EEDP-01-37
March 1996

Environmental Effects of Dredging Technical Notes

Grain Size and Total Organic Carbon Effects on Benthic Organisms

Purpose

The purpose of this technical note is to document the effects of grain size and total organic carbon (TOC) on benthic organisms and evaluate those effects in terms of their potential to confound the results of dredged material bioassays.

Background

Sediment toxicity tests must be able to assess the effects of sediment-associated contaminants without the influence of nontreatment factors (that is, sediment grain size, sediment TOC, ammonia toxicity, etc.). While nontreatment factors can affect survival in short-term acute toxicity tests, there is greater potential for such factors to affect end points measured in longer term chronic tests. Exposure in chronic bioassays generally represents a significant portion of an animal's life history and often encompasses one or more sensitive life-history stages (larval, juvenile, reproductive adults). In addition, end points measured in such tests are of a more subtle, sublethal nature (for example, growth and reproduction) and can be significantly influenced by small variations in exposure conditions (differences in grain size, TOC, etc.).

The influences of grain size and/or TOC on sediment toxicity test end points have gone largely unstudied. It has been generally assumed that the impacts of these factors on survival measured in acute toxicity tests are minimal relative to the effects of contaminants. However, as chronic tests are developed for regulatory testing, there is increasing concern over the potential influence of such factors on sublethal end points.

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size. Similar results were reported by Dobbs and Scholly (1986) for the polychaete *Pectinaria koreni*. Luckenbach, Huggett, and Zobrist (1988) found that the polychaete *Paraprinospia pinnata* selectively foraged on larger particles over the duration of the 4-hr laboratory experiment.

McFarland (1981) examined the effects of grain size on survival of two polychaetes in a 10-day test. Sediment types ranged from 100 percent coarse-textured to 100 percent fine-textured sediment. *Diopatra cuprea* showed extremely high survival in all sediment types. Survival for *N. arenaceodentata* decreased as the silt/clay content increased. In a 28-day test, Dillon, Moore, and Gibson (1993) examined effects of grain size on survival and growth in the polychaete *N. arenaceodentata*. Results of this study indicate that survival was unaffected by grain size (measured as percent sand, silt, clay). However, worm weight decreased as sediment grain size increased, contradicting the earlier findings of McFarland (1981) for *N. arenaceodentata*. This apparent contradiction may be explained by differences in test duration (10 versus 28 days) and age of animals at test initiation (adults versus juveniles).

The combination of grain size and organic carbon content was found by Ott (1986) and DeWitt, Ditsworth, and Swartz (1988) to have an impact on amphipod survival. Ott (1986) found that the mortality of *Rhepoxnius abronius* was higher in sediments with silt-sized particles and low organic content. DeWitt, Ditsworth, and Swartz (1988) found that survival of the same amphipod decreased with decreasing grain size in a 10-day bioassay. DeWitt, Ditsworth, and Swartz (1988) suggested that organic content (percent total volatile solids) and sediment water content may also have played a role in observed mortality. However, these factors were not examined independently in the experiment. McFarland (1981) experimented with the grass shrimp, *Palaemonetes pugio*, and found no grain size effects in a 10-day test with grain size treatments ranging from 100 percent sand to 100 percent mud.

In other laboratory studies, Bachelet and others (1992) and Butman (1987) examined larval settlement of the bivalve *Mercenaria mercenaria* in relation to sediment grain size and TOC. Bachelet and others (1992) found larval settlement to be unrelated to grain size and TOC in 4-hr static tests using biotic and abiotic substrates (for example, a natural organic-rich mud and an abiotic, glass-bead mixture). Butman (1987) found that the organism selected for beads over mud in a static test and mud over beads in a flow-through test.

Clements and Stancyk (1984) found that the brittlestar, *Micropholis gracillima*, had a preference for small grain size sediment regardless of organic carbon coatings (bovine serum albumin and bacteria). In contrast, Moriarity (1982), Roberts and Bryce (1982), and Hammond (1983) found a deposit-feeding holothurian (echinoderm) that selected for sediment based solely on percent organics (carbon, nitrogen) regardless of particle size.

In a habitat selection study, Tanda (1990) found that juveniles of the marbled sole (*Limanda jokohamae*) and the Japanese flounder (*Paralichthys olivaceus*) preferred medium grain size sediment. It was suggested that this selection was based upon the preference for the type of sand in which the animals could bury themselves.

Taghon (1982) found size and organic coating to play a major role in the selection of particles by deposit feeders. Cammen (1982) reported no consistent relationship in nutritional value (organic carbon, bacteria, chlorophyll *a*, and carbon-to-nitrogen ratio of organic matter) as related to particle size. However, this study examined only four sediments.

Pagano and others (1993) examined the effects of grain size on fertilization and embryological development of the sea urchin. In bioassays ranging from 72 to 120 hr, these researchers found no effect of grain size on either fertilization or embryogenesis.

In a 10-day bioassay with three freshwater invertebrates, Ankley and others (1994) found that survival of the amphipod *Hyalella azteca*, survival, reproduction, and growth of the oligochaete *Lumbriculus variegatus*, and survival of the midge *Chironomus tentans* were unaffected by sediment grain size. However, growth in the midge appeared to be influenced by grain size. Dry weights increased with increasing silicon oxide and decreased with aluminum oxide content. Ankley and others (1994) suggest that the midge was responding to the granular properties of the sediment rather than the mineralogy. Sandy sediments tend to have higher silicon oxide concentration. Similarly, other studies have shown that chironomid species perform better in sandy sediments (Dermott 1978, Winnell and Jude 1984, Ankley and others 1993).

Belanger and others (1985) examined substrate preference of adult freshwater bivalves (*Corbicula fluminea*) in a 3-day laboratory study. These results suggest that *C. fluminea* prefers fine grain sand, followed by organically enriched sand, with coarse-grained sand being the least preferred.

Field Studies

A number of field studies have examined the relationship of grain size and TOC to feeding in benthic invertebrates. Gaston (1987) found that the proportion of carnivorous polychaetes was highest in coarser sediments, and the proportion of subsurface deposit-feeders was highest in fine-grain sediment and increased with depth and percent organic carbon. In two feeding studies, Self and Jumars (1978) found an ampharetid polychaete that selectively ingested particles not based on grain size but on specific texture and specific gravity, while two spionid polychaetes (*Psedopolydora kempi japonica* and *Pygospio elegans*) selected sediment particles based on surface texture. The degree of selectivity for specific gravity was based on worm size, and the selection for specific gravity was demonstrated with the spionids in association with the ampharetid. In another feeding study, Luckenbach, Huggett, and Zobrist (1988) found grain size selection to vary with feeding duration in the polychaete *Paraprionospio pinnata*. The longer the animal fed, the larger the grain size sediment found in gut. Petch (1986) found that the polychaete *Lumbrineris latreilli* selectively ingested small grain particles. These particles were used by

L. latreilli for construction of burrows and feeding. Whitlatch and Weinberg (1982) found that *C. gouldii* ingested a greater percentage of larger grain size particles as worm size increased. Food selection of *C. gouldii* was based on natural and experimental (abiotic) sediments. Whitlatch and Weinberg (1982) also hypothesized that this selection may be based on the presence of an organic coating on particles with increasing particle size.

In their review, Butman, Grassle, and Webb (1988) discussed numerous studies showing correlations in the distributions of soft-sediment infaunal invertebrates with grain size. Yates and others (1993) used sediment grain size as a device for predicting invertebrate densities on which shorebird densities could be based. Using regression analysis, they concluded that sediment size distribution (coarse sand, fine sand, silt, or clay), organic carbon, and inundation time could predict invertebrate density directly.

In a field survey, Belanger and others (1985) found the highest densities of the freshwater bivalve *Corbicula fluminea* in fine sand environments, followed by organically enriched fine sand, with the lowest densities found in coarse sand. Belanger and others (1985) also stated that, although the sediment preference of *Corbicula* was fine sand, the organism could use a variety of substrates during habitat selection.

Summary

The laboratory and field studies reviewed in this paper suggest that grain size and TOC affect habitat selection, feeding behavior, and survival. The objective of this review was to document the effects of grain size and TOC on benthic invertebrates, with emphasis on the potential of these factors to affect the outcome of sediment bioassays. Only a few studies to date have examined the effects of such nontreatment factors on sediment toxicity tests (DeWitt, Ditsworth, and Swartz 1988; Kristensen 1988; Dillon, Moore, and Gibson 1993; Ankley and others 1994). Ankley and others (1994) found a relationship between grain size and growth in a midge. Dillon, Moore, and Gibson (1993) found no relationship between grain size and survival in the polychaete worm *N. arenaceodentata*. However, growth decreased with increasing grain size. DeWitt, Ditsworth, and Swartz (1988) suggested that organic carbon content contributed more to mortality of the amphipod *R. abronius* than any other factor.

While there are limited data on the potential effects of grain size or TOC on sediment bioassays, there is a large body of information on field distribution and habitat selection related to grain size and TOC (Field 1971, Gage 1972, Whitlatch 1977, Elftheriou and Basford 1989, Ishikawa 1989, Rakocinski and others 1993). However, Snelgrove and Butman (1994) concluded that even distribution could not be explained solely on the basis of grain size and TOC in different environments. Along with biological factors and experimental evaluations of sediments, animal distribution must be evaluated relative to sediment transport and hydrodynamic processes.

Field studies have many more influencing factors that regulate animal distribution and selection preferences than do laboratory studies. These factors include changes in temperature and salinity, water currents, phototaxis, mobility, interspecific competition, and larval settling preferences (Gray 1974).

No study in this review considered organic carbon alone as a causal factor in affecting benthic invertebrates. However, Snelgrove and Butman (1994) believed organic carbon to be a more important factor than sediment grain size in determining field distributions of benthic invertebrates, because organic matter is a prominent source of food for deposit-feeders.

Even within a single taxon, responses to grain size and TOC are highly variable. Some polychaetes have been shown to select for smaller particles (Dorset 1961; Hylleberg 1975; Cadee 1976; Whitlatch 1980; Jumars, Self, and Nowell 1982), while others have been shown to select for larger particles (Whitlatch 1974, 1980), and still others appear to be nonselective (George 1964, Hughes 1980).

Based on this review, few studies evaluated the effects of grain size and TOC in the absence of hydrodynamic forces. Even fewer studies addressed the potential for these factors to affect the outcome of laboratory sediment toxicity tests.

Conclusions

Based on this literature review, the following conclusions were made.

- Sediment grain size and TOC can affect habitat selection, feeding behavior, and survival, with effects being species-dependent.
- Grain size/TOC effects on habitat selection may actually be a result of hydrodynamic forces in the environment.
- Only three of the 46 studies reviewed examined the potential effects of sediment grain size and TOC on laboratory bioassays.
- Additional laboratory studies are required to determine the potential effects of grain size or TOC in laboratory sediment toxicity tests.

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