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The Peconic River: Concerns Associated with Different Risk Evaluations for Fish Consumption

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ABSTRACT *Risk evaluation and assessment have been used as tools to regulate and manage the risks to consumers of eating self-caught fish that have high levels of contaminants. Armed with these risk assessments, health agencies issue consumption advisories, and in some cases, close some waters to fishing. Recently, regulatory agencies have used contaminant levels in fish as a benchmark for remedial action on contaminated sites, using human health risk assessment as the justification. The US Environmental Protection Agency's new surface water criterion for mercury is based on mercury levels in fish tissue. When multiple regulatory agencies have jurisdiction over the same waters or remediation site there is the potential for differing risk evaluations. Using the Peconic River on Long Island, New York as a case study, the paper examines how and why county, state, and federal health risk evaluations for fish contaminated with mercury differed. While the same risk methodology was applied by all agencies, the assessments were conducted for different purposes, applied different consumption and fish biomass assumptions, and arrived at different conclusions. The risk evaluations invoked to design fish consumption advisories use mercury levels currently in fish, and are designed to prevent current exposure. However, the risk assessments that provide a basis for remediation consider many different pathways of exposure (not just ingestion), and deal with long-term exposure. The risk evaluations, and recommendations promulgated by those agencies, differ because they have different goals, use different assumptions, and often fail to communicate among agencies. It is suggested that it is valuable to have these different levels of risk evaluations to adequately address health issues. However, there are policy implications, which include making the distinctions between the types of risk assessments, their methods and assumptions, and the rationale for these assumptions. Further, assessors and managers should involve all interested stakeholders (including regulators and state health officials) in discussions about the use of risk, the assumptions of risk assessment, and the goals of those evaluations. The difficulties in the case of the Peconic were not due to differences in the original data, but rather in the goals and type of risk assessments performed. If all deliberations had been transparent during all phases of the decision-making and management process, the conflicts within the minds of the public, regulators and other agencies might have been avoided. This case study suggests that more reliability, circumspection and transparency should be built into the process where multiple agencies and multiple objectives are involved.*

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Introduction

In their everyday lives, people face hazards and must make individual decisions about the risks they face. However, the public depends upon the government to provide both safeguards and warnings about potential hazards, and to regulate or remediate where needed to reduce exposure to these hazards. With the ending of the Cold War, the US and many other nations are faced with hazardous waste left over from weapons development and production (DOE, 1995; Crowley & Ahearne, 2002). In most cases, these wastes are confined to Department of Energy (DOE) or Department of Defense (DOD) lands, but at other sites, contaminants leak onto adjacent land either at the surface through runoff or sediment transport, or through underground plumes. These eventually reach surface waters or groundwater. Once in streams and rivers, contaminants may move downstream or up the food chain through bioamplification, eventually accumulating in fish that are consumed by humans and other top-level predators, posing a health risk. This is especially true for mercury that can be methylated and then bioaccumulates and biomagnifies with trophic level, and the size and age of fish (Phillips *et al*., 1980; Braune, 1987; Lacerda *et al*., 1994; Lange *et al*., 1994; Bidone *et al*., 1997; Burger *et al*., 2001a). A similar relationship has been found in fish for other metals, such as selenium (Burger *et al*., 2001b), and for arsenic, cadmium, and chromium (Burger *et al*., 2002).

In many places in the US and elsewhere in the world, fishing provides an important source of protein and is a popular pastime (Toth & Brown, 1997; Burger, 2002). Despite common beliefs, consumption rates of self-caught fish may be high for some urban dwellers, such as those in metropolitan New York City (Burger *et al*., 1999c, Ramos & Crain, 2001). For some people who eat self-caught fish, fish may be the main affordable source of protein, while for others it may be the healthiest source. Fish provides many health benefits, including omega-3 fatty acids that reduce cholesterol levels and the incidence of heart disease and stroke, as well as pre-term delivery (Hunter *et al*., 1988; Horn, 1992; Anderson & Wiener, 1995). Yet, contaminant levels are sufficiently high in many freshwater and saltwater fish to provide potential adverse human health effects, particularly for developing fetuses and young children, and may counteract the cardioprotective effects (Guallar *et al*., 2002). For example, there is a positive relationship between mercury and PCB levels in fish, fish consumption by pregnant women, and deficits in neurobehavioral development in children (Jacobson *et al*., 1989, 1990; Institute of Medicine, 1991; Sparks & Shepherd, 1994; ATSDR, 1996; Jacobson & Jacobson, 1996; Schantz, 1996; Weihe *et al*., 1996; Grandjean *et al*., 1998).

The main responsibility for protecting human health lies with state agencies, which deal with the potential for adverse health effects from eating fish by issuing consumption advisories. The Federal government plays a secondary role in advisories. Most state agencies distribute fish consumption guidance primarily with fishing licenses, although some also have brochures for high-risk individuals, such as pregnant women and those in their child-bearing years (Burger & Gochfeld, 1991; Reinert *et al*., 1991; Burger *et al*., 1992, 1993, 1999a, 1999b; Velicer & Knuth, 1994; Knuth, 1995; Burger, 2000; Knuth *et al*., 2003). The advisories for mercury are mainly based on risk assessments, and try to balance encouraging information (fish are wholesome and beneficial) with warnings.

While issuing advisories is one method for reducing the potential risk to people from fish consumption, cleaning up the contamination is another, more long-term solution because it eliminates some or all of the source of contamination. Yet deciding on the levels of clean-up necessary to eliminate a health risk to future fish consumers is not a trivial task, but is one that involves several regulatory agencies at the state and federal level. Clean-up criteria decisions involve many variables including projected future land use (Klemic *et al.*, 2003). Some decisions are risk based, while others are technology or feasibility based.

This paper examines how and why county, state and federal health risk evaluations and assessments for fish contaminated with mercury can differ, using the Peconic River on Long Island, New York as a case study. The risk assessments discussed in this paper relate to the portions of the Peconic River that lie within the Department of Energy's Brookhaven National Laboratory (BNL at Upton, NY), and the region immediately downriver (east) from the laboratory (Figure 1). The regulatory and public controversy surrounding fish developed because, using the same data on contaminants in fish, the State of New York stated that no additional fish advisories were necessary, while the risk assessments conducted by DOE concluded that clean-up to protect fish consumers was necessary. Suffolk County also urged clean-up. The public was understandably confused because the state agencies said that no additional fish consumption advisories were required, suggesting no immediate risk, while the risk assessments conducted for DOE suggested that additional clean-up of sediment was required because of the risk to the public from mercury in fish. This caused consternation for DOE staff; they wondered why clean-up was necessary if no additional fish consumption advisories were required to protect the public. New York State has issued consumption advisories for freshwater fish within the state, based on mercury, and these advisories

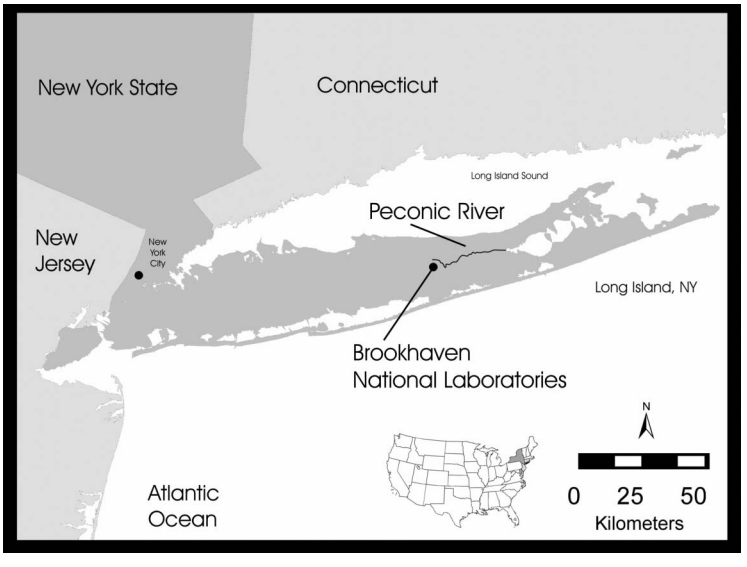

Figure 1. Map of Long Island region showing Brookhaven and Peconic River.

were sufficient to protect people fishing in the Peconic River. DOE officials initially did not realize that a statewide fish advisory was already in place.

While the specifics discussed in this paper apply to the Peconic River, the case study illustrates the major issues when risk evaluations are conducted for different purposes, with different assumptions, and are viewed by the public as contradictory. It is suggested that different risk evaluations are made by different agencies because they have different goals, use a different set of assumptions, and often do not communicate among agencies. For several agencies, the key issue is whether fish consumption advisories should be issued, while for others the question is whether and what remedial action should be taken. The differences partly relate to timing (consumption advisories are issued on a yearly basis; clean-up decisions are aimed at potential subsequent accumulation), methodologies (quantitative vs. qualitative rule-based risk evaluations), and philosophies (protecting one area such as fish consumers, vs. overall protection of human health, vs. protecting recreational and existence values). The remediation options are not specifically addressed in this paper, but instead the paper concentrates on the risk evaluations and assessments, and associated assumptions. The contaminant of greatest concern is methylmercury, although PCBs as well as radionuclides that came from BNL occur in fish in the Peconic River (Rapiejko *et al.*, 2001). Remediation of BNL is required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Study Site and Methods

The Peconic River

The Peconic River headwaters begin about 1.2 km upstream from BNL. The river (actually a stream only a few metres wide in many places) passes through the laboratory site, exits at the southeast perimeter, and gradually widens, passing through rural and suburban landscape, ultimately flowing through the town of Riverhead, where it enters Long Island Sound (Figure 1). The river is subject to great seasonal variation in flow, parts of it drying up altogether in some years (see below). Parts of the Peconic River are designated as a Wild, Scenic and Recreational River by the state of New York. BNL (5262 acres), 100 km east of New York City, is in Upton (Suffolk county) New York. BNL was established in 1947 to develop advanced technologies in support of the nuclear weapons mission of the Department of Energy, and now has programs in nuclear and high-energy physics, physics and chemistry of materials, environmental and energy research, neurosciences and medical imaging, and non-proliferation (DOE, 1996, 1999, 2003).

During remedial investigations conducted by BNL, elevated levels of pesticides, organic chemicals (PCBs), heavy metals (mercury, copper, silver), and radionuclides were detected in the sediments of the Peconic River (DOE, 2002a). The main contaminant of concern for the Peconic River is mercury, which came from the release of treated wastewater, which in turn flowed into streams at the headwaters of the Peconic River. Most of the contaminants were found in the top 6 inches of sediment. At issue is what remediation is appropriate for the Peconic River, given the levels of contamination, the potential for future changes in land use, and the levels of

risk that contaminants pose for humans and ecological receptors, particularly fish consumers (DOE, 2002b). Although there are not current discharges of concern, there are underground contaminant plumes, and contaminated sediments in the creeks that can move.

The Players

Fish consumption advisories are usually the purview of state regulatory agencies (either natural resource and conservation departments, or health divisions), although the federal Environmental Protection Agency (EPA) sometimes becomes involved when waters are held by two or more states. For the Peconic River, there are three jurisdictions interested: Suffolk County, the State of New York, and federal EPA. Other stakeholders include environmental groups, site neighbors, downstream communities, and other stakeholders, including DOE.

Most of the same entities are involved legally in determining final clean-up for contaminated sites under CERCLA, particularly the principle responsible party (in this case, DOE), the states, and EPA. However, the same departments within state or federal agencies may not have prime responsibility for both the health risks driving clean-up of soil (where ingestion by toddlers is usually the main pathway of concern), and those from consuming fish. Clean-up jurisdiction usually rests with an environmental agency while responsibility for advisories lies in a health agency. Further responsibility for the ecological risks from contamination may involve a different department or division (in the case of New York, the Department of Environmental Conservation).

Methodology

The overall protocol was to obtain all the documents (including correspondence) pertaining to human health and ecological risk evaluations and assessments for the Peconic River (DOE, 2002a, 2002b), examine the risk assessment methodology, attend public and agencies meetings where this issue was discussed, reconstruct the procedures and calculations, and determine the nature of the discrepancies between the different players. While DOE conducted a formal quantitative risk assessment (DOE, 2002a, 2002b), the other agencies used the Food and Drug Administration (FDA) action level and EPA risk evaluation methodologies for fish consumption. Local, state and federal agencies made their inter-agency communications available to the authors, and DOE also provided additional studies reflecting river flow and fish abundance conducted after the initial risk assessments.

The authors also attended public and inter-agency meetings where the issue of fish consumption, risk, and clean-up were discussed, and interviewed several key personnel from each agency (noted as personal communication below). The main objective in interviews was to determine the main interests of each agency, and its rationale(s). The positions and risk evaluations of Suffolk County, New York State, US Environmental Protection Agency and the Department of Energy are examined below. The study was particularly interested in the objectives of the agency, how these impacted both decisions and actions, and the degree of stakeholder involvement.

Results

DOE Using EPA Methodology

In the baseline risk assessment for the Peconic River, DOE conducted risk assessments using standard exposure scenarios (DOE, 2002b), which included cancer and non-cancer risks. The non-cancer risks mainly related to fish consumption and mercury. The cancer risks were examined for several media, including groundwater, soil, fish, surface water and sediments, for the maximally-exposed individual (DOE, 2002b). Their cumulative cancer risks to off-site residents, resident angler/hunters, non-resident angler/hunters, and trespassers on site were all within the EPA target range of 1×10^{-4} to 1×10^{-6} (DOE, 2002b).

DOE considered several non-cancer exposure scenarios, including off-site resident recreational anglers, off-site recreational anglers, off-site residents, on-site trespassers, future on-site resident recreational anglers, future on-site recreational anglers, and future on-site residents (DOE, 2002b, Figure 2). One assumption DOE made at the time of their human health risk assessments was that BNL would be in DOE ownership only for the next 50 years; an assumption that was not warranted given later DOE decisions that BNL would remain a DOE laboratory. Thus, at present it could be argued that since the land will likely remain under DOE ownership for the foreseeable future, the on-site resident scenarios are unwarranted. The evaluation here of their human health risk assessment procedures indicated they indeed followed EPA guidelines, using mainly EPA default assumptions (DOE, 2002b).

The DOE's choice of neighbor scenarios was reasonable, given the densely populated region, and the importance of recreation to the local population (Burger,

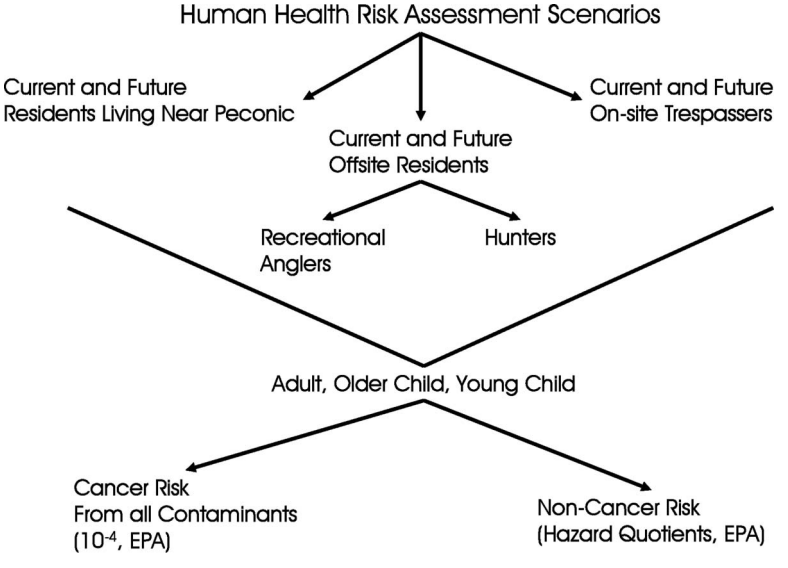

Figure 2. Human health risk assessment scenarios considered by the Department of Energy in their use of US Environmental Protection Agency methodology.

2004). The DOE risk assessments indicated that non-cancer health hazard quotients exceeded 1.0 for recreational angler adults and children based on assumed reasonable maximum exposure factors due to mercury in edible fish tissue and for younger children due to PCBs (DOE, 2002b).

However, the exposure assumptions used in these risk assessments may all tend to drive the risk in one direction, toward overestimates of exposure. For example, they assumed that people could fish all year, that there were always fish of legal size available to catch, and that people ate mainly fish from the Peconic River. These assumptions are for typical recreational anglers, rather than from site-specific data, and for a continuously flowing river (not one that is intermittent). Conditions in the Peconic River make these assumptions suspect. The Peconic River that flows through Brookhaven has low flow, long periods of dry conditions, small numbers and sizes of most fish, and low preferability as a fishing site (DOE, 2002b). The Peconic River derives more than 90 per cent of its flow from groundwater, and less than 10 per cent from runoff (Scorca *et al.*, 1999), which implies that flow in the river will depend upon the water table elevations. Scorca *et al.* (1999) reported that the flow in the Peconic River starts where the riverbed intersects the water table, which in some years is east of BNL, and in other years is west of BNL.

Because the flow of the Peconic River was in question, DOE commissioned a study (Sullivan, 2003) to examine flow in different months. The data were available for only 15 of the preceding 30 years. In this time period, there was no flow in a large section of the river through BNL for 3 of the years, and no flow for 6 months for an additional 4 years. Thus, in half of the years examined, fishing would have been impossible for at least 6 months each year, and for most of 3 years. Sullivan (2003) estimated that low river conditions (no flow off BNL) would occur between 15–70 per cent of the time, with high water (banks overflowing into the marshes) only 16–33 per cent of the time. The latter condition was observed in the spring of 2003, and the low water condition in 2002. The area of potential fish habitat (and therefore fish for catching) is strongly correlated with the water level in the Peconic River (Meixler & Bain, 2002). With little or no water in the river, fishing is impossible because there are no fish or fish cannot grow to very large sizes. In addition, fish populations are constrained when there is water, and fish must move in from downstream where fish populations reflect the carrying capacity of that region. Most rivers or lakes with fish consumption advisories are permanent; the Peconic River is not. Because of the variable flow in the river, from temporary flooding to being completely dry, the fish biomass varies as well.

There are a variety of habitats available in the Peconic River due to these variations in flow and water depth. Meixler & Bain (2002) collected data on available habitats (run, glide, pool) and fish biomass. Runs (steadily flowing reaches) are present at high water levels, while glides (slow running water) and pools are present at mid and low water levels. They found that among species, chain pickerel biomass was expected to be highest in all habitats. Fish biomass estimates ranged from 2.32 g/m^2 in pools to 5.69 g/m^2 in glides; thus fish biomass is highest at mid-water levels. Brown bullheads, one of the largest species in the river, ranged from 7–30 cm (about 3–12 inches); the range for all fish was 2.5–50 cm, with most of the fish in the 7–13 cm range (less than 6 inches). The legal size limit for pickerel in New York State, for example, is 15 inches (larger than most fish collected on site).

Together these data indicate that there is not continuous flow in the Peconic River. In some years there is no flow in the river as it leaves BNL, and the fish are generally small, with low biomass during most months of the year. Thus, there are relatively low fish populations, the effort to catch fish would be high, and fish populations would have to be supplemented to maintain high enough levels for anglers to reach the EPA default fish consumption rates. Thus, the usual assumptions for fish consumption derived from continuously flowing rivers are not reasonable for the Peconic River.

Suffolk County

The Suffolk County Department of Health Services was concerned about the potential health risk posed by contaminants in the Peconic River to downriver county residents who may engage in recreational fishing and other activities in and around the river. The residents of Suffolk County are the neighbors, and the ones most likely to be impacted by local exposure. Since county parklands abut the Peconic River downriver from BNL, potential risk to recreational fishermen and others was a real concern. They were also concerned about the risks from mercury to ecological receptors.

V. Minei, representing the Suffolk County Dept of Health Services/Division of Environmental Quality, contended (pers. comm. 5 February 2003) that the current low population of fish in the Peconic River was because of BNL, and that the County is working to increase fish populations through restoring habitat, restocking, and building fish ladders to allow spawning fish to swim to higher reaches of the river. This would allow large fish living downstream to migrate upstream.

Suffolk County did not conduct any independent risk assessments, and held the position that any residual contamination in the Peconic River off-site should be removed, largely based on the inadequacies in the human health risk assessments conducted by DOE (V. Minei, pers. comm, letters of 20 September 2002, 2 February 2003). Among the weaknesses Minei cited were the exclusion of data with the greatest contaminant levels, not summing across scenarios, and multiple routes of exposure for both radiological and non-radiological risks, and the potential for increased recreational use of the area with County restoration along the river.

The County was further concerned that any mercury remaining in the sediment would act as a continued source for fish in the Peconic River, that storm events could severely impact mercury mobility downriver by enhancing sediment migration, and that drought years would result in contaminated sediment being dry and exposed, thereby potentially contaminating groundwater. Since some nearby residents have wells, groundwater contamination is a County concern. Although Suffolk County did not have a legal say in the final remediation agreement, New York State was compelled to take the County's concerns into account in their own position.

State of New York

Two Departments of the State of New York have interests in the Peconic River: the Departments of Health (DOH) and of Environmental Conservation (DEC). The first

responsibility of the State is to issue fish consumption advisories, where applicable. This is largely a method of informing the public about a potential risk in the hopes of preventing high exposures. The DEC collects and analyses fish tissue, and the DOH interprets these levels with respect to the need to issue consumption advisories. These departments found that all fish collected from the Peconic River in 2001 had levels below the FDA Action Level (currently 1 ppm for methylmercury). Furthermore, the New York State Department of Health, Bureau of Toxic Substances Assessment concluded that no additional advisories were necessary at that time (E. G. Horn, pers. comm. letter of 30 April 2002). This led to the perception that New York State did not believe there was a risk from consumption of fish from the Peconic River. However, it should be noted that there is a general fish consumption advisory for all New York State waters of "do not eat more than one fish meal/week (0.5 lb = 226 g)" (New York State, 2002). The fish collected in 2001 thus did not rise to a level requiring additional consumption advisories for the Peconic River at that time (Table 1).

In addition to addressing the specific question of whether additional fish consumption advisories were required for the Peconic River, New York State also critiqued the overall remediation plan for BNL. Fish consumption was not the only route of exposure; the DEC was concerned about other human health risk assessments (and the exposure pathways), as well as risk to ecological receptors. The DEC stated that other risk scenarios not conducted by DOE should be examined (such as on-site gardening). The DEC also noted that risks from radiological and non-radiological contaminants should be summed, rather than computing risk contaminant by contaminant (J. B. Lister, pers. comm. letter of 22 April 2002). Risk should be summed for all contaminants in all media, and from different scenarios. Thus, while the contaminant levels in fish did not require additional consumption advisories, the potential risk from all contaminants (from all exposure routes) did pose a potential risk, in their estimation. Thus, they accepted the basic risk assessments of DOE, but

Table 1. New York State's contaminant analysis of fish collected from Peconic River in 2001

	Mean	**Highest value**	**FDA standard**
Total mercury	0.29 – 0.73	1.3[b]	1 ppm[c]
PCBs[a]	< 0.2–0.04	0.1	2 ppm
DDT,DDE,DDE[a]	–	0.06	5 ppm
Radionuclides	< 0.3	< 0.3	10[d](millirem/yr)

These results are based on 39 fish of four species from three sites downstream of BNL (E. G. Horn, letter of 30 April 2002). Table shows range of means across the samples (species x sites), maximum value, and the FDA standard used by New York State. All values are in parts per million on wet weight basis.

[a]Organochlorine results reported on per lipid basis.

[b]One fish, a Brown Bullhead, had mercury above 1 ppm.

[c]Current FDA Action Level is 1.0 ppm of methylmercury. Typically about 85–90% of the total mercury in fish is methylmercury.

[d]NYS DEC guideline of committed effective dose equivalent.

believed that cumulative risk from all media, contaminants and pathways should be summed.

Finally, the representative from New York State contended that the State's remediation program is not always entirely risk-based, but instead its goal is to return all sites to pre-contaminated conditions (R. Mitchell, NYSDOH, pers comm., 5 February 2003). Some stakeholders and regulators thus questioned the basis for using only risk as a driver for remediation of BNL. This addresses the question of how clean is clean, and New York State and Suffolk County both entertained the idea of returning BNL to pre-contamination conditions. In the authors' view, this is understandable, given the high population density of the area, the high land values, and the high demand for undeveloped land.

Environmental Protection Agency (EPA)

Although the federal EPA did not conduct its own risk assessment, it did evaluate the baseline risk assessment (Mary P. Logan, letter of 19 September 2002). It noted the need to consider the reasonably maximally exposed individual for both cancer and non-cancer health hazards, and to consider all ages in risk scenarios, as both New York State and Suffolk County had suggested. They were particularly concerned that consumption rates were given only for adults, and not for children of all ages. EPA further noted that there were no creel surveys of fishermen along the Peconic, resulting in a lack of site-specific data for the risk assessments. Such site specific data would have provided information on the timing of fishing, species caught, sizes of fish caught and ethnic differences in fishing and consumption patterns (see Burger *et al*., 1999a, 1999b).

Discussion

Risk Assessment Issue for Fish Consumption

The apparent discrepancy between the DOE risk assessment (following EPA protocols) for fish consumption (conducted as a resident fish consumer scenario), and the State of New York's evaluation can be viewed as a difference in the goals and objectives of the risk assessment (Table 2 and Figure 3). New York State was interested in reducing current risk from fish consumption (its mandate with respect to fish consumption advisories), while DOE needed to consider all risk sources, and contaminant exposure pathways. This is one of the key problems in risk assessment, the importance of clearly stating the goals and assumptions of the process and ascertaining that stakeholder concerns are understood and addressed. For the State of New York (and for EPA), the main issue was protecting the public from current risk deriving from chemicals in fish. For DOE, the main concern was clean-up of the Peconic River to reduce the risk from fish consumption (and other pathways), now and in the future.

The key question in the risk assessment methodology is the assumptions used in the risk assessment, and the construction of the scenarios themselves. Three types of information are required for assessments of the risks associated with fish consumption: contaminant levels in fish, consumption rates (particularly of target

Table 2. Major objectives of different agencies and their implications for stakeholders in the case of Brookhaven National Laboratory

Agency	Objective	Implications
NYS	Protect human health	Assess current risk from mercury and other contaminants in fish (not future risk)
EPA	Protect human and ecological health	Assess current risk to humans from fish consumption, and to the fish themselves
DOE	Effect remediation	Remediate to levels that reduce risk now and in the future to allow site closure or completion (assess all future risk from all sources, not just fish consumption)
Suffolk County	Protect human and ecological health for its residents	Obtain as much clean-up as possible to retain all options for its residents and ecological receptors

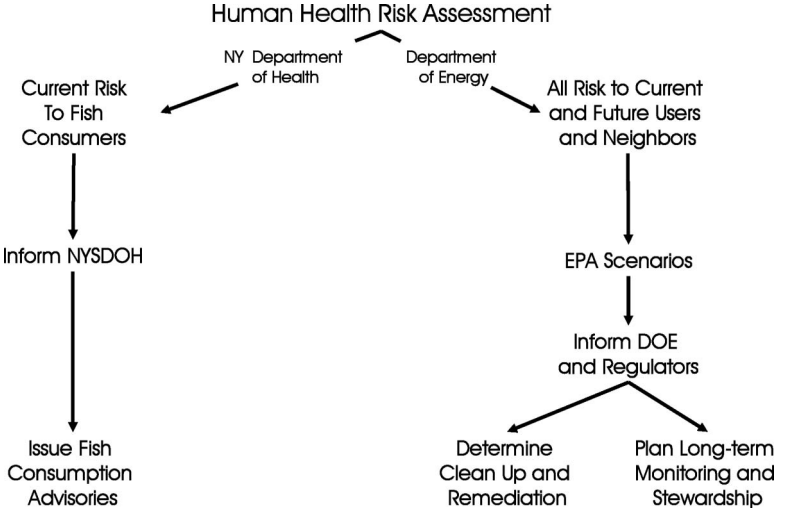

Figure 3. Differences in the use of human health risk assessments using data on contaminants in fish employed by the New York State Department of Health, and the US Department of Energy.

groups), and fishing behavior. Without site-specific data on consumption rates of off-site anglers who use the Peconic River in the area of interest, risk assessors are compelled to use EPA's default assumption of consumption rates. Local anglers who enjoy eating fish will generally seek favorable fishing areas, particularly when local waters shrink (as the Peconic frequently does), and legal-sized fish become unavailable. At such times, anglers may also increase their consumption of commercial fish. In conclusion, the assumptions used in the DOE risk assessment, based on EPA default assumptions, are unrealistic because the quantity and sizes of fish necessary are simply not available in the Peconic River.

Balancing Different Goals

The apparent discrepancy partially developed because the risk evaluations used to develop fish consumption advisories relate to contaminant levels in fish collected from the Peconic River at the time of collection, while those conducted by DOE (using EPA methodology) examine scenarios for exposure of current and future residents or intruders (for on-site or off-site residents). New York State was interested in whether there was additional risk from consuming the fish from these waters above and beyond those covered by their existing advisories. Thus, the NYS assessments were made within the context of the already existing fish consumption advisories for New York State waters (which acknowledge there is a risk from consuming the fish), while the DOE methodology assumed no risk from fish consumption. The state then issues consumption advisories, which are distributed with fishing licenses, placed in public places (such as bait and tackle stores), and announced in newspapers, along with information numbers for inquiries from the public. Such risk assessments are normally updated each year. While the public is involved in the risk communication aspects of such fish consumption advisories (how and where the information is transmitted), they usually are not involved in the risk assessments themselves (Burger, 2000, 2002).

However, the DOE risk assessments were based on clean-up to levels sufficiently low that there would be no further need for fish consumption advisories even if people intruded or lived on the site. This illustrates the importance of different agencies clearly stating the goals of their risk assessments, and making these goals clear to the public and other stakeholders. The process would benefit from involving the public and other stakeholders in setting the goals in the first place.

The relative risks to human vs. ecological receptors is another goal requiring comment. At present, the key risk identified was risk to people consuming fish, and not to ecological receptors. However, the large-scale removal of sediment to eliminate mercury and other contaminants would clearly destroy riverine and adjacent marshland habitat. The hidden risk thus relates to destruction of ecological receptors and habitats during remediation. The issue of contention then becomes whether marsh restoration would eliminate this concern, and there was, as is always the case in these situations, disagreement about the ability of ecologists to restore wetland habitats. Wetland restoration is underway, but fully functioning marshlands have not been achieved.

Balancing Different Risk Assumptions

State agencies often have two different objectives for the risk assessments of contaminants in fish (1) determining the risk to the fish and to their ecosystem, and (2) determining the risk to human health. Part of their responsibility under the latter is determining the risk levels required to issue consumption advisories or warnings. Often these objectives are administered by different agencies within state governments. The risk to fish and the component parts of ecosystems often falls within Non-game programs, while human health risk falls within the purview of Health departments. Fish advisories are either issued by one or the other, or by both jointly. Fish advisories are often reviewed annually, and are issued for some or all waters of a state.

Balancing Temporal Imperatives

One critical issue involved with the use of risk assessment, and associated assumptions, is whether the risk assessment is intended for short or long-term predictions of risk. Risk assessment is a formal process aimed at determining whether a given hazard poses a health risk to humans or the environment, and produces a prediction, with associated uncertainties. Uncertainties include potential future changes in factors that might increase mercury levels in the foods, increase uptake rates of mercury in the fish of interest, or change land use that might shift exposure. It is a question of examining current exposure as a result of existing conditions, vs. changes in future exposure conditions that might increase risk.

As noted earlier, in their deliberations, NYS examined the levels of mercury and other contaminants in the fish they collected, and determined that they did not exceed the FDA action levels and that no additional advisories were necessary. This ignores the fact that the FDA Action Level for mercury in fish, originally set in the 1970s for seizure of commercial fish shipments, took into account various economic and feasibility factors as well as health. Currently, FDA uses probabalistic approaches to exposure (Carrington *et al.*, 1997), and takes into account clarity and consistency (FDA, 2001), and has concluded that its action level does not need to be changed. The FDA action level is not a risk-based level (Mahaffey, 1999).

The DOE risk scenarios used the same data as NYS on contaminants in fish to conduct their risk assessments that showed that over a 70-year period, consuming fish from the river would pose a health risk. This assumes (1) that people continue to reside and fish along the river; (2) that the fish retain the same contaminant levels; and (3) that they continue to be available all year in sufficient quantities to be caught and of a sufficient size to be kept. The potential for other changes in the conditions in the Peconic River bears comment. Such changes could include rises in sea level which could inundate part or all of the Peconic drainage, and anthropogenic changes which might alter bank and flow conditions in the river. Such anthropogenic changes might include additional stocking of fish in the river, the building of fish ladders to increase reproduction in the river, and deepening of the channel downstream from BNL to increase fish production or the construction of bulkheads and channels. All of these might increase the number, species diversity, and sizes of fish in the river. However, unless these changes occur on the BNL itself, the flow would remain the same, making it unlikely that fish would be present on site for all months, in all years, in sufficiently large numbers and sizes to support the EPA default assumptions for the on-site angler scenario.

The DOE risk assessments assumed that DOE would relinquish ownership and control of BNL within a relatively short time frame. If BNL remains under DOE ownership, then (1) DOE would retain the responsibility for continued monitoring of all contamination to assure that there is no human and ecological receptor health risks, and (2) the on-site resident and angler/hunter scenarios would not apply (although the intruder scenario continues to be germane).

A Planning Framework for Risk Assessment, Risk Management and Risk Communication

The Presidential/Congressional Commission on Risk Assessment and Risk Management provides a framework for maximizing the effectiveness of risk assessment, by incorporating stakeholders as partners at every stage in the process including (1) defining the problems, context, and question for the risk assessment; (2) performing the risk assessment; (3) interpreting the risk assessment in terms of options available for reducing risk; (4) selecting and implementing the risk management options; and (5) evaluating the outcome to determine whether the risk management choices and accomplishments meet the needs of the agencies, regulators and other stakeholders (PCCRARM, 1997). If this model had been followed, the apparent differences in risk assessments regarding fish consumption may not have occurred.

In the case of fish from the Peconic River, stakeholder involvement with the different agencies varied. New York State regularly involves stakeholders in discussions about the best methods to communicate fish consumption advisories to the public, and EPA communicates its advice relative to contaminants in fish via the media. DOE has a citizens advisory group and regularly holds public meetings about their remediation decisions. Thus for DOE, stakeholder involvement about fish consumption was embedded within the context of potential remediation of the Peconic River (which in turn would affect mercury in fish).

This case illustrates that it is important to involve stakeholders early in the risk evaluation and risk assessment process, particularly for clean-up decisions. In part, the public controversy with regard to the fish consumption issue resulted from a lack of stakeholder input into the assumptions used in the risk assessment that were realistic for fishing in the Peconic River. That is, there were no surveys of either fishing patterns on the Peconic River, or of fish availability in the river prior to the formal DOE risk assessment. Thus the assessment used default EPA assumptions, which were not directly applicable to the Peconic River. Had the public been involved in discussions about the risk assessments before they were completed, data gaps might have been identified. Further, some anecdotal information on the river (e.g. did it flow all year, were fish available all year) and fishing (e.g. did people fish all year, how much did people fish) might have been available.

Finally, much of the confusion in the minds of both governmental agencies and stakeholders with regard to mercury and fish consumption in the Peconic River, and subsequent clean-up decisions based on risk from consuming fish, could have been averted by transparency in all agency processes, decisions and actions. Not only could all agencies have made their own actions transparent, but they could also have provided comparisons of their objectives, methodologies and conclusions with those of other agencies. Such comparisons could have been provided in written material, press releases and on the Internet.

Lessons for Environmental Managers

One important lesson that emerges from this case study is that risk assessments can be used in different ways for different objectives. Careful definition of the objectives, and communication of these to appropriate stakeholders, can go a long way toward

reducing misunderstandings. Two objectives of different agencies from the Brookhaven case study overlap, but are not congruent: (1) determining risk from contaminants in fish for the purposes of issuing fish consumption advisories, and (2) determining risk from contaminants in fish to current and future fish consumers given a number of different risk scenarios for the purposes of determining clean-up levels. In essence, alternative 1 is part of alternative 2, the part that is often of far more interest to the public. Since fish consumption is a realistic exposure pathway for humans, unless institutional controls prevent exposure, it is a viable and key risk scenario that should be part of any public policy and planning process.

The most useful risk assessments for fish consumption include site-specific data on both contaminant levels in fish (which BNL did have) and site-specific data on fishing behavior and consumption patterns (which BNL did not have). However, the exposure scenarios must be realistic within the potential biomass and sizes of fish in affected streams or rivers. The assumption about fish sizes and biomasses was a key parameter of the Peconic River risk assessments which was disputed, largely because the EPA risk methodology employed by DOE used default assumptions about consumption, rather than site-specific data. Further, one of the assumptions of the risk assessment was that fish of an edible (and legal) size would be available all year, or at least during the period when people would fish. This appears not to be the case.

A second important lesson is that there are two alternative approaches to clean-up which result from using risk assessment to determine different endpoints: (1) cleaning up contamination to achieve the lowest level possible, or to produce the lowest possible risk, and (2) cleaning up to the risk level required by, or appropriate for, future land use. The latter is a method of using the end state to influence the clean-up level and the resultant risk to humans and ecological receptors. That is, the expected land use should influence the level of clean-up so that the risk to humans and ecological receptors is reduced to a level consistent with this use, but not necessarily to a lower level consistent with other imaginable uses. Thus, if the site is to remain in DOE ownership, rather than be sold for residential use, clean-up levels should reflect this use.

The influence of future land use on clean-up levels was also controversial at Brookhaven because, while BNL itself will likely remain in federal ownership and thus will not be used by the public, downriver County lands are and will be used by local residents. Thus, the County is interested in having a wide range of options for future land use of its County-owned lands.

At Brookhaven, risk was not the main driver for determining the level of clean-up because future land use was disputed, as were risks from fish consumption and downriver risks to other ecological receptors. The assumptions of the risk scenarios were flawed: (1) no site specific data were available on consumption; (2) possible fish biomass and fish sizes were not incorporated; and (3) total available time the Peconic River flow is sufficient to support catchable fish was not incorporated in the risk assessment. At present, these factors are not incorporated into risk assessments because the EPA methodology assumes continuous flow in rivers, making it possible for fish to be continuously present and to grow to sufficient sizes to accumulate contaminants. The plans of county officials and private industry to stock fish, or to build fish spawning ladders to increase fish production in the Peconic River were not taken into account in the future use scenarios.

The regulatory impediments to using risk-based end states as one of the drivers for determining clean-up levels is an important topic for consideration by a wide range of public planners and stakeholders (DOE, 2000, 2002c). The reality of the 1990s and early 2000s has imposed cost and technological constraints on levels of clean-up (Burger *et al*., 2003), and has engendered the realization that not all land must (or should) be used for residential purposes. This places an additional burden on public policy makers and planners to clearly communicate to the public the reasons for different types of risk assessments and their assumptions.

Policy Implications

The analysis presented in this paper leads to policy recommendations for how consumption advisories are handled by different agencies, and these also have implications for other public issues. It is not a regulatory failing to have several agencies assess and manage risk of different aspects of the same policy issue. Such an arrangement provides a more thorough coverage of the risks that need to be managed, protecting different interests, providing the differences are clarified. New York State is free to address the immediate risks to the public, providing guidance to citizens about how much fish is safe to eat now. The DOE, and federal regulators can then attend mainly to long-term risk reduction to levels that will be safe for humans and ecological receptors, given current and future land uses. Thus, it is suggested that while there should be uniformity in the risk evaluations for fish consumers on the part of the State of New York, EPA, and DOE, there will not be uniformity in the risk evaluations overall because DOE must consider the risks from all contaminants on site, not just the mercury or PCBs in the fish. The agencies each acted according to their own mandates, partly resulting in confusion among different agencies, fishermen and the public about the discrepancies. Had the agencies themselves communicated early on in the process, the differences illustrated by Table 2 would have been clear. The conflict was more apparent than real.

This analysis indicated that the divergence in assessment was not a reflection of inherent uncertainty in the science of risk assessment, in the culture or training of the different risk assessors, or in the types of risk assessors involved, but rather in the scope of the risk assessments (one contaminant vs. many, one route of exposure vs. many), the mandates of the individual agencies, and the transparency of the deliberations. It is thought that the policy implications suggested by this study are: (1) there is a need for broader inclusion of all agencies and other stakeholders during all phases of risk evaluation, assessment and management; (2) the objectives, assumptions and methodologies used in any policies or advisories concerning risk be transparent throughout the process; (3) the uncertainties in risk evaluation be made clear (i.e. are there enough fish in the river to fish all year?), as well as their implications for risk evaluations; and (4) the temporal scales of the risk evaluations should be clarified. The confusion about the relative risk from mercury in fish (and its effect on clean-up) could have been avoided by addressing these issues.

The question of stakeholder involvement early in the process bears further examination. At a minimum, the involvement of state agency and DOE personnel in discussions of the goals of risk assessments for the consumption of fish would have highlighted the differences in their risk assessments at an early stage. This could have

led to earlier resolution of how much clean-up was required to satisfy the state and other stakeholders that the fish are safe to eat now, and in the future. With clearer agreement on the level of clean-up required, DOE could then have devoted its time and resources to determining the best way to accomplish this. A better understanding of the risks from fish consumption would have led to clearer communication with fishermen and the public about the nature of the risks. Communication at an earlier stage would have highlighted the different goals of the agencies: protection of human health in the case of fish advisories, and long-term protection that serves as a basis for remediaiton for DOE.

Some members of the fishing and conservation public were aware that the state did not feel that new fishing advisories were necessary, but were being told by DOE that additional clean-up of the river was required to protect human health. This created an unnecessary dissonance since the two statements were contradictory only if both were based only on the risk from fish consumption, but this was not the case. Involving the public at an early stage in understanding risk assessment for multiple endpoints and multiple contaminants would have reduced the public worry over fishing in the Peconic. Further, involvement of the public early in the process would have allowed them to contribute to the development of reasonable exposure scenarios that addressed their individual concerns. Then these risk assessments would have been directly responsive to the needs of the public.

To some extent this analysis indicates a risk communication problem, within agencies, among agencies, and between agencies and the public. Even within DOE there was confusion about why the state and DOE seemed to disagree on the risk, why the state and county personnel differed on whether there was a risk or not, and why there was confusion between the agency position and the public's understanding. All of these resulted partly from a lack of communication about the goals of each risk assessment, the responsibility of each agency for health and safety of the public, and the assumptions used to address these risks. The actual risk assessments for fish consumption did not, in fact, differ. This case study clearly demonstrates the importance of risk communication, both within and among agencies, as well as with the public at large, and suggests that each agency needs to clearly communicate its goals, mandates, and scope to others when conducting risk assessments or issuing advisories. It should become agency policy to make these aspects known along with information on risk assessments and consumption advisories.

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