Risk Assessment for the Effects of the USEPA Great Lakes Water Quality Guidance on Endangered Freshwater Mussels

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Abstract. In 1995, the U.S. Environmental Protection Agency (EPA) completed an Endangered Species Act consultation with the U.S. Fish and Wildlife Service (FWS) to ensure that the Great Lakes Water Quality Guidance (Guidance) would not jeopardize the continued existence of three federally endangered freshwater mussels in the Great Lakes watershed. The purpose of the Guidance is to establish consistent water quality standards for the watershed among all Great Lakes states through numerical limits on pollutants and through implementation policies. To determine the level of protection of aquatic life criteria for listed freshwater mussels (Family: Unionidae), FWS conducted a risk assessment using data from the limited studies available on toxicity to unionids, and on endangered species safety factors from the EPA Office of Pesticides Programs. The results indicated that the proposed acute criteria for nickel and chronic criteria for copper, zinc, nickel, cadmium, and chromium may not be protective of endangered unionids. To better assess contaminants effects on endangered mussels, EPA will conduct acute and chronic toxicity tests on surrogate mussel species for selected contaminants. This information will be used to determine if site-specific modifications in water quality standards are needed to protect endangered mussels in the Great Lakes watershed, and will be valuable for evaluating other water quality standards affecting freshwater mussels.

Introduction

In 1993, the U.S. Environmental Protection Agency (EPA) introduced the Great Lakes Water Quality Guidance (Guidance) for the purpose of establishing more uniform control of pollutants entering the Great Lakes watershed. Among several provisions, the Guidance specifies numerical limits (water quality criteria) for 32 pollutants to protect aquatic life, human health, and wildlife. The Guidance also contains methodologies for the development of water quality criteria and water quality values to be used for pollutants other than those for which criteria have been derived in the Guidance. In compliance with the Endangered Species Act of 1973, as amended, EPA initiated consultation with the U.S. Fish and Wildlife Service (FWS) to ensure that the continued existence of any threatened and endangered species within the Great Lakes watershed would not likely be jeopardized by the implementation of the Guidance.

Three endangered freshwater mussels—the clubshell (*Pleurobema clava*), northern riffleshell (*Epioblasma torulosa rangiana*), and white catspaw pearly mussel (*Epioblasma obliquata perobliqua*)—were determined to occur within the Great Lakes watershed. The clubshell was once widespread and abundant throughout Ohio River tributaries in Kentucky, Illinois, Indiana, and Ohio, as well as in more isolated systems in Michigan, Pennsylvania, and West Virginia (Dean 1890; Watters 1988; USFWS 1994). This species has declined drastically with a greater than 95% range reduction. Currently about a dozen populations are left, with the only remaining Great Lakes watershed clubshell populations in Fish Creek at the Indiana-Ohio border and in the St. Joseph River near the Michigan-Ohio border. The northern riffleshell also has suffered close to a 95% reduction in a range that was similar to, but smaller than, that of the clubshell. In the Great Lakes watershed, it is known to occur only in Fish Creek and the Detroit River (USFWS 1994). The white catspaw was historically found in the Wabash, Tippecanoe, and White rivers in Indiana and the Maumee River and tributaries in Indiana and Ohio. This species is now known to exist only in a single site in Fish Creek near the Indiana-Ohio border (USFWS 1990).

The declines in all three species have been attributed to a combination of factors. Among these are habitat loss and degradation due to siltation and pollution from stream channelization, gravel dredging, streambank clearing, coal mining, agricultural and urban runoff, sewage, and chemical outfalls

(USFWS 1994, 1990). The northern riffleshell also has been threatened recently by the invasion of the introduced zebra mussel (*Dreissena polymorpha*) (T. Weise, Michigan Department of Natural Resources 1995, pers. comm.).

Although few data are available on the toxicity of contaminants to mussels, it is generally believed that contaminants have been at least partially responsible for decreases in population density, range, and diversity of unionids, including the white catspaw pearly mussel, clubshell, and northern riffleshell (Havlik and Marking 1987; Neves 1993; USFWS 1990, 1994; Williams et al. 1993). Elimination of populations may be due to direct acute and chronic toxic effects that result in mussel mortality, reduced reproductive success, and reduced ability of glochidia to attach to fish host, or to indirect effects from reduction of food sources and host fish availability (Havlik and Marking 1987; Huebner and Pynnonen 1992).

Unlike fish that can leave affected areas, and other mobile organisms that can readily recolonize areas after contaminant impacts have diminished, mussels are sedentary and thus are unable to leave an area affected by contaminants. Adult mussels are able to close their valves for an extended period of time to avoid acute toxic effects (ASTM 1980; Holwerda and Veenhof 1984), but such a mechanism is not effective for chronic toxic effects. Juvenile mussels may also avoid brief acute exposures through valve closure, but due to their small size and limited nutritive reserves they risk the effects of restricted feeding (Jacobson et al. 1993). Glochidia often close in response to contaminant exposure, but they are unlikely to reopen and consequently are unable to attach to fish hosts. Glochidia and juvenile mussels also are believed to be more sensitive to toxicants than adults (Goudreau et al. 1993; Neves 1993). In areas where contaminants or other factors have reduced or extirpated populations, unionids cannot rebound or recolonize quickly because they are sedentary, long-lived, slow-growing, and their reproductive success may be dependent on a threshold density (Downing et al. 1993).

The mussel-contaminant literature is dominated by studies of bioaccumulation of metals, organics, and radionuclides (Bedford et al. 1968; Miller et al. 1966; Fikes and Tubb 1971; Brungs 1967; Adams et al. 1981; Anderson 1977; Garder and Skulberg 1965; Harrison 1969; Nelson 1962). Mussels are known to accumulate contaminants to high concentrations from sediments and water, but very few studies to determine the impact of such body burdens have been published. More recent literature includes a few studies examining toxicity of metals to larval and juvenile mussels (McCann 1993; Huebner and Pynnonen 1992; Jacobson et al. 1993; Keller and Zam 1991; Wade et al. 1989; Schweinforth and Wade 1990). These studies are limited to determination of acute toxicity (24-96 h) of metals to nine unionid species. No studies have been published, nor is any data available, on toxic effects to threatened or endangered unionid species.

Methods

EPA uses its national database to calculate water quality criteria. The closest relatives to unionid mussels in that database are aquatic snails and marine mollusks. Life cycles of these organisms differ considerably from that of unionids, as do their habitat preferences and feeding behavior. Thus, the potential for exposure and sensitivity to contaminants could vary markedly from that of unionid mussels. While using toxicity data from other mollusks is more appropriate than that obtained from fish, FWS believes that using unionid data specifically, where available, would provide a better indication of contaminant sensitivity in endangered unionids.

Given this, we conducted a risk assessment to determine the level of protectiveness of the aquatic life criteria in the Guidance for the three endangered mussel species using the most recent toxicity data available for unionid mussels (McCann 1993; Jacobson 1990; Jacobson et al. 1993; Keller and Zam 1991; Cherry et al. 1991; Schweinforth and Wade 1990; Wade et al. 1989; Wade et al. 1993). These data were collected from tests on glochidia and juveniles of seven unionid mussel species, including two (*Villosa nebulosa* and *Lampsilis fasciola*) that are considered appropriate surrogates for endangered mussels in the region (K.S. Cummings, Illinois Natural History Survey; G.T. Watters, Ohio Biological Survey, pers. comm. 1994). These studies had not been used by EPA in the development of Guidance aquatic life criteria because some of the studies were not available in time for inclusion in the database or had not undergone screening to determine if EPA data requirements for establishing regulatory criteria had been met. For the purposes of endangered species protection, FWS is required to use the "best scientific and commercial data available." We believe that the unionid studies fulfill this qualification because 1) these studies were conducted on more closely related organisms, 2) the studies were conducted on the most sensitive life stages, 3) the data would probably meet most or all of the criteria used by EPA to evaluate acceptability

(Stephan et al. 1985), and 4) we did not detect any inadequacies in the unionid studies that would render a risk assessment invalid.

The Family Acute Mean Value (FAMV) for nickel, cadmium, mercury, chromium VI, and pentachlorophenol (PCP) for the family Unionidae was calculated as the mean of the available toxicity data on each toxicant for all tested species within the family Unionidae (Wade et al. 1989; Jacobson 1990; Schweinforth and Wade 1990; Cherry et al. 1991; Keller and Zam 1991; Jacobson et al. 1993; McMann 1993) (Table 1). The FAMVs for copper and zinc were determined from a regression equation that corrected for water hardness, as in Stephan et al. 1985. The more typical Genus Mean Acute Value or Species Mean Acute Value could not be calculated because few genera are represented by multiple species in these studies, and there are only a few species for which more than one value is available.

The Criterion Maximum Concentration (CMC) is the highest concentration of a material to which aquatic organisms can be exposed for a brief period of time without causing an unacceptable acute effect (acute toxicity). The CMC was calculated by dividing the FAMV by two. Dividing by two results in a concentration that is not acutely toxic to nearly 100% of the individuals, rather than 50% represented by the LC_{50} (Stephan et al. 1985; Urban and Cook 1986).

The Criterion Continuous Concentration (CCC) is the highest concentration of a material to which aquatic organisms can be exposed indefinitely without causing unacceptable effects (chronic toxicity). Three alternatives were used in our analysis to estimate the CCC. To obtain the CCC-1, we divided the FAMV by an Acute-to-Chronic Ratio (ACR) (Stephan et al. 1985), which is a factor that is based on the ratio of acute toxicity of a chemical to its chronic toxicity derived from existing data. This methodology is similar to that used by EPA, except that EPA's Final Acute-to-Chronic Ratio (FACR) for each toxicant was based on mollusks other than unionids. We based our ACR on the only published chronic toxicity test on members of the family Unionidae, which determined the sublethal impact of manganese on the growth of juvenile *Utterbackia imbecillis* (formerly *Anodonta*) mussels over a 90-day period (Schweinforth and Wade 1990). Based on this test, the No Observable Effects Concentration (NOEC) for manganese was 6.0 mg/L Mn, while the 9-day LC_{50} from an earlier test (Wade et al. 1989) was 39 mg/L Mn, producing an ACR of 6.5. Thus, in the following calculations, each CCC-1 was estimated by dividing the corresponding FAMV by the ACR of 6.5.

The second and third methods used in our analysis to estimate the CCC are based on methods recommended by EPA Office of Pesticide Programs (OPP) to determine the risk of pesticide use to aquatic organisms (Urban and Cook 1986). Urban and Cook (1986) explain that a safety factor of 5, as used in risk assessment model for wildlife in the 1975 Regulations for the Enforcement of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), would result in the likely death of 0.1% of the typical population exposed to the pesticide. Because aquatic organisms are generally unable to move out of treated areas or switch to alternative food items, they are assumed to be at a higher risk of exposure than birds or mammals. Therefore, OPP recommended an additional factor of 2 be applied. Thus, a factor of 10 would result in a mortality rate of about 0.01%. The 1975 regulations also state that additional safety factors are needed to ensure protection of endangered species at the individual level. A safety factor of 20 is used in the regulatory risk criteria in the 1975 regulations for endangered species protection. Following this approach, we divided factors of 10 and 20 into the FAMV to obtain estimates of each CCC-2 and each CCC-3, respectively.

A regression equation was used to standardize hardnesses for copper and zinc to 50 mg/L as $CaCO_3$. There were too few data to produce a regression equation of the other metals.

Results

The Guidance acute criteria (Guidance CMCs) are all below the acute values for mussels (mussel CMCs) calculated in our analysis, except for nickel (Table 1). The Guidance CMC for nickel is nearly 14 times higher than the CMC calculated for mussels.

The Guidance CCC for copper is below the mussel CCC-1 (ACR method) and the mussel CCC-2 (safety factor of 10 method). However, the Guidance CCC is higher than the CCC-3, which was calculated with an endangered species safety factor of 20 (Table 1). The Guidance CCC for zinc is below but close to the mussel CCC-1, and higher than the CCCs calculated with safety factors of 10 and 20 (Table 1). For nickel, cadmium, and chromium VI, the Guidance CCCs are either above or very close to the mussel CCCs calculated from each of our three methods (Table 1). The Guidance CCCs for inorganic mercury and pentachlorophenol are well below any of the mussel CCCs calculated from each of our three methods (Table 1).

Table 1. Summary of CMC and CCC values calculated for mussels and a comparison to Guidance values. Shaded cells contain Guidance criteria that are higher than CMC or CCC values calculated for protection of endangered freshwater mussels. Values are in mg/L.

Chemical	# LC_{50} FAMV[a]	Mussel CMC[b]	Mussel CCC-1[c]	Mussel CCC-2[d]	Mussel CCC-3[e]	Mussel CMC	Guidance CCC	Guidance Values
Cu	30[f]	89.53	44.76	14.92	8.95	4.48	7.3	5.2
Zn	15[h]	406.81	203.40	67.80	40.68	20.34	67	60
Ni	1[g]	190	95	29.22	19	9.5	260	29
Cd	5[g]	9	4.5	1.38	0.9	0.45	2.1	1.4
Hg	3[g]	147	73.5	22.62	14.7	7.35	1.7	.91
Cr VI	3[g]	39	19.5	6	3.9	1.95	16	11
PCP	5[i]	610	305	93.85	61	30.5	5.3	3.3

[a]FAMV = Family Acute Mean Value; for Cu and Zn, calculated from a regression equation to correct water hardness to 50 mg/L; for Ni, Cd, Hg, Cr, and PCP, calculated as the mean for all unionid mussel data available for glochidia and juvenile mussels at 20-23°C.
[b]CMC = Criterion Maximum Concentration; calculated by dividing the FAMV by two.
[c]CCC-1 = Criterion Continuous Concentration; calculated by dividing the FAMV by 6.5, which is equal to the single acute-to-chronic ratio available for unionid mussels from Schweinforth and Wade (1990) and Wade et al. (1989).
[d]CCC-2 = Criterion Continuous Concentration; calculated by dividing the FAMV by 10 as in Urban and Cook (1986).
[e]CCC-3 = Criterion Continuous Concentration; calculated by dividing the FAMV by 20 as in Urban and Cook (1986).
[f]Jacobson (1990), McCann (1993), Keller and Zam (1991), Cherry et al. (1991).
[g]Keller and Zam (1991).
[h]McCann (1993), Cherry et al. (1991), and Keller and Zam (1991).
[i]Keller (1993)

Discussion

It is important to note that although all of our data are based on unionid species, we do not know if these test species adequately represent other potentially more sensitive endangered unionids. Much of the data are based on the abundant and widespread unionid species *U. imbecillis*. Because members of the genus *Utterbackia* are very tolerant to environmental perturbances, such as elevated temperature, low dissolved oxygen, siltation, and extended periods of no flow, *U. imbecillis* may be more tolerant to selected contaminants than many other mussel species (Wade et al. 1993). It has been recommended that federal and state regulatory agencies avoid relying heavily on *U. imbecillis* as a surrogate for other mussels, especially threatened and endangered species, when determining the protectiveness of water quality criteria (Neves 1993; Wade et al. 1993). Except for *Lampsilis fasciola* and *Villosa nebulosa*, no known tests have been conducted on unionid species that may be considered appropriate surrogates for assessing toxicity effects for the three Great Lakes watershed endangered mussels. Species that have been suggested as possibly more appropriate, based on phylogenetic relationships and similarities in life histories and reproductive strategies, are *Pleurobema sintoxia* for the clubshell; *Epioblasma triquetra, Villosa sp.*, and *L. fasciola* for northern riffleshell; and *E. triquetra* for white catspaw pearly mussel (K.S. Cummings, Illinois Natural History Survey; G.T. Watters, Ohio Biological Survey, pers. comm. 1994).

The Guidance criteria reflect an improvement over existing guidelines and thus would result in an overall reduction of pollutants entering the Great Lakes system. However, our analyses indicate that, using the specified uncertainty factors, the criteria still may not be fully protective of endangered freshwater mussels. The Guidance aquatic life CCCs are higher than our risk assessment chronic values for copper, zinc, nickel, and chromium, and the Guidance aquatic life CMC is higher than our risk assessment acute value for nickel. This means that the potential exists that discharges of these contaminants would be allowed at chronically toxic concentrations for the three endangered mussels. Discharges of nickel may be allowed at concentrations that would be acutely toxic to these mussels. Adverse effects to those mussels may then result in the form of direct mortality to individuals (particularly the early life stages), reduced reproductive success, and reduced ability of glochidia to attach to fish hosts.

The results of our risk assessment analysis from existing data should not be considered conclusive due to the restricted number of tests conducted, the limited number of species used, and the degree of uncertainty involved in risk assessments. However, these data do provide an indication of possible inadequacies in the Guidance aquatic life criteria for the protection of the endangered freshwater mussels in the Great Lakes watershed, and clearly point to the paucity of data on toxicity to freshwater mussels in general. As a result of the consultation with FWS, EPA has agreed to conduct acute and chronic toxicity tests on the most sensitive life stages of appropriate surrogate species for the Great Lakes watershed endangered mussels. The data from these studies will be used to determine the need for making any site-specific modifications in water quality standards for areas occupied by endangered freshwater mussels in the Great Lakes watershed. These studies should also prove helpful in the development of aquatic life criteria that are more protective of threatened and endangered freshwater mussels in other regions of the country.

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