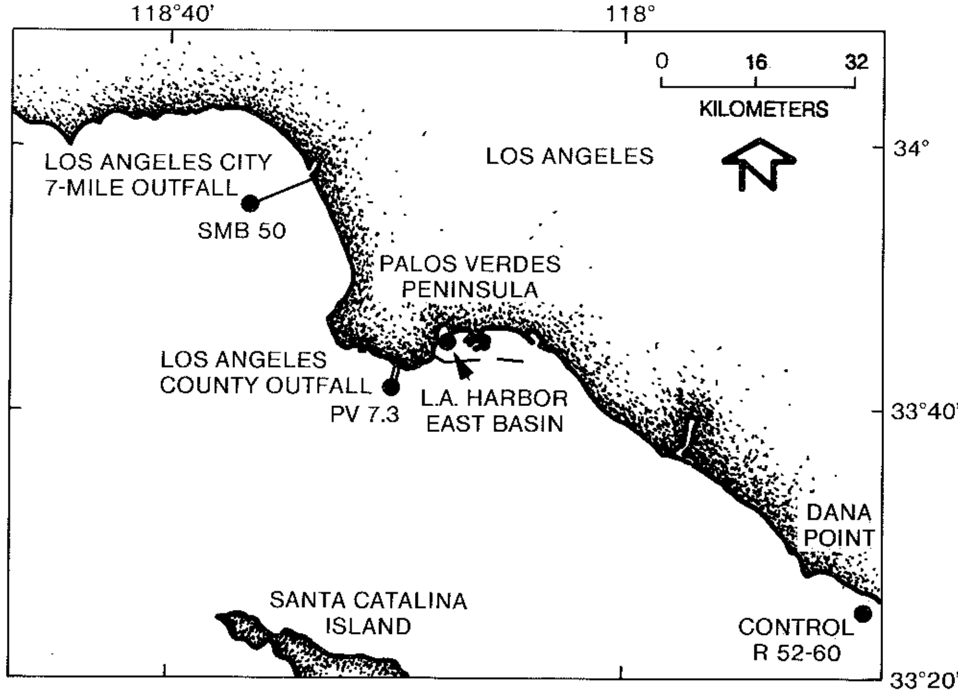

Figure 1. Sediment sampling sites.

Effects of Contaminated Sediments on Three Benthic Invertebrates

This paper summarizes three separate sediment exposure experiments conducted by Bruce E. Thompson, Steven M. Bay, and co-workers in laboratories at SCCWRP and California State University, Long Beach. Three different species of animals were used to test the same four sediment types: (1) SMB 50, sedimented sludge from near the Hyperion 7-mile outfall in Santa Monica Bay; (2) PV7.3, collected near the Palos Verdes outfall; (3) Los Angeles Harbor sediment taken from the East Basin; and (4) sediment collected near Dana Point, used as a control (Figure 1).

The sediment samples were collected with a Van Veen grab from which the top 5 cm was used. In the laboratory, they were homogenized by stirring, then sampled for analysis of sediment composition. Components analyzed were percent sand, percent total organic carbon (TOC), concentration of dissolved sulfides, chlorinated hydrocarbons (DDTs and polychlorinated biphenyls [PCBs]), polynuclear aromatic hydrocarbons (PAHs), and trace metals (Cd, Cr, Cu, Pb, and Zn) (Table 1). Sediment from SMB 50 had the highest levels of total organic carbon, sulfides, Cd, and Cu; PV7.3 had the highest concentrations of DDTs, PCBs, Cr, and Zn; and the harbor sediment contained the most PAHs and Pb. Although the reference sediment contained measurable quantities of most of these contaminants, they were an order of magnitude lower than the contaminants at the other sites and were within the range of reference values for this region (Thompson et al. 1987). The control sample also contained considerably less sand than the other samples.

Amphiodia urtica (brittlestar) is the most abundant infaunal organism in reference areas of the southern California mainland shelf, but it does not inhabit contaminated areas. This exposure was done to evaluate the sensitivity of *A. urtica* to contaminated sediments, to determine its usefulness as a test organism, and to determine an appropriate exposure system and endpoints for *A. urtica* in sediment toxicity testing. For this experiment, 10 individual ophiuroids were placed in each of three replicate aquaria containing each sediment type for 10 days in a static renewal exposure; the temperature was maintained at 15°C.

The mortality of *A. urtica* on each sediment type is shown in Figure 2. The control and harbor sediments had no mortalities. On PV7.3 sediment, only one organism in one tank died. All ophiuroids on the sludge sediment died. Thus, SMB 50 sediment (sludge) is acutely toxic to *A. urtica*.

Sicyonia ingentis (ridge-backed prawn) is one of the most abundant megafaunal species on the outer mainland shelf of southern California. It has been commercially harvested in a small fishery at Santa Barbara. This species was exposed to the four sediment types for 30 days at 12-15°C in a flow-through system in Dr. Donald J. Reish's laboratory at California State University, Long Beach. Ten adult prawns were used in each of three replicates of each sediment type. The parameters measured were mortality, growth rates (final-initial carapace lengths),

Table 1. Characteristics of sediments used in exposures.

Area	TOC (%)	Sand (%)	Dissolved Sulfides (mg/L)	Hydrocarbons (ng/g dry wt.)			Metals (µg/g dry wt.)				
				DDTs[a]	PCBs[b]	PAHs[c]	Cd	Cr	Cu	Pb	Zn
Control (Dana Point)	1.1	5.2	0.6	14	<59	<79	<0.56	32	18	<3.3	67
L.A. Harbor	2.8	38.0	0.3	763	1810	13642	2.2	110	132	194	410
PV7.3	4.3	29.1	23.6	13700	3484	4087	20	500	241	147	655
SMB 50	6.3	37.6	228.6	462	1118	5532	30	357	510	149	614

[a]DDTs include
o,p'-DDE
p,p'-DDE
o,p'-DDD
p,p'-DDD
o,p'-DDT
p,p'-DDT

[b]PCBs include
Aroclor 1242
Aroclor 1254

[c]PAHs include
Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
2,6-Dimethylnaphthalene
Other C2-naphthalenes
2,3,5-Trimethylnaphthalene
Other C3-naphthalenes
Biphenyl
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
C1-phenanthrene/anthracenes
C2-phenanthrene/anthracenes
C3-phenanthrene/antrhacenes
Anthracene
Fluoranthene
Pyrene
2,3-Benzofluorene
Benz[*a*]anthracene
Chrysene/Triphenylene
Benzo[*b*]fluoranthene
Benzo[*k*]fluoranthene
Benzo[*e*]pyrene
Benzo[*a*]pyrene
Perylene
9,10-Diphenylanthracene
Dibenz[*a,h*]anthracene
Benzo[*g,h,i*]perylene

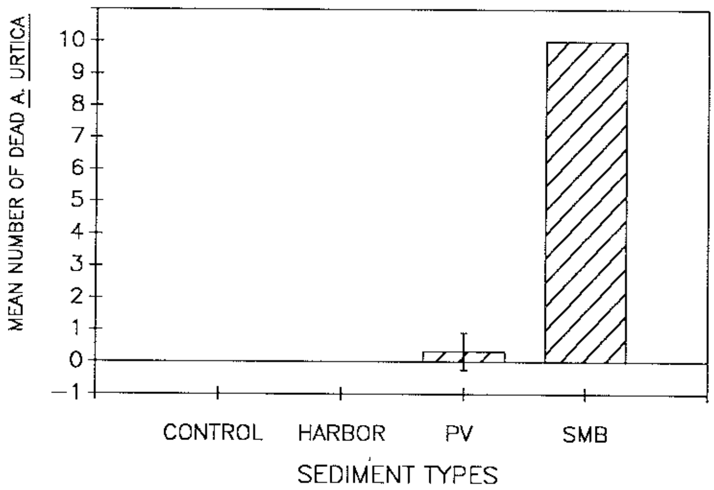

Figure 2. Mean (± standard deviation) mortality of *A. urtica* in each sediment after 10-day exposure. All brittlestars in SMB 50 died in all three replicates.

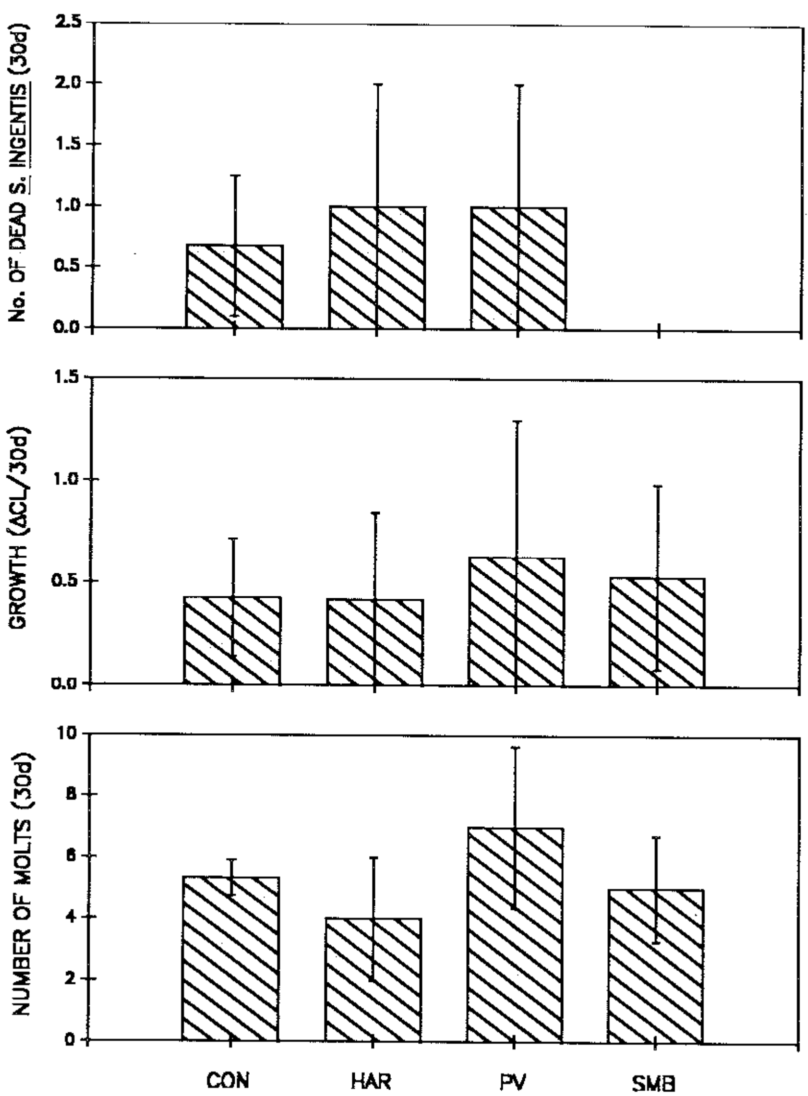

Figure 3. Mean (± standard deviation) mortality, growth, and number of molts for *S. ingentis* (n = three replicates; 10 prawns per replicate).

number of molts (counts of exoskeletons that were shed), and accumulation of contaminants in their hepatopancreas (Figures 3 and 4).

Prawns from PV7.3 sediment accumulated significant quantities of DDTs and PCBs; yet, no significant growth, mortality, or molt differences were found among prawns from any sediment type. The final trace metals concentrations in the hepatopancreas of prawns decreased from the initial concentrations and were similar among prawns from all four sediment types.

Lytechinus pictus (white sea urchin) is also one of the most abundant species on the mainland shelf off southern California. For this experiment, 15 urchins (diameter, 8 to 22 mm) were placed in each of three replicates of the four sediment types. They were exposed for 60 days in a flow-through system. The temperature was maintained at approximately 12°C throughout the exposure period. The parameters measured were mortality, growth rates (final-initial test diameter), gonad production (change in wet weight), and contaminant accumulation in urchin gonads (Figures 5 and 6).

No urchins on the control sediments died. On the harbor and PV7.3 sediments, only 1 and 3 urchins died, respectively, which was not significantly different from the controls. However,

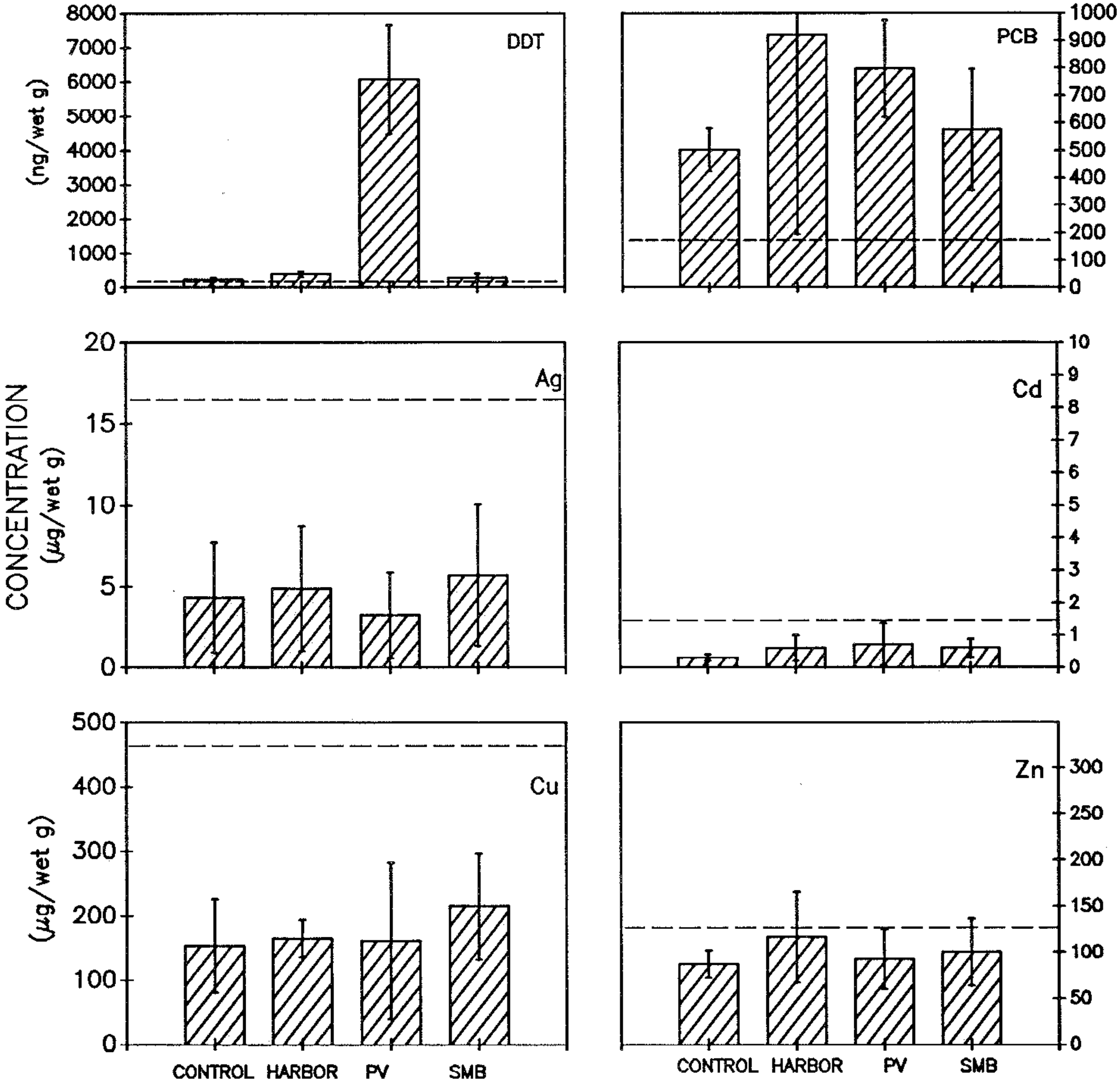

Figure 4. Mean (± standard deviation) contaminant concentrations in *S. ingentis* hepatopancreas after 30-day exposure in each sediment type. Dashed lines indicate initial concentrations.

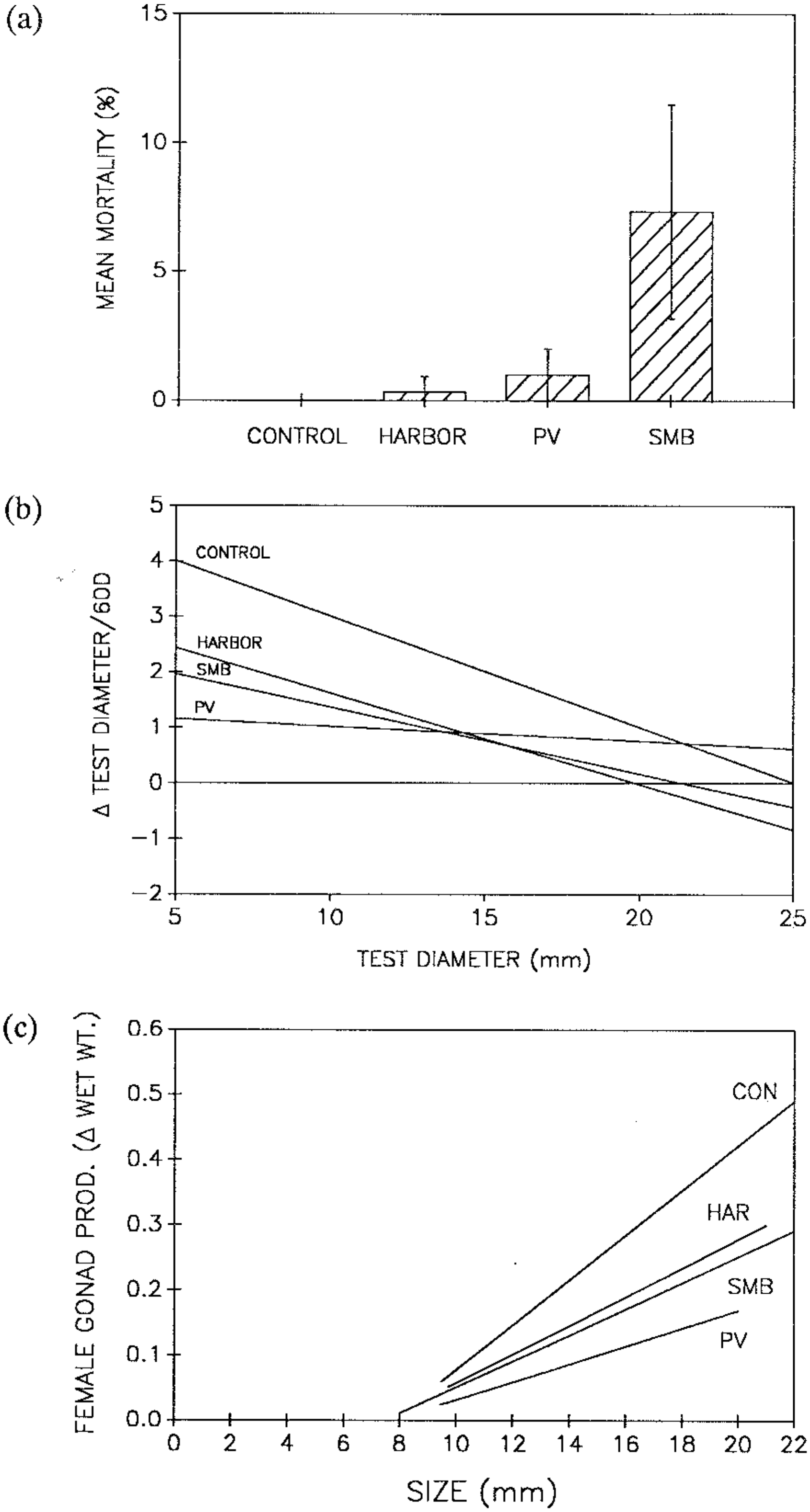

Figure 5. (a) Mean (± standard deviation) of *L. pictus* on each sediment type. (b) Size-growth regressions for *L. pictus* on each sediment type. (c) Size-gonad production regressions for *L. pictus* on each sediment type (n = three replicates; 15 urchins per replicate).

the urchins on the sludge sediment had significantly higher mortality than the control; about 49% of the SMB 50 urchins died. There were white bacterial mats on the surface of the sediment and a strong odor of sulfide.

For *L. pictus*, mortality rates in contaminated sediments were positively correlated with levels of dissolved sulfide, Cd, and Cu in the sediment and with Zn concentrations in the gonads. Hydrogen sulfide is suspected as the cause of the mortalities in the urchins.

Growth occurred in urchins from all sediment types, but the rate was significantly lower in urchins from contaminated sediments (Figure 5). In harbor and SMB 50 sediments, some urchins exhibited negative growth. Growth was inversely correlated with concentrations of PCBs, Cd, and Cr in sediments and DDTs in gonads.

Before exposure to contaminated sediments, urchin gonads accounted for approximately 2.3% of the wet body weight. There was a significant increase in gonad mass for urchins on all sediment types during the exposure because gametogenesis was apparently induced. After the 60-day exposure, gonad weight had increased to 11.3% wet body weight for the controls and 7% (the smallest increase) for the PV7.3 urchins. Female gonad production was significantly lower in SMB 50 and PV7.3 urchins than in the controls and

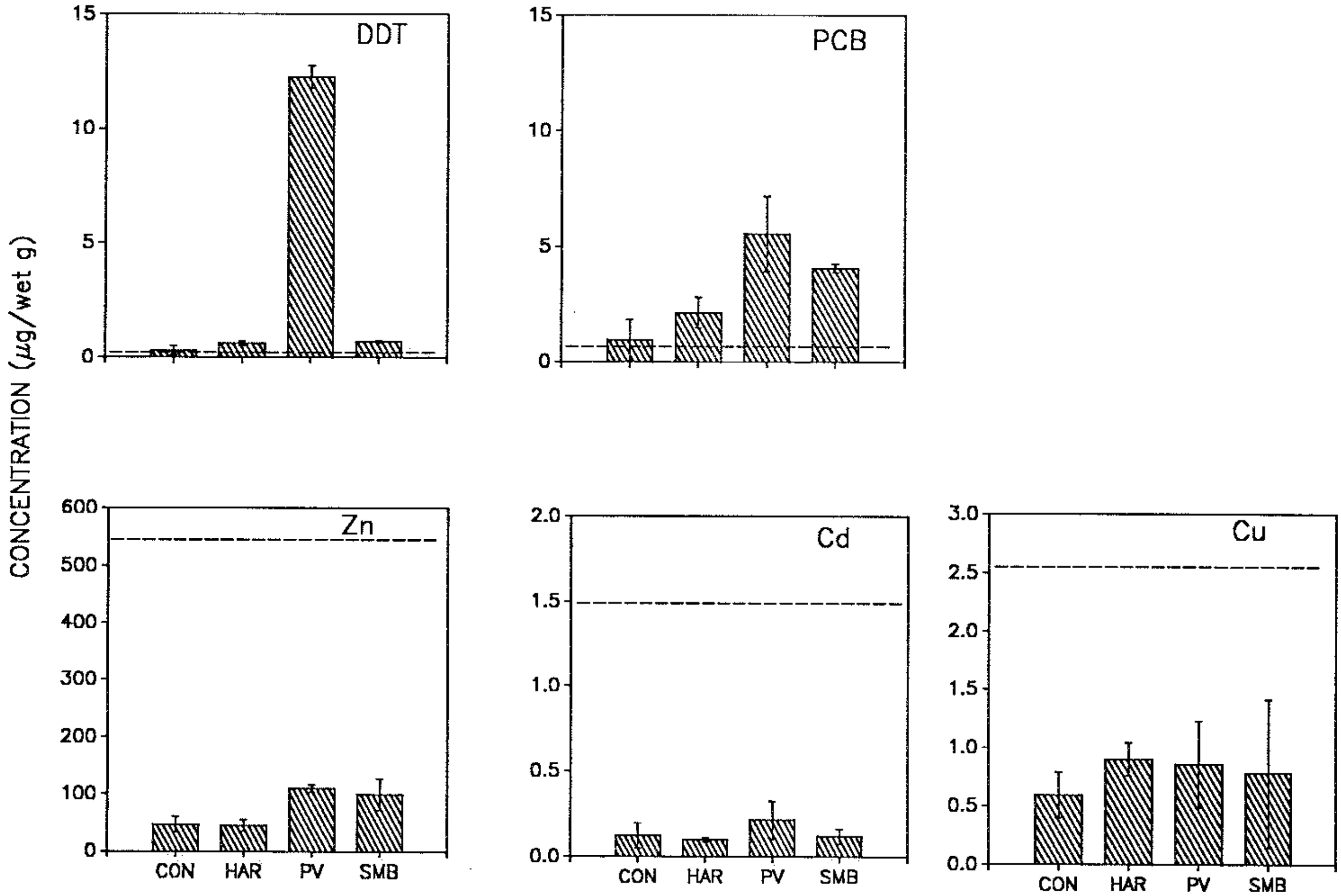

Figure 6. Mean (± standard deviation) contaminant concentration in *L. pictus* on each sediment type (n = three replicates; 15 urchins per composite sample). Dashed lines indicate initial concentrations.

was inversely correlated with sediment content of chlorinated hydrocarbons and trace metals.

The gonads of PV7.3 and SMB 50 urchins accumulated significant quantities of DDTs and PCBs; harbor urchins had a large increase in PCBs, but it was not significantly different from the control levels. As with *S. ingentis*, urchins from all four sediment types had a large decrease in Cd, Cu, and Zn concentrations.

Each of the three species exposed to contaminated sediments gave slightly different

Table 2. Summary of responses to contaminated sediments. A + indicates that a significant response was measured, - indicates that no significant response was measured, and NM indicates that the response was not measured.

Organism	Mortality	Growth	Gonad Production	Bioaccumulation
A. urtica	+	NM	NM	NM
S. ingentis	-	-	NM	+
L. pictus	+	+	+	+

responses (Table 2). Acute mortality occurred on SMB 50 sludge in *A. urtica* and *L. pictus*, but not *S. ingentis*. No significant chronic effects (growth or molt interruption) were observed in *S. ingentis*, but growth and gonad production were affected in *L. pictus*. Interestingly, accumulation of chlorinated hydrocarbons was observed in both *S. ingentis* and *L. pictus*, but in *S. ingentis* there were no measured effects. This demonstrates that measurement of bioaccumulation does not necessarily imply adverse effects. These results also show that both acute and chronic endpoints should be considered in evaluation of sediment toxicity.

The decrease in trace metals concentrations in both urchin gonads and prawn hepatopancreas is hard to explain. Since the decrease occurred in organisms from all four sediment types, including the control, it may simply reflect the dilution of trace metals in a growing tissue mass. It could indicate that the form of metals (in solution or on very fine particles) producing uptake in the field was not present in the exposure system.

In these exposures, it was not possible to ascribe causes of mortality, or impaired growth and gonad production to any one component in sediment. Effects may be due to any of the contaminants present, some unmeasured contaminant, or the additive nature of many contaminants. In addition, different contaminants may have different mechanisms of toxicity.

Exposures to separate contamination treatments (i.e., hydrogen sulfide only) are planned for this year. Size-specific mortality, growth, and reproduction rates are important terms in most population growth equations. Changes in any of these components probably translate into effects on populations. These exposure experiments are important to help achieve the goal of relating laboratory results to effects on populations in discharge-receiving areas.

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Reference

Thompson, B. E., J. D. Laughlin, and D. T. Tsukada. 1987. 1985 Reference Site Survey, C-221. Southern California Coastal Water Research Project, Long Beach, CA.