CHAPTER 18

Measurement of Toxicity in Reef Sediments

R. Scott Carr[1] and Marion Nipper[2]

The shoreline of the south coast of Moloka‘i is composed of narrow sandy beach deposits and muddy mangrove habitats that border the wide, low-energy reef flat. Such a setting is prone to the deposition of fine-grained particles, and increased siltation has occurred on the reef in historical times as a result of several factors (see Roberts and others, this vol., chap. 15, for a discussion of historical siltation). Terrigenous sediment runoff and deposition on coral reefs is recognized as a hazard to coral health. In addition to the smothering effect, terrigenous runoff can contain contaminants from urban and agricultural activities (fig. 1) that have the potential to affect the health and survival of the coral reef with its associated flora and fauna.

The probable biological effects of sediment-associated contaminants can be determined using porewater toxicity tests, which allow an assessment of the presence of bioavailable contaminants in toxic amounts (Carr, 1998; Carr and Nipper, 1998; Carr and others, 2003; Nipper and Carr, 2001). A sediment quality survey was conducted to assess the presence of bioavailable contaminants in toxic amounts in surficial sediments off the southern coast of Moloka‘i, Hawai‘i. The specific objectives of this study were to measure porewater toxicity by analyzing fertilization and embryological development success using the sea urchin *Arbacia punctulata* in conjunction with measurements of water-quality parameters (salinity, dissolved oxygen, pH, sulfide, temperature, ammonia, and dissolved organic carbon).

Materials and Methods

The toxicity of sediment collected from 10 stations was assessed using porewater tests during 2001, and a more focused study was conducted in 2002. Pore water was extracted on site using a diver-held syringe with an aquarium airstone attached (fig. 2). The syringe was inserted approximately 6–8 cm (2–3 in) below the sediment surface. Toxicity of the sediment pore water was determined using the fertilization and the embryological development tests with the sea urchin *Arbacia punctulata* (Carr and others, 2003). Complete methodology may be found in Carr and Nipper (2001, 2003).

[1] U.S.Geological Survey Marine Ecotoxicology Research Station, Unit 5863, 6300 Ocean Dr., Corpus Christi, TX 78412

[2] Texas A&M University-Corpus Christi, Center for Coastal Studies, Unit 5866, 6300 Ocean Dr., Corpus Christi, TX 78412

Figure 1. Aerial view, looking south, of agricultural activities in south-central Moloka‘i.

Toxicity Test Results

The toxicity test results for the 2001 survey are presented in figure 3. Porewater samples from stations 2, 4, 6, 9, and 10 were significantly toxic in the sea urchin fertilization test at a concentration of 100 percent, and samples from stations 2 and 9 were also toxic at a 50-percent dilution, denoting a higher concentration of bioavailable contaminants. Only the sample from station 9, on the fore reef off Kamiloloa, was significantly toxic even when diluted to 25 percent pore water, indicating a very high concentration of bioavailable contaminants.

The toxicity test results for the more focused 2002 survey are presented in figure 4. Only two samples from this survey were toxic to sea urchin early life stages. The sample from station 1 near Kapuāiwa coconut grove was marginally toxic to sea urchin fertilization at 100 percent pore water, and the sample from station 3 just east of Kaunakakai Wharf was significantly toxic to sea urchin embryological development at a concentration of 100 percent. Water-quality data and dissolved oxygen concentrations for the porewater samples have been reported elsewhere (Carr and Nipper, 2001, 2003) and were well within acceptable ranges.

What the Tests Showed

The primary objective of the initial study in 2001 was to determine if erosion problems in Moloka‘i have led to the deposition of contaminants in toxic amounts in the vicinity of the extensive coral reef system along the south shore. Porewater toxicity test results suggest that station 9 on the fore reef off Kamiloloa had the highest amount of bioavailable contaminants, with toxic effects in the sea urchin fertilization and embryological development tests at 50-percent and 25-percent porewater concentrations, respectively (fig. 3). If the contaminants occurring at station 9 originated from direct runoff from land-based activities, as opposed to an underground spring exiting offshore, the same chemicals would be expected to occur at stations 10 and 1, closer to shore. However, stations 10 and 1 were much less toxic. The higher toxicity at station 9 could be due to higher bioavailability of contaminants as a result of the apparent coarser nature of the sand at that station. Finer sediment was observed at stations 10 and 1. The role of both total and dissolved organic carbon (DOC) in binding organic contaminants (Di Toro and others, 1991; Haitzer and others, 1998) as well as some metals (Mahony

Figure 2. Diver conducting porewater extraction on the sea floor using a syringe with an aquarium airstone attached.

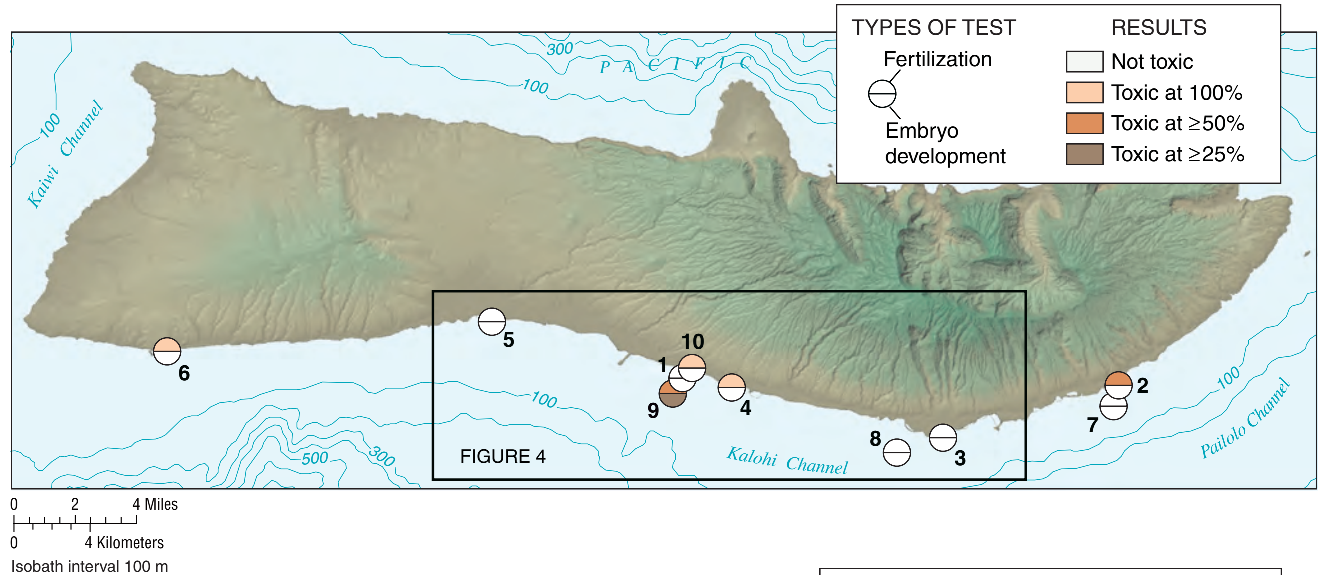

Figure 3. Toxicity test results on sea urchin fertilization and embryo development for sampling sites 1 to 10 on south coast of Moloka‘i in 2001 survey.

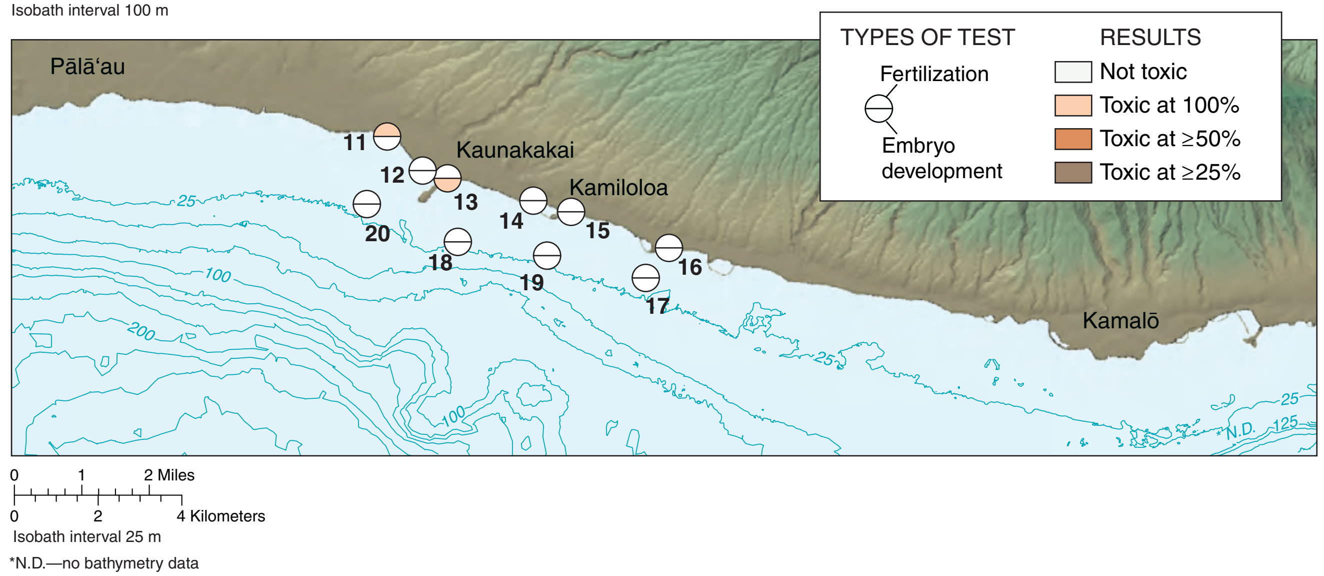

Figure 4. Toxicity test results on sea urchin fertilization and embryo development for sampling sites 11 to 20 on central south coast of Moloka‘i in 2002 survey.

and others, 1996) and reducing their bioavailablity is well recognized (Nipper and others, 2002). For the three stations mentioned above, the porewater DOC concentration was highest at station 1 (not toxic), and lowest at station 9 (highly toxic), with an intermediate value at station 10 (moderately toxic to sea urchin fertilization). This supports the suggestion that organic carbon content may have been at least partially responsible for the toxicity test results. Chemical analyses for the assessment of specific contaminants and their concentrations were not performed in this study.

Nearshore stations 4 (at One Ali‘i Park) and 6 (near Hale O Lono) were moderately toxic to sea urchin fertilization, and station 2 (at Pūko‘o) was also toxic at the 50 percent porewater dilution. The reason for the toxicity to the fertilization test only, and not to sea urchin embryological development, is likely to be related to the type of contaminants present at the sites. For instance, the sea urchin fertilization test is more sensitive than urchin embryos to a variety of metals, including copper, mercury, zinc, and silver (Nacci and others, 1986; Carr and others, 1996). It was not the objective of this initial survey to establish the category of contaminants present in the marine sediment tested.

The primary objective of the followup study in 2002 was to conduct a more focused survey in the region exhibiting toxicity previously and to attempt to identify the contaminants at a site that was highly toxic in 2001. Porewater toxicity test results for samples collected in August 2001 suggested that station 9 (offshore Kamiloloa) had the highest amount of bioavailable contaminants. That sample exhibited toxic effects in the sea urchin fertilization and embryological development tests at 50-percent and 25-percent porewater concentrations, respectively. However, a new porewater sample collected in August 2002 at this station (fig. 4, station 19) did not exhibit any toxic effects in either test. These data suggest that the contaminants that caused toxicity in the previous year were from a transient source and had been dispersed a year later. Dispersion of contaminants from such a coarse sand substrate, where the porewater DOC concentration was among the lowest measured from all the stations sampled on Moloka‘i, is not particularly surprising. Toxicity would only be expected to persist in such an environment if a continuous source of contaminants existed in the area, which apparently is not the case. Nearshore stations 11 and 13 were toxic to urchin fertilization and development, respectively, in 2002 (fig. 4). Station 11 was near a freshwater seep at Kapuāiwa Park, which might have brought land-based or ground-water contaminants to the area. Station 13 was on the eastern side of Kaunakakai Wharf, and the observed toxicity could be the result of runoff of contaminants generated by urban activity.

In conclusion, this study did not demonstrate the consistent presence of bioavailable contaminants in toxic amounts in most areas off southern Moloka‘i. Therefore, it appears that the degraded reefs are not the result of persistent contaminants or chronic contaminant inputs. These results, in conjunction with previous studies, suggest that transient events from ground water or runoff can introduce contaminants at toxic concentrations at some locations, but these inputs do not appear to be continuous.

Suggested citation:

Carr, R. Scott, and Nipper, Marion, 2008, Measurement of toxicity in reef sediments, *Chapter 18 of* Field, M.E., Cochran, S.A., Logan, J.B., and Storlazzi C.D., eds., The coral reef of south Moloka`i, Hawai`i; portrait of a sediment-threatened fringing reef: U.S. Geological Survey Scientific Investigations Report 2007-5101, p. 145-146 [http://pubs.usgs.gov/sir/2007/5101/sir2007-5101_chapter18.pdf].