CHAPTER 8
LOWER-BOUND ESTIMATES OF 1998 DAMAGES

8.1   INTRODUCTION

This chapter presents lower bound estimates of per fishing day and 1998 aggregate damages resulting from FCAs in the waters of Green Bay. Damages are measured in terms of what an angler would be willing to pay for the absence of FCAs.

In Section 8.2 we introduce two per-day WTP measures: WTP per fishing day and WTP per Green Bay fishing day; we relate them to annual damages per angler and provide estimates of these fishing measures (see also Appendix C). Section 8.3 calculates the 1998 annual damages for open-water fishing in the Wisconsin waters of Green Bay for our target population using the two per fishing day damage measures and estimates of 1998 fishing days for our target population. Section 8.4 applies benefits transfer methods to select per fishing day values for ice fishing in the Wisconsin waters of Green Bay by our target population and for fishing days in the Michigan waters of Green Bay, and computes 1998 annual damages for these fishing activities.

The damage estimates provided in this chapter are lower bound estimates. The per day estimates are for current Green Bay anglers and reflect reduced enjoyment when visiting Green Bay and the substitution of fishing days from Green Bay to other fishing sites, but do not account for the fact that these anglers may increase their total number of fishing days (to all sites and to Green Bay) in the absence of FCAs. The aggregate estimates omit Green Bay anglers who purchase their Wisconsin fishing licenses outside of the eight targeted counties, and omit damages to individuals who do not fish at Green Bay at all because of the FCAs.

8.2   *WTP* PER YEAR, PER FISHING DAY, AND PER GREEN BAY FISHING DAY

Concepts

In this section we define two per day fishing WTP measures, one that applies to Green Bay fishing days and one that applies to all fishing days (including days at Green Bay and all other sites), and two comparable lower-bound estimates of yearly damages for an angler's WTP^Y.

WTP per Green Bay fishing day, WTP^G, is how much an angler would pay per Green Bay fishing day for the absence of injuries. WTP^G multiplied by the angler's current number of open-water Green Bay fishing days (with injuries), D^G, is a lower-bound estimate of that angler's annual

willingness-to-pay, WTP^Y, for the absence of injuries. It does not account for the possibility that absent injuries, the angler might want to fish Green Bay more. Denote this lower-bound estimate of an angler's yearly damages, WTP^{Y_G}, where $WTP^{Y_G} = WTP^G \times D^G \leq WTP^Y$.

WTP per fishing day, WTP^F, is how much an angler would pay per fishing day, not just per Green Bay fishing day, for the absence of injuries to Green Bay. WTP^F multiplied by the angler's current total number of open-water fishing days (with injuries), D^F, is also a lower-bound estimate of WTP^Y, but includes more of the damages than does WTP^{Y_G}. Denote this second lower-bound estimate of yearly damages, WTP^{Y_F}, where $WTP^{Y_F} = WTP^F \times D^F \leq WTP^Y$ and $WTP^{Y_G} \leq WTP^{Y_F} \leq WTP^Y$.

When Green Bay is improved there are two ways an angler can increase his number of Green Bay fishing days: he can hold total fishing days constant but increase the proportion of those days to Green Bay, or he can both increase total fishing days and increase the proportion of those days to Green Bay. Unlike WTP^{Y_G}, WTP^{Y_F} incorporates the possibility that with the absence of injuries the proportion of fishing days the angler takes to Green Bay might increase, so $WTP^{Y_F} \geq WTP^{Y_G}$. WTP^{Y_F} is still a lower-bound estimate of WTP^Y because it does not account for the possibility that the angler might fish more in total if Green Bay were not injured.

Looking ahead, $WTP^F \leq WTP^G$, even though $WTP^{Y_F} \geq WTP^{Y_G}$; this is because WTP^F applies to all fishing days, whereas WTP^G applies to only Green Bay fishing days. An angler will pay no more per fishing day to have the FCAs at Green Bay removed than he would pay per Green Bay fishing day, because all fishing days are not necessarily to Green Bay.

Estimates

WTP^G is how much the utility from a Green Bay fishing day would increase if there were no FCAs, converted into dollars by dividing this increase in utility by the marginal utility of money. In the primary model, preferences are assumed not to vary across anglers, so WTP^G is the same for all anglers.[1]

Based on the parameter estimates reported in Appendix B (and discussed in Appendix B and Chapter 7), WTP values are reported in Table 8-1 for changes in FCA levels and changes in catch rates. $\widehat{WTP}^G$ (the estimated value of WTP^G) for reducing FCAs from FCA Level 4 to FCA Level1 (no FCAs) is $9.75; that is, $9.75 for every Green Bay fishing day. For comparison, $9.75 is 13% of the average reported cost of a Green Bay fishing day. The 95% confidence interval on the $9.75 estimate is $8.06 to $11.73.

FCA Level 4 represents FCAs by species that are equal to or less stringent than current levels (see the "Fish Consumption Advisory" subsection of Section 5.4.1 in Chapter 5), so $9.75 is a

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1. In Appendix D, we consider preference heterogeneity.

conservative estimate of the WTP^G for eliminating the need for FCAs. $\widehat{WTP}^G$ for reducing FCAs from Level 3 to Level 1 (no FCAs) is \$4.86. For reducing FCAs from FCA Level 2 to no FCAs, it is \$1.81. These latter estimates can be used to estimate damages after partial cleanup.

The value for FCA Level 6 is smaller than for both FCA Levels 4 and 5. Compared to FCA Level 4, FCA Level 6 has a less severe restriction on perch but a more stringent restriction on trout/salmon (see Table 5-3). Here, the perch restriction is likely to apply to more anglers, but the increased trout/salmon restriction of "do not eat" can be expected to be very bothersome, and thus these two changes roughly cancel. Compared to FCA Level 5, FCA Level 6 has a less severe restriction on walleye, but a more stringent restriction on trout/salmon. Because more anglers cited that they "often" or "always" target walleye than trout/salmon (Section 4.2 and Figure 4-2), it is not surprising that the values are larger for FCA Level 5 than for FCA Level 6.

One could offset the current damages from the FCAs with improved catch rather than money. The model estimates indicate that to do this, catch rates for all four species would have to increase by 61%. Note that increasing all catch rates by 61% would not compensate for past damages.

WTP^F is how much the utility from an average fishing day would increase if there were no Green Bay FCAs, converted into dollars by dividing the increase in utility by the marginal utility of money. Based on the parameter estimates reported in Appendix B (and discussed in Appendix B and Chapter 7), $\widehat{WTP}^F$ for reducing FCAs from Level 4 to Level 1 (no FCAs) is \$4.17; that is, \$4.17 for every fishing day.[2] Remember that \$4.17 applies to all fishing days, not just Green Bay fishing days, so it is less than $\widehat{WTP}^G$, which is \$9.75. The 95% confidence interval on the \$4.17 estimate is \$3.41 to \$5.00. As noted in Chapter 2, there are a number of studies that have estimated WTP per fishing day for reductions in FCAs and contaminants at different sites and for different species (see Table 2-13). The value of \$4.17 falls within the range in the literature. Values of $\widehat{WTP}^F$ for different resource changes are also reported in Table 8-1.

$\widehat{WTP}^F$ for reducing FCAs from FCA Level 3 to no FCAs is \$2.15, and for reducing FCAs from FCA Level 2 to no FCAs is \$0.82. Per fishing day values for 10% and 100% increases in catch rates from current levels are reported in Table 8-1. Note that these values apply to all anglers taking trips to the Wisconsin waters of Green Bay, not just to the anglers targeting these species.

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2. WTP^F is an increasing function of catch rates. The \$4.17 estimate is based on 1998 Green Bay catch rates. Historically, catch rates were better for all species. If instead the 13-year average catch rates from 1986 to 1998 are used, $\widehat{WTP}^F$ increases by 16%. WTP^G is not a function of catch rates. Thus, WTP^F should be relied on for the assessment of how catch rates affect FCA values. Therefore, using the 1998 damage estimate as a basis for past damages will understate past damages.

Table 8-1
WTP per Green Bay Fishing Day and per Fishing Day[a,b]

Resource Change	$W\hat{T}P^G$	$W\hat{T}P^F$
FCA Value		
FCA Level 9 → FCA Level 1	$21.71 [$19.00 - $24.81]	$8.52 [$7.48 - $9.50]
FCA Level 8 → FCA Level 1	$19.78 [$17.42 - $22.14]	$7.87 [$6.96 - $8.83]
FCA Level 7 → FCA Level 1	$14.32 [$12.35 - $16.41]	$5.92 [$5.15 - $6.84]
FCA Level 6 → FCA Level 1	$9.91 [$8.14 - $11.81]	$4.23 [$3.54 - $5.02]
FCA Level 5 → FCA Level 1	$11.22 [$9.71 - 13.26]	$4.75 [$4.01 - $5.57]
FCA Level 4 → FCA Level 1[c]	**$9.75** [$8.06 - $11.73]	**$4.17** [$3.41 - $5.00]
FCA Level 3 → FCA Level 1	$4.86 [$3.40 - $6.32]	$2.15 [$1.57 - $2.79]
FCA Level 2 → FCA Level 1	$1.81 [$0.46 - $3.18]	$0.82 [$0.19 - $1.51]
FCA Level 4 → FCA Level 1		
(13-year average catch)[d]	$9.75 [$8.15 - $11.39]	$4.83 [$3.99 - $5.84]
Catch Values[e]		
Yellow perch		
– 10% increase	$0.74 [$0.62 - $0.87]	$0.30 [$0.25 - $0.35]
– 100% increase	$3.72 [$3.13 - $4.27]	$1.52 [$1.29 - $1.75]
Trout/salmon		
– 10% increase	$0.77 [$0.53 - $0.99]	$0.31 [$0.23 - $0.40]
– 100% increase	$3.84 [$2.71 - $5.03]	$1.57 [$1.13 - $2.04]
Walleye		
– 10% increase	$0.40 [$0.33 - $0.47]	$0.16 [$0.13 - $0.19]
– 100% increase	$1.98 [$1.64 - $2.34]	$0.80 [$0.65 - $0.95]
Smallmouth bass		
– 10% increase	$0.65 [$0.52 - $0.80]	$0.26 [$0.20 - $0.32]
– 100% increase	$3.24 [$2.63 - $4.01]	$1.32 [$1.06 - $1.65]
All species at once		
– 10% increase	$2.56 [$2.23 - $2.92]	$1.04 [$0.91 - $1.18]
– 100% increase	$12.79 [$11.33 - $14.50]	$5.58 [$4,95 - $6.29]

a. Catch times are set at 1998 levels: perch – 0.75, trout/salmon – 19.4, walleye – 7.4, bass – 15.0.
b. Simulated 95% confidence intervals approximated using Krinsky-Robb procedure with 500 draws in brackets.
c. Bold entry represents the 1998 advisory levels.
d. Average catch times from 1986 to 1998: perch – 0.52, trout/salmon – 7.8, walleye – 6.9, bass – 5.0.
e. Catch rate is inverse of catch time. Computed with FCA level set at 4.

These values follow the pattern for the FCA values, with WTP^G slightly more than double the values for WTP^F. The values for increases in catch reflect the model assumption of decreasing marginal utility of increasing catch (because catch time in the utility function is the reciprocal of the catch rate).[3] The values for a 100% increase in catch rates are about five times the values for a 10% increase in catch rates. The values in Table 8-1 are comparable to the values for the most similar resource changes as reported in the literature [Table 2-14, see Samples and Bishop (1985), Milliman et al. (1992), and Chen et al. (1999)].

Next we compare the two lower-bound annual damage measures on a per angler basis, for which we use the scenario of a reduction in FCAs from Level 4 (current) to Level 1 (no FCAs). The annual value for Green Bay fishing days is WTP^{Y_G} = \$9.75 per Green Bay fishing day × 5.25 Green Bay fishing days = \$51.19 per Green Bay open-water angler. The annual value for all fishing days is WTP^{Y_F} = \$4.17 per fishing day × 13.19 fishing days = \$55.00. As noted above, while $\hat{WTP}^G > \hat{WTP}^F$, the annual damages per angler are reversed with WTP^{Y_F} about 7% larger than WTP^{Y_G}.

8.3 TWO LOWER-BOUND ESTIMATES OF TOTAL 1998 DAMAGES FOR OPEN-WATER FISHING IN THE WISCONSIN WATERS OF GREEN BAY

Annual total damages equal the estimate of total fishing days (either to Green Bay or to all sites) times the corresponding per fishing day damage estimate. These are lower-bound estimates because the damage per day values are lower-bound estimates. First we provide estimates of total fishing days, then we provide estimates of total damages. As noted above, the estimates in this section pertain only to open-water fishing by anglers who are active in Green Bay fishing and who purchased their Wisconsin fishing licenses in eight counties near to Green Bay.

Estimated Open-Water Fishing Days

An estimate of total 1998 Green Bay open-water fishing days by those who purchased licenses in one the eight counties is computed by multiplying the number of these anglers by the estimated mean number of open-water Green Bay fishing days, which is 5.25; its confidence interval is 4.67 to 5.82. The estimate of total 1998 open-water fishing days by these Green Bay anglers is obtained by multiplying the number of these anglers by their estimated mean number of fishing days, 13.19; its 95% confidence interval is 12.18 to 14.20.

The number of anglers who purchased licenses in the eight counties and actively fished Green Bay in 1998 was estimated using county data from WDNR on the number of licenses sold in 1997. Each resident fishing license, sportsman license, nonresident fishing license, nonresident 15-day

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3. If a linear relationship were assumed instead, values for small changes in catch rates would be smaller, and values for large changes in catch rates would be larger.

fishing license, and patron license is counted as one angler. Each resident husband-and-wife fishing license, nonresident family fishing license, and nonresident family 15-day fishing license is conservatively counted as two anglers.[4] Finally, each two-day sports license and nonresident 4-day fishing license is conservatively counted as half an angler (i.e., it is assumed each angler purchasing these licenses purchases two on average) because it would not be cost-effective for an individual to buy more than two of these types of licenses (on the other hand, assuming they purchase fewer than two two-day licenses would result in more anglers and higher damages). Given these definitions, in 1997 154,783 anglers purchased their licenses in one of the eight counties (Appendix F, Table F-8). The number of anglers in 1998 is assumed to be the same because 1998 license data are currently unavailable.

Some of these anglers do not fish Green Bay. Based on the telephone screener, the percentage of license holders in the targeted counties that fished Green Bay in 1998 is 31.4% with a 95% confidence interval of 29.6% to 33.2%. Applying 31.4% to the total number of anglers, we estimate that in 1998 approximately 48,602 anglers purchased their license in one of the eight counties and fished Green Bay, which has a 95% confidence interval of 45,877 to 51,327.

Multiplying 48,602 anglers by the estimated mean Green Bay open-water fishing days of 5.25, we estimate that in 1998 there were approximately 255,160 Green Bay open-water fishing days by anglers who purchased their licenses in one of the eight counties. The 95% confidence interval is 224,000 to 287,000. Multiplying 48,602 anglers by the estimated mean total open-water fishing days of 13.19, we estimate approximately 641,060 total open-water fishing days by anglers who purchased their license in one of the eight counties and who fished Green Bay. The confidence interval on this estimate is 580,000 to 702,000.

Annual Open-Water Fishing Damages in Wisconsin Waters of Green Bay

$\hat{WTP}^G$ multiplied by the current number of open-water Green Bay fishing days in 1998 by Green Bay anglers who purchased their licenses in one of the eight counties is a lower-bound estimate on aggregate damages for this group. We estimate in 1998, this group of anglers fished the open waters of Green Bay 255,160 days, so a lower-bound estimate of 1998 damages to this group is $2.49 million ($9.75 × 255,160). The confidence interval on this estimate is $1.93 million to $3.05 million.[5]

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4. It would not be cost-effective to purchase one of these licenses unless two individuals intended to fish.

5. Confidence intervals for aggregate annual damages are approximated assuming the percentage of licensed anglers active at Green Bay, the mean number of days, and estimated *WTP* are uncorrelated random variables. The separate confidence intervals for all of these variables are reported throughout this chapter. The number of license holders is not assumed to be random, and the product of these variables gives aggregate damages. The confidence intervals for aggregate damages (and aggregate days later in the chapter) are approximated using asymptotic variances.

$\hat{WTP}^F$ multiplied by the total number of fishing days in 1998 by Green Bay anglers who purchased their licenses in one of the eight counties is another lower-bound estimate on aggregate damages for this group. We estimate that in 1998 this group of anglers fished a total of 641,060 days on open water, so a second lower-bound estimate of 1998 damages to this group is $2.67 million ($4.17 × 641,060). The confidence interval is $2.13 million to $3.22 million. It is larger than the other lower-bound estimate because it accounts for the possibility that anglers might spend a larger proportion of their fishing days at Green Bay if it were not injured.

8.4 BENEFITS TRANSFER TO ESTIMATE THE DAMAGES ASSOCIATED WITH THE GREEN BAY ICE FISHERY AND THE MICHIGAN GREEN BAY FISHERY

The benefits transfer approach involves estimating damages for an assessment area by using values derived from the application of primary economic methods in other studies, rather than collecting primary valuation data for the assessment area. In this section, we will apply the unit value method, a benefits transfer approach identified in the U.S. DOI regulations [43 CFR § 11.83 (c)(2)(vi)], to value damages from PCBs and resultant FCAs to ice-fishing days in the Wisconsin waters of Green Bay, and all fishing days in the Michigan waters of Green Bay.

There are two sites involved in a benefits transfer: the targeted site (to which values will be transferred) and the study site (where a primary study of damages has been completed). To assess the suitability of the benefits transfer approach we must compare the targeted site to the study site and consider three questions: are the sites similar, are the populations similar, and are the changes being valued similar?[6] Our primary study site is the Wisconsin waters of Green Bay, our population is Green Bay anglers who purchased their licenses in one of the eight counties, and the change being valued is a reduction in PCBs and resultant removal of FCA restrictions.

Ice Fishing on the Wisconsin Waters of Green Bay

The first transfer of values is to ice-fishing days on the Wisconsin waters of Green Bay. The site is very similar to the study site as it is the exact same location, but at a different time of year. Yellow perch dominates Green Bay ice fishing as it does the open-water fishing, accounting for 90% of the ice-fishing catch in 1998 (WDNR creel). Other species caught are walleye, burbot, and northern pike.

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6. For an overview of the benefits transfer technique see Brookshire and Neill (1992), Boyle and Bergstrom (1992) and Desvouges et al. (1992), all in a special section of *Water Resources Research* devoted to benefits transfer.

The ice-fishing anglers are very similar to the open-water anglers. From our telephone survey we found that 73% of the anglers who ice fished on Green Bay in 1998 also fished the open waters of Green Bay in 1998. Green Bay open-water anglers who also ice fish in the waters of Green Bay are slightly more avid about ice fishing than anglers who only ice fish (averaging 6.4 Green Bay ice-fishing days, SE=0.56, compared to 5.4 Green Bay ice-fishing days, SE=0.72). Therefore, Green Bay open-water anglers in the target population account for about 76% of the ice-fishing days.

The change being valued is the same for the primary study and the targeted area, as FCAs for ice fishing on the Wisconsin waters of Green Bay are the same as those for open-water fishing on the Wisconsin waters of Green Bay.

As such we can apply the estimated WTP per Green Bay fishing day for open-water days, $9.75, to the number of Green Bay ice-fishing days. From our telephone survey we found that Green Bay ice-fishing days were equivalent to 18.24% of Green Bay open-water fishing days for all anglers who had open-water or ice fished on Green Bay in 1998.[7] Our estimate of Green Bay fishing days for 1998 is 255,160. Multiplying this by 18.24% we get an estimate of 46,541 Green Bay ice-fishing days.

Thus, a lower-bound estimate of the 1998 damages associated with the injuries the Wisconsin Green Bay ice fishery for our target population from PCBs and the resultant FCAs is $0.454 million ($9.75 times 46,541 Green Bay ice-fishing days).

All Fishing in the Michigan Waters of Green Bay

The second transfer of values is to the Michigan Waters of Green Bay. This site is very similar to the study site as they are both portions of Green Bay. They share a similar mix of species, with yellow perch, walleye, and trout/salmon making up at least 95% of the Michigan Green Bay fishery (see Section 2.1 for more detail).

The individuals using the fishery are also similar. As discussed in Chapter 3 we expect the fishing in Green Bay to be a fairly localized activity, and that most Michigan Green Bay angling would be done by anglers in nearby counties. Therefore most of the anglers live in a similar region. Comparing the Wisconsin and Michigan counties that surround Green Bay we find similar socioeconomic characteristics, with Michigan having a somewhat higher unemployment and lower per capita income (see Table 8-2).

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7. We use the ratio from the telephone survey because the Green Bay ice-only anglers are not included in the followup mail survey. Note also that by using a ratio, the recall, nonresponse, and sampling bias adjustments are carried forward to the ice-fishing damage calculation.

Table 8-2
Comparison of Wisconsin and Michigan Counties near Green Bay

	Population (7/1/1998)	Percent over 65 Years (1995)	Percent over 25 Years (1990)	Percent High School Grads over 25 (1990)	Percent College Grads over 25 (1990)	Percent Unemployed (1994)	Per Capita Personal Income (1993)
6 Michigan counties near Green Bay[a]	170,746	15%	64%	78%	14%	8%	$16,539
8 Wisconsin counties near Green Bay[b]	727,752	13%	63%	78%	16%	5%	$19,509

a. Alger, Delta, Dickinson, Marquette, Menominee, and Schoolcraft.
b. The eight targeted counties.

Source: U.S. Census Bureau website http://www.census.gove/statab/USA96/.

The Michigan change being valued is different from Wisconsin because FCAs are less restrictive in the Michigan waters of Green Bay. Current levels of FCAs in the Michigan waters of Green Bay are closest to our Level 2 for the general population, and our Level 4 for women who are pregnant, nursing, or expect to bear children, and for children (hereafter, when we refer to FCAs for women, we refer specifically to this subset of women).

FCA Level 2 allows unlimited consumption of yellow perch and smallmouth bass and restricts trout/salmon and walleye to no more than one meal a week. The Michigan advisory for the general population (see Table 2-10) allows unlimited consumption for yellow perch and smallmouth bass, and has a range of restrictions for trout/salmon and walleye from unlimited for chinook salmon and smaller sizes of brown trout and walleye, to do not eat for larger sizes of brown trout and walleye.

FCA Level 4 allows one meal a week for yellow perch, and one meal a month for all other species. The Michigan advisory for women and children allows one meal a week for perch, one meal a month for smallmouth bass, and a range of one meal a week to do not eat for trout/salmon and walleye, dependent on the part of Green Bay and size of fish (one meal a week applies only for walleye and rainbow trout less than 18"). Based on the average size of fish caught in Lake Michigan (Appendix F, Table F-7) the "eat no more than one meal a week" advisory could apply to as much as one-half of the fish caught and kept.

From our primary study, the estimated *WTP* per Green Bay fishing day for a reduction from FCA Level 2 to no FCAs is $1.81, and from FCA Level 4 to no FCAs is $9.75.

The women and children advisories could be a concern to male or female anglers with household members for whom the advisories apply. From our survey we find that about 45% of anglers are of an age most likely associated with having and raising small children: 18 to 40 years old. In fact, about 28% of our sample of anglers are age 18 to 40 and have at least one household member who is less than 16 years old, and thus may be concerned with the advisories aimed at women and children. To be conservative, we assume that 14% of the fishing days (half of the 28% of anglers) are by anglers for whom the women and children advisory would be a concern. This reflects that in some of these households the children may be older and no additional children are expected, and that fish may be consumed in different amounts by different household members. Therefore, we select an average *WTP* per Green Bay fishing days for the absence of PCBs on the Michigan Waters of Green Bay of $2.92 (14% times $9.75 plus 86% times $1.81).

Comparing the WDNR and MDNR creel surveys we found that all fishing on the Michigan waters of Green Bay was equivalent to 58.83% of the March to December fishing on the Wisconsin waters of Green Bay in 1998 (see Table 2-1). Therefore we estimate that there were 150,103 days on the Michigan waters of Green Bay (58.83% times 255,160 Wisconsin Green Bay days).

Thus, a lower-bound estimate of the 1998 damages associated with the Michigan waters of Green Bay from PCBs and the resultant FCAs is $0.438 million ($2.92 times 150,103 Michigan Green Bay fishing days).