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Factors in Exposure Assessment: Ethnic and Socioeconomic Differences in Fishing and Consumption of Fish Caught along the Savannah River

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South Carolina has issued fish consumption advisories for the Savannah River based on mercury and radionuclide levels. We examine differences in fishing rates and fish consumption of 258 people interviewed while fishing along the Savannah River, as a function of age, education, ethnicity, employment history, and income, and test the assumption that the average consumption of fish is less than the recreational value of 19 kg/year assumed by risk assessors. Ethnicity and education contributed significantly to explaining variations in number of fish meals per month, serving size, and total quantity of fish consumed per year. Blacks fished more often, ate more fish meals of slightly larger serving sizes, and consumed more fish per year than did Whites. Although education and income were correlated, education contributed most significantly to behavior; people who did not graduate from high school ate fish more often, ate more fish per year, and ate more whole fish than people who graduated from high school. Computing consumption of fish for each person individually indicates that (1) people who eat fish more often also eat larger portions, (2) a substantial number of people consume more than the amount of fish used to compute risk to recreational fishermen, (3) some people consume more than the subsistence level default assumption (50 kg/year) and (4) Blacks consume more fish per year than Whites, putting them at greater risk from contaminants in fish. Overall, ethnicity, age, and education contributed to variations in fishing behavior and consumption.

KEY WORDS: Ethnicity; fish consumption; advisories; Savannah River; methylmercury; risk perception.

1. INTRODUCTION

Recreational and subsistence fishing are important aspects of rural culture and tradition, particularly in the southern United States, where the fishing season extends for many months.[1] Fish can provide an important source of low-fat protein and contribute to lowering blood cholesterol.[2] However, the presence of contaminants in fish may pose a health hazard, particularly for high risk groups such as pregnant women and their fetuses, and young children.

There are concerns about the safety of non-commercial fish, shellfish and wildlife.[3–5] From 1994 to 1995, 15% of the nation's lake acres and 4% of the river miles were under fishing or consumption advisories, an increase of 14% over the previous year. Mercury accounts for 46% of the advisories; other contaminants of concern are PCBs, chlordane, dioxins, and DDT.[6] Although some of the apparent in-

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crease may be due to increased monitoring, there is still cause for concern. A relationship exists between mercury levels, fish consumption, and deficits in neurobehavioral development in children,[7–9] although the positive benefits with respect to cardiovascular health must also be considered.[10–12]

Because fishermen may consume large quantities of fish (in excess of 0.35 kg/day),[13, 14] it is critical to examine fishing behavior, fish consumption, and cooking patterns among fishermen in places with consumption advisories. An effective risk reduction and risk management strategy can be implemented only with site-specific information. Furthermore, such information from many sites can lead to both an empirical and theoretical understanding of the risk from fish consumption.

There is often a discrepancy between knowledge about fish advisories and the behavior of the fishing public.[15, 16] The public does not know about the warnings, they do not know about the *correct* warnings, or they are choosing not to follow them. People may choose not to follow advisories because they do not believe them, they do not agree with the advice, or they have no alternative if fish is their main or only source of protein.[17] However, the failure of the public to follow consumption advisories or select fish or cooking methods to reduce risk may be due partially to the failure of risk communicators or state agencies to reach the appropriate target audiences.[18]

Designing an appropriate risk communication strategy requires understanding how ethnicity, income, and age relate to differences in fishing behavior, consumption patterns, and potential risk. Fleming et al.,[19] working in the Florida Everglades, reported that Blacks were less likely to know about health advisories than were other ethnic groups. Considering the significant social role fishing plays within some Black communities (e.g., Mississippi Delta[1]), it appears critical to understand fishing and consumption behavior of Blacks in a variety of communities in order to develop an overall risk management strategy.

In this paper we examine the fishing and consumption patterns of Black and White persons fishing along the Savannah River. We examine differences in fishing and consumption patterns as a function of ethnicity, income, education, age, and employment to provide a framework for designing a risk management strategy. There are few studies of fishing behavior and consumption patterns that are able to separate the effects of income, ethnicity, and education, and our study was designed to address this. Based on mercury, the state of South Carolina has issued fish consumption advisories for waters of the state, including the Savannah River.[20] South Carolina updated the advisories for the Savannah River to include risks from radionuclides. The portion of the river with the most stringent advisories is adjacent to the Department of Energy's (DOE) Savannah River Site (SRS).

2. METHODS

Under a university-approved protocol, 258 people who were fishing on the Savannah River were interviewed. We sampled three sections of river: along SRS, upriver from the site to the Augusta Lock and Dam, and downriver from the site to Barton's Landing (301 bridge (Fig. 1, about 90 km of river). The DOE's SRS (SRS, 310 sq mi, 803 sq km) is situated in South Carolina. Before the DOE purchased the site in 1952, much of the site had been cleared for agriculture, except for the bottomland swamps along the Savannah River. During the DOE tenure, the land was off limits to the public except for controlled game hunting. Pine and other forests have grown up, and many populations of amphibians, reptiles, birds, and mammals, including some endangered species, increased since the late 1950s.[21]

Interviews were conducted both on land and on the water (by boat) from 3 April until 22 November 1997. To ensure a wide distribution of people and fishing methods, interviews were conducted nearly every week, and each person was interviewed only once. We interviewed fishermen on 54 days, including weekdays and weekend days, and conducted interviews from dawn to dusk. Our overall design was to move systematically down the river from the Augusta Lock and Dam, interviewing at all locations where we found fishermen, before beginning again at the dam. We often saw the same people at the same fishing sites, and they expressed interest in the progress of the survey work. Most interviews were conducted by the same two people who had lived and worked in the region their entire lives.

The protocol was to alternate interviewing people along the three sections of the river, depending on weather, water level, and fishing conditions. That is, when people were fishing for a particular fish, they often concentrated in some regions of the river in preference to others. Furthermore, we could not interview people when the water level was high because the fishing was poor, and we encountered no one

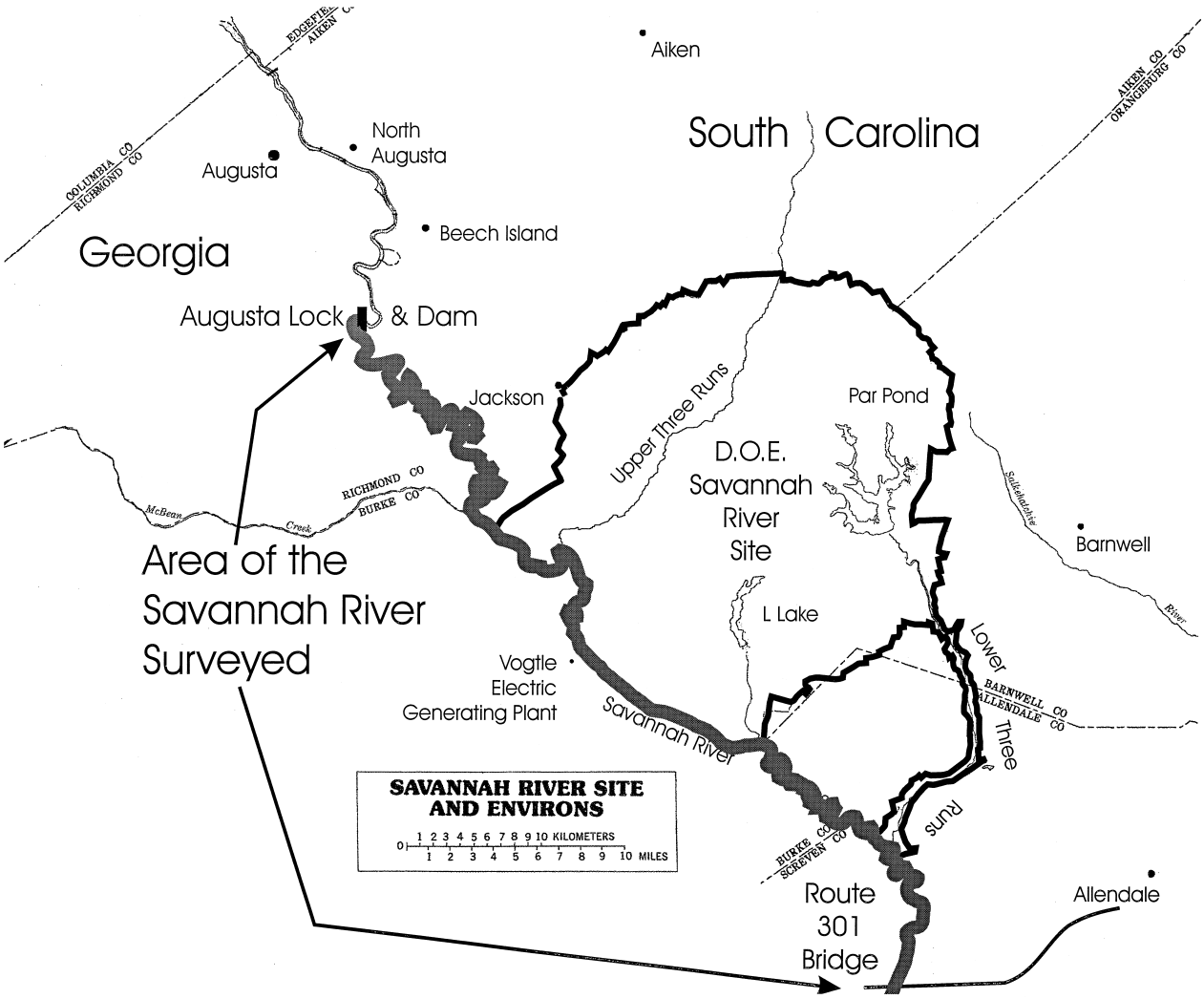

Fig. 1. Map of the Savannah River Site and the Savannah River showing the Augusta Lock and Dam and the Interstate-95 bridge that bound the study area.

fishing. Upon reaching a sampling site, we interviewed all the fishermen. Only 10 people out of 268 approached refused to be interviewed, largely because they did not have the time to participate. Most interviews took 30–45 min because people wanted to talk about fishing, their catch, and how they prepared fish.

The questionnaire contained questions about fishing behavior, consumption patterns, cooking patterns, warnings and safety of the fish, and personal demographics. Some demographics questions (sex, age, ethnicity, residence) were asked at the beginning, and more sensitive questions (income, education, and employment) were asked at the end to reduce rejection rates. Because our sample was largely male, we did not examine the data by gender except in our initial model-building (see below). Prior surveys had indicated that some people are reluctant to disclose their income or education. However, after a friendly and lengthy interview with local interviewers, most people were willing to give this information at the end of the survey. People were asked to give their household income. Information on fishing behavior, consumption patterns, and knowledge of consumption advisories is presented in this paper; data on sources of information is presented elsewhere.[22]

We used nonparametric analysis of variance (SAS Proc NPAR1WAY with Wilcoxon option), yielding a χ^2 statistic to examine differences among groups. We also used ANOVA with Duncan Multiple

Range Test to identify which groups differed from each other (SAS GLM procedure[22]). We use a significance level of $p < 0.05$.

We used multiple regression procedures (SAS PROC GLM) to examine the relative contribution of the independent variables (ethnicity, income, age, and education) to the dependent variables that we were most interested in from a risk perspective (years fished on the Savannah River, serving size, meals/month, and total ounces of fish consumed per year).[23] This procedure allows for interactions among variables. Other questions dealt with fishing behavior patterns, and these data are presented descriptively to aid in risk management.

Initially, we developed models for each of the four dependent variables, using each independent variable separately. This allowed us to determine that gender did not enter significantly in any of the models, and was not used further. All other independent variables were used in the models. We used a models-building procedure in which we added the dependent variable that contributed the most to explaining the variation, and then again developed models using each of the other four variables. In this manner, we determined the best models. We continued until all significant variables were added. Because we had already assessed the correlation among variables (Table I), and the independent variables were not highly correlated, we did not see collinearity as a problem. We also constructed models with all the interaction terms (i.e., education $\times$ income) to determine if any would contribute significantly to explaining the variation (in addition to each variable separately); no interactions were significant. Education was also added as a squared value to evaluate a nonlinear effect.

3. STUDY POPULATION

Our population was drawn from people fishing along a 90 km segment of the Savannah River, upriver, along, and downriver from the SRS, and was meant to be representative of fishermen anywhere along the Savannah River or similar fishing areas in the region.

Of the 258 people interviewed, 89% were men; 70% were White, 28% were Black, and 2% were other. Thirty-four percent of the population in the counties adjacent to the stretch of river surveyed is Black, compared with 28% of the population of Georgia and South Carolina.[24] Only 29 (11%) people worked or had worked at SRS. The age range of those interviewed was from 16 to 82 years (mean = 43 $\pm$ 1).

The average income of those interviewed was $21,490/year (range of $0 to $60,000), compared to the regional income around SRS of approximately $27,647.[24] The Blacks who were interviewed had lower annual income than the Whites. For Blacks, age was negatively correlated with both income and years in school (Table I), whereas for Whites, age and income were positively correlated. However, for both Blacks and Whites, income and schooling were only very weakly correlated.

Of those interviewed, only 14% had less than a high school education, compared to 21% for Georgia and 23% for South Carolina generally[24]; conversely only 11% of our sample graduated from college, compared to 19.8% for South Carolina and 21.8% for Georgia.[25]

4. RESULTS

Although most of those interviewed were men, they indicated that their wives and children ate fish as often as they did, and children began eating fish at 3–5 years of age, depending on species of fish. Preferred fish in descending order of frequency were bream (the local term for sunfish; *Lepomis* spp), catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*). These accounted for most of the fish caught.

4.1. Factors Affecting Fishing and Consumption

Fishing behavior and consumption rates for the study population are shown in Table II. People fishing along this stretch of the Savannah River eat an average of 1.4 kg of fish per month, mainly deep fried (not including pan fried). The average number of years people had fished on the Savannah River was 24 years, although some people had fished for more than 50 years (Fig. 2). For both Blacks and Whites, serving size and number of fish meals per month were positively correlated (Table I).

After assessing variables individually, we developed multivariate linear regression models for the dependent variables: number of years fished on the Savannah River, fish meals per month, serving size, and ounces of fish per year. The best models explained variation in average years fished by educa-

Table I. Correlations between Demographic and Fish Consumption Questions Asked of Black and White Fishermen along the Savannah River. Blacks are Above and Whites Are Below the Line. Given are Kendall-Tau Probabilities. (NS = not significant)

	(1) Age	(2) Income	(3) School	(4) Fished	(5) Distance	(6) Meals	(7) Serving	(8) Deep fry	(9) Oz.
[1)]Age	—	−0.16 (0.07)	−0.18 (0.048)	0.36 (0.001)	NS	NS	NS	NS	NS
[2)]Income	0.14 (0.01)	—	0.37 (0.001)	NS	NS	NS	NS	NS	NS
[3)]Years of schooling	NS	0.18 (0.003)	—	−0.18 (0.08)	NS	NS	NS	NS	NS
[4)]Years fished Savannah River	0.39 (0.001)	0.12 (0.03)	−0.12 (0.048)	—	NS	NS	NS	NS	NS
[5)]Distance traveled	NS	NS	NS	NS	—	NS	NS	NS	NS
[6)]Fish meals/month	NS	−0.15 (0.02)	−0.13 (0.044)	NS	NS	—	NS	−0.18 (0.07)	0.92 (0.001)
[7)]Average fish serving	NS	NS	0.17 (0.01)	NS	NS	0.17 (0.02)	—	NS	0.26 (0.007)
[8)]Percent fish deep fry	NS	NS	−0.19 (0.007)	0.13 (0.042)	NS	NS	NS	—	0.19 (0.058)
[9)]Oz. of fish/year	NS	−0.11 (0.09)	NS	NS	NS	0.91 (0.001)	0.33 (0.001)	NS	—

tion, age, and income. The best models explained variations in serving size, fish meals per month, and total kg of fish consumed per year as a function of ethnicity and education (neither age or income entered significantly; Table III). The independent variables explained only 5% of the variation in serving size, but from 15% to 33% of the variation in total consumption per year, number of fish meals/month, and years fished on the Savannah River.

4.2. Ethnic Differences in Fishing

There were significant differences in nearly all measures of fishing behavior, consumption, and cooking methods as a function of ethnicity (Table IV). Blacks ate larger portions of fish and ate fish more often than did Whites (Fig. 3). The higher number of meals per month that Blacks consumed resulted in significant differences in the average consumption of fish per year. Figure 4 shows the distribution by race of people consuming fish in both pounds and kilograms, with the vertical lines indicating the recreational (19 kg/year) and subsistence (50 kg/year) consumption levels used as the default exposure assumptions for risk assessments by South Carolina (SC DHEC, pers. comm.). Furthermore, a significantly higher proportion of Blacks than Whites ate whole fish rather than fillets (Table IV).

Table II. Mean and Standard Error of Select Questions Asked of Fishermen along the Savannah River

	Mean	Range
Number of years fished	31 ± 1	(1–73)
Years fished Savannah River	24 ± 1	(1–73)
Distance traveled (km)	37 ± 7	(2–960)
How often they eat fish/month	3.61 ± 0.28	(0–24)
Serving size of fish (g)	376.1 ± 5.45	(0–625)
Fish/month (kg)	1.46 ± 0.13	(0–9.55)
Fish/year (kg)	17.60 ± 1.51	(0–114.5)
Percent that deep fry	82 ± 2	(0–100)
Percent that eat whole fish	85 ± 2	(50–100)
Age	43 ± 1	(16–82)
Years of schooling	12 ± 0.1	(6–18)
Income	$21,491 ± $758 ($0–$60,000)	

4.3. Income and Education Differences

There were few significant differences as a function of income, although people with lower incomes ate fish significantly more often than those with higher incomes (Table V). There were significant differences as a function of education (Table VI). Fishermen who had not graduated from high school ate fish more often, consumed more fish per month and per year, deep fried more often, and had lower incomes than people with more education. The subgroup with a high school education, however, had fished for significantly longer than the subgroups with

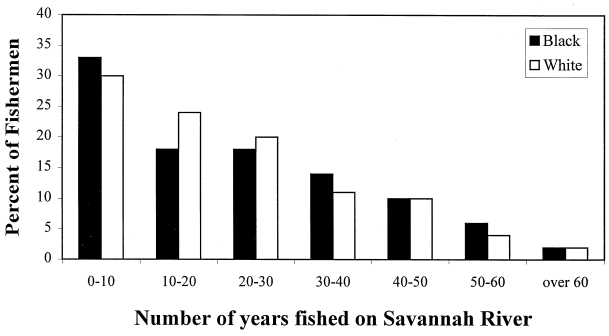

Fig. 2. Number of years subjects had fished on the Savannah River by race.

Table III. Models Explaining Variation in Fishing Behavior and Consumption of Fishermen along the Savannah River. No Interactions Were Significant. Values Shown $F(p)$

	Years fished Savannah River	Serving size	Fish meals per month	Total grams of fish per year
Model				
F	19.4	2.0	6.9	7.3
dF	5,206	5,194	5,199	5,179
p	0.0001	0.08	0.0001	0.0001
r^2	0.33	0.05	0.15	0.18
Factors entering (F, p)				
Ethnicity	NS	3.5 (0.06)	13.2 (0.004)	12.2 (0.0006)
Education	2.9 (0.09)	NS	14.0 (0.0002)	17.7 (0.0001)
Age	72.3 (0.0001)	NS	NS	NS
Income	3.0 (0.08)	NS	NS	NS
Education^2	5.6 (0.02)	3.1 (0.08)	13.8 (0.0003)	18.1 (0.0001)

less than or more than a high school education (Table VI).

The relationship between total fish consumption (kg/year) and education, however, was also explained by a nonlinear function (see Table II), shown in Fig. 5. There are two curves for total fish consumption as a function of education, one for Whites and one for Blacks. At all education levels, Blacks ate more fish than Whites.

4.4. Employment at SRS

There were a number of significant differences as a function of employment (Table VII). People who currently worked at SRS had fished on the river for fewer years, ate fish less often per month, and consumed less fish per year than did people who did not work at SRS.

5. DISCUSSION

Because fish consumption is a major pathway of exposure to a number of environmental contaminants (e.g., methylmercury, polychlorinated biphenyls), risk assessors must take consumption of ''local'' fish into account when estimating risk or crafting consumption advisories. Different assumptions are made for fish consumption by recreational (19 kg/year) and subsistence (50 kg/year) fishermen. This study illustrates two aspects of fishing behavior and consumption by people fishing along the Savannah River that bear on exposure and risk. We investigated the pro-

Table IV. Differences as a Function of Ethnicity for Fisherman Interviewed along the Savannah River (mean ± SE; NS = not significant)

	Black	White	Kruskal–Wallix χ^2 (p)[a]
Number interviewed	72 (28%)	180 (70%)	
Number of years fished	34 ± 2 (1–73)	31 ± 1 (1–70)	NS
Years fished Savannah River	24 ± 2 (1–73)	24 ± 1 (1–70)	NS
Distance traveled (km)	15 ± 1 (5–32)	42 ± 9 (2–960)	5.84 (0.02)
How often they eat fish/month	5.37 ± 0.57 (0–20)	2.88 ± 0.30 (0–24)	16.97 (0.001)
Serving size of fish (g)	387 ± 10.2 (0–597)	370.53 ± 6.60 (199–625)	3.73 (0.05)
Fish/month (kg)	2.13 ± 0.24 (0–7.96)	1.17 ± 0.14 (0–9.56)	12.38 (0.001)
Fish/year (kg)	25.55 ± 2.92 (0–95.46)	14.03 ± 1.70 (0–114.5)	12.38 (0.001)
Percent that deep fry	81 ± 4 (0–100)	75 ± 2 (0–100)	NS
Percent that eat whole fish	79 ± 4 (0–100)	64 ± 3 (0–100)	8.46 (0.004)
Age	47 ± 2 (23–77)	42 ± 1 (16–82)	NS
Years of schooling	12 ± 0.3 (3–18)	12 ± 0.1 (5–18)	12.99 (0.002)
Income	$18,571 ± $1,140 ($0–$49,000)	$22,431 ± $957 ($0–$60,000)	7.69 (0.006)

[a] Based on the Kruskal–Wallis nonparametric analysis of variance.

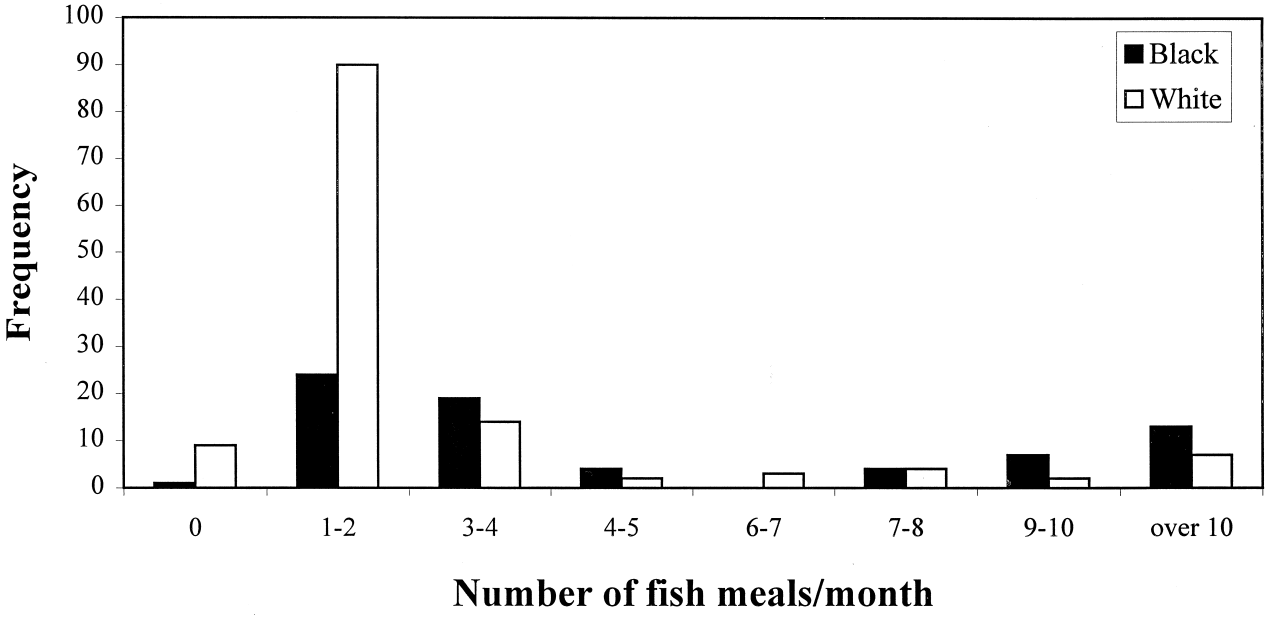

Fig. 3. Number of fish meals eaten per month by race.

portion of our Savannah River fishing sample that might be significantly exposed to potentially harmful chemicals because they are consuming more than 19 kg/year of fish from the Savannah River, and also the demographic variables (ethnicity, education, income) that explain variations in exposure.

5.1. Methodological Considerations

Information on sport fish consumers has been obtained by at least two methods (and combinations, thereof): surveys based on fishing license holders, and surveys of anglers while they are fishing (often

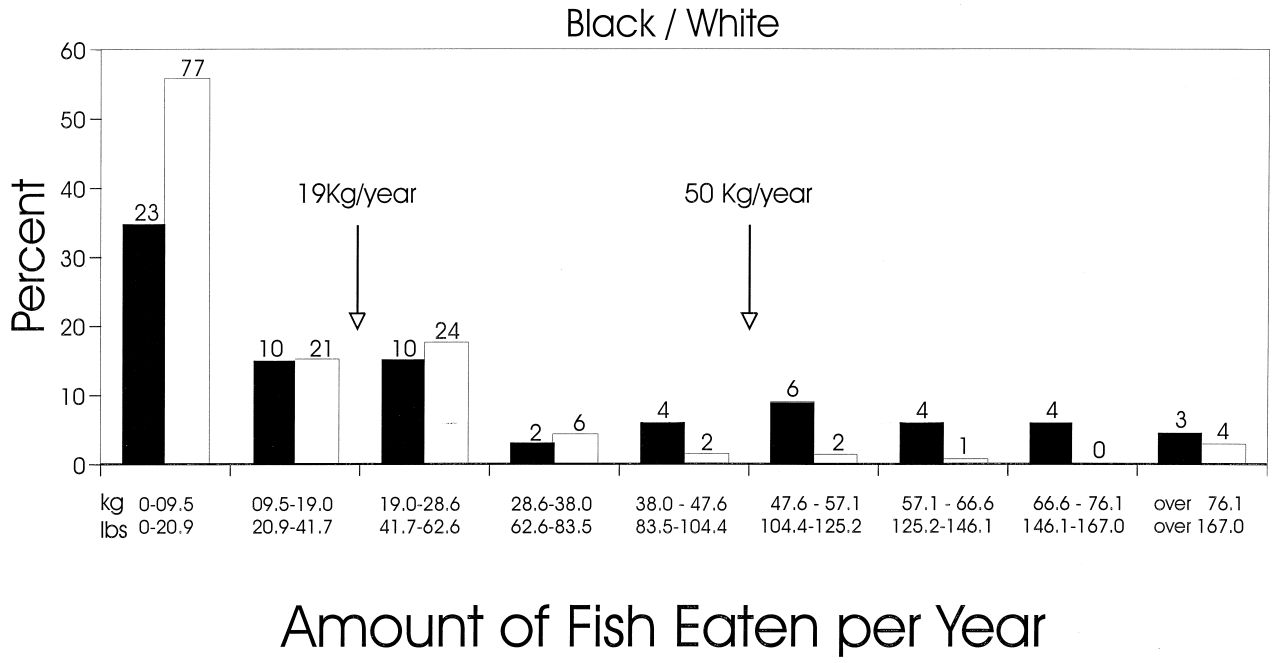

Fig. 4. Amount of fish consumed per year by race; 19 kg/year and 50 kg/year are the values used by South Carolina in its risk assessment for recreational and subsistence fishermen.

Table V. Differences as a Function of Income for Fishermen along the Savannah River (mean ± SE; NS = not significant)

	Income less than or equal to $20,000	Income greater than $20,000	Kruskal–Wallis χ^2 (p)
Number interviewed	138 (54%)	99 (38%)	
Number of years fished	30 ± 1 (1–73)	32 ± 2 (1–70)	NS
Years fished Savannah River	22 ± 2 (1–73)	24 ± 2 (1–60)	NS
Distance traveled (km)	32 ± 9 (2–800)	31 ± 4 (3–160)	NS
How often they eat fish/month	3.97 ± 0.36 (0–20)	3.39 ± 0.52 (0–24)	5.31 (0.02)
Serving size of fish (g)	375.00 ± 8.10 (0–625)	379.05 ± 7.27 (199–568)	NS
Fish/month (kg)	1.58 ± 0.16 (0–8.00)	1.44 ± 0.24 (0–9.55)	NS
Fish/year (kg)	18.93 ± 1.88 (0–95.46)	17.25 ± 2.82 (0–114.5)	NS
Percent that deep fry	77 ± 3 (0–100)	76 ± 3 (0–100)	NS
Percent that eat whole fish	72 ± 3 (0–100)	64 ± 4 (0–100)	NS
Age	42 ± 1 (16–82)	43 ± 1 (19–75)	NS
Years of schooling	12 ± 0.2 (3–16)	13 ± 0.2 (5–18)	20.20 (0.001)

called ''creel surveys''). The former has the advantage of being truly population-based, whereas the latter may lack external validity because they depend on a convenience sample. However, creel surveys have the advantage of obtaining information on unlicensed, subsistence anglers and those who might not otherwise answer a mail or telephone survey.

There are inevitably sampling biases in any design that depends on the presence of people at designated places.[26] In this study, we interviewed people who were fishing on the river, and were therefore limited to those people we found. We tried to reduce this bias by conducting our interviews at all times of the day, on all days of the week, along different sections of the river. Furthermore, we approached everyone we encountered and experienced a very low refusal rate (4%), thus reducing any bias due to selection of people to interview.

There is a potential recall bias with respect to the frequency of eating fish and the size of a fish meal. We dealt with the latter by providing them with a reference for quantity (a 6.5-oz. can of tuna). We dealt with the former by asking them in three different places about consumption rates, thereby providing an internal validity check. For example, everyone who said that they did not consume fish on one part of the questionnaire later gave their fish meal size as zero when asked about specific species of fish. The correlation between average serving size reported for eating fish on one part of the survey compared to the average serving size reported for specific fish species on the questionnaire was over 0.9. Although it

Table VI. Differences as a Function of Education for Fishermen Interviewed along Savannah River (mean ± SE; NS = not significant; significant differences between means found by Duncan Test indicated by letters)

	Not high school graduate	High school graduate	College or technical training	Wilcoxon χ^2 (p)
Number interviewed	45 (17%)	154 (60%)	59 (23%)	
Number of years fished	36 ± 2 (8–68) A	31 ± 1 (1–73) A,B	28 ± 2 (1–70) B	NS
Years fished Savannah River	23 ± 3 (1–60) A,B	26 ± 1 (1–73) A	17 ± 2 (1–52) B	9.69 (0.008)
Distance traveled (km)	24 ± 4 (2–96)	36 ± 9 (2–960)	54 ± 24 (5–800)	NS
How often they eat fish/month	5.93 ± 0.85 (0–24) A	3.02 ± 0.27 (0–20) B	3.36 ± 0.67 (0–24) B	11.96 (0.003)
Serving size of fish (g)	383.12 ± 13.30 (227–625)	366.10 ± 6.81 (0–597)	397.73 ± 11.78 (199–597)	NS
Fish/month (kg)	2.61 ± 0.44 (0.02–9.55) A	1.15 ± 0.11 (0–8.00) B	1.52 ± 0.31 (0.20–9.55) B	9.45 (0.009)
Fish/year (kg)	31.30 ± 5.26 A (0.18–114.55)	13.79 ± 1.36 B (0–95.46)	18.20 ± 3.66 B (0.23–114.5)	9.45 (0.009)
Percent that deep fry	77 ± 5 (0–100)	80 ± 3 (0–100)	70 ± 4 (0–100)	NS
Percent that eat whole fish	75 ± 6 (0–100) A	76 ± 3 (0–100) A	44 ± 6 (0–100) B	25.35 (0.0001)
Age	49 ± 2 (16–82) A	43 ± 1 (16–82) B	41 ± 2 (20–75) B	NS
Income	$14,359 ± $1,183 A ($0–$32,000)	$21,347 ± 897 B ($0–$55,000)	$27,134 ± 1,864 C ($0–$60,000)	28.41 (0.0001)

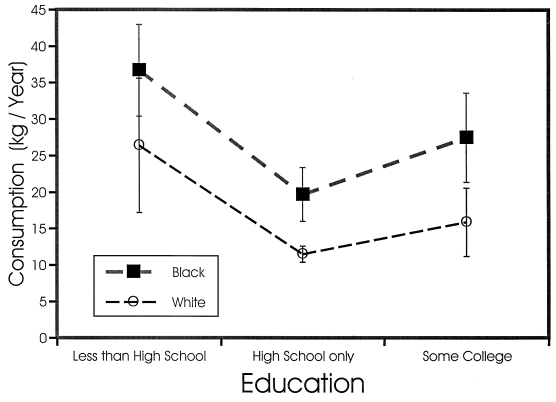

Fig. 5. Curvilinear relationship between educational level and fish consumption by race. Shown are mean ± standard error.

is difficult to obtain accurate information about fishing and consumption and about contaminants in the fish consumed, this information is critical for estimating risk and determining whether advisories are warranted.[27]

An additional aspect deals with the form of questions. Our experience indicates that minimizing the total length of the survey is important and, also, asking similar questions two or more different ways in the questionnaire is helpful in showing internal consistency. When asking about the portion size of fish, we used a standard 6.5-oz can of tuna as a model; this proved to be very helpful in obtaining consistency of results among people. The questions that proved most difficult to answer related to the percent of time people cooked fish by different methods. We suggest that it was difficult to distinguish between deep fry and fry, largely because some people pan fry with a substantial quantity of oil.

We had two categories for how people obtained the fish they ate: self-caught and bought. After completion of the survey we concluded that it would have been useful to distinguish between fish obtained directly from the wild by themselves, friends, or family, and store-bought or restaurant fish. Several people mentioned that attending fish fries held by neighbors and family was an important and frequent social event.

5.2. Advisories and Exposure

The Savannah River runs between South Carolina and Georgia. Georgia has not issued any consumption advisories, although they have pamphlets that explain to the public how to reduce any risk from eating fish. However, South Carolina has issued a fish consumption advisory for the Savannah River from the Augusta Lock and Dam to the I-95 bridge,[20] beyond our interview area. Mercury concentrations provided the basis for the recommended consumption amounts, although specific ingestion levels were also based on cesium-137 and strontium-90. Pregnant women, women planning to get pregnant, and infants and children are advised not to eat fish from the river.[20] Thus, fishermen must decide whether to follow the advice of South Carolina (consumption advisory) or Georgia (no advisory). Whenever two states share waters, but give conflicting advice, confusion can result.[27,28]

Recommended adult consumption limits, according to South Carolina, range from 1 to 4.7 lbs

Table VII. Differences as a Function of SRS Employment for Fishermen Interviewed along Savannah River (mean ± SE; NS = not significant)

	SRS	Non SRS	Kruskal–Wallis X^2 (p)
Number interviewed	29 (11%)	229 (89%)	
Number of years fished	25 ± 2 (2–50)	32 ± 1 (1–73)	3.04 (0.05)
Years fished Savannah River	22 ± 3 (1–50)	24 ± 1 (1–73)	NS
Distance traveled (km)	42 ± 9 (5–160)	36 ± 8 (2–960)	NS
How often they eat fish/month	1.38 ± 0.24 (0–4)	3.83 ± 0.30 (0–24)	9.42 (0.002)
Serving size of fish (g)	373.30 ± 14.75 (199–597)	376.46 ± 5.86 (0–625)	NS
Fish/month (kg)	0.62 ± 0.14 (0.02–2.39)	1.55 ± 0.14 (0–9.55)	5.36 (0.02)
Fish/year (kg)	7.41 ± 1.63 (0.23–28.64)	18.59 ± 1.63 (0–114.5)	5.36 (0.02)
Percent that deep fry	84 ± 5 (0–100)	76 ± 2 (0–100)	NS
Percent that eat whole fish	71 ± 7 (0–100)	68 ± 3 (0–100)	NS
Age	38 ± 2 (21–60)	44 ± 1 (16–82)	7.37 (0.03)
Years of schooling	13 ± 0.3 (12–16)	12 ± 0.1 (3–18)	7.81 (0.02)
Income	$32,172 ± 2,552 ($2,000–$60,000)	$20,002 ± $732 ($0–$60,000)	23.34 (0.001)

(0.45–2.14 kg) of fish per month (up to 25.7 kg/yr) of largemouth bass and from 1.5 lbs (680 g) to no limit for other fish (depending on river segment). Our consumption rate for fishermen along the Savannah River (number of meals per month × average serving size) ranged up to 49.1 kg/per year (mean of 2.82 kg) for Blacks, and ranged up to 9.5 kg/year (mean of 1.17 kg) for Whites. It is highly unlikely for any one fishermen to eat only largemouth bass (the species with the most stringent advisories),[20] because they are difficult to catch consistently, and other species of fish caught are brought home for consumption. Even so, these data indicate that some fishermen are exceeding the limits advised by South Carolina.

Long-term risk, however, is a function of the amount of fish eaten, the contaminants therein, and the number of years of exposure. The average time fished in this study was 32 years, with an average of 24 years fished on the Savannah River. This is high, particularly because some people had fished the Savannah River for 50 to 73 years. In our study, Whites fished an average of 2.9 times per month and Blacks 5.4 times per month. In a comparable study in the Everglades, Fleming et al.[19] reported that fishermen had fished an average of 16 years and 1.8 times/month.

Most of our subjects were men, but one of the questions dealt with the amount of fish their wives and children ate. Women and children ate the fish as often as men, and children began to eat the fish at 3–5 years of age. Thus, women and children are clearly eating the fish from the Savannah River. Although we did not specifically ask about pregnancy, only one person mentioned limiting fish consumption during pregnancy, and everyone said their wives ate the fish, all the time, whenever they themselves ate fish. Our data suggest, therefore, that women are not avoiding the fish, nor are they avoiding feeding the fish to children.

Nervous system development in the fetus is the most sensitive endpoint for organic mercury,[13] and is now used in risk assessments to develop reference doses (RfDs) or their equivalent. Data sources used are based on the Iraq organomercury epidemic,[13] and on prospective longitudinal studies in the Seychelles[8] and the Faroe Islands.[9] The EPA IRIS data base lists an RfD of 0.1 μg/kg/day,[29] but the EPA Division of Water has based its fish advisories on an oral RfD = 0.06. The Agency for Toxic Substances and Disease Registry has proposed an RfD of 0.5[30] based on the Seychelles neurodevelopmental study[8] without incorporating an uncertainty factor for interindividual variation. The data from the Faroe Island study[9] would support a lower value and, indeed, Stern[13] computed an RfD of 0.07 based on data from Iraq. Thus, there is still disagreement about the RfD, with a range of slightly less than an order of magnitude.

5.3. Fish Consumption: Frequency and Amount

Since detailed individual data on fish consumption frequency and serving size are seldom available, most studies examine fish consumption by multiplying the average number of meals per month times the average serving size to obtain the amount of fish eaten, although nutritional epideiologists recognize that this method may underestimate consumption.[31] In this study, computing average fish consumption by this method would yield a rate of 16.2 kg/yr for Blacks (instead of the actual value of 17.6 kg/yr). However, we found that the people who ate fish the most often also ate the largest fish meals, increasing their total consumption over a year. This has the effect of placing more people at greater risk than would appear from examining only averages (see Table IV). This supports the importance of understanding the distribution of exposure variables rather than merely their parameters. Furthermore, there were significantly more Blacks at the high consumption levels than Whites.

These data indicate that studies of fish consumption should take into account individual differences in both rate of fish consumption and quantity of fish consumed per meal. Examining only averages does not give a complete picture of the consumption patterns of those potentially most at risk, but systematically biases towards a low estimate. The data further suggest that the factors that contribute to the total amount of fish eaten per year (= exposure) include ethnicity, education, and age. Income did not enter any of the models independently as a significant variable.

5.4. Ethnic and Socioeconomic Differences and Risk

There is a growing literature on ethnic differences in environmental attitudes and risk, although much of this literature deals with environmental hazards, such as hazardous wastes,[32–34] rather than the health risks from consuming fish. Several studies have indicated that Blacks are generally less con-

cerned than Whites[32–35] about environmental hazards. However, Burby and Strong[36] reported that Blacks were more concerned about environmental pollution than Whites, and Burger[37] found that Blacks living near SRS in Columbia, South Carolina, were equally or more concerned about environmental problems than Whites in the same area. Furthermore, a number of studies have shown differences in fishing behavior between Blacks and Whites, at least with respect to attitudes toward fishing,[1] but little attention has been directed to studies of exposure differences. Fleming et al.[19] working in the Florida Everglades, noted that Blacks were less likely to know about the health advisories than other ethnic groups examined, and Toth and Brown[1] reported higher levels of consumption of fish among Blacks compared to Whites. Furthermore, in their models, economic and subsistence came out as more important contributors to the reasons Blacks gave for fishing than for Whites.

It is important to provide good communication with regard to risk balancing because the beneficial qualities of fish may offset the harm from contaminants. The Alaska Division of Public Health, for example, reached this conclusion with regard to traditional food consumption in Alaska.[38,39] Their reports concluded that the contaminant levels in traditional foods were sufficiently low that the benefits to the native population outweighed the risks.

In this study from the Savannah River, there were significant ethnic differences in nearly all measures of fishing and consumption, and these differences were not attributable to income. However, there was a clear relationship between educational level, ethnicity, age, and fish consumption. On average, the Blacks in our sample had less education and ate more fish per year than did the Whites. The relationship is nonlinear, however in that people, both Black and White who had a high school education ate significantly less fish than people with more or less education (refer to Table V). The reasons for the high fish consumption in people with less and more education is interesting, and may relate to knowledge levels: people with less education (who tend to make less money) may eat more fish because it is a cheap and good source of protein, and people with more education may be more aware of the positive cholesterol-reducing benefits of fish. We cannot separate these two explanations from our data, but suggest that it is important to do so.

In general, Blacks ate larger meals of fish and ate fish more often than did Whites. This suggests that potential exposure is higher for Blacks than for Whites, although the risk depends on the levels of contaminants in the fish. However, given that South Carolina has issued consumption advisories for this portion of the Savannah River, these data suggest that Blacks consuming fish from the study area have a potentially greater exposure to contaminants than do Whites.

The fishermen examined from Savannah River differed considerably from several studies that indicate that the ''average'' angler is middle-class, White, male, between the ages of 30 and 40 (reviewed in Ebert[12]). The use of general demographics to determine the potential risk of fish consumption patterns for specific waters may seriously miss the mark. For example, Jacobs *et al.*[40] showed that the per capita consumption of fish for the United States was only 0.016 kg/day, far lower than the 0.048 kg/day for the present study. Site-specific information on both demographics and fish consumption is essential to the development of both risk assessment and risk management. It is impossible to target the population at risk if sufficient information on the population is not available.

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