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Water Quality Impacts on Recreational Fishing

by

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Fishing

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"Water Quality Impacts on Recreational Fishing". Marc O. Ribaudo (ERS, USDA)

The complete evaluation of the offsite impacts of national policies or programs which affect levels of agricultural nonpoint source pollution requires linking extensive water quality changes to changes in recreational activity. A participation model for recreational fishing which includes water quality variables is developed, and estimated as a logit model.

Water Quality Impacts on Recreational Fishing

Of great interest to those trying to assess the offsite benefits from soil conservation is the mangitude of these impacts on water based recreation, i.e. fishing, swimming, and boating. Studies have indicated that water pollution damages to recreation are substantial, and that large benefits could result from improving water quality (Freeman; Heintz, Hershaft and Horak; Unger; Feenberg and Mills). If reducing agricultural sources of pollution can substantially improve over-all water quality, then large benefits in terms of improved recreational opportunities can be gained.

Agriculture does many things to affect water quality at both the micro and macro levels. At the farm level, farmers can choose from a variety of crop management, tillage, soil conservation, and chemical management techniques. His choices affect the amounts of sediment and chemicals washing off the land.

More importantly, and of interest here, are the national policy decisions which influence all farmers' production decisions. Policies include not only conservation policies, but also price support and acreage reduction programs. Such programs or policies can have a substantial impact on national water quality, by influencing acreage in production, intensity of production, and degree of conservation. At ERS we would like to be able to assess the offsite benefits from such national policies. To do this requires some way of linking water quality to recreational behavior at the national level. A site by site approach would be extremely difficult, since national policies or programs influence water quality in many areas simultaneously. Also, the number to site studies required to analyze such changes would be prohibitively large. Alternatively, a national model can be developed.

In this paper, the focus will be on recreational fishing. A model will be developed which predicts changes in the number of recreational fishermen as water quality parameters change. This information can be used in the estimation of the offsite benefits from reducing nonpoint source pollution.

Model

The model developed in this paper is based largely on the approach Vaughan and Russell (1982) developed for estimating the freshwater fishing benefits from reducing water pollution. They outlined a sequential decision model consisting of three parts:

1) decision whether or not to fish in a given year;
2) if yes, whether to do cold-water, warm-water, or rough fishing;
3) how much to do of each.

This paper addresses the first decision; whether or not to fish. It is hypothesized that the individual's decision whether to fish is a function of the supply and quality of water, as well as socio-economic variables. The use of supply side variables in such a decision model is based on Deyak and Smith's (1978) adaptation of the household production function. What makes this paper unique is the way in which quality is included in the model. Vaughan and Russell were concerned with expressing water quality in terms observable by fishermen. They used the availability of fishable water as a way of incorporating water quality into their model. In this paper measures of pollutant concentrations are included directly in the model. Because no separate estimate of fishable water is needed when investigation the impact of changes in pollutant loadings, the model is easier to use.

A probability of participation model was used to represent the decision to fish. The equation was specified as a logit model. The data set used to determine fishing participation was the Fish and Wildlife Service's 1980 Hunting and Fishing Survey. This survey consists of two parts. A screening survey was conducted by phone on a sample of 340,000 individuals across the U.S. to obtain basic participation and socio-economic data. Follow-up personal interviews were conducted on a subsample of those in the screening survey to get more detailed information on hunting, fishing, and other wildlife related recreational activities. The survey reflects the attitudes and behavior of those older than 10 years of age.

The screening survey provides a rich source of data for the logit model, as one of the questions asked was whether the respondent did any fishing in 1980, including lake, stream, and salt water fishing. The binary yes-no response is the dependent variable in the logit equation.

Explanatory Varibles

Since the decision to fish is being analyzed in the household production framework, both supply and demand variables are included. The supply variables are those representing the quality and availability of water. Demand vaiables are those socio-economic and other variables reflecting individuals' tastes and preferences.

Water quality - Water quality is the variable of interest in the model. It is the variable which links nonpoint source pollution loadings and changes in recreation activity. Three of the major pollutants generated by agriculture were chosen to represent water quality: total suspended sediment (TSS), total Kjedahl nitrogen (TKN), and total phosphorus (TP). There are many other pollutants which affect fisheries, but their presence tends to be restricted to certain stream segments or lakes.

It might be argued that the concentrations of TSS, TKN, and TP are not observable by fishermen, and that it is the more observable variables such as catch rate, odor, and algae growth which influence behavior. I believe this to be true, but I also believe that concentrations of pollutants included here act as proxies for the more observable parameters. Besides, a national data set is not available for the observable parameters.

Data on water quality was obtained from USGS's National Stream Quality Assessment Network (NASQUAN) for the geographic units used in the Hunting and Fishing Survey. For the survey each state was divided into between 1 and 10 wildlife regions (340 in all). These wildlife regions were later regrouped into 129 regions by the Bureau of Census to insure the privacy of the respondents. Data from NASQUAN was used to characterize the concentrations of TSS, TKN, and TP within each of these regions. For each NASQUAN station a two year average of TSS, TKN, and TP was calculated. If a region contained more than one NASQUAN station, a simple mean of the average concentrations was calculated. Eighteen regions did not have a NASQUAN station located within them, so the observations from these regions were dropped from the analysis. It was hypothesized that the concentrations of the pollutants in the region of residence (home region) would have a negative impact on the probability of fishing.

Another issue is how to include pollutant concentrations in the model. They can be included separately, or in the form of some overall pollution index. I believe that an index is more appropriate. If any one of the pollutants is in a high enough concentration to affect recreation, then the levels of the other pollutants are irrelevant. In the model presented here, a dummy variable is used to represent whether regional TSS, TKN, or TP concentrations are above pre-specified threshold levels at which recreational use of the water is assumed to become impaired. If TSS was above its threshold of 180 mg/1, or if TKN concentrations were above 1.8 mg/1 and TP concentrations were above 0.2 mg/1 then the dummy variable was assigned a value of 1. The threshold concentrations used are based on concentrations reported to pose likely severe impacts on aquatic ecosystems (Zison, Haven, and Mills). It was assumed that fishermen would notice the impacts of these or greater concentrations on their ability to catch fish. This specification does not allow for benefits to be realized from changes in water quality restricted to above or below the threshold. However, it is felt that relatively small benefits are possible when highly polluted water is slightly improved, or when clean water is further improved.

One of the shortcomings of the NASQUAN data is that the stations are located only on rivers. Estuaries and lakes are not represented. The assumption had to be made that average concentrations reflected lakes and estuaries as well as rivers. There are obvious problems with this assumption, as lakes and estuaries act as pollutant sinks. A constant influx of water containing relatively low concentrations of pollutants may result in a build-up of pollutants to levels which can cause quality problems.

The regions were not of uniform size, and many were small enough such that travel to adjacent regions would not be very costly. As a result, quality of adjacent regions could not be ignored in the decision to fish. For each home region the adjacent regions were identified. In some cases, a region consisted of an entire state, making it less likely that quality of adjacent regions would have an impact for most residents on the probability of fishing. An arbitrary criterion for determining the importance of adjacent regions was assumed. If the distance from the geographic center of a home region to the nearest adjacent region was greater than 200 miles, then the adjacent region was considered to be the home region itself. The average concentrations of TSS, TP, and TKN were calcualated for all adjacent regions, and a 0-1 dummy variable created to represent whether any one of the pollutants was above its threshold. The presence of one pollutant above the threshold was hypothesized to have a negative impact on the decision to fish.

Supply of water–The decision to fish was expected to be a function of the supply of surface water. For each region the surface area of rivers and lakes was determined from data contained in the 1982 National Resource Inventory. Because of the wide variation in the size of regions, per-capita supply was used. It was hypothesized that supply in the home region would have a positive impact on the decision to fish.

Per-capita supply of water in adjacent regions was also included in the model for the same reasons the quality of water in adjacent regions was included. It was expected that per-capita supply of water in adjacent regions has a positive influence on the probability of fishing.

Ocean/Great Lakes-The dependent variable in the model is whether any fishing was done, including salt water fishing and fishing in the Great Lakes. A dummy variable was used to indicate whether a region is adjacent to the Great Lakes, the Atlantic or Pacific Oceans, or the Gulf of Mexico. It was felt that the presence of such large bodies of water would increase the availability of fishing opportunities, and the probability of engaging in recreational fishing.

Income-Household income of respondents was included in the equation and expected to have a positive influence on the decision to fish. Even though a higher income increases the cost of leisure, it is felt that since less time is needed to provide basic family needs, more leisure time will be demanded. This variable was obtained from the survey. Since income categories were specified in the survey, the midpoint of each interval (in thousands of dollars) was used to represent the range. The category $50,000 and above was entered as $75,000.

Urban/Rural-Whether the respondent lived in an area designated urban or rural was hypothesized to influence the decision to fish. This data was obtained from the survey. A dummy variable was used to represent whether the respondent lived in an urban area or rural area, as defined by the 1980 Census. It was expected that living in a rural area would increase the probability of fishing. Rural residents tend to be closer to fishing opportunities than urban residents, and are more oriented towards outdoor recreation in general.

Upbringing-Recreational experiences as a child probably have a lot to do with the types of activities engaged in as an adult. If a respondent grew up in a rural area, he/she may have acquired a desire to engage in recreational fishing which is kept through adulthood. The survey reported the size of the community each respondent lived in until age 16. A dummy variable was used to represent whether a respondent grew up in a city with a population greater than 50,000. It was hypothesized that this variable would have a negative impact on the probability of fishing.

Region-The final set of explanatory variables represents regional differences in the perception of water quality. The natural quality of lakes and streams varies across the country due to geologic, geographic, and climatic differences. Therefore, the expectations of water quality in, say, the south are probably different than they would be in New England. Nine dummy variables were used to represent the 10 Farm Production Regions (FPR's). Other regional definitions are possible, but these regions have relevance for agricultural policy analysis.

Age-Age was hypothesized to have a negative influence on the decision to fish, and increases in age were expected to have an increasingly negative effect. This relationship was represented by two variables, age in years and age squared. It was expected that the age variable would have a positive sign, while the age squared variable would have a negative sign.

Sex-The sex of the individual was expected to influence the decision to fish. A 0-1 dummy variable was used to represent the sex of the respondent. Men (represented by a 1) were expected to show a greater propensity to fish than women.

Results

The participation model was estimated using SAS's LOGIST procedure. After accounting for missing values, a total of 10,458 observations were left to estimate the model. The results and model statistics are presented in table 1. The model seems to have performed quite well. All of the explanatory variables except some of the regional dummies are significant at the 10 percent level. The signs of all variables except one (Ocean/Great Lakes) are as expected. The model chi-square is significant at the 1 percent level. Neither the index of rank correlation between predicted probabilitites and observed outcomes nor R^2 inspire a great deal of confidence in the forecasting ability of the model. However, the model will not be used to predict changes in the probability of fishing for simultaneous changes in all variables. Instead, it will be used to evaluate changes only in water quality.

The water quality dummy variables have the correct signs, and are significant. This implies that the water quality of home and adjacent regions, in relation to the thresholds, is affecting the decision to fish, even though the pollutant concentrations themselves are not observable.

All of the variables respresenting regions had positive signs. This implies that residents in the Northeast (represented in the intercept) have the least inclination to fish.

A somewhat surprising result is that the proximity to the Great Lakes or salt water has a negative impact on the decision to fish. Vaughan and Russell also found this result when using the 1975 Hunting and Fishing Survey. Their explanation, and the one given here, is that the nearness of such large water bodies encourages competing recreation activities such as swimming and boating, so there is a smaller likelihood of fishing.

Evaluated at the means, the model predicts the probability of participation at 29.3 percent, which is very close to the sample proportion of participation of 27.7 percent. The marginal impacts of changes in the explanatory variables on the probability of participation are presented in table 1.

The estimated equation can be used to estimate how changes in the proportion of regions meeting water quality threshold criteris affect participation in recreational fishing. As an example, assume that the concentrations of TSS, TKN, and TP are reduced 50 percent in the Corn Belt (Illinois, Iowa, Indiana, Missouri, and Ohio). The improvement in water quality reduces the percentage of population in the Corn Belt facing poor water quality in their home region from 56.7 percent to 28.4 percent. In addition, the percentage of people facing poor water quality in their adjacent region decreases from 50.4 percent to 31.7 percent. Improvements in water quality do not only benefit the residents of the Corn Belt. The percentage of people in the Lake States facing poor water quality in their adjacent region also decreased, from 12.7 percent to 7.7 percent. The results of these water quality improvements is an increase in the proportion of people in the Corn Belt and Lake States participating in recreational fishing. In the Corn Belt the percentage of the population older than 10 years of age engaging in fishing increases from 29.1 percent to 30.3 percent, or by 365,000 individuals. In the Lake States, the increase in the percentage of population engaging in fishing increases from 36.7 percent to 37 percent, or by approximately 23,000 individuals. When estimating the benefits from improving water quality, these additional, "new" fishermen must not be excluded, as they would be if only the impacts to current fishermen were included.

One complexity of using the equation is handling the quality of adjacent regions. Each home region is part of the adjacent region of another home region. An improvement in the water quality of a home region implies an improvement in a portion of another home region's adjacent region. Whether the threshold criteria is met for the adjacent region must be determined by recalculating the average concentrations.

Conclusions

Water quality in the form of an index reflecting some threshold criteria for pollutant concentrations can be included in a national fishing participation model. The resulting equation can be used to evalute water quality changes which occur simultaneously across the nation. The estimated equation can also be used to evaluate water quality changes at the FPR level. This would enable an analysis of various targeting schemes for water quality improvement.

There is some degree of arbitrariness to the water quality index. The key is to select an index which represents conditions at which fishermen notice sufficient drops in catch to affect their decision to fish. When the model was run with an index defined for threshold levels approximately half of those reported above, the water quality index variables were not significant, implying that fishermen expected to catch fish in water supposedly of poor quality. These thresholds were too low. The model could be run with a number of different index definitions to see whether a "best" index emerges.

The estimation of benefits from a water quality improvement requires the estimation of the second component of the sequential decision model. For those who fish, an equation relating fishing visits to explanatory variables, including water quality, must be estimated. Together, the participation model and the visitation model can be used to estimate the total change in fishing activity. An economic value can be placed on the change in activity by using "standard" fishing day values found in the literature.

The effectiveness of the participation model can be greatly improved if better water quality data were available. The NASQUAN monitoring stations are widely scattered and cover only rivers. The quality of esturaries and lakes was only implied by the quality of the regions containing them. Availability of national catch rate data would also be valuable, as it would be a measure of water quality more observable to potential fishermen. This would enable the use of a continuous variable to represent water quality, rather than the binary variable. The implication of this is that benefits may be realized for changes in water quality which do not involve the thresholds.

Despite its shortcomings, the model estimated in this paper should be able to provide information to national scale policy analyses which up until now had not been available.

Table 1--Results of logit model estimation.

Variable	Mean	Coefficient (X^2)	Partial Derivative
Intercept		-2.70 (580.69)***	
Water quality of home region	.373	-.124 (3.81)**	-.026
Water quality of adjacent region	.416	-.122 (2.76)*	-.025
Supply in home region	2.44	.018 (6.56)***	.004
Supply in adjacent region	2.64	.033 (10.00)***	.007
Urban/rural	.675	-.276 (28.27)***	-.057
Upbringing	.277	-.357 (39.24)***	-.074
Ocean/Great Lakes	.523	-.255 (16.00)***	-.051
Income	20.85	.012 (60.31)***	.002
Age	32.77	.077 (264.83)***	.016
Age squared	1525.3	-.001 (289.76)***	.0002
Sex	.49	1.12 (549.50)***	.23
Appalachian	.116	.103 (1.16)	.021
Corn Belt	.153	.402 (18.53)***	.083
Delta	.049	.385 (9.19)***	.079
Lake States	.092	.544 (29.58)***	.112
Mountain	.053	.186 (1.75)	.038
N. Plains	.028	.297 (2.94)*	.061
Pacific	.163	.449 (20.67)***	.092
Southeast	.085	.421 (16.76)***	.087
S. Plains	.097	.457 (15.18)***	.094

*significant at 10 percent level; **significant at 5 percent level; ***significant at 1 percent level; Model X^2 = 1070.95 with 20 D.F.; R^2 = .093. Index of rank correlation (Somer's Dyx) = .42.

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