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Estimating Post-Harvest Benefits from Increases in Commercial Fish Catches with Implications for Remediation of Impingement and Entrainment Losses at Power Plants

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Estimating Post-Harvest Benefits From Increases in Commercial Fish Catches with Implications for Remediation of Impingement and Entrainment Losses at Power Plants[1]

by

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Abstract

A variety of regulations may affect commercial fish catches. We take here as a case in point steps to reduce losses of aquatic organisms due to impingement and entrainment (I&E) at power plants. Methods to evaluate the benefits of such measures are needed for benefit-cost analysis. We use a new approach to estimating ex vessel demand by Holt and Bishop (2002) to address the portion of the benefits that occur post-harvest, that is, down the marketing chain after fishermen sell their catches. The model deals with the dockside prices and quantities for six major commercial species harvested from the U.S. Great Lakes. We use the model to explore the potential magnitude of post-harvest benefits for Great Lakes fisheries. We then turn to a possible approach to benefits transfer for cases where such a model is not available. A semi-realistic case example involving I&E losses to Great Lakes fisheries illustrates how benefits transfer would work.

Introduction

When fish catches increase as a result of regulations, benefits may accrue through the production and marketing chain that begins with those who supply inputs to fishermen and ends with final consumers. This paper is concerned with methods of measuring the *post-harvest* welfare effects that may accrue to fish wholesalers, retailers, and final consumers. Using a model of ex vessel fishing demand by Holt and Bishop (2002), we explore potential methods of estimating these effects for Great Lakes fish and draw implications for benefits transfer.

The analysis is motivated in part by a real world policy issue. Changes in cooling water intake structures and other steps at power plants can reduce impingement and entrainment of aquatic organisms (hereafter referred to I&E losses) at power plants, but at a cost. Reducing I&E losses could have many benefits, including the benefits associated with increased commercial fish harvests.

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At the outset, we will examine post-harvest benefits in a simple conceptual model that will help us account for a full set of commercial use benefits and provide a context for the rest of the paper. Then we will turn our attention to possible empirical methods for estimating post-harvest benefits using the Holt-Bishop model. This will demonstrate how the model could be used to estimate post-harvest benefits from increases in Great Lakes catches. Obviously the fish harvesters themselves and those who supply them with inputs may also benefit, but we will not delve into empirical procedures for evaluating benefits to fishermen and their suppliers here. The paper will conclude by laying out an approach to benefits transfer, with an application to the Great Lakes.

The Conceptual Model

Figure 1 is a simple supply and demand model that will illustrate how an increase in supply, say as a result of reduced I&E, would translate into benefits. It follows the convention of modeling fish demand as an inverse demand system, where the price, P, is a function, P(F), and F is the output of fish to this market. We take this to be the dockside or ex-vessel demand. An inverse demand function is used because fish are perishable and must be marketed soon after they are caught. Hence, price is driven by quantity rather than vice versa in the short run. For simplicity, we assume that this fishery is managed on a quota basis where the current quota is F^1 so that the ex-vessel price is P^1. Assuming a quota makes the story simple. Roughly the same principles apply under other management regimes, such as closed seasons and gear restrictions, since the goal is usually the same, that is to limit total catch. Average cost is equal to marginal cost at C, again by assumption. A more complicated model could have an upward sloping marginal cost function.

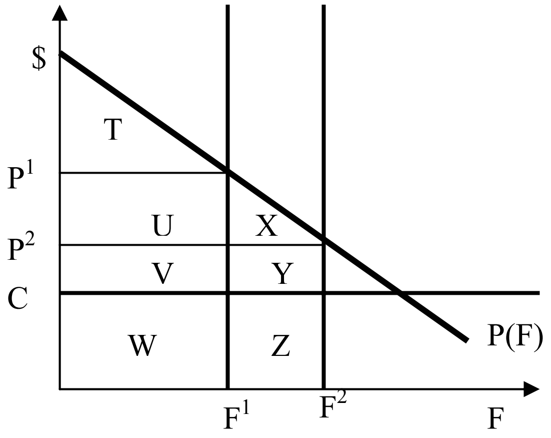

Figure 1: Conceptual Model of Benefits from an Increase in Fish Catch

Consider P(F) for a moment. This is not the demand for a finished product, but for an intermediate good, fish that have just been harvested. What does it tell us about social welfare? Let us assume that the markets down the marketing chain from fish harvesters to final consumers are competitive and adjust quickly to changes in dockside supply and that none of the demand functions at successive stages is perfectly elastic. This will allow us to expect that P(F) will reflects the dockside prices that would prevail after all the downstream markets have adjusted. Hence, P(F) is not a Marshallian demand function, since all other prices down the processing and marketing chain and across the compliments and substitutes for the fish species in question would not be held constant if the supply of that fish species would change. Rather P(F) is a "general equilibrium demand function" (Just, Hueth, and Schmitz, 1982; Thurman and Easley, 1992) expressing the prices of F that would prevail after markets in the rest of the economy have adjusted to changes in F. As the derived demand for F, it represents the maximum marginal willingness to pay for F by processors, marketers, and final consumers. To the extent that firms down the marketing chain will earn rents at the margin and consumers will earn consumer surplus at the margin as F changes, their marginal values would be reflected in P(F). And the definition of the so-called welfare triangles under P(F) is a bit broader than is usual in textbook examples, which deal with final demand. Here, the welfare triangle includes not only consumer surplus but also post-harvest rents.[3]

So let's consider the welfare implications of catching F^1 of fish. Total benefits from this fishery at F^1 are given by Area T+U+V+W. Fish harvesters earn total revenue equal to U+V+W. W is the total input costs, leaving rents to fish harvesters of Area U+V. Area T represents consumer surplus and post-harvest rents to firms down the marketing chain.

As we noted at the outset, we will not deal empirically with costs or rents to fish harvesters. Nevertheless, we will want to keep track of them conceptually in accounting for benefits. It is well known that theory predicts zero rents to fishery resources under open access. However, there could still be rents in the fishery for two reasons. One is that if the quota of F^1 is allocated to fishing firms as individual quotas, then the fishery would no longer be operating under open access.[4] Second, even if rents *to the resource* are zero, there could still be rents *to other resources* such as scarce fishing skills. Thus, we will allow positive rents to be a possibility in accounting for benefits.

Now suppose that the quota is increased to F^2. For example, remedial steps that reduce fish losses due to I&E might increase the harvestable surplus of fish. Let us do the benefit-cost analysis in three steps that are set up to help avoid confusion later on.

- In step 1, we assess the net benefits for consumers and downstream firms. With an increase in quantity from F^1 to F^2 and a decline in price from P^1 to P^2, consumers and downstream producers gain U + X.
- In step 2, let's assess the net benefits to harvesters. Their total revenue is now Area V+W+Y+Z. Hence the change in total revenue is Area Y + Z – U, which

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[3] As is well known, the welfare triangles associated with P(F) are not "exact" welfare measures because of possible income effects. We do not bother to address that issue explicitly here, but the empirical results presented below do involve estimates of "exact" measures of welfare.

[4] Or the quota could be enforced by at tax of t per unit caught where $t = P^1 – C$, with the rents going to the taxing entity.

could be positive or negative. Costs increase by Area Z. Hence, the change in rents associated with fish harvesting is Y –U, which again could be positive or negative. Consumer surplus and downstream rents become Area T+U+X.

- In step 3, we calculate the increase in net social benefits when the quota increases from F^1 to F^2 by adding the results of steps 1 and 2, which leaves Area X+Y. Area U does not result in an increase in total benefits because it is merely a transfer from harvesters to downstream firms and consumers and cancels out.

This framework helps conceptualize what we want to do in the rest of this paper. In the next section, we will explore what Step 1 might look like for an actual benefit-cost analysis using the Holt-Bishop model of Great Lakes demand. Our estimates will be the conceptual equivalent of Area U + X in this simple model. Steps 2 and 3 of the process suggested in the preceding paragraph would require data on fishing costs, which will not be addressed here.

Next, we will consider an approach to benefits transfer that is suggested by the simple model. It may not be feasible to do an empirical demand model for each case where changes in I&E losses due to new regulations need to be evaluated or other steps are taken that increase supply. If one wanted to try to use the results of an actual empirical study in one region of the country to get a rough estimate of what downstream rents plus consumer surplus would be for fisheries in another region where no empirical analysis exists, how might one proceed? One approach would be to start with total revenues of fish harvesters. Since most significant commercial fisheries are regulated, there are often data available to estimate the ex-vessel value of catches.

Suppose for the time being that Figure 1 represents the situation for the Great Lakes as reflected in an actual empirical study. We know total revenue at baseline, which is equal to Area U+V+W. We can use the empirical model to predict price and the associated increase in post-harvest benefits that will result from an increase in catch. For example, we already saw in Figure 1 how an increase in catch to F^2 would result in a price of P^2 and an associated increase in post-harvest benefits of Area U+X. Let K^2 equal the ratio of this increase in downstream rents plus consumer surplus to total revenues of the fishery, where 2 is a superscript, not an exponent. That is, K^2 = (Area U + X)/(Area U + V + W). (The superscript 2 signifies that this is the value of the ratio K associated with an increase in catch to F^2.)

Now let's carry the approach a step farther in the following way. Let us think of F^1, the current catch as a parameter, the baseline. Define the change in catch as a proportion, $L^2 = (F^2 - F^1)/F^1$. We could do this for other values of F, say F^3, F^4, and so on. Likewise, we can calculate $L^3 = (F^3 - F^1)/F^1$, $L^4 = (F^4 - F^1)/F^1$, and so on. And associated with each L would be a K, K^2, K^3, K^4, and so on, expressing the change in post-harvest benefits associate with each F, expressed as a proportion of baseline total revenue. Using our empirical model in Figure 1, we could consider alternative values of F and each associated value of L and K until we had traced out a function, K = K(L). Each value of L, the proportional increase in catch, would be associated with a proportional increase in benefits. This function would be empirically based on the Great Lakes fishery as depicted in Figure 1.

Now consider a fishery in another area, perhaps a coastal fishery. Before the intervention in question, the other fishery has total revenues, which we will symbolize as R, the ex vessel value of the catch there. Symbolize the catch in this new fishery as G, and suppose the intervention (e.g., I&E remediation) will lead to an increase in the quota there from G^1 to G^2. Let $Q = (G^2 - G^1)/G^1$. The benefits transfer approach we propose would calculate $K = K(Q)$, where $K(.)$ is still based empirically on the Great Lakes situation in Figure 1. Then one would estimate the resulting increase in post-harvest rents plus consumer surplus for the costal fish as $K(Q)*R$.

The next step is to examine the Holt-Bishop model and consider possible magnitudes of downstream rents and consumer surplus from some hypothesized changes in Great Lakes catches. This will allow us to explore the magnitudes of K(L) for typical Great Lakes species and eventually to consider the efficacy of our proposed approach to benefits transfer.

Valuing Increases is Catch Using the Holt-Bishop Model

There have been numerous efforts over the years to estimate the demand for fish. Well-known examples from the published literature include Barten and Bettendorf (1989), Thurman and Easley (1992), Eales, Durham, and Wessells (1997), and Beach and Holt (2001). Our paper (Holt and Bishop, 2002) was our attempt to improve the methods available by adapting the work of Diewert and Wales (1988a, 1988b) to inverse demand systems.

The Holt-Bishop model is a "semiflexible normalized quadratic inverse demand system." It is *flexible* in the sense that, within limits, it allows the estimated demand functions to be shaped to better fit the data, but it is *semi*flexible in that it imposes enough structure to meet the curvature conditions of microeconomic theory, a desirable property in a model to be used in welfare analysis. Our demand system is *quadratic* to allow for non-linear demand functions if the data call for them. An *inverse* demand system is used to capture the fact that, for highly perishable fish products, prices are endogenously determined based on landings. It is a demand *system* in that six demand functions for different fish species were estimated simultaneously. The demand system is *normalized* to address technical issues that are beyond the scope of this paper.

The model was estimated for six types of fish landed at Great Lakes ports in the U.S. These included lake whitefish, lake trout, yellow perch, lake herring, chubs, and smelt. Though many other fish are caught from the Great Lakes, these six account for a large share of the catch in terms of value. For example, in 1999, the last year for which data have been published, these six species accounted for more the 92 percent of the Great Lakes commercial catch in dollars. Other species typically have low prices and/or are caught in smaller quantities.

We started with monthly data for the period 1971 through 1991. Monthly catches and prices were combined into bimonthly values to avoid the problem of very small catches in some months. A summary of the data can be found in Holt and Bishop (2002, Table 1). The amount of variation in the data was sufficient to allow us to ferret out the demand relationships across the six types of fish. And it turned out that our model fit the data quite well and outperformed the popular Almost Ideal Demand System across several criteria when the latter was fitted to the same data set.

For purposes of this paper, we applied the model as estimated in Holt and Bishop (2002) to estimate the post-harvest welfare implication of increases in two of the Great Lakes most important species, lake whitefish and yellow perch, with the results displayed in Tables 1 and 2 respectively. Figures in the table are for average conditions between 1971 and the end of 1991. In both tables, compensating variation (post-harvest benefits) was estimated for 1 percent, 5 percent, and 10 percent increases in catch. These percentages, as expressed in the first column of the tables, are the analogue of the proportional increases in catches, L, in the conceptual model discussed in the preceding section. For example, in Table 1, we estimated that at L = 5 percent for whitefish, post-harvest compensating variation would increase by $292,000 after rounding. Likewise, in Table 2, at L = 10 percent for yellow perch, post-harvest welfare would increase by about $265,000.

Table 1: Post-Harvest Compensating Variation from Increases in Great Lakes Whitefish Catches.

Catch Increase (L)	Value	Compensating Variation (CV)	CV/Value (K)
1%	$ 5,657,206	$ 58,342	1.0%
5%	$ 5,657,206	$ 291,539	5.2%
10%	$ 5,657,206	$ 582,654	10.3%

Table 2: Post-Harvest Compensating Variation from Increases in Great Lakes Yellow Perch Catches.

Catch Increase (L)	Value	Compensating Variation (CV)	CV/Value (K)
1%	$ 3,025,070	$ 26,524	0.9%
5%	$ 3,025,070	$ 132,493	4.4%
10%	$ 3,025,070	$ 264,667	8.7%

The right-hand percent columns in the two tables show compensating variation as a percentage of the dockside value of the catch before the hypothetical increases occurred. These figures are the analogue of K for the simple model. That is, for example, if L = 10 percent for yellow perch, K = 8.7 percent.

For both whitefish and perch, the relationship K(L) is very close to being linear and is slightly steeper for whitefish. The slope for whitefish is approximately unity, while the slope for perch is approximately 0.9.

The estimates of K for lake whitefish and yellow perch are more or less typical of the Great Lakes commercial species included in the model. For example, under average conditions, for a 10 percent reduction in catch as considered in Table 8 of Holt and Bishop (2002), K ranged from about 8 percent for smelt to 12.12 percent for chubs for a weighted average of 10.03 percent. Hence, for the Great Lakes, we propose that $K = K(L)$ can be approximated by $K = L$ for relatively small changes in catches. That is, at least for the Great Lakes species included in the Holt-Bishop model, the change in post-harvest rents and consumer welfare as a percentage of ex vessel value is estimated to be, on average, approximately equal to the percentage change in catch.

Now, if $K = L$ holds to a reasonable approximation for the major Great Lakes species, would such a relationship be suitable for benefits transfer to other species and regions? Admittedly, this is a purely pragmatic approach. Beyond saying that as similar products, fish products might have similar demand structures, there is no theoretical reason to suppose that post-harvest changes in welfare, as a percentage of dockside value, should be similar across fisheries. The consistency across Great Lakes species is encouraging in this regard, but it is hardly conclusive. But there is encouraging evidence about the robustness of this relationship. Beach and Holt (2001) estimated a model very similar to Holt and Bishop (2002) for nine types of fish in the South Atlantic region. The weighted average value of K for a 10 percent reduction in catch was very close to 10 percent, which would further support the case for $K = L$. At this point, the only other study that we have found that would provide a point of comparison involved red drum in the Gulf of Mexico, where Thurman and Easley (1992, p. 236) estimated that post-harvest welfare would by 6 percent for a 10 percent reduction in catch. This would indicate that $K = L$ might not be as robust across fisheries as we would like, but more research is needed before much more can be said.

Implications for Benefits from I&E Remediation

For any of the species covered in the Holt-Bishop model, estimation of post-harvest benefits would be relatively straightforward. Beyond running the model and reviewing the results for changes in circumstances since 1991 (when the data set ended), only minor steps like allowing for inflation and discounting would be needed.

On the other hand, if the analysis needed to address a species or an area not covered by the model and original research is not feasible, benefits transfer would be necessary. We can illustrate how this would work using a Great Lakes example.

U.S. EPA's estimates of I&E losses at the Monroe and J.R. Whiting power plants on Lake Erie are presented in Table 3. These estimates were developed for the 2002 Proposed Section 316(b) Phase II Existing Facilities Rule. EPA developed these estimates using I&E data collected by the Monroe and J.R. Whiting power plants in the

1970s and extrapolated the estimates of I&E at all in-scope facilities based on average daily flow at all Great Lakes facilities affected by the rule. EPA will be revising the set of facilities defined to be in the Great Lakes region and the estimated I&E impacts in the analysis for the final Phase II rule. Thus, these results are used for illustrative purposes only. Full details on the methods used to estimate I&E impacts are provided in the Case Study Document for the proposed rule (U.S. EPA, 2002).

Table 3: Estimated Commercial Harvest Lost from Impingement and Entrainment in the Great Lakes Under Conditions Assumed in the EPA Analysis (pounds per year)

Species	**Estimated I&E Losses at J.R. Whiting and Monroe**	**Estimated I&E Losses at all Great Lakes In-Scope Facilities**
Bullhead	52	206
Channel catfish	767	1,518
Common carp	239,478	949,180
Gizzard shad	2,555,854	10,130,218
Sucker spp.	1,233	4,887
White bass	115,827	229,544
Burbot	206	408
Freshwater drum	19,148	75,894
Smelt	810	1,605
Whitefish	73	143

Two species that were included in the Holt-Bishop analysis appear on this list, whitefish and smelt. However, the quantities of both species are too small to affect the prices much, if at all, so the Holt-Bishop model is not directly applicable to this problem. The other species in the list are not included in the Holt-Bishop model and, hence, would need to be valued using benefits transfer. If the figures in Table 3 were final estimates, how might benefits transfer work?

Carp, gizzard shad, suckers, and freshwater drum are relatively abundant species that are variously referred to as rough fish or underutilized species. Their production is much more limited by markets than by biological abundance. This is reflected in their dockside values, which averaged $0.09, $0.04, $0.07, $0.11 per pound, respectively, over 1995-99 (compared to $2.43 for yellow perch and $0.75 for whitefish). The upshot is that increased abundance due to lower I&E losses would not be likely to increase catches much if at all. Hence, there would be few if any direct benefits to commercial fishing from lowering I&E losses of these species.[5] Furthermore, a few hundred dollars worth of channel catfish (dockside value of $745 based on average 1995-99 prices) and burbot ($127) can safely be ignored.[6]

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[5] It is conceivable that commercial fishing could be positively or negatively affected through ecosystem effects. If such impacts were identified, the methods proposed here could be applied.

[6] Prices here come from the National Marine Fisheries Service web site, http://www.st.nmfs.gov/st1/commercial/landings/gl_query.html

That leaves white bass as the focal point for the analysis. Let us assume that conditions in Great Lakes are currently similar to those in the 1970s (when the studies used by EPA to estimate losses were done) and will continue to be so for the foreseeable future. Thus we assume that average annual catches are about 1.7 million pounds with an ex vessel value of about $500,000. These are the actual averages over the period beginning in 1971 and ending in 1979. If we assume that remediation is totally effective, this would mean an increase in annual catches of 230,000 pounds (Table 3) or about 14 percent. Applying the result from the Holt-Bishop model, that is, K = L, the estimated post-harvest benefits would be 14 percent of ex vessel revenue or about $70,000 per year before adjusting for inflation.

Conclusions

For species and regions covered by empirical research like that found in Holt and Bishop (2002), post harvest changes in rents and consumer welfare from changes in catch can be addressed directly and should not be problematical. Where such research results are not available and cannot be produced in a timely manner, the only recourse will be to benefits transfer. Assuming that K = L in such cases seems to us to be a reasonable approach for now. The robustness of this formula across Great Lakes and South Atlantic fisheries provides an adequate basis for proceeding in this way. As more research becomes available, the formula may need to be modified or a new approach may present itself, but that is always the case with benefits transfer methods.

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