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Fishing in a Polluted Estuary: Fishing Behavior, Fish Consumption, and Potential Risk

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People make subjective judgments about hazards relying on what they know and feel. These risk perceptions may be based on accurate or inaccurate information and are often optimistically biased. The existence of uncertainties in the evaluation of many environmental hazards effects how risks are perceived. This paper examines fish consumption and risk perception of urban fishermen in the New York/New Jersey estuary, in areas where there were consumption advisories. We interviewed 318 fishermen and crabbers in the Arthur Kill, Raritan Bay, and New Jersey shore. Fish were eaten an average of at least four times per month in all regions, but fishermen in the Arthur Kill fished most frequently, averaging over eight times per month. Although 60% of fishermen and crabbers in the Arthur Kill reported hearing warnings about consuming fish caught in these waters, 70% of fishermen and 76% of crabbers said they ate their catch. Significantly fewer fishermen in the Bay and Shore regions had heard warnings (28% and 30%, respectively), and more reported consuming their catch (88% and 82%, respectively). In all regions, most people thought that the fish were safe to eat, many believing they were "fresher" than store bought fish. Thus, most people ignored the consumption advisories in effect for these waters. Some of these people are consuming high quantities of fish and crabs, and thus are exposed to potentially deleterious levels of contaminants. In general, people failed to consider the possibility of chronic effects and did not perceive that this enjoyable, familiar pastime could be hazardous. Further, fishermen generally had great confidence in their own knowledge, which proved to be inaccurate in many cases, and often expressed distrust in the information source (government). Clearly, simply issuing consumption advisories is insufficient to promote risk-reducing behavior.

KEY WORDS: Fish; toxics; consumption.

1. INTRODUCTION

To respond to environmental hazards, people must first perceive a risk. Slovic[1] pointed out that the majority of people make subjective judgments about hazards that rely on intuition rather than only facts, and labeled these "risk perceptions." He indicated that acceptance of a given level of risk is influenced by a number of factors including the degree of voluntariness, familiarity, and personal control associated with the activity. The outcome of these influences is that people often underestimate the risks involved with enjoyable, familiar, or voluntary activities.[2,3] In addition, comparative risk judgments are often optimistically biased and individuals believe their own risk from a given voluntary activity to be less than that of others.[4] For example, most people consider themselves to be safer car drivers than average. Optimistic biases may reduce the motivation to engage in risk-reducing behaviors and therefore have important consequences in risk perception.[5]

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People usually rely on what they have heard or seen when evaluating a risk, which may be based on incomplete or inaccurate information. Even when they have access to accurate information, whether the message is believable or not will depend on the perceived trustworthiness of the source.[6] Mitchell[7] examined risk perceptions of neighbors of Superfund sites and found that technical information from government sources that were involved in the planning of response actions were greatly mistrusted. Nevertheless, increased access to information in the last few years has resulted in people being better informed and less tolerant of environmental risks.[8]

Many risks faced by people today are very different from those of 20 years ago. Americans view themselves as being exposed to increasing environmental hazards, and have become more concerned about risk.[9,10] Both the number and kinds of risks have changed as a result of changes in technology and these new risks are often subtle and hard to quantify. Risks arising from environmental contaminants are problematic because of the inability of science to produce answers to concerns about these risks.[8] People have difficulty thinking about risk when faced with uncertainty. One way of coping with this uncertainty is to deny its existence, which contributes further to overconfidence.[3] Thus, the uncertainty of the magnitude of risk in the environmental arena effects how the risk is perceived.

One class of environmental hazards people are exposed to is toxic contaminants in food. Whereas people assume that food purchased in supermarkets is safe because of food and drug laws, the situation is less clear for foods obtained by hunting or fishing. The objective of this study was to examine the relationship between perception of the safety of fish and fish consumption habits of fishermen at sites in coastal New Jersey including a polluted estuary (Arthur Kill) and offshore coastal waters (Raritan Bay and the Atlantic shore). The fishermen's awareness of fishing advisories and their perceived risk in consuming the fish caught in these areas were also assessed.

The New York/New Jersey Harbor estuary is one of the most industrialized and urbanized estuarine systems in the world, and toxic concentrations rank among the highest in the country.[11,12] Although levels of many pollutants declined following enactment of environmental laws in the 1970s,[13] the accidental release of petroleum and hazardous chemicals is a significant recurrent source of chemical pollution in the New York Bight.[14] Major marine shipping lanes are located on the Arthur Kill. From 1982 to 1991, the majority of petroleum and chemical spills in the harbor occurred in this area.[14] There are a variety of toxic chemicals in this estuary that are of environmental concern including metals such as copper, lead and zinc; organic chemicals such as polycyclic aromatic hydrocarbons (PAHs); and chlorinated pesticides such as DDT, chlordane, and dieldrin.[11] In addition, these contaminants pose problems for humans as well as wildlife. Of major importance for human health risk are polychlorinated biphenyls (PCBs), dioxin, cadmium, lead, and mercury.[15,16]

Much of the current loading of toxics in the New York/New Jersey harbor estuary, a result of past production, use, and disposal,[13] enter the estuary from wastewater discharges, tributary inputs, leaching from landfills, and accidental spills.[11,17] The toxics of concern are those that are stable and persistent in the aquatic environment, are lipophilic, and bioaccumulate in the food chain resulting in potential human exposure from consuming fish and shellfish.[18,19]

Chemical contamination of fish is important today because of increasing consumption of fish due to the potential reduction in blood cholesterol.[15] Consumption of contaminated fish may be an important source of human exposure for fat soluble pollutants.[20,21] Contaminant concentrations vary by species and size of fish.[22] One method of reducing exposure to toxics from fish is to issue advisories concerning types of fish and consumption rates. Both New York and New Jersey have issued advisories for blue crabs (*Callinectes sapidus*), blue fish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and American eels (*Anguilla rostrata*)[22,23] in the Arthur Kill. Similar, although less stringent, advisories are in effect for Raritan Bay and adjacent coastal waters.

Advisories issued by government authorities are generally aimed at individuals who may eat a large amount of fish from a particular area (e.g., recreational fishermen) and at high risk individuals (e.g., children and pregnant women). The New York State Department of Health (NYSDOH) issued a general health advisory for the Arthur Kill of not more than one meal (8 oz. or 230 g) of fish per month.[23] Blue Crabs are limited to a maximum of six per week. The advisory recommends that high risk individuals (women of childbearing age, infants, and children under 15) should not eat any species caught in this area.

The New Jersey Department of Environmental Protection (NJDEP) issued advisories for Bluefish (over 6 lb.) and eels of one meal per week (statewide advisory), and for Striped Bass of no consumption from the Arthur Kill and one meal per week in the Bay and Shore regions.[22] Blue Crabs from the Arthur Kill should not be harvested or eaten. High risk individuals (infants, children under 15 years, nursing mothers, women of childbearing age) are advised not to consume these species of fish or crabs. Since 1984, the NJDEP has maintained an administrative order prohibiting the sale and consumption of Striped Bass and Blue Crabs from the Arthur Kill.[16]

This study examines the consumption habits of recreational fishermen who are fishing in the Arthur Kill, Raritan Bay, and adjacent offshore coastal waters. We were particularly interested in whether fishermen were aware of the advisories and how they perceived the risk in eating fish caught in these waters; and whether they were exposed to deleterious levels of toxics in fish and if their risk perceptions matched the severity of the hazard.

2. METHODS

2.1. The Study Sites

Data were collected from people fishing along the shore in three main regions in New Jersey: the Arthur Kill, Raritan Bay, and the shore. In the Arthur Kill data were collected from fishermen and crabbers on public piers and marinas in the townships of Elizabeth, Carteret, Sewaren, and Perth Amboy. Data were also collected from fishermen at two sites on the south side of the Raritan Bay and at two sites on the Atlantic shore. In addition, information was collected from fishermen on party boats operating scheduled charters out of the three main study regions.

The Arthur Kill is a tidal waterway, 25 km in length, that lies between New Jersey and Staten Island (New York) and forms part of the New York–New Jersey harbor estuary.[24] The area is densely populated, heavily industrialized, and is perhaps the most used and abused of any in the world.[25] Local residents use this waterway for recreational activities, including boating, fishing, crabbing, and birdwatching.[26] The Raritan Bay and the New Jersey shore are important recreation destinations for both residents and visitors, although there is a higher proportion of nonlocal fisherman than in the Arthur Kill. Many party boats run daily from all these areas, taking up to 50 people to fish in the deeper waters of the Bay or open ocean. Boats originating from the Arthur Kill and the Raritan Bay spend most of their time in the waters of the Lower New York and Raritan Bays, while those originating from shore harbors, such as Point Pleasant, generally fish off-shore in the Atlantic Ocean.

There are fishing advisories in all these areas. The Arthur Kill, part of the Newark Bay complex, has the most stringent advisories.[22] Fish advisory signs appeared in two of the four Arthur Kill sites in mid- to late-July. The signs advised (in English and Spanish) against the consumption of striped bass and blue crabs. None were seen at any other sites over the study period.

2.2. Sampling Procedures

Interviews of fishermen and crabbers were conducted in the Arthur Kill from mid-May to the end of September, 1994. Each of the four sites within the Arthur Kill were visited at least three times per month, except the Carteret site, which was first visited on August 11. All other interviews (those at sites outside the Arthur Kill and on boats) were conducted between July 15 and August 26. All fishermen present at a particular site were approached and most willingly participated in the survey.

All interviews were conducted by HM and the questions were asked in the same order each time. Before beginning an interview, the interviewer introduced herself, explained the nature of the project, and asked if they would mind answering questions about their fishing and fish-eating habits. Usually the interviewees were happy to answer the questions. Each person was interviewed once although many were present on later visits. Each interview usually lasted 20 minutes.

Before each interview, the date, time, location, weather conditions, activity of the subject and the number of people in the group were recorded. When there was a group, a single individual was selected as spokesperson, this was usually the most talkative or oldest person in the party. Most interviewees freely revealed their town of residence, age, and occupation. Occupations were classified as white collar, blue collar (unskilled or semiskilled nonprofessional), retired, student, and other. Local was defined as living within a 16 km straight line distance from the fishing site. Questions included how often they fished in a month, how often they caught fish, how many they usually caught, how often they ate fish, if they ate their catch, how they cook the fish, and if they had a preference for smaller or larger fish. They were asked if they thought the water and fish were safe, and if they had heard any warnings about eating the fish in the area. If they answered yes, they were asked where they had heard the warning. Finally, they were asked to identify whether particular species of fish occurred in fresh or saltwater.

Table I. Comparison of People Fishing at Arthur Kill, Raritan Bay, and New Jersey Shore[a]

	Arthur Kill	Raritan Bay	NJ Shore	χ^2 (p)
No. of interviews	168	60	44	—
Age	48.2 ± 1.4 (11–83)	47.7 ± 2.2 (14–82)	35.5 ± 1.9 (11–62)	18.6 (0.0001)
No. people in group	1.5 ± 0.1 (1–4)	1.5 ± 0.1 (1–3)	1.6 ± 0.1 (1–5)	NS
No. times fish/month	8.8 ± 0.6 (0–30)	5.7 ± 0.8 (0–25)	5.6 ± 1.0 (0–25)	17.5 (0.0002)
No. times fish eaten/month	4.8 ± 0.3 (0–24)	4.6 ± 0.4 (0–16)	4.3 ± 0.5 (0–16)	NS
Serving size (ounces)	11.5 ± 0.5 (0–32)	10.3 ± 0.5 (0–16)	10.6 ± 0.8 (0–30)	NS

[a] Given are means and standard error; range is given in parentheses. NS = not significant.

Means and standard errors are presented in the text unless otherwise noted. Differences in responses among regions were determined using EXCEL 5.0 and SAS (1985).

3. RESULTS

3.1. Demographics

Of the 318 interviews conducted, 214 were in the Arthur Kill (168 fishermen, 49 on boats, and 46 crabbers), 60 were in the Raritan Bay (all fishermen, 33 on boats), and 44 were at the New Jersey shore (all fishermen, 18 on boats). The interviewees were predominantly male (89% in the Kill, 96% in the Bay, and 86% at the Shore). Age varied significantly between regions with averages ranging from 35.5 at the Shore to 48.2 in the Kill (Table I). Most fishermen were solitary. The average number of people in each group was less than two in all regions although the range varied (Table I).

Data on crabbers were available only for the Arthur Kill. Ages ranged from 9 to 74 with an average of 42.1 (±2.3). The average number of people in each crabbing group was slightly higher than that for fishermen (1.8 ± 0.1) with a range of 1 to 4. Crabbers in this area were almost exclusively local residents (91%) and were mostly blue-collar workers (56%) or retired (22%).

The proportion of fishermen who lived locally differed between the regions. Most of the fishermen in the Arthur Kill (85%) were local residents while in the Bay and Shore the proportion was only 27% and 25%, respectively ($\chi^2 = 95.9$, $df = 2$, $P < 0.0001$). The distribution of occupations between the three study regions also differed significantly ($\chi^2 = 41.8$, $df = 8$, $P < 0.0001$). The percent of fishermen who were retired was highest in the Arthur Kill while that of white-collar workers was lowest in this region (Fig. 1).

3.2. Fishing Behavior and Potential Exposure

Fishermen in the Arthur Kill fished more frequently than those in either of the other two regions (Table I). At least 70% of fishermen in all regions indicated that they ate their catch (Table IIA). Fishermen also gave some of their catch away, threw some back, or used some for bait. Less than 3% reported selling their catch. Over 37% of fishermen in all three regions said they preferred to eat larger fish than smaller fish of a given species, and this did not vary significantly between regions.

The average number of times fish were eaten in a month was 4.6 and showed little variation between regions (Table I). Only 7% of fishermen ate fish more than 8 times per month and about 70% ate fish 4 times or less per month. This was consistent across all three study regions. However, the maximum number of times fish were eaten in a month was highest in the Arthur Kill (Table I). The average serving size also showed little variation between regions, but again the range varied with the maximum serving size in the Arthur Kill (Table I).

Over 40% of the fishermen interviewed reported that more than half the fish they ate were fish they caught themselves, and almost 20% said they ate *only* fish they caught. There was no significant difference between the regions, and many fishermen expressed concern regarding the quality and freshness of fish bought

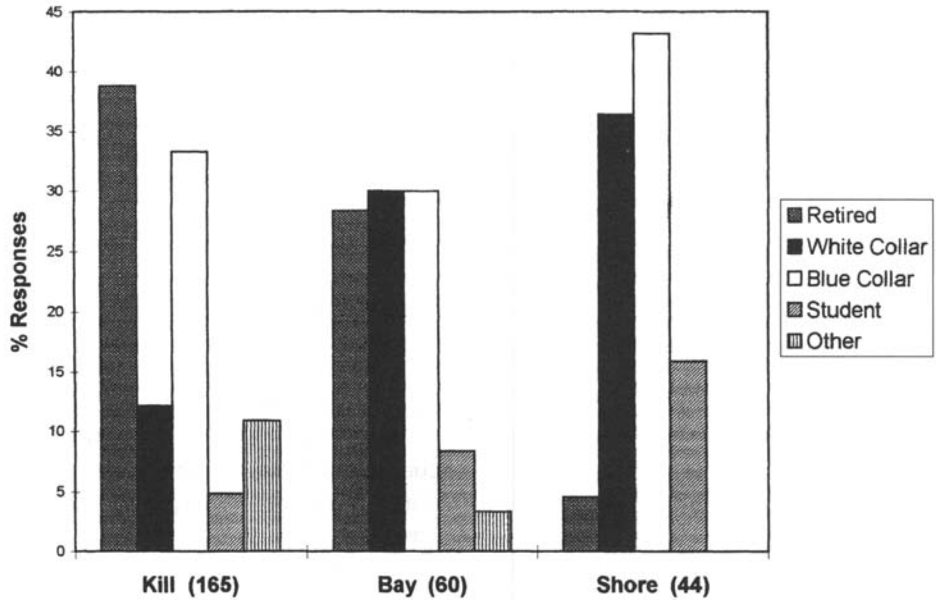

Fig. 1. Occupational composition of fishermen interviewed in the Arthur Kill, Raritan Bay, and New Jersey shore (total number of responses for each region is given in parentheses).

Table IIA. Perception of Health Risk of Fishermen and Crabbers, as Percentage Responding Yes, in Three New Jersey Study Regions[a]

	Arthur Kill fishermen	Raritan Bay fishermen	NJ Shore fishermen	χ^2 (p) (for fishermen)	Arthur Kill crabbers
Number of interviews	168	60	44	—	46
Is the water safe?	66	75	93	15.5 (=0.004)	65
Are the fish safe to eat?	61	87	91	24.6 (<0.0001)	78
Heard any warnings about eating the fish here?	60	28	30	25.2 (<0.0001)	61
Do you eat your catch?	70	88	82	8.9 (=0.012)	76

[a] Significance values are given for differences between responses of fishermen in the three regions. NS = not significant.

in stores. Most fishermen did not fish in the cold winter months so these responses apply mainly to the amount of caught fish that is eaten during the warmer months. However, some fishermen indicated that they froze their catch to provide fish for the rest of the year. Most fishermen (78%) also bought fish to eat and 58% reported buying more than half the fish they eat. A small number of fishermen (5%) did not eat any fish at all. More than 63% of all fishermen said that they never ate whole fish, and more than 96% usually ate fillets.

Some fishermen in all regions ate some fish whole. This proportion was higher, but not significantly so, in the Arthur Kill. This difference may be a result of the higher numbers of African Americans fishing in the Arthur Kill and their preference for porgies (*Stenotomus chrysops*), which are small fish that are usually fried and eaten whole. Most fishermen reported using more than one cooking method, and most fish were fried or broiled/grilled. Fishermen in the Arthur Kill fried their fish (72%) more than those in the other two regions, where broiling/grilling was preferred (52% and 66% in the Bay and Shore regions, respectively).

Data on crabbers were only available for the Arthur Kill. More than 75% of crabbers ate their catch and more than 55% reported that they gave some of their catch away. Few (4.3%) said they sold any. No crabbers re-

Table IIB. Perception of Health Risk, as Percentage Responding Yes, by Fishermen from the Arthur Kill on Foot and in Boats[a]

	Foot fishermen	Boat fishermen	χ^2 (p)
Number of interviews	119	49	—
Is the water safe?	56	90	28.7 (<0.0001)
Are the fish safe to eat?	47	94	31.9 (<0.0001)
Heard any warnings about eating the fish here?	60	61	NS
Do you eat your catch?	61	94	18.5 (<0.0001)

[a] NS = not significant.

ported throwing any crabs back unless they were under the legal limit; all crabbers said they threw females back (required by law). Over 65% of the crabbers interviewed said that at least three-quarters of the crabs they ate were crabs they had caught themselves (Fig. 2A), while 46% reported eating *only* crabs that they caught. These crabbers often said that the crabs were too expensive in the store and were not fresh.

The number of crabs eaten at a meal ranged from 0 to 25 with an average of 9.5 ($\pm$1.0). The average number of times crabs were consumed in a month was 3.7 ($\pm$0.5), with the highest being 16. Most crabbers ate only cleaned crabs (discarding the hepatopancreas), with fewer than 3% eating whole crabs. A variety of cooking methods were used and most crabbers reported using more than one method. The most common included boiling (85%), frying (26%), and steaming (24%).

3.3. Knowledge and Risk Perception

The percent of correct responses to fish habitat varied by more than 10% between two of the three study regions for eight of the 21 fish species. Of these eight species, the number of correct responses varied significantly for only four (Table III). The greatest disparities occurred for haddock, pickerel, tilefish and striped bass. Fishermen in the Bay had more correct responses than elsewhere. The fish with the highest percentage of correct responses overall were common, marine species: >95% correctly identified the habitats for shark, bluefish, tuna, flounder, and swordfish (Table III). The fish with the noticeably lowest percentage of correct responses was a freshwater commercial fish that is relatively new to North America: <12% in all regions correctly identified the habitat for tilapia (Table III).

Responses to the questions of whether the water and fish were safe showed significant difference between the study regions. The percentage of positive responses to both questions were lowest in the Arthur Kill (Table IIA). Despite hearing warnings, many fishermen in the Arthur Kill still felt that the water was clean and the fish safe for consumption. Fishermen in Raritan Bay thought that the fish were safer than the water (Table IIA). A frequent comment justifying this was that the fish were migratory, coming from cleaner waters, and not spending enough time in these waters to become contaminated. There was a relationship between fish consumption and fish safety such that over 70% of fishermen responded yes to both questions or no to both questions.

Boat fishermen thought the water and fish were safe (85% and 92%, respectively), whereas fewer foot fishermen held this view (65% and 59%, respectively). Significantly more boat fishermen ate their catch than foot fishermen (χ^2 = 27.9, df = 1, P < 0.0001). Differences in perceptions of water and fish safety between boat and foot fishermen *within* each region were significant only for the Arthur Kill (Table IIB). Fishermen on boats originating from the Arthur Kill believed that the waters and fish of the Lower New York and Raritan Bay were significantly safer than those of the Arthur Kill (χ^2 = 37.4, df = 1, P < 0.0001; χ^2 = 56.6, df = 1, P < 0.0001, respectively).

Data on crabbers were available only for the Arthur Kill. Overall, crabbers thought that both the water and the crabs were safe, although they believed that the crabs were safer than the water (Table IIA). These crabbers thought the crabs were able to avoid contamination by an efficient filtering system that allowed the crab to remove contaminants from the water. Seventy-nine percent of crabbers who had heard warnings about eating the crabs in these waters admitted to consuming their catch. In addition, there were significantly more crabbers who thought the crabs were safe than fishermen who thought the fish were safe in the Arthur Kill (χ^2 = 13.3, df = 2, P = 0.001; Fig. 2B).

In all areas, a significant proportion of fishermen who had heard warnings still ate their catch (Arthur Kill, 66%; Bay, 100%; Shore, 70%). Significantly fewer people fishing in the Bay and Shore regions had heard any advisories regarding eating fish from these areas as opposed to those fishing in the Arthur Kill (Table IIA). Most people heard warnings through newspapers and magazines, and 20% of fishermen in the Arthur Kill mentioned posted signs as a source of warning (Table

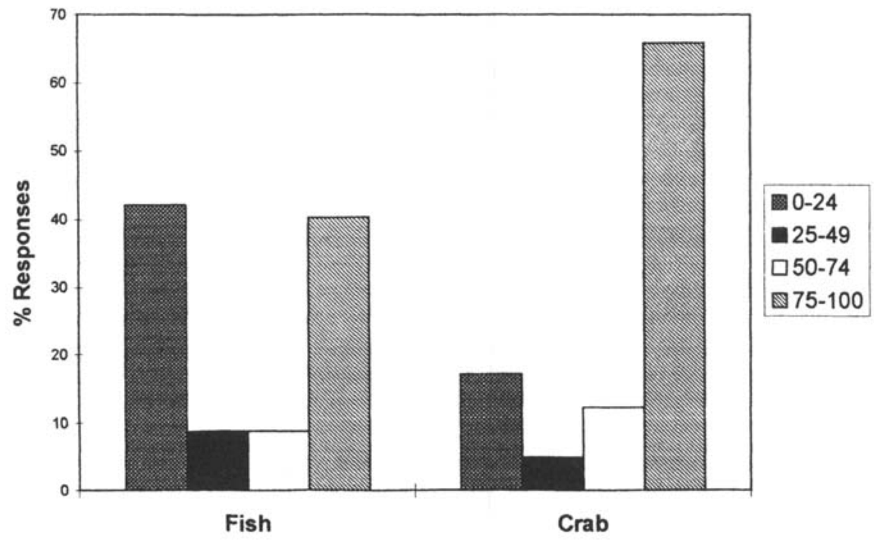

Fig. 2A. Percentage of the fish/crabs eaten that are self-caught by fishermen and crabbers in the Arthur Kill.

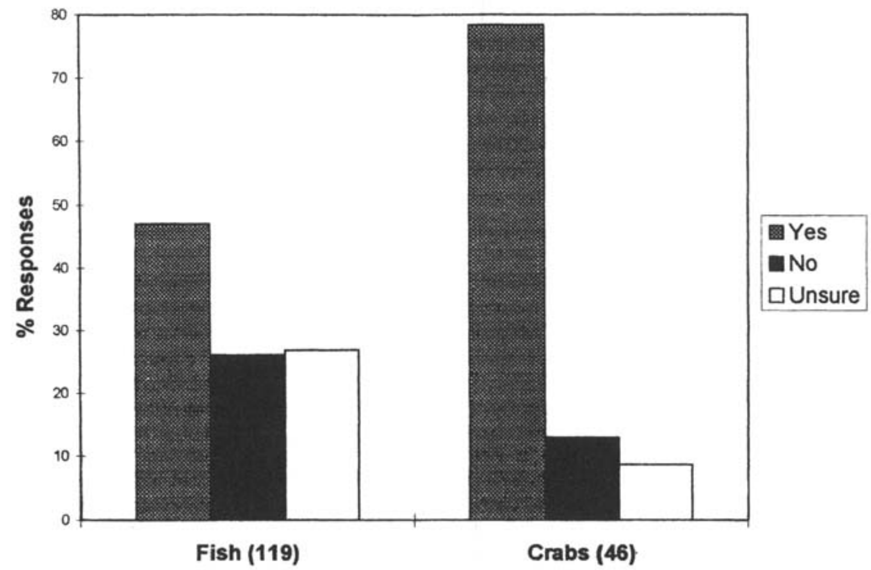

Fig. 2B. Comparison of responses by fishermen and crabbers to whether the fish/crabs in the Arthur Kill are safe (total number of responses for each group is given in parentheses).

IVA). Many fishermen expressed doubts about the governments' motives for issuing warnings. The proportion of people who had not heard warnings in the Arthur Kill declined from June (37%) to September (29%). The number of people who reported learning of warnings by signs increased from June (4%) to September (36%), presumably due to the posting of signs at two sites in this region.

4. DISCUSSION

This study illustrates three issues of risk perception in fishermen including exposure, knowledge about risk, and public health concerns. First, are the fishermen exceeding advisory limits and consequently being exposed to potentially harmful levels of toxics? Second, is the knowledge base correct that these fishermen use to es-

Table III. Knowledge of Fish Species and Habitat, Showing Percent of Correct Responses Overall and in Each of Three New Jersey Study Regions[a]

Fish species	All regions	Arthur Kill	Raritan Bay	NJ Shore	χ^2 (*p*)
Shark (*Carcharhinus* spp.)	98.7	98.5	98.3	100	NS
Bluefish (*Pomatomus saltatrix*)	98.7	98	100	100	NS
Tuna (*Thunnus* spp.)	97.3	97	98.3	97.7	NS
Flounder (*Paralichthys dentatus*)	96.7	97.5	98.3	90.7	NS
Swordfish (*Xiphias gladius*)	95.3	93.4	100	97.7	NS
Cod (*Gadus* spp.)	94	93.9	95	93	NS
Snapper (*Lutianus griseus*)	92.4	93.4	90	90.7	NS
Bass (*Microterus salmoides*)	92	91.4	91.7	95.3	NS
Striped Bass[b] (*Morone saxatilis*)	91.7	93.4	96.7	76.7	15.4 (<0.001)
Trout (*Cristivomer* spp.)	84.4	81.3	90	90.7	NS
Halibut[b] (*Hippoglossus* spp.)	79.7	75.8	88.3	86	NS
Catfish (*Ictalurus punctatus*)	78.7	77.8	83.3	76.7	NS
Carp (*Cyprinus carpio*)	77.1	75.8	81.7	76.7	NS
Haddock[b] (*Melanogrammus* spp.)	75.1	69.2	93.3	76.7	14.4 (<0.001)
Pickerel[b] (*Esox* spp.)	74.8	69.7	91.7	74.4	11.8 (<0.01)
Hake* (*Merluccius* spp.)	66.8	65.2	78.3	58.1	NS
Tilefish[b] (*Lopholatilus* spp.)	66.4	63.6	80	60.5	6.3 (<0.05)
Yellow-tail[b] (*Bairdiella chrysura*)	66.1	62.1	71.1	76.7	NS
Perch (*Morone americana*)	65.1	62.6	75	62.8	NS
Salmon[b] (*Salmo* spp.)	58.8	62.6	56.7	44.2	NS
Tilapia (*Tilapia* spp.)	6.6	6.6	3.3	11.6	NS

[a] NS = not significant.
[b] Indicates species for which the difference in correct response was greater than 10% between at least two regions.

Table IVA. Sources of Information on Warnings in Three Regions of New Jersey, Expressed as Percentages. People Could Have Had Multiple Sources

	Arthur Kill	Raritan Bay	NJ Shore
None heard	40	72	70
Newspapers/magazines	39	25	21
Signs	20	2	0
Word of mouth	11	2	5
Radio/TV	6	2	7

timate risk? Third, should the perception that a potential risk exists be modified and the public (or certain sectors thereof) be encouraged to change their consumption behavior accordingly to reduce health risks?

4.1. Exposure

This study found that fishermen in the Arthur Kill ate an average of 11.5 oz (330 g) of fish per meal and an average of 4.8 meals per month. This results in average monthly consumption of 1584 g (Table I). These results indicated that these fishermen are exceeding the limits advised by both states. Although 70% of fishermen in the Arthur Kill reported eating their catch, nearly 60% reported buying more than half the fish they eat. Presumably they are supplementing fish from these waters with store-bought fish. This may reduce the effective exposure to an average of approximately two potentially contaminated fish meals per month. This assumes that store-bought fish pose no hazard. Many of these fishermen fish only in the warmer months and, if this is considered to be 6 months, this further reduces potential exposure to an average of one 11.5 oz meal per month. Even this very conservative estimate of exposure is in excess of the general health advisory issued by the New York State Department of Health (NYSDOH).[23]

Another way to examine exposure, however, is to compute maximum exposure in any single week. Although the average consumption rate of fish in the Arthur Kill was 4.8 times per month, 11 fishermen reported eating fish more than 12 times per month. One reported consuming fish 24 times per month or 5–6 times per week (Table I). Hence they encountered a possible exposure of 1500 g/week; clearly exceeding the approximate consumption levels in the advisories.

Table IVB. Risk Assessment for Fishermen and Crabbers in the Arthur Kill

Component	Fish		Crabs	
	Average consumption	Worst case	Average consumption	Worst case
Grams consumed/month	1584	6600	5624	24320
Grams consumed/day[a]	52.8	220	187	810
Conc. of PCBs (ppm)	2.0	2.0	0.35[b]	0.35[b]
PCBs consumed in μg/kg/day[c]	1.5	6.3	0.94	4.1

[a] Computed from monthly rate.
[b] After Hauge.[16]
[c] Assuming 70 kg body weight.

A third method is to consider the maximum exposure of the most exposed groups. Almost 20% of fishermen ate only the fish they caught and they consumed from 2 to 20 fish meals per month. Even if these exposure data apply to only 6 months of the year, there are a significant number of individuals who are clearly exceeding the fish consumption advisories of both states.

Hauge[16] found evidence for widespread contamination of the edible portions of marine species in these waters. PCBs are one of the major hazards of concern. The Food and Drug Administration (FDA) has set an action level of 2.0 ppm for PCB concentration in fish and crabs.[27] Elevated levels of PCBs (i.e. exceeding FDA action levels) have been found in samples of bluefish, blue crab (hepatopancreas/muscle mixture), and striped bass from the waters of the New York/New Jersey harbor estuary.[16] The FDA has also established an estimated tolerable daily intake (TDI) for PCBs of 70 μg/day or 1 μg/kg body weight/day for a 70-kg person.[27]

The average consumption rate found in the Arthur Kill in this study (330 g/meal and 4.8 meals/month) is 1584 g/month or 52.8 g/d. In a 70 kg person this is 0.75 g/kg body weight/d. If the contamination level of the fish is 2 ppm PCB this results in an intake of 1.5 μg PCB/kg body weight/d, 50% higher than the FDA's TDI (Table IVB). Our estimate of maximum exposure (20 fish meals per month) leads to a worst case scenario of a daily intake of 6.3 μg PCB/kg (Table IVB). High potential exposure levels have also been found in other studies. Humphrey[28] found consumers of Lake Michigan fish were exposed to up to 4 μg PCB/kg body weight/d.

In the Arthur Kill, 30% of fishermen ate fish more than 4 times per month for an average monthly intake of over 1600 g. This is in excess of the tolerable daily intake for PCBs recommended by the FDA, assuming a 2 ppm contamination level. Thus, there is a significant number of people in this fishing population that may be exposed to potentially harmful levels of PCBs (Table IVB).

Crab consumption is clearly in excess of health advisories in New Jersey, where selling or harvesting blue crabs in the Arthur Kill is prohibited. Crabbers here eat an average of 9.5 crabs per meal with an average consumption of 3.7 meals per month. In addition, more than 60% of these crabbers report that at least three-quarters of the crabs they eat are those they catch in these waters (Table III). Even though these crabbers are active only during the warmer months, they are consuming crabs in direct opposition to government health advisories. The data indicates that, compared to fishermen, crabbers are more likely to eat their catch and their diet consists of a higher proportion of crabs caught in the Arthur Kill as opposed to being store bought (Fig. 2A).

Hauge[16] found significant PCB contamination in the hepatopancreas of crabs caught in these waters (3.29 ppm). Muscle tissue contained levels below the FDA action limit (0.35 ppm). The average consumption of crabs in this study (9.5 crabs/meal and 3.7 meals/month) is 35.15 crabs per month or 5624 g/month (assuming only 160 g of muscle tissue is consumed from a single crab). This is 187 g/day. If the contamination level of the crab is 0.35 ppm PCB this results in an intake of 0.94 μg PCB/kg/d, for a 70 kg person (187 g/d × 0.35 ppm divided by 70 kg). This is marginally less than the FDA's TDI and there are crabbers consuming as many as 25 crabs per meal or as often as 16 times per month during the summer season. A 70-kg person consuming 9.5 crabs/meal, 16 times a month (the maximum we reported) would be exposed to 4.1 μg PCB/kg/d (Table IVB). Clearly there are people being exposed to levels of PCBs in excess of the FDA's recommended limits.

The above risk analysis was for PCBs. Yet fish and crabs in the Arthur Kill contain mercury and other contaminants that also pose a health hazard.[1,29] In addition,

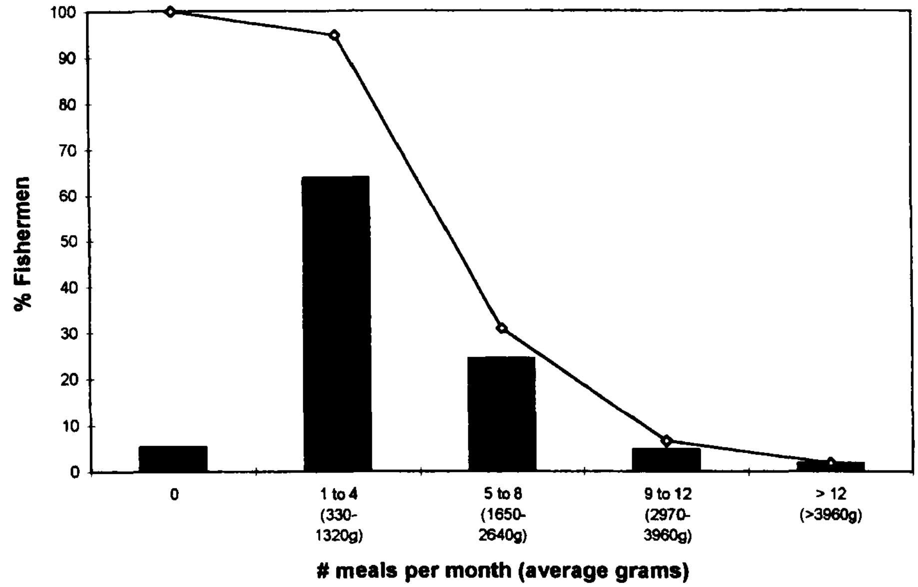

Fig. 3. Meals of fish consumed per month by fishermen in the Arthur Kill. Line shows cumulative total.

interactions between the variety of toxics in these waters are complex, making it difficult, if not impossible, to predict synergistic or antagonistic effects.[30]

Price *et al.*[31] suggest that the method of gathering data will affect the estimate of consumption, exposure, and subsequent risk. Using their analysis, the survey method used in our study overestimates the consumption rate of fishermen as a result of oversampling frequent anglers. In addition, since fishermen were interviewed only once, extrapolation of their behavior assumes it is consistent throughout the year.[32] Recall bias is also a factor that should be recognized. Fishermen may not accurately recollect the amount of fish they eat.[20,33]

Although these factors are likely to reduce real exposure for the population as a whole and even for the majority of fishermen, there remains a substantial proportion of the surveyed population who consume fish and crabs from these waters in excess of health advisories and may consequently be at risk. In addition, potential exposure to chemicals in these organisms may also be affected by the method of preparation and must also be considered.

Most people surveyed skinned and gutted the fish before cooking, removing the more contaminated internal organs. However, the most popular cooking method for fish in the Arthur Kill was frying. This may not reduce contaminant levels in the fish.[20] Broiling or grilling were the preferred methods in the Bay and Shore regions, which reduces the risk because potentially contaminated liquid drains from the fish. Although most crabbers did not eat the hepatopancreas, most did not remove it before cooking which would further reduce potential contaminant levels.[22]

4.2. Knowledge and Risk Perception

The New Jersey Department of Environmental Protection (NJDEP) first established consumption advisories and fishing bans in 1982[16] and we expected that fishermen would be aware of current advisories in these waters. Substantially more fishermen in the Arthur Kill, where advisories are more inclusive, were aware of current advisories than those in the other study regions. However, even in the Arthur Kill only 60% of fishermen were aware of the bans (Table IIA). Despite hearing warnings, over 65% the people interviewed in the Arthur Kill believed the water and fish to be safe. Similar discrepancies were observed in both the Bay and Shore regions (Table IIA). These findings are similar to those of Burger *et al.*[33] and Belton *et al.*[20] In addition, of the fishermen who said they had heard warnings, the majority (70%) admitted to eating their catch anyway (Fig. 3).

The causes of this dissonance between risk perception of the fishermen and the recommendations of government advisories are unclear. Several factors may be important including: the level of knowledge and understanding the fishermen possess; acknowledgment by the fishermen that a potential risk exists; and the level of trust in the organization issuing advisories.[3,6,7,10]

People make risk judgments based on what they believe to be true and thus their confidence that the information they receive is correct becomes an important issue. In this study, both fishermen in the Raritan Bay and crabbers in the Arthur Kill believed that the fish were less contaminated than the water (Table IIA). Fishermen commonly believed this was because the fish came from cleaner waters and did not spend enough time in polluted waters to become contaminated. Crabbers thought the crabs could filter contaminants out of the water. These fishermen reached conclusions about the safety of the fish and crabs based on the facts they believed to be true.

Many toxics bioaccumulate, resulting in higher concentrations in the organism than in the water.[16,19,34] Organisms that are at the top of the food chain contain high levels of contaminants due to dietary accumulation.[35] Thus, carnivorous fish, such as Bluefish, accumulate higher levels of toxics than herbivorous fish, such as *Tilapia*. Contaminant levels also increase with both the age and size of the fish.[22,36] Over 37% of fishermen in this study preferred larger fish to smaller fish of a given species.

In addition to these specific misconceptions regarding bioaccumulation and the age and size of fish, our results indicate that fishermen generally did not have a very good knowledge of fish habitat. If fishermen are relying on an incomplete understanding of fish species, behavior, and environmental interactions, their conclusions will ultimately be incorrect. These conclusions about the safety of the fish were reached on the basis of inaccurate information. Further, if the fishing portion of the public does not possess reliable information about an activity they participate in regularly, it is likely that the remainder of the public has an even less reliable knowledge base.

Familiarity is also a factor in risk perception.[1] Most fishermen interviewed fished frequently and had positive long-term experience with fishing in the area. Of those who had heard warnings, the majority continued to eat their catch. Many felt they could make the fish completely safe for consumption by using particular cleaning and cooking methods.[20,33] Weinstein[5] suggests that this optimistic bias concerning personal risk arises in situations where people believe that signs of susceptibility will appear early and the absence of any signals means that they will not be at risk in the future either. In view of the chronic effects attributed to the intake of small quantities of toxic chemicals over a period of time,[37] these optimistic views may contribute to hazardous intake of toxics. Burger and Gochfeld[38] also noted a lack of consideration of chronic effects among fishermen in Puerto Rico.

Acknowledgment of potential risk is also influenced by the credibility of the risk message and is ultimately affected by the trustworthiness of the source.[6] In this survey, many fishermen expressed doubts about the governments' motives for issuing warnings, supporting the idea that the government is no longer as trusted as it once was.[8] In addition, the complexity of ecosystems makes it difficult to obtain definitive answers to questions of chemical exposure and resultant effects,[39] and a variety of sources of uncertainty in toxicological and exposure data limit the accuracy of human health risk estimation.[36] This scientific uncertainty often serves to reduce public confidence further.[40]

4.3. Reducing Risk

Fishing is an enjoyable and relaxing pastime and, as such, it is difficult to convince people that it may be hazardous.[20] It is also voluntary, and the public will accept risks a thousand times greater for voluntary as opposed to involuntary activities.[41] With increasing awareness and knowledge of environmental hazards in recent years, attention has focused on mechanisms for making information available to the public. The next step is to develop strategies that encourage people to acknowledge that a potential risk exists, and then to change their behavior appropriately.

However, even though signs appeared at two of the four Arthur Kill sites during the survey period, fishermen and crabbers continued to use these sites. The signs stated (in English and Spanish) that the harvesting and consumption of crabs was prohibited, yet people set traps right next to the signs! Health advisories currently in effect were also published by the New Jersey Department of Environmental Protection (NJDEP) in the New Jersey Fish and Wildlife Digest. This publication is available at no charge at most fishing stores and marinas.

Optimistic biases may arise because no acute effects are experienced. In addition, fishermen and crabbers in this study justified eating the fish and crabs they caught in the Arthur Kill over those bought in stores because they were "fresher." This unreal optimism reduces the motivation to take precautions, and campaigns that lead these fishermen to realize that their actual risk status is likely to be *above* that of the average, nonfishing population may be valuable. Weinstein[42] suggested that this recognition is a powerful motivator for change.

It is important for risk communicators to realize that people's beliefs change slowly and may persist even in the light of opposing evidence, and faulty beliefs may be held with confidence.[3] The results of this study indicate that many fishermen believe that fish habitat and filtration ability, as well as cooking methods, reduce the level of contaminants to an acceptable level. Although the New Jersey Department of Environmental Protection (NJDEP) disseminates information and demonstrates fish preparation and cooking methods to reduce risk,[20] additional information needs to be presented about the types of contaminants and the significance of bioaccumulation. Potentially important for risk communication is the indication in this study of a relationship between fish consumption and fish safety; fishermen tend to eat fish they think are safe and not eat it if they believe it is unsafe. People trust information more when it is consistent with their currently held expectations or beliefs and it has been suggested that trust is becoming an important issue in risk perception.[10,43]

As a result of increasing public distrust in institutions involved in risk management, the dissemination of risk information has had less impact than it could have in reducing the differences between expert risk assessments and the perception of the public.[10] Agencies issuing warnings must improve their credibility in the public eye, and involving independent parties in sampling, testing, and reporting may help the process of rebuilding trust in government agencies.[7]

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