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Effects of Suspended Sediments on Aquatic Ecosystems

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Abstract.—Resource managers need to predict effects of pollution episodes on aquatic biota, and suspended sediment is an important variable in considerations of freshwater quality. Despite considerable research, there is little agreement on environmental effects of suspended sediment as a function of concentration and duration of exposure. More than 70 papers on the effects of inorganic suspended sediments on freshwater and marine fish and other organisms were reviewed to compile a data base on such effects. Regression analysis indicates that concentration alone is a relatively poor indicator of suspended sediment effects ($r^2 = 0.14$, NS). The product of sediment concentration (mg/L) and duration of exposure (h) is a better indicator of effects ($r^2 = 0.64$, $P < 0.01$). An index of pollution intensity (stress index) is calculated by taking the natural logarithm of the product of concentration and duration. The stress index provides a convenient tool for predicting effects for a pollution episode of known intensity. Aquatic biota respond to both the concentration of suspended sediments and duration of exposure, much as they do for other environmental contaminants. Researchers should, therefore, not only report concentration of suspended sediment but also duration of exposure of aquatic biota to suspended sediments.

The effects of suspended sediments on fish and aquatic life have been studied intensively. The available information on suspended sediment effects has been collated and analyzed in numerous reviews of the literature (Cordone and Kelly 1961; Petticord 1980; Alabaster and Lloyd 1982). However, although these reviews are both detailed and synoptic, they have not established general principles characterizing environmental effects of suspended sediments.

In this paper, we review the available literature in an attempt to identify factors that contribute to effects of suspended sediments on fish and aquatic life. This information should provide researchers with guidance on which data ought to be collected to develop a verified model of the environmental effects of suspended sediment. Experience with environmental toxicants suggests that severity of effects is related not only to concentration of a substance, but also to duration of exposure. In addition, frequency of pollution episodes, ambient water quality, species and life history stage affected, and the presence of disease organisms and other environmental toxicants may all affect the toxicity of a substance. Much of the reported work on effects of inert suspended sediments fails to include information other than concentration and an organism's response. Apparently, many researchers in this field assume that effects are dependent only on concentration, or that the time frame (although not explicitly stated) is implied (e.g., the time required for eggs to develop into fry). We analyzed the information available to determine which model provides better predictive power, the implicit concentration–response model currently in use or a concentration–duration response model similar to those currently used to assess the effects of toxicants.

Data-Base Development

Our search for a relationship between the magnitude of suspended sediment pollution and severity of effect involved collation and analysis of relevant data scattered throughout the literature. Researchers have reported a diverse assortment of effects. For the purpose of this assessment, effects were grouped into one of three categories:

(1) *Lethal effects.*—Lethal effects kill individual fish, cause population reductions, or damage the capacity of the ecosystem to produce fish. This category also includes reductions in population size that are believed to be caused by sublethal or behavioral effects.
(2) *Sublethal effects.*—Sublethal effects injure the tissues or physiology of the organism, but are not severe enough to cause death.
(3) *Behavioral effects.*—Behavioral effects change

TABLE 1.—Ranking of effects of suspended sediments on fish and aquatic life.

Rank	Description of effect
14	>80 to 100% mortality
13	>60 to 80% mortality
12	>40 to 60% mortality, severe habitat degradation
11	>20 to 40% mortality
10	0 to 20% mortality
9	Reduction in growth rates
8	Physiological stress and histological changes
7	Moderate habitat degradation
6	Poor condition of organism
5	Impaired homing
4	Reduction in feeding rates
3	Avoidance response, abandonment of cover
2	Alarm reaction, avoidance reaction
1	Increased coughing rate

activity patterns or alter the kinds of activity usually associated with an organism in an unperturbed environment.

Subsequently, effects were ranked according to severity of the effect on fish and aquatic life, as outlined in Table 1.

Although many articles deal with inert sediments and fisheries, we included in this analysis only those containing information on concentration of sediment in the water, length of time the organism was exposed to that sediment, and the nature of the effect. Many potentially useful articles lacked one or more pieces of essential information and were therefore excluded. In a few instances, missing information was supplied by the author of the original article or from a second published source.

Estimates of concentration and duration, or both, were used in some instances, but only when there were sufficient additional details in the original publication, or elsewhere, to do so with reasonable certainty. Many publications that provided no explicit measure of time of exposure did include a sufficiently detailed account of the context and circumstances of the pollution episode to permit useful estimates of exposure duration. In some instances, when information on the concentration of sediment in the water was not reported, information from authoritative sources other than the original reference was used. Typically, these outside sources provided correlations that permitted the conversion of turbidity measurements into concentrations of suspended sediment. In other instances, authors provided additional information in the form of personal communications. The rationale for each estimate of time and concentration are contained in Newcombe (1986).

Effects on Salmonid Fishes

There is a substantial body of knowledge about effects of suspended sediments on salmonid fishes. Previously published reviews (Cordone and Kelly 1961; Sorensen et al. 1977; Langer 1980; Alabaster and Lloyd 1982) indicate that salmonid fisheries can be affected by inert sediment (1) acting directly on free-living fish, either by killing them or by reducing their growth rate or resistance to disease, or both; (2) interfering with the development of eggs and larvae; (3) modifying natural movements and migrations of fish; (4) reducing the abundance of food organisms available to the fish; and (5) reducing the efficiency of methods used for catching fish. Tables 2–4 summarize the literature pertaining to lethal, sublethal, and behavioral responses of salmonid fishes to suspended sediment.

Effects of Aquatic Invertebrates

Benthic invertebrates in streams can be affected by elevated levels of suspended sediment in several ways. First, many benthic invertebrates are grazers and depend on periphyton for food. Any change in suspended sediment concentration that adversely affects algal growth, biomass, or species composition can adversely affect secondary production. Other invertebrates are filter feeders. Increases in suspended sediment levels tend to clog feeding structures, reduce feeding efficiency, and therefore reduce growth rates or stress or kill these organisms (Hynes 1970). Second, invertebrates that inhabit exposed streambed substrates are subject to scouring, which can damage exposed respiratory organs or make the organism more susceptible to predation through dislodgment (Langer 1980). Table 5 is a compilation of information on effects of suspended sediment on aquatic invertebrates. These data suggest that aquatic invertebrates are at least as sensitive to high levels of suspended sediment as salmonid fishes, and perhaps more so.

Effects on Periphyton

Effects of suspended sediment on algae are likely primarily related to its effect on light penetration. However, high levels of suspended sediment in conjunction with high flow rates can scour algae off streambed substrates and thereby reduce periphyton biomass (Alabaster and Lloyd 1982). In addition, increases in nutrients or toxic compounds, or both, adsorbed on suspended sediments can alter growth rates and biomass of algae.

TABLE 2.—Summary of data (in situ observations) on exposures to suspended sediment that resulted in lethal responses in salmonid fishes. Within species groups, stress indices are arranged in increasing order. For exposure, C = concentration (mg/L) and D = duration (h).

Species[a]	Exposure C	Exposure D	Stress index ($\log_e$·[$C \times D$])	Effect	Rank of effect	Source
				Arctic grayling		
Arctic grayling	25	24	6.397	6% mortality of sac fry	10	Reynolds et al. (1988)
	23	48	7.007	14% mortality of sac fry	10	Reynolds et al. (1988)
	65	24	7.352	15% mortality of sac fry	10	Reynolds et al. (1988)
	22	72	7.368	15% mortality of sac fry	10	Reynolds et al. (1988)
	20	96	7.560	13% mortality of sac fry	10	Reynolds et al. (1988)
	143	48	8.834	26% mortality of sac fry	11	Reynolds et al. (1988)
	185	72	9.497	41% mortality of sac fry	12	Reynolds et al. (1988)
	230	96	10.002	47% mortality of sac fry	12	Reynolds et al. (1988)
	20,000	96	14.468	10% mortality of age-0 fish	10	McLeay et al. (1987)
	100,000	96	16.077	20% mortality of age-0 fish	10	McLeay et al. (1987)
				Salmons		
Chinook salmon	488	96	10.755	50% mortality of smolts (high T°C)	12	Stober et al. (1981)
Coho salmon	509	96	10.797	50% mortality of smolts (high T°C)	12	Stober et al. (1981)
Chinook and sockeye salmon	1,400[b]	36	10.827	10% mortality of juveniles	10	Newcomb and Flagg (1983)
Coho salmon	1,200	96	11.654	50% mortality of juveniles	12	Noggle (1978)
	1,217	96	11.668	50% mortality of presmolts (high T°C)	12	Stober et al. (1981)
Chinook and sockeye salmon	207,000[b]	1	12.240	100% mortality of juveniles	14	Newcomb and Flagg (1983)
	9,400	36	12.732	50% mortality of juveniles	12	Newcomb and Flagg (1983)
Chum salmon	97	3,912[b]	12.847	77% mortality of eggs and alevins	13	Langer (1980)
	111	3,912[b]	12.981	90% mortality of eggs and alevins	14	Langer (1980)
Chinook and sockeye salmon	82,000	6	13.106	60% mortality of juveniles	12	Newcomb and Flagg (1983)
Coho salmon	18,672	96	14.400	50% mortality of presmolts	12	Stober et al. (1981)
Chinook salmon	19,364	96	14.436	50% mortality of smolts	12	Stober et al. (1981)
Chum salmon	28,000	96	14.804	50% mortality of juveniles	12	Smith (1939)
Coho salmon	28,184	96	14.811	50% mortality of smolts	12	Stober et al. (1981)
	29,580	96	14.859	50% mortality of smolts	12	Stober et al. (1981)
	35,000[b]	96	15.027	50% mortality of juveniles	12	Noggle (1978)
Chinook and sockeye salmon	39,400	36	15.145	90% mortality of juveniles	14	Newcomb and Flagg (1983)
Chum salmon	55,000	96	15.479	50% mortality of juveniles	12	Smith (1939)
				Whitefish		
Whitefish	16,613	96[b]	14.282	50% mortality of juveniles	12	Lawrence and Scherer (1974)
				Trouts		
Rainbow trout	200[c]	24	8.476	5% mortality of fry	10	Herbert and Richards (1963)
	7	1,152	8.995	17% reduction in egg-to-fry survival	10	Slaney et al. (1977b)
	21	1,152	10.094	62% reduction in egg-to-fry survival	13	Slaney et al. (1977b)
	200[c]	168	10.422	8% mortality of fry	10	Herbert and Richards (1963)
	90	456	10.622	5% mortality of subadults	10	Herbert and Merkens (1961)

TABLE 2.—Continued.

Species[a]	Exposure C	Exposure D	Stress index ($\log_e$ [C × D])	Effect	Rank of effect	Source
	68	720[b]	10.799	25% reduction in population size	11	Peters (1967)
	37	1,440	10.883	46% reduction in egg-to-fry survival	12	Slaney et al. (1977b)
	47	1,152	10.889	100% mortality of incubating eggs	14	Slaney et al. (1977b)
	57	1,440	11.315	23% reduction in egg-to-fry survival	11	Slaney et al. (1977b)
	270[d]	456	11.721	10–35% mortality of subadults	11	Herbert and Merkens (1961)
	270[e]	456	11.721	80% mortality of subadults	13	Herbert and Merkens (1961)
	101	1,440	11.888	98% mortality of eggs (high metals and NH_3 levels)	14	Turnpenny and Williams (1980)
Brown trout	110	1,440	11.973	98% mortality of eggs	14	Scullion and Edwards (1980)
Rainbow and brown trout	300	720[b]	12.283	97% reduction in population size	14	Peters (1967)
Rainbow trout	1,000–2,500	144	12.437	100% mortality of eggs	14	Campbell (1954)
	157	1,728	12.511	100% mortality of eggs	14	Shaw and Maga (1943)
	810[d]	456	12.820	5–80% mortality of subadults	13	Herbert and Merkens (1961)
	810[c]	456	12.820	80–85% mortality of subadults	14	Herbert and Merkens (1961)
	200[c]	2,352	13.061	50% mortality of fry	12	Herbert and Richards (1963)
	1,000–2,500	480	13.641	57% mortality of fingerlings	12	Campbell (1954)
	4,250	588	14.731	50% mortality (life stage not specified)	12	Herbert and Wakeford (1962)
	160,000	24	15.161	100% mortality (life stage not specified)	14	D. W. Herbert, personal communication in Alabaster and Lloyd (1982)
	49,000	96	15.363	50% mortality of juveniles	12	Lawrence and Scherer (1974)
	1,000–6,000	1,440[b]	15.432	85% reduction in population size	14	Herbert and Merkens (1961)
Brown trout	1,040	8,670	16.024	85% reduction in population size	14	Herbert et al. (1961)
	5,838	8,670	17.750	85% reduction in population size	14	Herbert et al. (1961)

[a] Scientific names: Arctic grayling, *Thymallus arcticus*; chinook salmon, *Oncorhynchus tshawytscha*; coho salmon, *O. kisutch*; sockeye salmon, *O. nerka*; chum salmon, *O. keta*; whitefish, *Coregonus* sp.; rainbow trout, *Oncorhynchus mykiss*; brown trout, *Salmo trutta*.
[b] Estimated.
[c] Wood fiber.
[d] Kaolin.
[e] Diatomaceous earth.

Models of Suspended Sediment Effects

The literature on suspended sediment effects on fish and aquatic life is dominated by the tacit assumption that the implicit concentration–response model applies. This model suggests that if the concentration of suspended sediment is known, then the response of aquatic biota can be predicted. However, for environmental toxicants (copper and ammonia, for example), it is known that responses are dependent not only on concentration but also on duration of exposure. It is our hypothesis that the concentration–duration response model, commonly applied to contaminants, also applies to suspended sediment effects.

To test this hypothesis, the information collated from the scientific literature was ranked by severity of effect and plotted against suspended sediment concentration (Figure 1) and intensity (concentration times duration of exposure; Figure 2). The results indicated that the natural logarithm of the concentration of suspended sediment was

TABLE 3.—Summary of data on exposures to suspended sediment that resulted in sublethal responses in salmonid fishes. Within species groups, stress indices are in increasing order. For exposure, C = concentration (mg/L) and D = duration (h).

Species[a]	Exposure C	Exposure D	Stress index ($\log_e \cdot [C \times D]$)	Effect	Rank of effect	Source
				Arctic grayling		
Arctic grayling	100	1	4.605	Reduction in feeding rate	4	McLeay et al. (1984)
	100	1,008	11.521	6% reduction in growth rate	9	McLeay et al. (1984)
	300	1,008	12.620	Physiological stress	8	McLeay et al. (1987)
	300	1,008	12.620	10% reduction in growth rate	9	McLeay et al. (1987)
	1,000	1,008	13.823	33% reduction in growth rate	9	McLeay et al. (1987)
				Salmons		
Coho salmon	14	1	2.639	Reduction in feeding efficiency	4	Berg and Northcote (1985)
	100	1[b]	4.605	45% reduction in feeding rate	4	Noggle (1978)
	250	1[b]	5.521	90% reduction in feeding rate	4	Noggle (1978)
	300	1[b]	5.704	Feeding ceased	4	Noggle (1978)
	53.5	12	6.465	Physiological stress, changes in behavior	8	Berg (1983)
Chinook salmon	1.5–2.0[c]	1,440	7.832	Gill hyperplasia, poor condition of fry	8	Anderson, U.S. Fish and Wildlife Service, personal communication
	6[c]	1,440	9.064	Reduction in growth rate	9	MacKinlay et al. (1987)
	75	168[b]	9.441	Harm to quality of habitat	7	Slaney et al. (1977a)
	84[d]	336	10.248	Reduction in growth rate	9	Sigler et al. (1984)
	1,547	96	11.908	Histological damage to gills	8	Noggle (1978)
				Trouts		
Cutthroat trout	35	2	4.248	Feeding ceased, cover sought	4	Bachmann (1958)
Rainbow trout	500	9	8.412	Physiological ill effects	8	Redding and Schreck (1980)
	171	96	9.706	Histological damage	8	Goldes (1983)
Steelhead	84[d]	336	10.248	Reduction in growth rate	9	Sigler et al. (1984)
Rainbow trout	50[e]	960[b]	10.779	Reduction in growth rate	9	Herbert and Richards (1963)
	50[f]	960[b]	10.779	Reduction in growth rate	9	Herbert and Richards (1963)
Trout	270	312[b]	11.341	Histological damage to gills	8	Herbert and Merkens (1961)
Rainbow trout	50[c]	1,848	11.434	Reduction in growth rate	9	Sykora et al. (1972)
	5,000–300,000	168	13.641–17.736	Fish survived, but gill epithelium harmed	8	Slanina (1962)
Brook trout	12[c]	5,880	11.164	Reduction in growth rate, reduced condition	9	Sykora et al. (1972)
	100[c]	1,176[b]	11.675	Reduction in growth rate	9	Sykora et al. (1972)
	24[c]	5,280	11.736	Reduction in growth rate	9	Sykora et al. (1972)

[a] Scientific names: cutthroat trout, *Oncorhynchus clarki*; steelhead = anadromous rainbow trout; brook trout, *Salvelinus fontinalis*.
[b] Estimated.
[c] Lime-neutralized iron hydroxide.
[d] Fire clay.
[e] Coal dust.
[f] Wood fiber.

poorly correlated with the ranked response of aquatic biota (r^2 = 0.14, NS). Regression of the natural logarithm of suspended sediment intensity against ranked response was more strongly correlated (r^2 = 0.64, $P < 0.01$). This analysis suggests that suspended sediment effects on aquatic ecosystems can be better predicted with a concentration–duration response model developed from the available information.

Stress Index

Pollution episodes reported in the primary literature span a wide range of suspended sediment concentrations and exposure times. The range of the product of these two variables (concentration and duration of exposure) is even larger, spanning many orders of magnitude. To compress this range and provide numbers of manageable size, the natural logarithm of the product was taken as an index of severity, which we refer to as a stress index.

The considerable variability among data in the literature limits our ability to test the stress index for predicting precise responses of aquatic biota to exposures to suspended sediment. Variables in the data include, but are certainly not limited to, species, life history stage and physiological con-

TABLE 4.—Summary of data on exposures to suspended sediment that resulted in behavioral responses in salmonid fishes. Within species groups, stress indices are in increasing order. For exposure, C = concentration (mg/L) and D = duration (h).

Species	Exposure		Stress index ($\log_e$·[$C \times D$])	Effect	Rank of effect	Source
	C	D				
				Arctic grayling		
Arctic grayling	100[a]	1	2.303	Avoidance response	3	Suchanek et al. (1984a), Suchanek et al. (1984b)
				Salmons		
Coho salmon	54	0.02	0.077	Alarm reaction	2	Berg (1983)
	88	0.02	0.565	Alarm reaction	2	Bisson and Bilby (1982)
	4.3[b]	1	1.447	Avoidance response	3	Updegraff and Sykora (1976)
	88	0.08	1.952	Avoidance response	3	Bisson and Bilby (1982)
	25	4	4.605	Sport fishing declines	4	Phillips (1970)
Salmon	8	24	5.257	Sport fishing declines	4	A. H. Townsend, unpublished, cited in Lloyd (1985)
Chinook salmon	650	1	6.477	Homing performance disrupted	5	Whitman et al. (1982)
Coho salmon	6,000[a]	0	8.700	Avoidance response	3	Noggle (1978)
				Whitefish		
Whitefish	0.7	1	−0.416	Overhead cover abandoned	3	Lawrence and Scherer (1974)
				Trouts		
Rainbow trout	100[a]	1	2.303	Avoidance response	3	Suchanek et al. (1984a), Suchanek et al. (1984b)
	100[c]	0.25	3.219	Coughing rate increased	1	Hughes (1975)
	250[d]	0.25	4.135	Coughing rate increased	1	Hughes (1975)
	66	1	4.190	Avoidance response	3	Lawrence and Scherer (1974)
Trout	8	24[a]	5.257	Sport fishing declines	4	A. H. Townsend, unpublished, cited in Lloyd (1985)
Rainbow trout	665	1[a]	6.500	Overhead cover abandoned	3	Lawrence and Scherer (1974)
Brook trout	4.5	168[a]	6.628	Overhead cover abandoned	3	Gradall and Swenson (1982)

[a] Estimated.
[b] Lime-neutralized iron hydroxide.
[c] Coal dust.
[d] Wood fiber.

dition of the organism affected, water temperature, dissolved oxygen concentration, particle size distribution and chemical composition of the sediment, and presence of other contaminants. Information on the degree to which these variables exacerbate or ameliorate the effects of suspended sediments is incomplete. Therefore, it is not yet possible to formulate generalizations about the nature or magnitude of their effects. Wide diversity and lack of precision in descriptions of organism responses represent another stumbling block in analyzing the available data, necessitating the response ranking used in this analysis. In many cases the effect reported was not necessarily the most serious effect on the organism at a given concentration and duration of exposure. Also, the duration of exposure reported does not necessarily represent the threshold for adverse effects. For example, reduction in the feeding rate of Arctic grayling was reported at 100 mg total suspended sediment/L for 1 h (McLeay et al. 1984). However, the same effect was reported for an 840-h exposure (McLeay et al. 1984). It is likely that the longer exposure would have more severe effects on the organism, but both effects were ranked the same.

Conclusions

Resource managers need information that relates the magnitude of pollution episodes to effects on aquatic ecosystems so the effects of various development schemes (e.g., coal and placer mining proposals) can be evaluated.

The implicit concentration–response model of suspended sediment effects currently in use provides little predictive ability. The dose concentration–duration response model (e.g., dose measured as pollution intensity) proposed in this paper provides better results. The stress index provides a convenient tool for assessing the severity of environmental effects when there is insufficient time or resources to complete a detailed environmental assessment. The predictive ability of this tool will

TABLE 5.—Summary of data on the effects of suspended sediment on aquatic invertebrates.

Taxon	Exposure C	Exposure D	Stress index ($\log_e$ [$C \times D$])	Effect	Rank of effect	Source
Zooplankton	24[a]	0.15	1.281	Reduced capacity to assimilate food	4	McCabe and O'Brien (1983)
Benthic invertebrates	8	2.5	2.996	Lethal: increased rate of drift	10	Rosenberg and Wiens (1978)
Macro invertebrates	53–92	24[a]	7.462	Lethal: reduction in population size	10	Gammon (1970)
Benthic invertebrates	1,700	2	8.132	Lethal: alteration in community structure and drift patterns	10	Fairchild et al. (1987)
Zoobenthos	10–15	720[a]	9.105	Lethal: reduction in standing crop	10	Rosenberg and Snow (1977)
Benthic invertebrates	8	1,440	9.352	Lethal: up to 50% reduction in standing crop	12	Rosenberg and Wiens (1978)
Cladocera	82–392	72[a]	9.745	Lethal: survival and reproduction harmed	12	Robertson (1957); from Alabaster and Lloyd (1982)
Benthic fauna	29	720[a]	9.947	Lethal: populations of Trichoptera, Ephemeroptera, Crustacea, and Mollusca, disappear	14	M.P. Vivier, personal communication in Alabaster and Lloyd (1982)
Benthic invertebrates	16	1,440	10.045	Lethal: reduction in standing crop	12	Slaney et al. (1977b)
Cladocera and Copepoda	300–500	72	10.268	Lethal: gills and gut clogged	14	Stephan (1953) cited in Alabaster and Lloyd (1982)
Benthic invertebrates	32	1,440	10.738	Lethal: reduction in standing crop	12	Slaney et al. (1977b)
Zoobenthos	>100	672[a]	11.115	Lethal: reduction in standing crop	12	Rosenberg and Snow (1977)
Benthic invertebrates	62	2,400	11.910	Lethal: 77% reduction in population size	13	Wagener and LaPerriere (1985)
	77	2,400	12.127	Lethal: 53% reduction in population size	12	Wagener and LaPerriere (1985)
Bottom fauna	261–390	720[a]	12.365	Lethal: reduction in population size	12	Tebo (1955)
Benthic invertebrates	390	720[a]	12.545	Lethal: reduction in population size	12	Tebo (1955)
	278	2,400	13.411	Lethal: 80% reduction in population size	13	Wagener and LaPerriere (1985)
Stream invertebrates	130[b]	8,760	13.945	Lethal: 40% reduction in species diversity	14	Nuttall and Bielby (1973)
Benthic invertebrates	743	2,400	14.394	Lethal: 85% reduction in population size	14	Wagener and LaPerriere (1985)
	5,108	2,400	16.322	Lethal: 94% reduction in population size	14	Wagener and LaPerriere (1985)
Stream invertebrates	25,000[b]	8,760	19.204	Lethal: reduction or elimination of populations	14	Nuttall and Bielby (1973)

[a] Estimated.
[b] China clay.

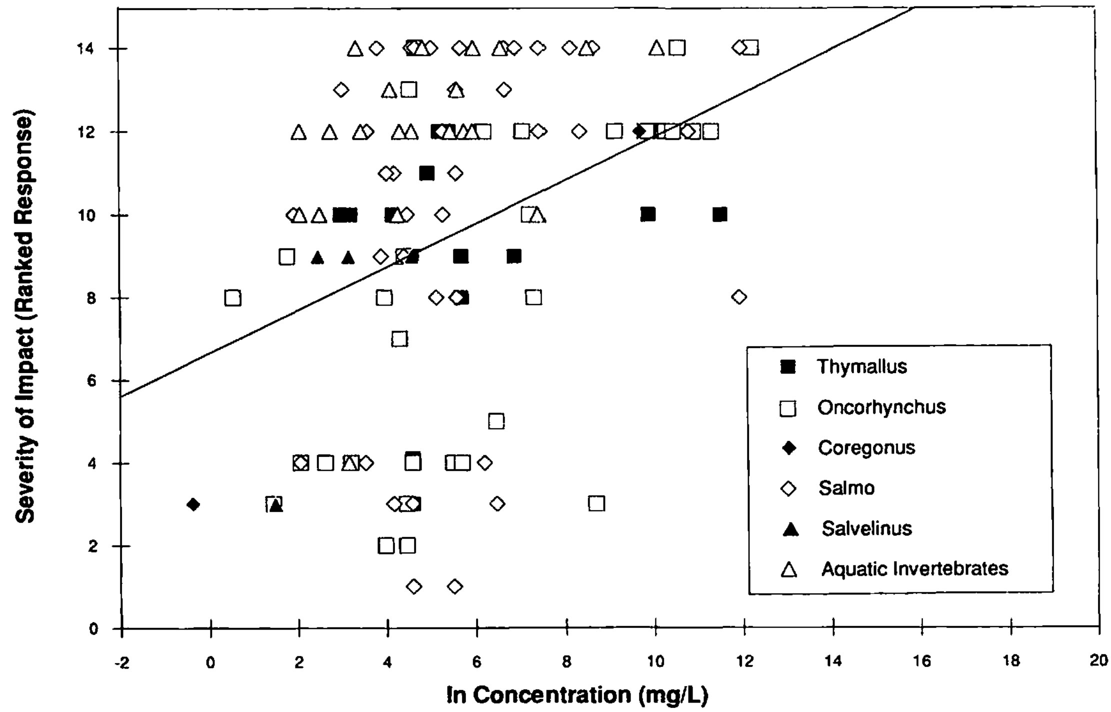

FIGURE 1.—Relationship between $\log_e$ (ln) of suspended sediment concentration and severity of effects on salmonid fishes and aquatic invertebrates. Severity of effect = 0.524 $\log_e$ concentration + 6.738; $r^2 = 0.141$, $N = 120$.

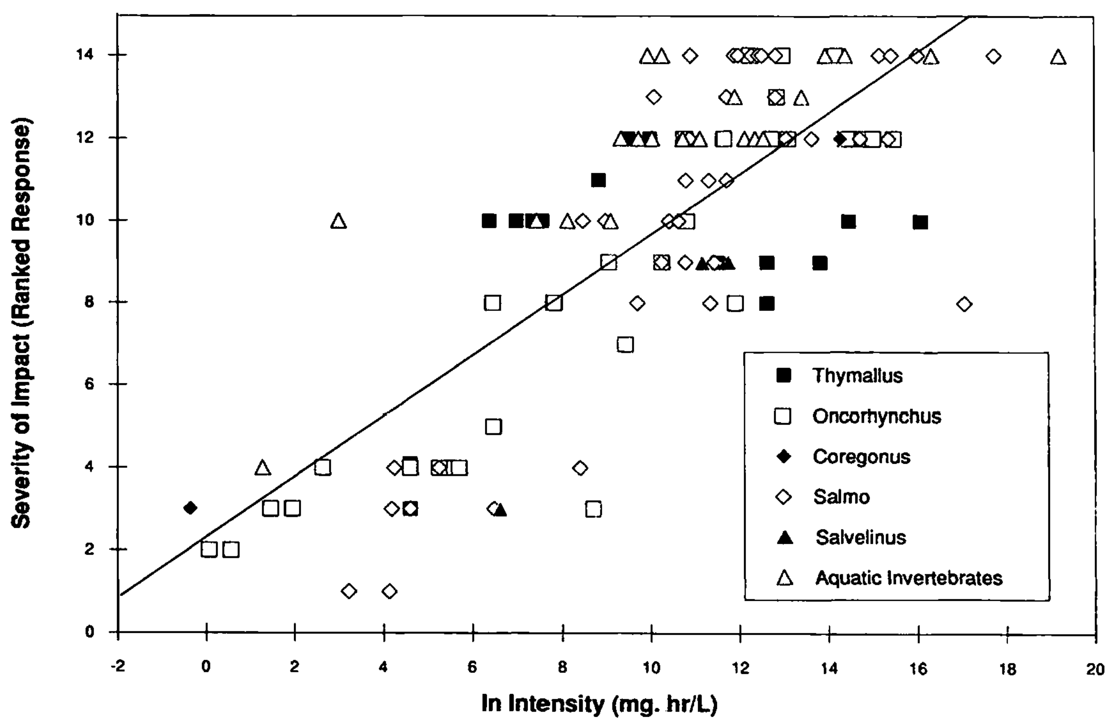

FIGURE 2.—Relationship between $\log_e$ (ln) of suspended sediment intensity and severity of effects on salmonid fishes and aquatic invertebrates. Severity of effect = 0.738 $\log_e$ intensity + 2.179; $r^2 = 0.638$, $N = 120$. Intensity is concentration (mg/L) times duration of exposure (h).

improve as more and better information on effects of suspended sediment on aquatic biota become available.

Future research in this field ought to be reported in terms of concentration of suspended sediment, duration of exposure, and response. In this way our ability to predict the environmental effects of pollution events will be improved. In addition, studies ought to concentrate on dissociating the effects of exposures to suspended sediment from the confounding effects of other variables.

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