



ELSEVIER

The Science of the Total Environment 299 (2002) 145–161

**the Science of the
Total Environment**
An International Journal for Scientific Research
Into the Environment and its Relationship with Man

www.elsevier.com/locate/scitotenv

Fishing along the Clinch River arm of Watts Bar Reservoir adjacent to the Oak Ridge Reservation, Tennessee: behavior, knowledge and risk perception

Kym Rouse Campbell^{a,b,*}, Richard J. Dickey^{a,b}, Richard Sexton^{a,b}, Joanna Burger^{b,c}

^a*The Cadmus Group, Inc., 78A Mitchell Road, Oak Ridge, TN 37830, USA*

^b*Consortium for Risk Evaluation with Stakeholder Participation, New Brunswick, NJ, USA*

^c*Division of Life Sciences, Nelson Biological Laboratory, Rutgers University,
Environmental and Occupational Health Sciences Institute, Piscataway, NJ, USA*

Received 15 January 2002; accepted 26 June 2002

Abstract

Catching and eating fish is usually viewed as a fun, healthy and safe activity. However, with continuing increases in fish consumption advisories due to the contamination of our environment, anglers have to decide whether or not to eat the fish they catch. The Clinch River arm of Watts Bar Reservoir is under a fish consumption advisory because of elevated PCB concentrations in striped bass (*Morone saxatilis*), catfish (*Ictalurus* spp.) and sauger (*Stizostedion canadense*) due in part from contaminants released from the US Department of Energy's (USDOE's) Oak Ridge Reservation (ORR) in East Tennessee. To obtain information about the demographics, fishing behavior, knowledge, fish consumption and risk perception of anglers, a survey was conducted of 202 people actively fishing either on land or by boat along the Clinch River arm of Watts Bar Reservoir adjacent to the ORR from Melton Hill Dam to the Poplar Creek confluence or on Poplar Creek within ORR boundaries from mid-March to early November 2001. Even though 81% of people interviewed knew about the fish consumption advisories for the study area, 48% of them thought the fish were safe to eat, while 38% ate the fish that they caught from the study area. Approximately 36% of anglers who had knowledge of the fish consumption warnings ate fish from the study area. Providing confirmation that people fish for many reasons, 35% of anglers interviewed did not eat fish at all. The majority of anglers interviewed knew about the fish consumption advisories because of the signs posted throughout the study area. However, few people knew the correct fish advisories. Significantly fewer blacks had knowledge of the fish consumption warnings than whites. Information resulting from this study could be used to design a program with the objective of reaching the people who may be most at risk from eating fish caught from the Clinch River arm of Watts Bar Reservoir.

© 2002 Elsevier Science B.V. All rights reserved.

Keywords: Fish consumption advisories; Risk perception; Oak Ridge Reservation; Watts Bar Reservoir; Clinch River

*Corresponding author. Tel.: +1-865-425-0401; fax: +1-865-425-0482.

E-mail address: kcampbell@cadmusgroup.com (K. Rouse Campbell).

0048-9697/02/\$ - see front matter © 2002 Elsevier Science B.V. All rights reserved.

PII: S0048-9697(02)00276-0

1. Introduction

The safety of recreational and subsistence fishing is important to both the general public and government agencies. In the United States, the number of acres of lakes under fish consumption advisory increased from 20.4% in 1999 to 23% in 2000, while the number of river miles under advisory increased from 6.8% in 1999 to 9.3% in 2000 (USEPA, 2001). In 2000, 100% of the Great Lakes and their connecting waters and 71% of coastal waters of the contiguous 48 states were under advisory. Compared to 1999, the total number of advisories in the United States increased for four major contaminants (mercury, PCBs, dioxins and DDT) in 2000 but remained the same for chlordane (USEPA, 2001). Although approximately 80% of advisories have been issued at least in part because of mercury, other contaminants are likely to be present in many of the advisory locations. The increase in fish consumption advisories is of concern and could be due to an increase in the number of contaminant assessments performed, the improved quality of monitoring and data collection methods, or a real increase in contamination (Burger et al., 2001a,b). There has also been an increase in public awareness of health risks associated with eating contaminated fish and wildlife in recent years. The mean per capita freshwater/estuarine fish consumption in the United States has risen, from 6.5 g/day in 1973–1974 to 16.6 g/day in 1989–1992 (Jacobs et al., 1998). Fish provides many benefits and is an excellent, low-fat source of protein (Anderson and Wiener, 1995). Fishing is also an enjoyable activity that has many social benefits (Toth and Brown, 1997). Therefore, understanding fishing behavior, people's knowledge of advisories and the compliance of people fishing in waters with consumption advisories is essential.

This paper addresses whether anglers had heard of fish consumption advisories, their sources of information, and details of fishing behavior that relate to risk reduction for people fishing on the Clinch River arm of Watts Bar Reservoir adjacent to the ORR or Poplar Creek within ORR boundaries. Detailed data on fish consumption patterns and additional information on fishing behavior are

presented in Campbell et al. (in press). A similar study was conducted on people fishing on the Savannah River along the USDOE's Savannah River Site (SRS) in South Carolina (Burger, 1998; Burger et al., 1999a, 2001a,b). The consumption of freshwater fish is common among Tennessee anglers, with more than 50% of reservoir anglers consuming fish taken from reservoirs, and 15% consuming 10 or more meals during the spring and summer fishing season (Jakus et al., 1997). It is critical to understand how the fishing public perceives fishing and consumption advisories in order to place stakeholder concerns at the beginning of any effective risk assessment and risk management process (Commission on Risk Assessment and Risk Management, 1996). This paper is part of the Consortium for Risk Evaluation with Stakeholder Participation's (CRESP's) continuing work to develop risk methodologies for humans and ecosystems.

The USDOE's 14 200 ha (35 000 acre) ORR is located along the Clinch River arm of Watts Bar Reservoir beginning at Clinch River Kilometer (CRK) 17.7 [Clinch River Mile (CRM) 11] and extending upstream of Melton Hill Dam to CRK 69 (CRM 43) in eastern Tennessee. It contains three main facilities: the Y-12 Plant; the K-25 Site (now known as the East Tennessee Technology Park); and Oak Ridge National Laboratory (ORNL) (Fig. 1). Effluent discharges and runoff from all three USDOE facilities enter the Clinch River arm of Watts Bar Reservoir via either White Oak Creek at CRK 33.8 (CRM 21) or Poplar Creek and its tributaries at CRK 19.3 (CRM 12) (Bevelhimer and Adams, 1996). Contaminants that have been released from the three USDOE facilities include a variety of radionuclides, metals and organic compounds that originated from research, industrial and waste management activities (USDOE, 1988). The ORR was added to the National Priority List as a Superfund site in December 1989 (Bevelhimer and Adams, 1996). The majority of the contaminant load currently in the reservoir is a result of ORR releases prior to 1980, primarily in the 1950s and 1960s (Turner et al., 1984). In recent years, source reduction activities on the ORR have reduced the release of contaminants to the off-site environment, and all

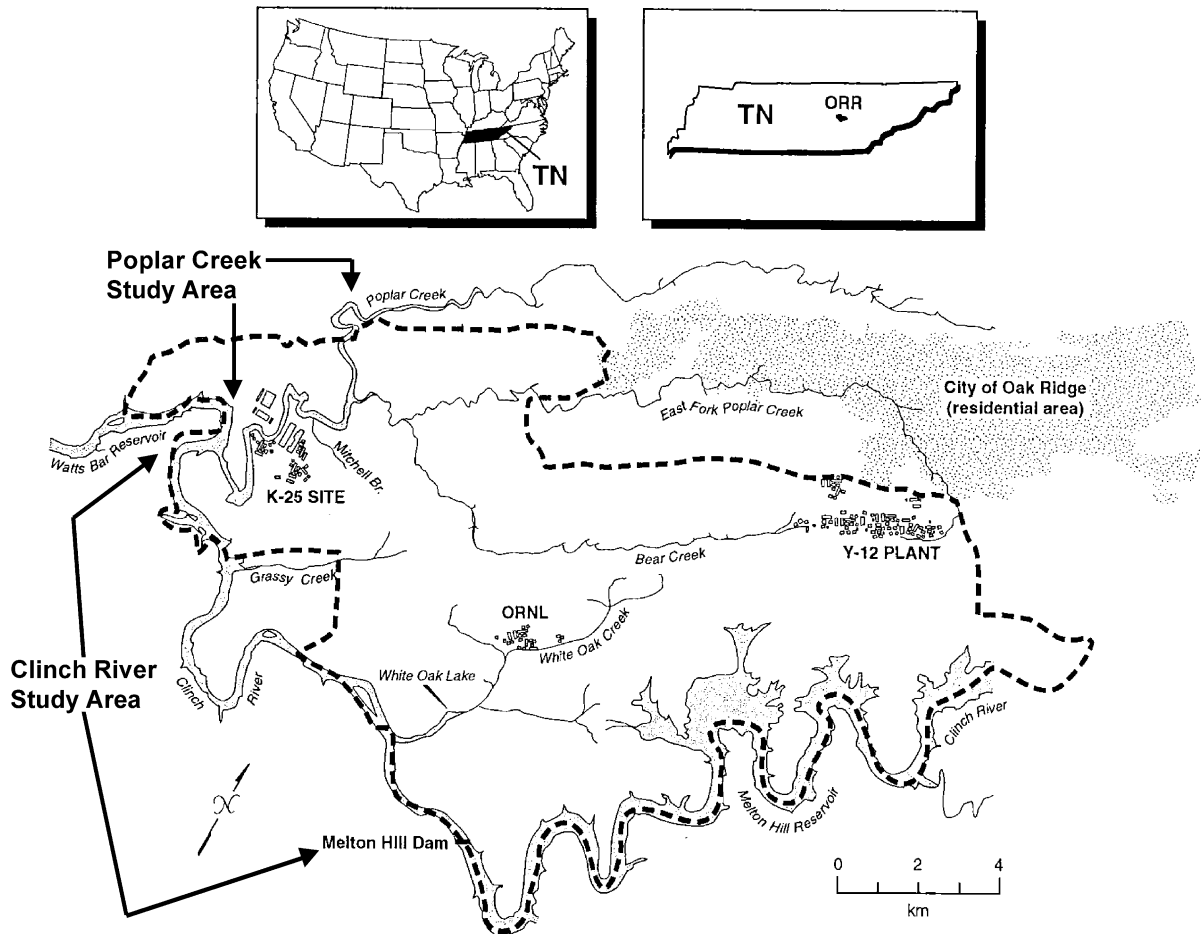


Fig. 1. Map of the study area for the Clinch River/Poplar Creek fish consumption survey.

surface water discharges are now under National Pollutant Discharge Elimination System (NPDES) permits (Bevelhimer and Adams, 1996). In addition to contaminants released from the ORR, the Clinch River also receives waste from municipal water treatment facilities and urban runoff from the city of Oak Ridge (Bevelhimer and Adams, 1996).

The primary contaminants responsible for advisories in Tennessee are PCBs, but mercury, chlordane and dioxin are sometimes the cause for advisories (Jakus et al., 1997). The Clinch River arm of Watts Bar Reservoir is under a fish consumption advisory due to elevated PCBs in striped bass, which should not be eaten, and a precaution-

ary advisory for catfish and sauger because of high PCB concentrations. Striped bass, a popular sport fish, are large piscivores known to range throughout Watts Bar Reservoir on a seasonal basis whose primary prey are high-lipid shad (Cheek et al., 1983). Catfish are a popular food fish particularly for subsistence anglers in Tennessee and are omnivorous, bottom-dwelling fish with relatively high lipid contents (Bevelhimer and Adams, 1996). The sauger's diet consists of almost exclusively fish, with small shad being the primary prey (Etnier and Starnes, 1993). Fish with high lipid contents can accumulate high concentrations of some types of contaminants (i.e. PCBs, mercury). The advisories were issued when PCB concentra-

tions in fish fillets approached the US Food and Drug Administration's action level of 2.0 mg/kg (Bevelhimer and Adams, 1996). A precautionary advisory means that children, pregnant women and nursing mothers should not consume the fish species named, and all other persons should limit consumption of the named species to one meal per month. Because of mercury, PCBs and other contaminants resulting from current and historical releases from the ORR, the advisory for Poplar Creek states that no fish should be consumed and contact with the water should also be avoided.

2. Methods

The area selected for this study included the Clinch River arm of Watts Bar Reservoir from Melton Hill Dam to the confluence with Poplar Creek and Poplar Creek from the confluence with the Clinch River to the intersection with Poplar Creek Road (Fig. 1). Melton Hill Dam was chosen as the upstream boundary for the study because it completely blocks any movement of fish.

Anglers were interviewed using a questionnaire that was almost identical to one used in a similar study conducted along the Savannah River adjacent to the USDOE's SRS in South Carolina (Burger, 1998; Burger et al., 1999a), with minor modifications specific for the study area. Interviews were conducted both on land (86%) and on water by boat (14%) from March 10 through November 1, 2001. Interviews were conducted nearly every week (weather permitting), and each person was interviewed only once to ensure a wide distribution of people and fishing methods. People fishing were interviewed on 65 days, including weekdays (48) and weekend days (17), and interviews were conducted from dawn to dusk. Everyone encountered, who was not previously interviewed, was interviewed. The majority of the interviews were conducted by the same two people who have lived in the area their entire lives. The same people were often seen at the same fishing sites, and they often asked how the survey work was progressing.

People were interviewed along different sections of the study area depending on the time of year, time of day (whether or not power generation was

occurring at Melton Hill Dam), weather and fishing conditions. When a particular species of fish was being sought after, anglers often concentrated in a particular portion of the study area, in preference to others. Fishermen were interviewed on land along the 1.6-km reach of the Clinch River immediately below Melton Hill Dam (Melton Hill Dam tailwaters) and along the upper portions of Poplar Creek, where it was accessible from shore along Blair Creek Road. People were consistently found fishing from shore along Melton Hill Dam tailwaters (84% of surveys), although fishing slacked off during the hot summer months (July and August). This location was a preferred fishing spot for catching black and white crappie (*Pomoxis nigromaculatus* and *Pomoxis annularis*, respectively) in the spring and fall, white bass (*Morone chrysops*) in the spring and early summer and striped bass in the summer. Because of the swift current and little warning when water was to be released from the dam, interviews by boat were not conducted in the 1.6-km reach of the Clinch River immediately below the dam. Interviews were conducted by boat along the 16-km reach of the Clinch River from below Melton Hill Dam tailwaters to the confluence with Poplar Creek and the lower 6.4-km of Poplar Creek. These areas were surveyed by boat at least once a week, with the exception of during July and August (surveyed every 2 weeks). After early summer when fishing for white bass slacked off, people were not found fishing from shore along Upper Poplar Creek despite numerous attempts, and surveys were discontinued in this area.

The interview form included questions about fishing behavior, consumption patterns, cooking patterns, warnings and safety of the fish and personal demographics. Demographics questions were usually asked at the beginning of the interview (age, residence, sex, ethnicity), while more sensitive questions (income, education and employment) were asked at the end to reduce rejection rates (Burger, 1998; Burger et al., 1999a; Burger and Waishwell, 2001). Most people were willing to answer sensitive questions at the end of the survey after a long, friendly interview with 'locals.' When people fishing were approached for an interview, they were asked questions about

Table 1

Information on where interviewed anglers live, including distance traveled to fish, which indicates the area to cover when disseminating information

	All anglers			Anglers who catch and eat fish from the study area		
	Percent of all anglers (N=202)	Percent of blacks (N=18)	Percent of whites (N=183)	Percent of all anglers (N=77)	Percent of blacks (N=6)	Percent of whites (N=71)
Knox County	48.0	50.0	48.1	46.7	66.7	45.1
Anderson County	20.3	38.9	18.0	19.5	33.3	18.3
Loudon County	7.9	0	8.7	10.4	0	11.3
Roane County	5.9	0	6.6	7.8	0	8.5
Morgan County	3.5	0	3.8	5.2	0	5.6
Blount County	2.5	0	2.7	2.6	0	2.8
Cumberland County	1.5	0	1.6	0	0	0
From Tennessee, but not from local area	6.4	0	7.1	5.2	0	5.6
From out of state	3.9	11.1	3.3	2.6	0	2.8
Mean (\pm S.E.) distance traveled to fish (km)	61.6 \pm 5.2 (N=181)	46.3 \pm 17.1 (N=17)	63.2 \pm 5.5 (N=163)	57.4 \pm 5.6 (N=73)	44.2 \pm 19.8 (N=6)	58.7 \pm 5.9 (N=67)

fishing to ‘break the ice,’ and anglers usually continued to fish during the interview. Since getting answers to the interview questions was most successful when people were encouraged to talk about fishing, most interviews took 30 to 45 min.

Using JMP[®]'s Fit Y by X Platform, one-way analysis of variance (ANOVA) was used to determine whether there were differences among variables as a function of ethnicity, age, education and income, and contingency tables analysis with the Pearson χ^2 statistic was used to calculate percentages and determine differences between groups (SAS Institute, Inc., 2000). A level of $P < 0.05$ was accepted as significant.

3. Results

Two hundred and two people who were fishing in the study area were interviewed. Only 10 people (5% of total) were fishing in Poplar Creek when interviewed, while 95% of anglers were found fishing in the Clinch River portion of the study area. Approximately 10% of the anglers approached refused to be interviewed, largely because they were in a hurry (to leave or to run back down the Clinch River to get more bait shad to keep fishing for striped bass below the dam) or needed to pay attention to what they were doing (safely navigating their boat in the dangerous area just below the dam or in the high current).

3.1. Angler demographics

Of the people interviewed, 90.5% were white, 9% were black and 0.5% were ethnic Chinese (one person). Ninety-five percent of the anglers interviewed were men, and all women interviewed (10) were white. The average age of people interviewed was 39 ± 1 years and ranged from 11 to 74 years. Three people (1.5% of those interviewed) worked or had worked at the ORR. People interviewed had fished an average of 31 years, with a range from 1 to 68 years. The average length of time that people had fished in the study area was 11 ± 0.8 years; however, two people had fished the study area for over 50 years. Twenty-two people were fishing in the study area for the first time or for the first time in years when interviewed. Anglers fished an average of approximately 83 days per year, ranging from 1 to 312 days per year. The mean days fished per year did not differ significantly by ethnicity (blacks=73.3 days per year; whites=83.8 days per year). Most people interviewed lived in Knox County, one of the counties adjacent to the study area (Table 1). Approximately 89% of black anglers were from either Knox or Anderson Counties (another county adjacent to the study area), while approximately 66% of whites interviewed were from Knox and Anderson Counties. Differences between the distances traveled to fish by black and white anglers

Table 2
Relationships of ethnicity, income, education and age on perceptions and eating fish from study area

	Sample size	Percent that say the fish are safe to eat	Sample size	Percent that have heard of advisories	Sample size	Percent that eat fish from the study area
<i>Ethnicity</i>						
Black	15	46.7	18	61.1	18	33.3
White	180	50.0	182	82.3	183	38.8
χ^2 (<i>P</i>)		0.062 (NS)		5.08 (0.02)		0.81 (NS)
<i>Income</i>						
Less than \$20 000	41	51.2	43	81.4	43	51.2
\$20 000–\$29 000	54	48.1	55	78.2	56	33.9
\$30 000–\$39 000	46	54.3	46	84.8	46	39.1
\$40 000–\$60 000	40	45.0	42	76.2	42	26.2
More than \$60 000	10	40.0	10	100.0	10	40.0
χ^2 (<i>P</i>)		1.19 (NS)		3.71 (NS)		11.06 (NS)
<i>Education Level</i>						
Not a high school graduate	36	58.3	35	88.6	36	50.0
High school graduate	69	50.7	72	72.2	72	38.9
Some college, trade school, vocational school, associates degree	45	48.9	47	80.8	47	42.5
Bachelors degree	34	44.1	35	85.7	35	25.7
Graduate degree (Masters or Ph.D)	11	27.3	11	100.0	11	9.1
χ^2 (<i>P</i>)		3.73 (NS)		7.99 (NS)		15.05 (NS)
<i>Age</i>						
Less than or equal to 29 years	48	50.0	49	75.5	49	34.7
30–39 years	59	40.7	61	75.4	61	31.1
40–49 years	38	55.3	41	82.9	41	39.0
Greater than or equal to 50 years	50	56.0	50	91.8	50	50
χ^2 (<i>P</i>)		3.19 (NS)		6.04 (NS)		8.31 (NS)

were not significant (Table 1). The average income of anglers interviewed was \$30 936/year (range from 0 to \$175 000). Approximately 82% of the people interviewed had finished high school and 23% of those had at least a bachelors degree. Education levels ranged from 4th grade to Ph.D. There were no significant differences in yearly income or education level between blacks and whites.

3.2. Information sources, knowledge and perceptions about advisories

Although it varied by ethnicity, income, education level and age (Table 2), 48% of the people interviewed believed that the fish caught in the study area were safe to eat. People with lower incomes and education levels generally thought

that the fish were safer to eat than those with higher incomes and education levels (Table 2). In general, people 40 years of age and older thought the fish were safer to eat than those under 40. Forty percent of Poplar Creek anglers thought that the fish were safe to eat (Table 3).

Eighty-one percent of the anglers interviewed had heard of fish consumption advisories for the study area. There was a significant difference in the percent of people that had heard warnings about fish consumption as a function of ethnicity (Table 2). Within races, there was no significant difference between income, education and age as a function of having knowledge of the fish consumption advisories for the study area (Table 4). All people interviewed who made more than \$60 000 a year or had a graduate degree knew about the fish consumption advisories for the study

Table 3

Characteristics of anglers interviewed with relation to where they were found fishing when interviewed

	Clinch River portion of study area		Poplar Creek portion of study area	
	<i>N</i>		<i>N</i>	
Ethnicity	192	9.4% black 90.1% white	10	100% white (all men)
Income (mean ± S.E.) (\$)	188	31 237 ± 1545	9	24 667 ± 7060
Education (mean ± S.E.) (years)	191	13.1 ± 0.2	10	13.1 ± 0.9
Age (mean ± S.E.) (years)	191	39.7 ± 1.0	10	33.8 ± 4.5
Percent that say the fish are safe to eat	186	50	10	40
Percent that have heard of advisories	191	80.6	10	90
Percent that eat fish from the study area	192	38.5	10	30

area. Generally, more people that were 40 years of age or older had heard about the fish consumption advisories for the study area than those younger than 40. Almost all of the people (nine out of 10) found fishing in Poplar Creek when interviewed had heard about the fish consumption warnings (Table 3).

Of the people that knew about the fish consumption advisories for the study area, approximately 63% of them knew about the advisories because of the signs posted by the boat ramps and parking areas in the study area. The majority of both black and white anglers knew of the fish consumption advisories because of the posted signs (Fig. 2). Almost 16% of anglers knew about the fish consumption advisories because of the Tennessee Wildlife Resources Agency (TWRA) pamphlet of fishing regulations that is given to people when they purchase fishing licenses or is available from locations that sell fishing licenses. However, none of the black fishermen that were aware of the consumption advisories for the study area knew

of them because of the TWRA pamphlet (Fig. 2). Other people and the newspaper (approx. 14 and 4%, respectively) were the other largest sources of knowledge about fish consumption warnings in the study area.

Approximately 24% of the anglers who knew about the fish consumption advisories for the study area mentioned contamination, pollution, or contaminated fish. Approximately 6.5% of people interviewed mentioned PCBs, but no black fishermen mentioned them (Table 5). Eleven percent of anglers mentioned mercury. Of the people who knew about the fish consumption warnings, 4.3% of them talked about limiting fish consumption; however, limiting consumption was not mentioned by any of the black fishermen who knew about the warnings (Table 5). No one mentioned that pregnant women, nursing women and children should limit how much fish they eat. Approximately 5% of interviewed anglers stated either that fish, in general, were not safe to eat or not to eat any fish, while 5% of people said that certain

Table 4

Mean (± S.E.) income, education and age conditional on awareness of fish consumption advisories

	Black				White			
	<i>N</i>	Heard	<i>N</i>	Not heard	<i>N</i>	Heard	<i>N</i>	Not heard
Income (\$)	11	34 273 ± 4422	7	30 000 ± 5500	147	31 333 ± 1777	30	26 717 ± 3932
Education (years)	11	13.8 ± 0.8	7	13.4 ± 1.0	150	13.2 ± 0.2	31	12.6 ± 0.5
Age (years)	11	38.6 ± 2.7	7	37.6 ± 3.4	150	40.3 ± 1.2	31	34.9 ± 2.6

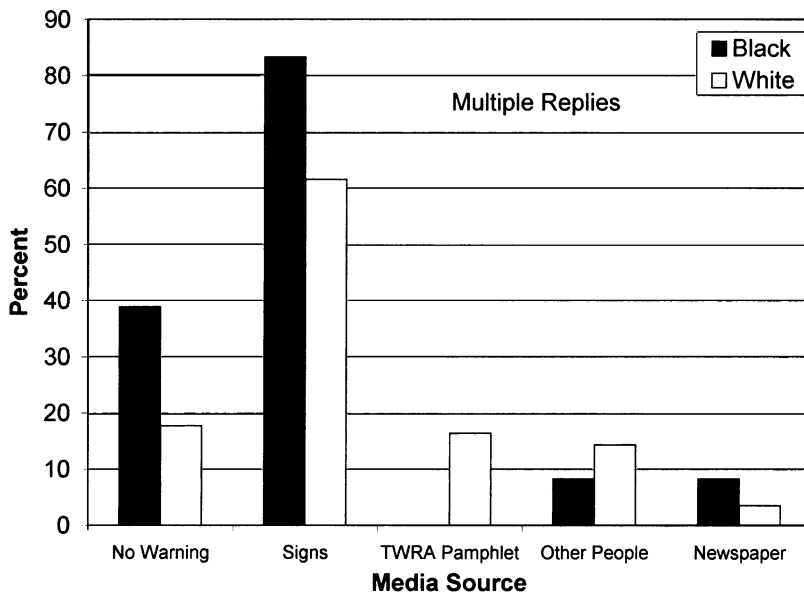


Fig. 2. Media sources for information on fish consumption advisories for blacks and whites interviewed while fishing the Clinch River/Poplar Creek study area.

types of fish should not be eaten (Table 5). Approximately 9.5% of people interviewed mentioned striped bass, 17.7% mentioned catfish, and only 1.7% of anglers mentioned sauger (Table 5). More white anglers who knew about the fish consumption advisories mentioned striped bass, while more black fishermen mentioned catfish and sauger (Table 5).

When asked who was to blame for the fish consumption warnings, 35% of people interviewed who had knowledge of the warnings mentioned either the USDOE, ORNL, or other facilities located within the ORR. Approximately one-third of both black and white fishermen blamed the USDOE for the fish contamination (Table 5). Approximately 16% of anglers who knew about the advisories blamed no one, society in general, or progress. Approximately 12% of anglers did not know who was to blame for the fish consumption warnings, while approximately 13% blamed industry and factories. No black fishermen blamed the Tennessee Valley Authority (TVA) for the contaminated fish or were unable to provide a reason for the fish consumption advisories (Table 5).

Approximately 35% of the anglers interviewed did not eat fish. Of the 65% who did eat fish, only 38% of them ate fish from the study area. In general, more people who made less than \$20 000 a year, did not graduate from high school, or were 50 years of age or older ate fish from the study area than those who made more money, had more education, or were younger (Table 2). There was a clear, although not significant ($P=0.058$), trend between education level and percent of people who ate fish from the study area. The more education a person had, the less likely they were to eat fish from the study area (Table 2). Thirty percent of Poplar Creek anglers ate fish from the study area, while the remaining 70% did not eat fish at all (Table 3).

Just over 36% of people who had knowledge of the fish consumption advisories ate fish from the study area; this value varied by ethnicity (Table 5). Approximately 47% of anglers (14.3% of black anglers, 54.8% of white anglers) who did not know about the fish consumption warnings consumed fish they caught from the study area. While it varied by ethnicity (Table 5), 29% of people

Table 5

Ethnic differences in detailed information obtained from anglers interviewed who had knowledge of fish consumption advisories and anglers who catch and eat fish from the study area

Anglers interviewed who had knowledge of fish Consumption advisories (<i>N</i> =163)	Percent of blacks (<i>N</i> =11)	Percent of whites (<i>N</i> =152)
<i>Fish warnings about?</i>		
Contamination, pollution, or contaminated fish mentioned	16.7	23.8
PCBs mentioned	0	7.0
Mercury mentioned	11.1	10.7
Limiting fish consumption mentioned	0	4.7
All fish not safe to eat or don't eat any fish mentioned	11.1	4.7
Don't eat certain types of fish	5.6	5.1
Striped bass mentioned	5.6	9.8
Catfish mentioned	27.8	16.4
Sauger mentioned	5.6	1.4
<i>Blame for fish consumption warnings?</i>		
USDOE, ORNL, or other ORR facilities	29.4	35.7
No one, society in general, people, progress	23.5	14.8
Industry and factories	23.5	11.5
TVA, the dam	0	9.3
The government	5.9	8.2
Don't know	0	12.6
Yes to 'Eat fish from study area?'	45.5	35.8
Yes to 'Eat fish but not from study area?'	9.1	30.5
Anglers interviewed who catch and eat fish from study area (<i>N</i> =77)	Percent of blacks (<i>N</i> =6)	Percent of whites (<i>N</i> =71)
Yes to 'Do you know about the fish consumption advisories?'	83.3	76.1
<i>Where else do you fish?</i>		
Waters which are clean and have fish consumption advisories mentioned	60	52.2
Only waters which have fish consumption advisories mentioned	20	31.2
Only waters which are clean mentioned	20	13.0
<i>Parts of fish eaten?</i>		
100% fillets	83.3	95.8
50% fillets, 50% whole fish	16.7	1.4
Yes to 'Fat removed before cooking?'	83.3	78.8
Yes to 'Skin removed before cooking?'	83.3	95.5
<i>How fish cooked?</i>		
100% fry	83.3	60.6
50% fry, 50% broil	0	4.2
50% fry, 50% bake	0	16.9
50% fry, 50% grill	0	4.2
100% bake	0	4.2
Equal% of fry/broil/bake	16.7	0

interviewed who knew about the fish consumption warnings ate fish but not from the study area.

3.3. Fishing behavior and consumption of anglers who eat fish from the study area

The 38% of people who caught and ate fish from the study area included 71 white anglers and six black fishermen. The majority of all anglers (76.6%), as well as both black and white anglers, who ate fish from the study area knew about the fish consumption advisories (Table 5). Because of the small sample size of blacks, analyzing the data statistically for ethnic differences was usually not valid; however, important trends and percentages of results are presented. The distance traveled to fish, the availability of alternative fishing sites, the fish species caught and eaten and cooking methods are some aspects of fishing behavior and consumption that could be modified to reduce the risks associated with contaminants in fish or used to focus on particular populations at risk. The majority of people interviewed who caught and ate fish from the study area either lived in Knox or Anderson Counties (Table 1). One hundred percent of black anglers were from either Knox or Anderson Counties, while approximately 63% of whites interviewed who caught and ate fish from the study area were from either county. The differences between the distances traveled to fish by black and white anglers who caught and ate fish from the study area were not significant (Table 1).

People who caught and ate fish from the study area fished an average of approximately 94 days per year, with a range from 4 to 312 days per year. Ethnic differences in days fished per year were not significant (average days fished for blacks: 114 days, average days fished for whites: 92 days). When asked where else they fished, anglers who caught and ate fish from the study area mentioned both clean waters and waters that were under a fish consumption advisory 52.7% of the time, while they mentioned only other waters under fish consumption advisories 31.1% of the time. Both black and white anglers provided similar answers (Table 5). Other reservoirs that are under fish consumption advisories because of PCBs were often mentioned; they included Fort

Loudoun (mentioned 33.7% of the time), Watts Bar (mentioned 21.1% of the time) and Melton Hill (mentioned 16.8% of the time). Norris Reservoir, which is not under a fish consumption advisory, was mentioned 23.1% as an alternative fishing location by anglers who caught and ate fish from the study area.

Over 71% of anglers who caught and ate fish from the study area ate only fish that they caught themselves. Black fishermen ate only fish that they caught 66.7% of the time, while 73.2% of white anglers ate only fish that they caught. Anglers who caught and ate fish from the study area ate only fish that they caught an average of 88.9% of the time.

The types of fish most often mentioned by anglers interviewed who caught and ate fish from the study area were crappie (29.2%) and striped bass (25%). White bass, sauger and catfish were other fish species that were commonly caught and eaten from the study area (18.4, 10.1 and 8.9%, respectively). There were no ethnic differences regarding the kinds of fish most often caught and eaten by people interviewed who caught and ate fish from the study area (Fig. 3).

People who caught and ate fish from the study area froze most of the following types of fish for later consumption: crappie (84.8%), striped bass (85%), white bass (75.9%), sauger (82.3%), catfish (80%) and largemouth/smallmouth bass (*Micropterus* spp.) (62.5%). Black fishermen who caught and ate fish from the study area froze 100% of most of the fish that they caught (Fig. 4).

Most of the people (approx. 95%) who caught and ate fish from the study area ate fish fillets 100% of the time; this trend did not differ with regard to ethnicity (Table 5). Some anglers who caught and ate fish from the study area (approx. 3%) ate fillets 50% of the time and whole fish 50% of the time (Table 5). Two people (both white) ate fillets 90% of the time. Approximately 94% of anglers who caught and ate fish from the study area removed the skin before cooking, while approximately 79% of them removed the fat before cooking (Table 5).

Approximately 62% of people who caught and ate fish from the study area fried all of the fish that they ate. The majority of both black and white

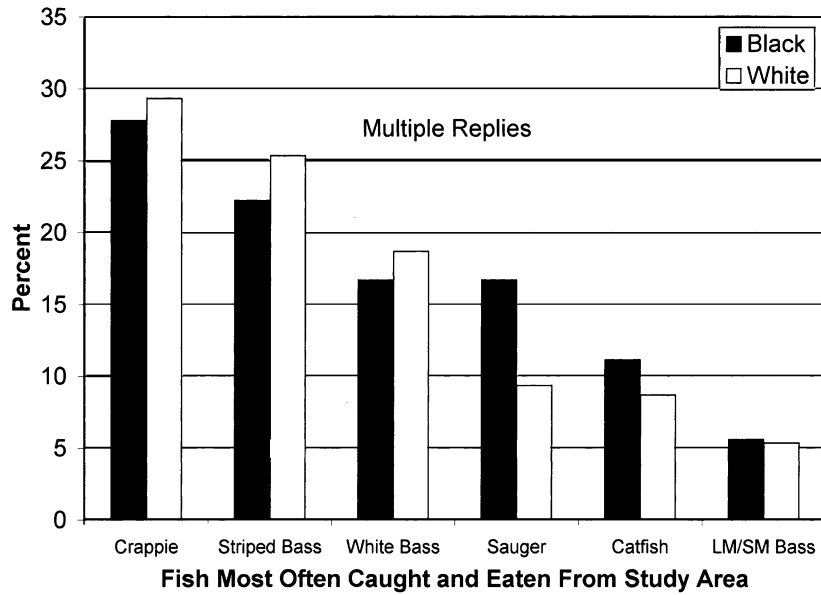


Fig. 3. Types of fish most often caught and eaten from the study area by blacks and whites interviewed while fishing the Clinch River/Poplar Creek study area.

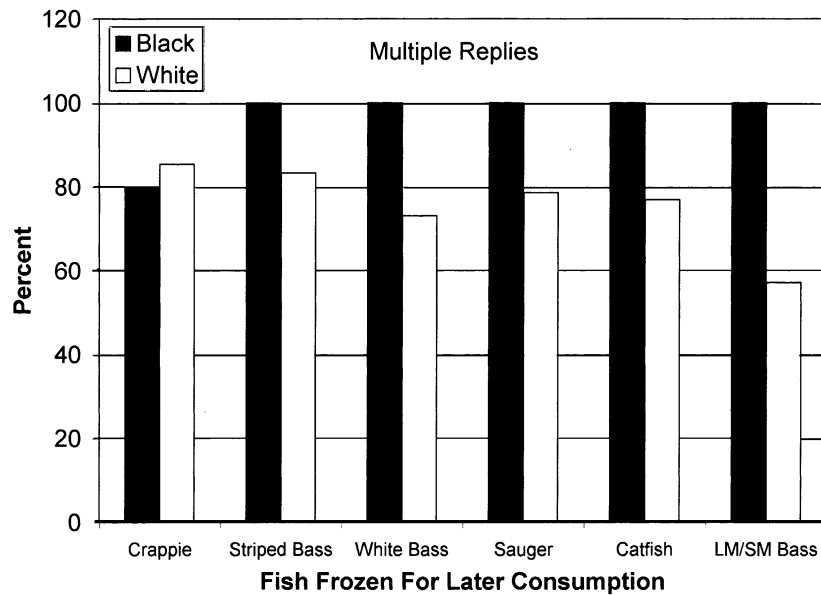


Fig. 4. The percent of the time that the types of fish most often caught and eaten from the study area are frozen for later consumption by blacks and whites interviewed while fishing the Clinch River/Poplar Creek study area.

fishermen fried all of their fish (Table 5). A percentage of white fishermen fried 50% of their fish and broiled, baked, or grilled the rest (Table 5). Three white anglers who caught and ate fish from the study area baked 100% of their fish (Table 5).

4. Discussion

The objectives of this study were to obtain information on the demographics and knowledge, sources of information and compliance of fish consumption advisories for people fishing on the Clinch River arm of Watts Bar Reservoir adjacent to the ORR or Poplar Creek within ORR boundaries. Details of fishing behavior that relate to risk perception and risk reduction were also obtained.

4.1. Demographics

The demographic information obtained during the survey was representative of the region. For example, 9% of the people interviewed were black, while the black population in the local area is as follows: 3.9% (Anderson County); 8.6% (Knox County); 1.1% (Loudon County); 2.7% (Roane County); and 8.2% (City of Oak Ridge) (US Census Bureau, 2001a). The estimated percent of high school graduates or higher in Tennessee is 77.7% (US Census Bureau, 2001b), while 82% of anglers interviewed had finished high school. Twenty-three percent of people interviewed had at least a bachelors degree, while 20.9% of people in Tennessee are estimated to have at least a bachelors degree (US Census Bureau, 2001b). Compared to the average income of \$30 936 per year for anglers interviewed, income estimates for Tennessee are as follows: \$36 145 (median household income); \$19 405 (per capita income); and \$27 205 (median males with earnings) (US Census Bureau, 2001c). In contrast to the study conducted along the Savannah River adjacent to the SRS where blacks made significantly less money than whites (Burger, 1998), there were no ethnic differences in this study with regard to income.

4.2. Knowledge of advisories

Fish consumption advisories are sometimes used in place of environmental remediation if they are

considered more cost-effective than cleaning up the resource, with the assumption that anglers adjust their behavior in response to the warning (Jakus et al., 1997; Burger et al., 2001c). However, this study, as well as many other previous studies, confirms that it is not unusual for people to know about fish consumption advisories but think the fish are safe to eat anyway. Although 81% of the anglers interviewed in this study had heard about the fish consumption advisories for the study area, 48% of them believed that the fish caught in the study area were safe to eat, while 38% caught and ate fish from the study area. In addition, approximately 36% of people interviewed who had knowledge of the fish consumption warnings ate fish from the study area. People who caught and ate fish from the study area often caught, immediately ate and froze for later consumption the fish species (striped bass, catfish and sauger) under advisory (Figs. 3 and 4). In the study conducted along the Savannah River adjacent to the SRS, 82% of the anglers thought the fish were safe to eat even though 62% had heard some warnings about eating the fish (Burger, 1998).

The results of a study of urban anglers in the Newark Bay complex, New Jersey demonstrated that while 60% of them had heard about fish and crab consumption advisories, they either did not believe or were unconcerned about the health effects from eating contaminated species (Pflugh et al., 1999). Nearly 90% of people thought that the fish and crabs were safe to eat even though approximately 40% had heard some warnings about their safety in a study of people fishing and crabbing in Barnegat Bay and Great Bay, New Jersey (Burger et al., 1998). MacDonald and Boyle (1997) found that 63% of anglers in Maine knew about the statewide mercury contamination advisory on lakes and ponds, but less than one-quarter of these anglers actually adjusted their fishing behavior in response. In a population-based telephone survey of the eight Great Lakes states, only half of Great Lakes sport fish consumers reported awareness of a health advisory concerning eating Great Lakes sport fish (Tilden et al., 1997). May and Burger (1996) found that over two-thirds of anglers in a New York/New Jersey estuary who knew about advisories still ate their catch. The

results of a study conducted by Fleming et al. (1995) indicated that although 71% of people knew about the advisory regarding eating mercury-contaminated fish from the Florida Everglades, they did not change their consumption habits. In a mail survey, Diana et al. (1993) found that 70% of people who fished in Lake Ontario ate at least one species of restricted fish. Only 19% of people fishing the catchment basins of Jamaica Bay Wildlife Refuge, New York City thought the water or fish were contaminated or unsafe, despite state warnings to the contrary, and almost 85% of them ate all the fish they caught (Burger et al., 1993). In a survey of fishermen and crabbers in a Puerto Rican estuary near Humacao that had been declared a Superfund site, all users consumed the fish and crabs they caught even though nearly everyone interviewed knew about the mercury contamination (Burger and Gochfeld, 1991). Simply issuing fish consumption advisories is insufficient to promoting risk-reducing behavior.

As part of an extensive investigation, Bevelhimer and Adams (1996) reviewed creel survey data collected by the TWRA since 1977 for Watts Bar Reservoir to determine the responses of anglers to fish consumption advisories and determined that compliance with the advisories was limited. They found that while the angling effort for catfish in Watts Bar Reservoir had decreased markedly, the actual harvest over the same time period had decreased by only 9%. Based on these data, the advisories do not appear to be having the desired effect on the consumption of catfish. Despite a 'do not consume' advisory, the creel survey data indicated a steady increase in angling effort for striped bass, and the trend in harvest estimates appears to be increasing for this non-native species. However, striped bass are desired more for sport than for food. Assuming that fish stocks respond positively to consumption advisories, 'sport' anglers (those who catch and release) view advisories as a benefit because the quality of the fishing experience is better as the number of quality fish increases (Jakus et al., 1997, 1998). Many of the striped bass catch-and-release fishermen we interviewed, including professional striped bass fishing guides, were happy about the advisory for striped bass because they believed it protected the fishery.

4.3. Compliance

Why do people ignore fish consumption advisories? Fishing is perceived as a familiar, enjoyable pursuit, and it is difficult for people to believe that such a pleasant and healthy activity could be hazardous to their health (Burger et al., 1993; May and Burger, 1996). Non-compliance of consumption advisories occurs because of the deamplification of risk in hazards that are familiar and enjoyed, such as fishing and fish consumption (Burger, 2000). People have fished the study area for many years without experiencing any obvious bad health effects. Anglers often do not trust the government in general or government agencies that issue advisories (May and Burger, 1996). This was a prevalent attitude of people interviewed, especially in those that have lived in the local area for many years, due to releases, spills and discharges of contaminants resulting from USDOE operations on the ORR that were kept secret for many, many years. The fact that over one-third of anglers interviewed who knew about the fish consumption advisories blamed the USDOE for the problem also showed their lack of trust of government (Table 5). While releases from the ORR have been the major cause of pollution of the Clinch River arm of Watts Bar Reservoir, the ORR is not the only source contributing to the fish consumption advisories. Other reservoirs in the local area (e.g. Fort Loudoun, Tellico, Melton Hill) that do not receive discharges from the ORR are under fish consumption advisories due to PCBs, indicating that the PCB contamination is a regional problem. Because contamination of the ORR and surrounding areas as a result of USDOE operations is common knowledge, it was not surprising that only approximately 20% of anglers interviewed were unaware of the fish consumption warnings. During the interview, anglers often appeared to have great confidence in their own knowledge, even though their information was not accurate.

In contrast to the studies mentioned above, Jakus et al. (1997) observed a statistically significant response by reservoir anglers in Middle and East Tennessee to consumption advisories in a telephone survey. With all else being equal, anglers were less likely to choose to visit a reservoir with

an advisory than a similar reservoir without an advisory. A high degree of compliance by anglers to fish consumption advisories for Lake Ontario was observed in a study by Velicer and Knuth (1994). However, they interviewed angler group leaders, whose actions may not be representative of the general fishing population.

Another assumption in the approach of using fish consumption advisories instead of environmental remediation is that adequate, alternative fishing sites are available (Jakus et al., 1997). The results of this study suggest that many adequate, alternative fishing sites are available. Anglers who caught and ate fish from the study area also fished at the numerous reservoirs, rivers and streams available throughout the regional area, including both unpolluted sites and other waters under advisory (Table 5). In fact, of the 65% of anglers who did eat fish, 27% of them did not eat fish from the study area but ate fish caught from other locations (i.e. trout from unpolluted mountain waters).

The results of this study indicate that the signs posted throughout the study area were effective at informing people that there was a fish consumption advisory (Fig. 2) but, for some reason, were not effective at communicating the correct advisories. Anglers either did not read them carefully or did not remember what they read. Despite the detailed information included on the posted signs and in the TWRA fishing regulations pamphlet regarding the fish consumption advisories, few people knew the correct fish advisories (Table 5), and not one person mentioned that pregnant women, nursing mothers, or children should limit consumption of certain fish species. Results were similar in the study conducted along the Savannah River adjacent to the SRS; no one reported the correct consumption advisories, and only one person talked about the importance of pregnant women limiting consumption (Burger, 1998).

The fact that 35% of the anglers interviewed did not eat fish at all shows that people often fish for reasons other than obtaining food and how important fishing is to the local culture. In addition, based on the amount of time people fished (an average of 31 years and 83 days per year), fishing is an important activity for many people inter-

viewed. Fishing as a leisure, outdoor activity has been shown to be an integral part of the culture for people living in the South (Toth and Brown, 1997). Toth and Brown (1997) also found significant differences in the attitudes of blacks and whites toward fishing in the southeastern United States, with subsistence playing a greater role for blacks than whites. People often fished in groups, and catching fish for fish fries was important. Black men fished significantly more days per year than whites in the study conducted along the Savannah River adjacent to the SRS (Burger, 1998) and in a study by Burger (1997). However, in this study, whites fished as often as blacks.

One of the important aspects of this study was the ethnic differences in the knowledge of fish consumption advisories (Table 2), which was also a key finding in the study conducted along the Savannah River adjacent to the SRS (Burger, 1998). While in the Savannah River study there were significant differences in the percent that had heard warnings as a function of ethnicity and income, in this study only ethnic differences were significant. However, the data were divided into five income categories in this study, while only two income classes were used in the Savannah River study (Burger, 1998). Burger et al. (1999b) reported ethnic differences in knowledge about the safety of the fish, sources of information about fishing and awareness of fishing advisories or of the correct advisories in a study of people fishing in the Newark Bay complex of the New York–New Jersey Harbor. Blacks, individuals of lower income and those with less education were less likely to know about fish consumption warnings in a study of people fishing in the Florida Everglades (Fleming et al., 1995). Velicer and Knuth (1994) also found differences in the knowledge about fish safety, with migrant workers being less aware of advisories than others fishing on Lake Ontario, New York. However, the transient nature of the workers may have contributed to their lack of knowledge.

4.4. Risk reduction

Knowledge about the characteristics of people who don't know about the fish consumption warn-

ings, how people obtain information about fish consumption advisories and aspects of fishing and fishing behavior can contribute to reducing the risk to people that eat fish from the study area. Even though some local anglers informed us that Poplar Creek was heavily fished during the spring, the results of this study indicate that people are fishing in Poplar Creek, but at low densities (Table 3). In this study, income, education and age did not significantly affect whether people had knowledge of fish consumption warnings or if they thought the fish from the study area were safe to eat, and only ethnicity significantly affected whether anglers had heard of the warnings (Table 2). An interesting result was that no black anglers knew of the fish consumption advisories because of the TWRA fishing regulations pamphlet (Fig. 2). The pamphlet may not be available where they purchase their fishing licenses. Ethnic differences in knowledge of advisories suggests that methods could be developed for different ethnic groups (Velicer and Knuth, 1994). Information could be provided to leaders within the black community. In addition, fish consumption advisory information could be provided to black women, who may become pregnant and who may be responsible for preparing and cooking fish. Since most people interviewed lived in Knox and Anderson Counties, an information campaign directed at those areas would reach most of the people fishing the study area. Behaviors that could be modified to reduce risks without changing how much fish is eaten include changing the species of fish consumed and altering cooking methods (Morgan et al., 1997). The fact that crappie, which are not under advisory, were the type of fish most often caught and eaten by those who ate fish from the study area suggests that educating people to eat species of fish not under advisory to reduce risks would not be difficult (Fig. 3). In fact, many anglers who caught and ate fish from the study area only ate crappie. The majority of people interviewed ate mostly fish fillets and removed the skin and fat before cooking (Table 5), and, whether they knew it or not, were already practicing risk-reducing behaviors. However, most anglers fried their fish (Table 5), and frying is known to seal in the contaminants. Encouraging anglers who eat fish from the study

area to cook their fish using a contaminant-reducing method, such as grilling, should be encouraged.

In late 1997, a brochure was developed as a collaboration between: the Tennessee Department of Environment and Conservation; the TWRA; the Tennessee Department of Health; the Oak Ridge Local Oversight Committee, Inc.; and the Agency for Toxic Substances and Disease Registry (ATSDR) called 'Watts Bar Reservoir, Fish Advisory Pointers.' This excellent brochure clearly explains the fish consumption advisories and includes many ways to minimize risks related to the fish consumption advisories such as eating crappie and bluegill (*Lepomis macrochirus*), eating small fish, and removing the fat and skin before cooking. It also includes positive information about Watts Bar Reservoir and catching fish. In addition, it advises people not to eat turtles, turtle eggs, or shellfish from the reservoir. A question was specifically asked during the study (have you heard any warnings about eating turtles or turtle eggs?) to see if anyone knew about the brochure. No one had heard about the warnings regarding eating turtles and turtle eggs, and not one person specifically mentioned the brochure as a source of knowledge regarding fish consumption advisories. This informative brochure needs to be distributed more widely or in such a way that it reaches people who catch and eat fish from the study area.

5. Conclusion

This study obtained information about the demographics, fishing behavior, knowledge, fish consumption and risk perception of people fishing along the Clinch River arm of Watts Bar Reservoir adjacent to the ORR, which is under a fish consumption advisory. Approximately 48% of people interviewed thought the fish were safe to eat and 38% of them ate the fish that they caught from the study area even though 81% knew about the fish consumption advisories. In addition, approximately 36% of anglers who had knowledge of the fish consumption warnings ate fish from the study area. Approximately 35% of people interviewed did not eat fish at all, which confirmed that people fish for reasons other than obtaining food. Most anglers interviewed knew about the fish consump-

tion advisories because of the signs posted throughout the study area, but few people knew the correct fish advisories. Over one-third of people blamed the USDOE for the contamination causing the fish consumption warnings. Knowledge of the fish consumption advisories was significantly affected by ethnicity. Whether they are aware of it or not, many anglers are practicing risk-reducing behaviors, such as eating species not under advisory, removing fat and skin before cooking (for PCBs) and eating fillets. Even though an excellent brochure has been developed and circulated in the last 5 years, the results of this study demonstrate that there is a need to provide information to the people who may be most at risk from eating fish caught from the Clinch River arm of Watts Bar Reservoir, provide information to develop a targeted information program, and verify that many people are not complying with the fish consumption advisories.

Acknowledgments

This research was funded by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) through the US Department of Energy (AI#DE-FC01-95EW55084 and DE-FG26-00NT-40938). We appreciate the helpful comments of an anonymous reviewer on an earlier version of this manuscript. Thanks to all the anglers who took the time to participate in this study. The analyses and interpretations made in this paper are solely the responsibility of the authors and do not necessarily reflect the views of the sponsoring organizations.

References

- Anderson PD, Wiener JB. Eating fish. In: Graham JD, Wiener JB, editors. *Risk Versus Risk: Tradeoffs in Protecting Health and the Environment*. Cambridge, MA: Harvard University Press, 1995. p. 104–123.
- Bevelhimer MS, Adams SM. Assessing contaminant distribution and effects in a reservoir fishery. *Am Fish Soc Symposium* 1996;16:119–132.
- Burger J. Consumption advisories and compliance: The fishing public and the deamplification of risk. *J Environ Planning Manage* 2000;43:471–488.
- Burger J. Fishing and risk along the Savannah River: Possible intervention. *J Toxicol Environ Health* 1998;55:405–419.
- Burger J. Recreation and risk. *J Toxicol Environ Health* 1997;52:269–284.
- Burger J, Gochfeld M. Fishing a Superfund site: Dissonance and risk perception of environmental hazards by fishermen in Puerto Rico. *Risk Anal* 1991;11:269–277.
- Burger J, Waishwell L. Are we reaching the target audience? Evaluation of a fish fact sheet. *Sci Total Environ* 2001;277:77–86.
- Burger J, Gaines KF, Peles JD, Stephens Jr WL, Boring CS, Brisbin Jr IL, Snodgrass J, Bryan Jr AL, Smith MH, Gochfeld M. Radiocesium in fish from the Savannah River and Steel Creek: Potential food chain exposure to the public. *Risk Anal* 2001a;21:545–559.
- Burger J, Gaines KF, Boring CS, Stephens Jr WL, Snodgrass J, Gochfeld M. Mercury and selenium in fish from the Savannah River: Species, trophic level, and locational differences. *Environ Res* 2001b;87:108–118.
- Burger J, Gochfeld M, Powers CW, Waishwell L, Warren C, Goldstein BD. Science, policy, stakeholders and fish consumption advisories: Developing a fish fact sheet for the Savannah River. *Environ Manage* 2001c;27:501–514.
- Burger J, Stephens Jr WL, Boring CS, Kuklinski M, Gibbons JW, Gochfeld M. Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Anal* 1999a;19:427–438.
- Burger J, Pflugh KK, Lurig L, Von Hagen LA, Von Hagen S. Fishing in urban New Jersey: Ethnicity affects information sources, perception and compliance. *Risk Anal* 1999b;19:217–229.
- Burger J, Sanchez J, Gochfeld M. Fishing, consumption and risk perception in fisherfolk along an East Coast estuary. *Environ Res* 1998;77:25–35.
- Burger J, Staine K, Gochfeld M. Fishing in contaminated waters: Knowledge and risk perception of hazards by fishermen in New York City. *J Toxicol Environ Health* 1993;39:95–105.
- Campbell KR, Sexton R, Dickey RJ, Burger J. Ethnic and socioeconomic differences in fishing and consumption of fish caught in the Clinch River arm of Watts Bar Reservoir adjacent to the Oak Ridge Reservation, Tennessee. *Risk Anal*, in press.
- Cheek TE, Van Den Avyle MJ, Coutant CC. Distribution and habitat selection of adult striped bass, *Morone saxatilis* (Walbaum), in Watts Bar Reservoir, Tennessee. Oak Ridge, TN: Oak Ridge National Laboratory, Environmental Sciences Division, 1983. ORNL/TM-8447.
- Commission on Risk Assessment and Risk Management. Report of the Commission on Risk Assessment and Risk Management. Washington, DC: US Congress, 1996.
- Diana SC, Bisogni CA, Gall KL. Understanding anglers' practices related to health advisories for sport-caught fish. *J Nutr Educ* 1993;25:320–328.
- Etnier DA, Starnes WC. *The Fishes of Tennessee*. Knoxville, TN: University of Tennessee Press, 1993. (681 pp).
- Fleming LE, Watkins S, Kaderman R, Levin B, Ayyar DR, Bizzio M, Stephens D, Bean JA. Mercury exposure in

- humans through food consumption from the Everglades of Florida. *Wat Air Soil Pollut* 1995;80:41–48.
- Jacobs HL, Kahn HD, Stralka KA, Phan DB. Estimates of per capita fish consumption in the U.S. based on the continuing survey of food intake by individuals (CSFII). *Risk Anal* 1998;18:283–291.
- Jakus PM, Downing M, Bevelhimer MS, Fly JM. Do sportfish consumption advisories affect reservoir anglers' site choice? *Agric Resour Economics Rev* 1997;26:196–204.
- Jakus PM, Dadakas D, Fly JM. Fish consumption advisories: Incorporating angler-specific knowledge, habits and catch rates in a site choice model. *Am J Agr Econ* 1998;80:1019–1024.
- MacDonald HF, Boyle KJ. Effect of a statewide sport fish consumption advisory on open-water fishing in Maine. *North Am J Fish Manage* 1997;17:687–695.
- May H, Burger J. Fishing in a polluted estuary: Fishing behavior, fish consumption and potential risk. *Risk Anal* 1996;16:459–471.
- Morgan JS, Berry MR, Graves RL. Effects of commonly used cooking practices on total mercury concentration in fish and their impact on exposure assessments. *J Exposure Anal Environ Epidemiol* 1997;7:119–134.
- Pflugh KK, Lurig L, Von Hagen LA, Von Hagen S, Burger J. Urban anglers' perception of risk from contaminated fish. *Sci Total Environ* 1999;228:203–218.
- SAS Institute, Inc. JMP®, Version 4.0.4, Statistical Discovery Software. Cary, NC: SAS Institute, Inc, 2000.
- Tilden J, Hanrahan LP, Anderson H, Palit C, Olson J, MacKenzie W. Great Lakes Sport Fish Consortium. Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environ Health Perspect* 1997;105:1360–1365.
- Toth Jr JF, Brown RB. Racial and gender meanings of why people participate in recreational fishing. *Leisure Sci* 1997;19:129–146.
- Turner RR, Olsen CR, Wilcox WJ. Environmental fate of mercury and ¹³⁷Cs discharged from Oak Ridge facilities. In: Hemphill DD, editor. *Trace Substances in Environmental Health—XVIII, A Symposium*. University of Missouri, Columbia, MO 1984. p. 329–338.
- US Census Bureau. Profiles of general demographic characteristics, 2000 census of population and housing, Tennessee, US Department of Commerce, Economics and Statistics Administration, 2001a.
- US Census Bureau. Profile of selected social characteristics: 2000, Census 2000 supplemental survey summary tables, US Department of Commerce, Economics and Statistics Administration, 2001b.
- US Census Bureau. Profile of selected economic characteristics: 2000, Census 2000 supplemental survey summary tables, US Department of Commerce, Economics and Statistics Administration, 2001c.
- US Department of Energy (USDOE). Historical radionuclide releases from current DOE Oak Ridge Operations Office facilities. Oak Ridge, TN: Oak Ridge Operations Office (OR-890), 1988.
- US Environmental Protection Agency (USEPA). EPA Fact Sheet, Update: National Listing of Fish and Wildlife Advisories. US Environmental Protection Agency, Office of Water, 2001. EPA-823-F-01-010.
- Velicer CM, Knuth BA. Communicating contaminant risks from sport-caught fish: The importance of target audience assessment. *Risk Anal* 1994;14:833–841.