. The usual welfare formulas assume that both marginal and inframarginal consumers incur losses, but this overestimates the welfare loss. For undamaged sites, the marginal consumers (those who decided not to take a trip that they otherwise would have taken) were hurt, but the inframarginal consumers (who took trips to these sites) were not affected.

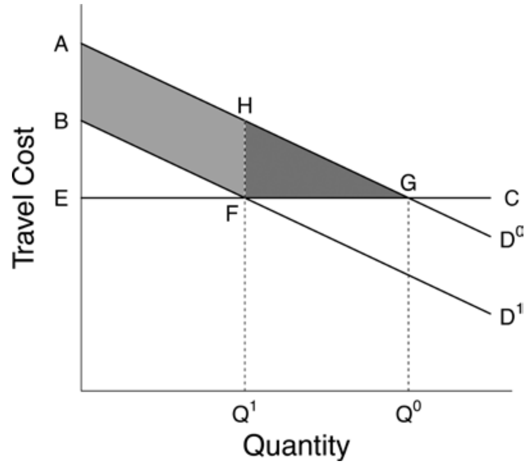
In this paper, we describe and illustrate a method for measuring welfare losses that appropriately accounts for welfare losses at both damaged and undamaged sites. The method is a special case of the more general procedures given by Leggett (2002) and Train (2015) for calculating welfare when anticipated and realized attributes of alternatives differ.[2] Consumers make decisions based on what they expect or anticipate the attributes of sites to be, and then obtain utility based on the attributes that are actually experienced at the chosen site. Our analysis incorporates the distinction between ex ante decisions and ex post welfare, as discussed, for example, by Just, Hueth, and Schmitz (2004).

Below we describe the calculation of welfare losses when households' trip-making decisions are based on the expected or anticipated conditions at sites, but their utility is based on the actual conditions at the visited site at the time of the visit. We illustrate the properties of the method with a site-choice model, by calculating losses for several hypothetical events that differ in the magnitude of the reduction in lost trips and in the distribution of the lost trips over damaged and undamaged sites. We then show how the method can be used to adjust aggregate loss estimates without using the individual-level data on which the aggregate estimates are based, under the assumption of demand being linear in the relevant range. As an example for an actual event, we apply this adjustment to publically available estimates of aggregate use-value losses from the Deepwater Horizon spill.

[2]See also Ben-Akiva, McFadden, and Train's article (2016) and its citations.

Figure 1

Consumer Surplus at Site with Anticipated Oiling



In addition to assisting in the measurement of the welfare impacts of environmental events, the analysis also has implications for the value of information. We provide formulas for the loss in welfare at undamaged sites; this loss occurs because people did not know that the sites were not actually damaged. Informing people of which sites are damaged can eliminate at least some of this loss, and can avoid the loss completely if the information is fully accurate at the time of people's travel decisions. The value of the information is the magnitude of this avoided loss.

2. Specification

To establish concepts, we first consider a situation with one site and linear demand, depicted in Figure 1. When the site is not injured, demand is line D^0, which represents the marginal willingness to pay for trips to the site. Given a cost of C to visit the site, the number of visitors is Q^0 and consumer surplus is the triangle AEG. If the site is damaged, demand (i.e., willingness to pay) drops to line D^1, the number of visitors drops to Q^1, and consumer surplus becomes BEF. The loss in consumer surplus from the site being damaged is the area ABFG (the light gray plus the dark gray shaded areas). This is the usual measure of loss of use-value from site degradation.

Now consider a case in which consumers make their travel decisions based on the expectation that the site will be damaged, but the site ends up not being damaged. Consumer surplus is the difference between the willingness to pay for the site in its undamaged condition, which is given by D^0, and the cost of visiting the site, C, integrated from 0 to Q^1, which is the area AEFH. The consumers who choose not to go to the site because of the expectation of its being damaged lose surplus in the amount of the area of HFG. However, the consumers who go to the site anyway (i.e., the Q^1 visitors) incur no loss. The total loss in consumer surplus is HFG (the dark gray shaded area).

We can generalize this analysis for a standard travel cost model with multiple sites and nonlinear demand. Let J be the set of alternatives, such as the set of sites in a site-choice model conditional on taking a trip, or the set of sites plus the "stay home" alternative in a model of trip generation and destination choice. In the absence of the environmental event, the utility that person n obtains from alternative i is decomposed, in the usual way, into a part that is observed by the researcher and a part that is unobserved: $U_{ni} = V_{ni} + \varepsilon_{ni}$. We assume that the person's assessment of the utility provided by a visit to the site is accurate in the absence of the relevant event (e.g., a spill). This assumption is consistent with standard travel cost models and allows us to focus on only event-induced differences between expectations and realizations. If the unobserved component ε_{ni} is the independent and identically distributed extreme value, then the probability of choosing alternative j is given by the logit formula (McFadden 1974):

$$P_{nj}^0 = \frac{e^{V_{nj}}}{\sum_{i \in J} e^{V_{ni}}}. \qquad [1]$$

Under this demand model, the average surplus that is obtained from this choice over a subpopulation of observationally equivalent people is given by the log-sum formula (Small and Rosen 1981):

$$CS_n^0 = \ln\left(\sum_{i \in J} e^{V_{ni}}\right) / \alpha + K, \qquad [2]$$

where α is the marginal utility of income (i.e., the coefficient of travel cost) and K is a constant of integration.[3]

Now consider an event that damages some sites. Suppose first that the location of the damage is known by the public. The utility that person n obtains from alternative i is denoted $V_{ni} - d_i + \varepsilon_{ni}$, where $d_i = 0$ if site i was not damaged by the event and $d_i > 0$ if site i was damaged. Following common practice, the drop in utility at each damaged site is assumed to be the same for all people; it is estimated by observing the drop in visitation at the site and determining the value of d_i under which the travel cost model predicts this drop in visitation. The probability of choosing alternative j is

$$P_{nj}^1 = \frac{e^{V_{nj} - d_j}}{\sum_{i \in J} e^{V_{ni} - d_i}}. \qquad [3]$$

Consumer surplus becomes

$$CS_n^1 = \ln\left(\sum_{i \in J} e^{V_{ni} - d_i}\right) / \alpha + K, \qquad [4]$$

and the loss of consumer surplus from the event (as given, e.g., by Parsons and Kealy 1992) is

$$\Delta CS_n = \frac{1}{\alpha}\left[\ln\left(\sum_{i \in J} e^{V_{ni}}\right) - \ln\left(\sum_{i \in J} e^{V_{ni} - d_i}\right)\right]. \qquad [5]$$

Suppose now that people expect the damage to occur as described above, but some sites that people expected to be damaged were actually undamaged. Let $k_i = 1$ if people expected site i to be damaged but it was actually undamaged, with $k_i = 0$ otherwise. The probability of choosing each alternative, based on people's expectations, is given by equation [3] above. However, people who go to any of the

[3] The expression for consumer surplus takes different forms in different choice models; see, for example, McFadden (1978, 1981) for nested logit and Train (1998) for mixed logit. The analysis in the current paper is applicable to other models, with appropriate change in the probability and surplus formulas.

sites with $k_i = 1$ obtain greater utility than they had expected. Total consumer surplus in this case is the amount people *expected* to obtain (which is CS_n^1), plus, for each site that people thought was damaged but actually was not, the extra utility that the people who go to the site experience when they discover that the site is not damaged (Train 2015):

$$CS_n^{1*} = CS_n^1 + \sum_{i \in J} k_i \, P_{ni}^1 d_i \,/\, \alpha. \quad [6]$$

The first part of [6] is the consumer surplus that the people would have obtained if their expectations had been realized: the log-sum term based on their expectation that each site i deteriorated by d_i. However, as we have said, the people who go to a given site that was not actually damaged obtain the actual utility from the site, rather than the expected utility. The second part of [6] contains, for each site that is actually undamaged when people expected it to be damaged (such that $k_i = 1$), the difference between the actual and expected utility at that site (which is d_i), for the share of people who choose that site (which is P_{ni}^1).

The loss of consumer surplus from the event is the difference between the original consumer surplus in [2] and the consumer surplus after the event in [6]:

$$\Delta CS_n^* = \Delta CS_n - \sum_{i \in J} k_i P_{ni}^1 d_i \,/\, \alpha. \quad [7]$$

In most applications, the model is calibrated such that the probabilities sum over individuals to the actual number of trips at each site after the event: $\sum_n P_{ni}^1 = Q_i^1$, where Q_i^1 is the number of trips to site i after the event. This condition is met by either (1) determining the number of postevent trips to each site and finding the values of d_i at which the model correctly predicts these numbers,[4] or (2) determining values for the d_i's that represent the expected injury caused by the event and using the demand model with these d_i's to calculate the number of postevent trips at each site. In either case, when the model correctly predicts trips at each site, aggregation of [7] over people gives the aggregate loss as

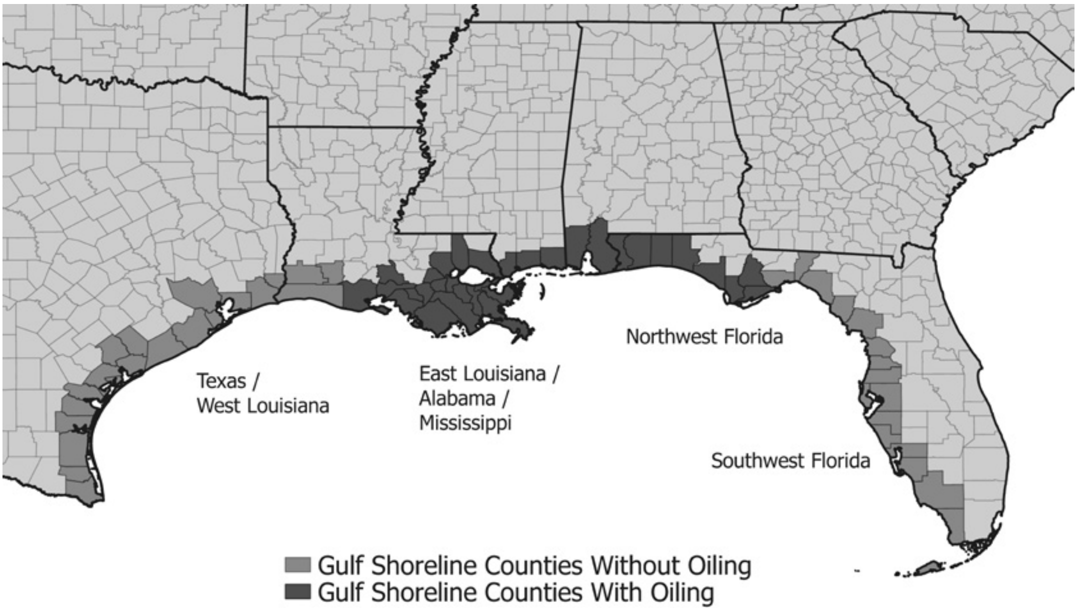
$$AL = \left(\sum_n \Delta CS_n \right) - \left(\sum_{i \mid k_i = 1} Q_i^1 d_i \,/\, \alpha \right). \quad [8]$$

In this formula, $\sum_n \Delta CS_n$ is the traditional measure of aggregate loss, namely, the change in consumer surplus that would occur if the expected change in utility at each site had actually occurred. With a standard logit model, this is the change in log-sum terms from the preevent conditions to the expected postevent conditions. At sites for which $k_i = 1$, the expected injury did not actually occur, and the people who went to these sites after the event did not incur the loss that was expected. The second term in [8] subtracts out the losses that were expected but not realized for the people who visited these sites after the event.

The formula in [8] can be related to Figure 1 for pedagogic purposes, noting that Figure 1 is for linear demand, while formula [8] is usually applied for nonlinear logit demand. In Figure 1, the aggregate loss is the triangle FGH. This loss can be calculated as the area ABFG minus ABFH. Area ABFG is the loss in consumer surplus that would occur if the site was actually injured; it is equivalent to $\sum_n \Delta CS_n^1$ in equation [8]: the traditional measure of loss. Area ABFH is the loss that the Q^1 people who visited the site after the event expected to experience but in fact did not experience. This area is the equivalent of $Q_i^1 d_i \,/\, \alpha$ in equation [8]. It is subtracted from the traditional measure of loss because the loss did not actually occur for these Q^1 people. The only lost surplus that remains is the loss incurred by the people who decided, based on expectations, not to go to a site that ended up not being injured.

[4] In this discussion, we have considered d_i to be the loss in utility that arises from site j being damaged. However, as we are describing here in the text, d_i is often estimated as the change in the site's alternative-specific constant under which the travel cost model correctly predicts the observed drop in visitation at each site. Given this estimation procedure, d_i is actually a measure of whatever people take into consideration when choosing where to travel after the event; this might be the expected reduction in utility over a distribution of possible levels of damage to the site, or an ad hoc uncertainty correction by the decision-maker. In any case, it affects behavior but, as shown in equation [7], is netted out of the loss calculation for sites that did not incur damage.

Figure 2
Map of Shoreline Counties and Oiling in the Gulf of Mexico



3. Comparison of Loss Formulas for Hypothetical Scenarios

We illustrate the differences among the alternative welfare measures by constructing a series of hypothetical situations that represent different percent reductions in number of trips and different distributions of lost trips between damaged and undamaged sites. To facilitate discussion, the setting for the hypothetical situations is made similar to that of the Deepwater Horizon spill, but with different numbers and location of lost trips than actually occurred. In Section 4, we apply the approach for the actual Deepwater Horizon spill, using publically available estimates of losses at sites and an assumption of linear demand.

Figure 2 depicts shoreline counties along the Gulf of Mexico with and without oiling after the spill, as identified by the National Oceanic and Atmospheric Administration (NOAA).[5] To represent the location of oiling in our illustrations, we partition the shoreline counties along the Gulf of Mexico into four segments, whose names are given in Figure 2.

We estimated a standard logit model of destination choice for multiday trips on a sample of households who lived sufficiently far from the Gulf of Mexico that an overnight trip to the Gulf could be expected to have been planned in advance.[6] Each multiday trip that the sampled households took for the purpose of outdoor water recreation over a six-month period was included in the estimation, with the choice set defined as counties in the United States.[7] The estimated model is given in Table 1, with

[5] NOAA's maps are available at https://gomex.erma.noaa.gov. The NOAA maps differentiate sites by the amount of oil that was observed and by the date of the observation, while our Figure 2 ignores these distinctions, differentiating only on the basis of whether any oil was observed at any time covered by the NOAA maps. The welfare formulas described earlier are applicable to more refined differentiation over time and by level of damage, as we discuss briefly in the last section.

[6] This was defined as households living in the continental United States outside of Texas, Louisiana, Arkansas, Mississippi, Alabama, Florida, Georgia, or Tennessee.

[7] The model is for choice of destination conditional on taking a trip, which means that a "no trip" alternative is not included. For models that represent households' choices among alternatives on each choice occasion, which include a "no trip" alternative, the same formulas for loss are applicable, with the log-sum term changed appropriately if the model is nested logit (as described in footnote 3.)

Table 1
Multinomial Logit Model of Site Choice

Variable	Coefficient	Std. Err.
Travel cost	–0.002997	0.000003
Traveler accommodations	0.001929	0.000047
Marinas	0.017766	0.000494
Texas/western Louisiana	1.625088	0.119935
Eastern Louisiana/	1.606578	0.120460
Mississippi/Alabama	1.606578	0.120460
Northwestern Florida	3.012854	0.102829
Southwestern Florida	3.687023	0.060068
South Atlantic	2.429463	0.003009
North Atlantic	2.246683	0.003373
Great Lakes	1.833613	0.003324
Pacific	2.483375	0.004055
Number of households	7,786	
Number of trips	14,277	
Log-likelihood	–85,233.64	

Table 2
Trips by Sampled Households to Gulf Shoreline Counties

Region	Trips
Texas/western Louisiana	63
Eastern Louisiana/Mississippi/Alabama	75
Northwest Florida	111
Southwestern Florida	388

details about the sample and construction of variables given in the appendix.

The estimated travel cost coefficient is –0.002997. By MacNair's approximation (see Ben-Akiva, McFadden, and Train 2016), this estimate implies that the reduction in consumer surplus from environmental damage to a set of sites is about \$334 (=1/0.002997) times the number of lost trips, where "lost trips" is the reduction in trips to these sites that is attributable to the damage. This is an approximation to the change in log-sum term in equation [5] for damage that actually occurs, and is more accurate the smaller the probability of going to the damaged sites. We return to this approximation below, to compare with our exact loss calculations.

We calculate the loss in consumer surplus to the sampled households in five hypothetical scenarios representing different conditions. The sample consists of 7,786 households, and the number of trips made to each of the four Gulf segments is given in Table 2. The losses in all scenarios are calculated for these households with these baseline trips. Table 3 summarizes the results, giving the losses for each scenario calculated under each method.

S1. A hypothetical spill that reduces trips to southwestern Florida beaches by 50% without damage to any sites.

We consider first a hypothetical oil spill that people anticipate might despoil the gulf coast of southwestern Florida, resulting in a 50% reduction in trips to the area, but that does not actually make landfall. As given in Table 2, the sampled households made 388 trips to this area in the original situation (without the spill), such that there are 194 lost trips attributable to the spill. We assume that areas outside of southwestern Florida are not affected: the spill does not, and is not anticipated to, cause damage in these areas. The losses, under any form of measurement, are exclusive to southwestern Florida.

Under the procedure of calculating losses only at sites that are damaged, the welfare loss from this hypothetical spill is zero: no beaches were damaged, which translates, by this procedure, into no calculated losses.

The second approach is to calculate losses for all sites with lost trips using the standard formula that does not differentiate between marginal and inframarginal trips. The site-specific constant for southwestern Florida is adjusted so that the model correctly predicts the loss in trips to this area; this change in the constant is used as d_i for southwestern Florida and $d_i = 0$ for all other i. Inserting these values into equation [5] and aggregated over sampled households, the loss in consumer surplus is \$68,069. This comes to \$351 per lost trip, which is close to the MacNair approximation of \$334. This amount assumes losses both for the people who chose not to visit the sites because of the spill and for people who visited the sites anyway despite the potentially damaged conditions at the beaches.

Finally, consider calculating losses by equation [7], which includes all sites with lost trips but appropriately differentiates between marginal and inframarginal trips. The total

Table 3

Losses (in Dollars) for Hypothetical Scenarios under Each Welfare Loss Calculation Procedure

	Equation [5] on Sites That Were Damaged	Equation [5] on Sites That Lost Trips	Equation [7] on Sites That Lost Trips
S1: 50% lost trips in SW FL but no oiling	0	68,069	20,970
S2: 100% lost trips in SW FL but no oiling	0	133,976	133,976
S3: 5% lost trips in SW FL but no oiling	0	6,900	176
S4: 5% lost trips in SW FL with oiling	6,900	6,900	6,900
S5: 10% lost trips in oiled areas, 5% lost trips in nonoiled areas	6,354	15,006	6,771

loss to the sampled households under this procedure is $20,970, or $108 per lost trip. This is considerably below the $351 per lost trip from the previous calculation because the previous measure inappropriately assumes that each lost trip represents lost surplus for both marginal and inframarginal trips, while equation [7] recognizes that, for the subset of lost trips to nonoiled areas, surplus drops only for the lost trips themselves and not the remaining (inframarginal) trips.

The total loss in consumer surplus in this scenario is about 31% (=20,970/68,069) of the total loss we would expect if the sites were actually damaged. In Figure 1, with linear demand and $Q^1 = 0.5 \times Q^0$, the loss when the site is not oiled is one-third as large as when the site is oiled (see footnote 8). The calculation based on equation [7] is less than that indicated by Figure 1 because the logit demand is slightly convex in the relevant areas rather than linear. The difference is fairly small, with the losses using the logit model being only 7.5% less than if demand were linear in the relevant range. We utilize this point in Section 4.

S2. A hypothetical spill that reduces trips to southwestern Florida beaches by 100% without damage to any sites.

Suppose the situation is the same as above except that visitation is reduced by 100% at the southwestern Florida sites, as would occur if the sites were closed (as given by, e.g., Parsons et al. 2009). In this case, there are no inframarginal consumers, and so the welfare loss by equation [7] is the same as by [5]. Under the first approach, where losses are calculated only at damaged sites, the estimated loss is zero. Under the second approach, where losses are calculated at the sites with lost trips using the traditional formulas, the estimated loss is $133,976. Note that this loss is obtained in [5] by raising d_i sufficiently for the southwestern Florida sites to choke off demand to those sites, or, equivalently, by eliminating the sites from the summation in the log-sum term. The loss by [7] is the same as by [5] because the probability of going to a southwestern Florida site after the spill is zero.

S3. A hypothetical spill that reduces trips to southwestern Florida beaches by 5% without damage to any sites.

Consider now the same situation as scenario S1, but with only 5% lost trips instead of 50%. The loss under the first approach is $0, since none of the sites were damaged. Under the second approach, using equation [5] on sites with lost trips, the lost surplus is $6,900, which assigns losses to inframarginal visitors to undamaged sites even though they incurred no loss. Using equation [7], the total loss is $176. The loss under equation [7] is now only 2.55% of that under equation [5], which is much smaller than the 31% that we obtained with 50% lost trips. The reason is clear: with only 5% lost trips, a large portion of the calculated loss under the traditional equation [5] is attributable to inframarginal trips that do not actually incur a loss.[8]

[8] With linear demand as in Figure 1, the ratio of lost surplus under the two calculations is $(L \times 0.5)/[1 - (L \times 0.5)]$, where L is the share of trips lost because of the spill. When $L = 0.50$, the ratio of damages under the alternative formulas is 0.25/0.75 = 1/3: one-third of the estimated losses from

S4. A hypothetical spill that makes landfall in southwestern Florida and reduces trips by 5% without damage to other sites.

Consider now the same situation as above, but in this case the oil does make landfall in southwestern Florida. As in scenario S2, trips to southwestern Florida are reduced by 5%, while no other areas are affected. Under this scenario all three approaches to calculating damage produce the same estimate of damages. Applying equation [5] only to damaged sites (southwestern Florida) produces a total loss of $6,900. Under the second approach, using equation [5] on all sites with lost trips, the total loss is identical, since all of the lost trips were to damaged sites. The loss under equation [7] also equals $6,900, since $k_i = 0$ for all i.

S5. A hypothetical spill that makes landfall in some Gulf areas and reduces trips throughout the Gulf.

Consider a spill that, at the time people are making their travel plans, might hit any of the beaches along the Gulf coast but ends up making landfall in eastern Louisiana, Mississippi, Alabama, and northwestern Florida, but not Texas, western Louisiana, or southwestern Florida. Assume a 10% reduction in trips to areas that were oiled and a 5% reduction in trips to the Gulf areas that were not oiled. This scenario follows the pattern of oiling shown in Figure 2 but does not represent the actual numbers of lost trips from the Deepwater Horizon spill.

Under the first procedure, lost consumer surplus is calculated only for the sites that were oiled. The change in the constants for eastern Louisiana, Mississippi, Alabama, and northwestern Florida are determined that provides a 10% reduction in trips to each of these areas. Equation [5] is applied to these sites, with d_j equal to these calibrated changes in constants and zero for all nonoiled sites. The total loss for the sampled households is calculated to be $6,354. There are 19 lost trips, such that the loss in consumer surplus per lost trip is $334, which matches the MacNair approximation of $334 from our travel cost model's trip cost coefficient.

Under the second procedure, we apply equation [5] for all sites with lost trips, whether or not the site was actually damaged, with d_j equal to the calibrated changes in constants for all sites with lost trips and zero for all sites without lost trips. Total loss in consumer surplus is $15,006 for the sampled households. There are 41 lost trips, such that the loss is $366 per lost trip. This is a bit further from the MacNair approximation than in the first calculation. The reason is due to the properties of the approximation: its accuracy rises as the probability of visiting the damaged sites decreases. In the current calculation, more sites are considered to be affected than in the previous calculation, such that the probability of visiting affected sites rises and the accuracy of the approximation drops.

Third, we apply equation [7], which accounts for lost trips at all sites but recognizes that the oil did not actually make landfall in Texas, western Louisiana, or southwestern Florida. The loss in consumer surplus is $6,771, which is $165 per lost trip.

4. Adjustment to Aggregate Estimates Assuming Linear Demand

With linear demand as in Figure 1, the ratio of lost surplus under [7] compared to [5] is $(L \times 0.5)/[1 - (L \times 0.5)]$ where L is the share of trips lost because of the spill. This fact can be used to approximate the lost surplus in [7], given results that were generated by [5] (or the analogue to [5] if a model other than logit was used), along with information on the percent reduction in trips to undamaged sites.

We apply this method to publically available estimates of aggregate lost use-value for the Deepwater Horizon spill. The data underlying the individual-level calculation of these

equation [5] represents losses from marginal trips (i.e., due to the trips not being taken to the sites) and the other two-thirds constitutes losses from inframarginal trips (trips that were taken anyway.) When $L = 0.05$, the ratio is much smaller: $0.025/0.975 = 0.0256$. With $L = 0.05$, the vast majority of loss in surplus under the traditional measure constitutes losses to people who went to the beaches anyway.

loss estimates have not yet been made public. The approximation based on linear demand is therefore useful in this case.

The government trustees and their team of researchers have estimated the human use losses from the Deepwater Horizon spill and have described their methods and results in a series of technical papers that they have made publically available.[9] For the period June 2010 to January 2011, separate estimates of shoreline-use losses were calculated for the northern Gulf (consisting of Louisiana, Mississippi, Alabama, and the Florida panhandle) and for the Florida peninsula (consisting of the coast of Florida from the panhandle to the keys).[10] The losses were calculated by the nested logit equivalent to equation [5], as described by English and McConnell (2015). For the northern Gulf, the shoreline-use losses were estimated at \$260 million from a 45.2% decline in trips during this period. For the Florida peninsula, the losses were estimated at \$159 million from a 22.2% decline.[11] In both calculations, the same percent decline in trips was applied to each site within the area in each month.

As shown in Figure 2, sites in the northern Gulf were oiled, but the Florida peninsula coast was not. The trustees' estimates embody the first and second methods: applying the traditional welfare formula to sites that were injured, the loss is estimated at \$260 million; and applying the traditional formula to sites with lost trips (whether injured or not), the loss is estimated at \$419 million (\$260 million from the northern Gulf plus \$159 million from the Florida peninsula).

Since the Florida peninsula sites did not end up being damaged, the people who went to those sites during the period June 2010 to January 2011 did not incur a loss, but the people who decided not to go to the sites lost the surplus they would have gained by going. Given a 22.2% decline in trips during this period at Florida peninsula sites, the trustees' estimate of \$159 million translates, under linear demand, into \$20 million in estimated losses, accounting for the fact that the sites were not damaged. These are the losses incurred by people who decided not to use the shoreline after the spill. The remaining \$139 million of the trustees' estimate is attributable to losses that were expected for people who went to the Florida peninsula, but ended up not being realized.

Combining the northern Gulf estimate of \$260 million with the adjusted estimate of \$20 million for the Florida peninsula gives \$280 million in total. This figure is between the estimates based on traditional formulas at injured sites only (\$260 million) and at all sites with lost trips (\$419 million.)

The differences among the estimates are fairly large, which suggests the importance, when estimating the recreational losses from an event, of correctly accounting for sites that were not damaged but experienced a reduction in visitation. However, the differences are small in relation to the \$8.8 billion settlement for the natural resource damages of the Deepwater Horizon spill.[12] It is doubtful, therefore, that the method for handling undamaged sites with lost trips would have had much of an impact on the final outcome of this case.

5. Discussion

In our calculations we have assumed that each site was either damaged or undamaged, but the method described by equation [7] can readily account for the timing of the damage at each site. For example, a site might have incurred damage on day *X* and have been restored to its

[9] The complete administrative record for the Deepwater Horizon spill is available at www.doi.gov/deepwater horizon/adminrecord. Materials covering damages related to lost human use are available in section 5.10.

[10] Shoreline-use losses were also estimated separately for the northern Gulf for February–November 2011, for the northern Gulf and Florida peninsula for May 2010, and for hours before 10 a.m. during the period June 2010–January 2011 (which had not been included in the trip counts for the estimates reported in the text above). However, there is not sufficient information provided in the public documents to adjust these estimates for the inframarginal trips to undamaged sites.

[11] The dollar loss estimates are given by English and McConnell (2015). The percent reduction in trips is given by Tourangeau and English (2015).

[12] A description of the settlement is available at www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan/. Materials covering recreational losses in the settlement are available in section 4.10.

original condition by day *Y*. Lost trips (if any) before day *X* and after day *Y* would be handled by equation [7], and lost trips between days *X* and *Y* would be handled by equation [5], with "lost trips" defined as the trips not taken because of the event. The data requirements become more challenging, but the concepts are straightforward.

A more difficult issue is the relation of expectations to realizations. We have examined the situation where people expected undamaged sites to be damaged. The people who went to these sites anyway were pleasantly surprised, and those who did not go to these sites because of the anticipated damage lost an enjoyable experience. The opposite could also occur: people could go to a site expecting it to be the same as usual, only to find that it has been damaged; some of them would not have taken the trip if they had known the conditions. The framework of this paper is also applicable to this latter situation, as well as to more general relations between anticipated and realized utilities. The main challenge is empirical, in identifying expectations and realizations, and their relation to utility.

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