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Effects of Pentachlorophenol on Field- and Laboratory-Developed Estuarine Benthic Communities*

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A study of the response of benthic communities exposed to pentachlorophenol (PCP) was conducted to obtain additional information on the effects of this widely used chemical on the estuarine environment and to compare its effect on estuarine benthic communities developed in the field and in the laboratory. PCP is used as a wood preservative, an insecticide, a fungicide and a bactericide, and is toxic to many aquatic organisms (RAO 1978). In earlier laboratory experiments (TAGATZ et al. 1977, 1978), developing benthic communities, from planktonic larvae settling in sand-filled aquaria, were continuously exposed to PCP. In the present study, already established communities were exposed to PCP.

MATERIALS AND METHODS

Prior to PCP exposure, benthic communities were established in 16 laboratory aquaria (by planktonic larvae in continuously supplied seawater) and in 16 field aquaria in Santa Rosa Sound, Florida (by naturally occurring animals) during 8 weeks (March 10 to May 5, 1980). Aquaria, 32 cm X 32 cm X 6 cm deep, were constructed of acrylic plastic, and filled with sand from the site selected for locating the field aquaria. Sand was air-dried and sifted (to remove shell fragments) before use; 92% of the particles ranged between 0.18 and 0.60 mm. Aquaria were numbered for identification and grouped by fours (in the form of squares); four groups were used in the field and four in the laboratory.

Field aquaria were placed by SCUBA divers in 4 meters of water, at the approximate depth and about 100 meters from the pump-intake that supplied unfiltered seawater to the laboratory aquaria. The aquaria were positioned in the substratum so that their surfaces were level with the surrounding sand, and covered with 1/4-inch (6.4 mm) hardware cloth to keep out large predators, such as crabs.

Each group of four laboratory aquaria was placed in an open plastic box, deeper than the aquaria to allow a 3-cm layer of water over the sand. Seawater with its constituent plankton was delivered continuously at 2 L/min to the center of each box; water flowed from the box through notched side openings. Illumination consisted of alternating 12-hr periods of light and darkness.

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After 8 weeks of community development, field aquaria were collected, brought into the laboratory, and placed in boxes (field boxes) identical with and adjacent to boxes that contained laboratory aquaria (laboratory boxes). All field aquaria retained their sand, but accumulated fragmented layers of dead sea-grass (Thalassia testudinum). Each field box contained an aquarium randomly selected from each field group of four aquaria; laboratory aquaria were rearranged so that each laboratory box contained an aquarium randomly selected from each group of four laboratory aquaria.

The eight boxes (32 aquaria) provided four replicates for a control and four replicates for each of three PCP exposures (1.5, 15 and 150 µg/L, nominal concentrations) for both field- and laboratory-developed communities. Three of four field boxes and three of four laboratory boxes were exposed for 7 days to PCP. Desired dilutions of stock (5.7 g technical grade PCP and 1.2 g KOH per liter of distilled water) were metered by pump and mixed with the seawater entering the center of each box. Aquaria used as controls received water free of PCP. Samples of water were taken from each box after 1, 3, and 7 days for determination of PCP concentrations by gas chromatography (TAGATZ et al. 1977). Salinity of the water pumped into the laboratory from Santa Rosa Sound during the 9-week study averaged 18 ^{o}/oo (7 to 32 ^{o}/oo); temperature, 18 ^{o}C (14 to 23 ^{o}C).

After a 1-week exposure to PCP, animals were collected by sieving the contents of the aquaria, with a 1-mm-mesh sieve, and later identified. Results are presented as pooled data from each PCP concentration and the control. One-way analysis of variance (SAS 1979) and Duncan's post hoc analysis (WINER 1971) were used to compare numbers of animals in control and contaminated aquaria (α = 0.05). Field and laboratory results were compared by two-way analysis of variance. The interaction term of the two-way model was tested, using the error mean square to determine significant effects (α = 0.05) between concentrations and location (field, laboratory).

RESULTS AND DISCUSSION

The averages and ranges of PCP concentrations measured in water from field-developed communities exposed in the laboratory to the pesticide were non-detectable (<0.2 µg/L, control), 0.9 µg/L (0.7 to 1.1), 13 µg/L (11 to 15), and 141 µg/L (74 to 190); in water from laboratory-developed communities, non-detectable (control), 1.1 µg/L (0.8 to 1.3), 13 µg/L (11 to 14), and 140 µg/L (72 to 197).

Harvest of field communities yielded 346 animals representing 32 species of 6 phyla (Table 1); that of laboratory communities, 800 animals representing 24 species of 5 phyla (Table 2). In decreasing order of numerical abundance, dominant phyla in the field communities were Annelida, Mollusca, and Arthropoda; in the laboratory communities, Mollusca, Chordata, Annelida, and Arthropoda. Animals in each of the other phyla represented less than two percent

of the total number of animals collected. Of an overall total of 43 species, only 13 (30 percent) appeared in both field and laboratory communities. However, the most abundant annelid and mollusk were the same for both situations. Two-way analysis of variance indicated some differences in effect of PCP concentration between field and laboratory communities. Differences in effect of concentration on numbers of individuals and species of the three abundant phyla that occurred in both field and laboratory aquaria (annelids, arthropods, and mollusks) were apparent only among the mollusks.

TABLE 1
Animals in field-developed benthic communities collected from control aquaria and from aquaria exposd to PCP for 7 days. Replicates were pooled.

Taxon	PCP, µg/L				Total Animals
	Control	0.9	13	141	
ANNELIDA					
Cistenides gouldii	7	4	17	18	46
Capitella capitata	12	13	10	10	45
Neanthes succinea	12	8	13	7	40
Mediomastus californiensis	0	2	5	6	13
Capitellides jonesi	1	1	0	1	3
Haploscoloplos fragilis	0	2	1	0	3
Haploscoloplos robustus	1	0	1	0	2
Laeonereis culveri	0	0	0	2	2
Macroclymene elongata	0	1	0	0	1
Nereis pelagica	0	0	1	0	1
Orbinia ornata	0	0	0	1	1
Spiophanes bombyx	0	0	0	1	1
Total annelids	33	31	48	46	158
MOLLUSCA					
Ensis minor	20	15	22	1	58
Mitrella lunata	4	5	2	0	11
Diastoma varium	3	2	4	0	9
Mangelia stellata	3	1	3	0	7
Acteocina canaliculata	4	0	1	0	5
Anomalocardia auberiana	1	1	3	0	5
Crepidula maculosa	1	2	1	0	4
Mulinia lateralis	0	1	2	0	3
Laevicardium mortoni	0	1	1	0	2
Anadara transversa	0	0	1	0	1
Total mollusks	36	28	40	1	105
ARTHROPODA					
Neopanope texana	18	10	2	4	34
Gammarus mucronatus	6	5	3	0	14

TABLE 1
(Continued)

Taxon	Control	PCT, µg/L 0.9	13	141	Total Animals
Grandidierella bonnieroides	4	6	1	1	12
Melita nitida	2	5	3	0	10
Cymadusa compta	2	1	0	0	3
Alpheus heterochaelis	1	0	0	0	1
Edotea montosa	0	0	1	0	1
Total arthropods	33	27	10	5	75
RHYNCHOCOELA					
Tetrastemma sp.	1	1	2	1	5
CHORDATA					
Gobiosoma bosci	2	0	0	0	2
COELENTERATA					
Actiniidae	0	0	1	0	1
TOTAL ALL PHYLA					
Individuals	105	87	101	53	346
Species	20	21	24	12	32

TABLE 2

Animals in laboratory-developed benthic communities collected from control aquaria and from aquaria exposed to PCP for 7 days. Replicates were pooled.

Taxon	Control	PCP, µg/L 1.1	13	140	Total Animals
MOLLUSCA					
Ensis minor	113	104	146	4	367
Mulinia lateralis	70	56	58	21	205
Diastoma varium	2	3	1	0	6
Anomalocardia auberiana	1	0	0	0	1
Laevicardium mortoni	0	0	1	0	1
Mitrella lunata	1	0	0	0	1
Total mollusks	187	163	206	25	581
CHORDATA					
Molgula manhattensis	24	34	39	7	104

TABLE 2
(Continued)

Taxon	Control	PCP, µg/L 1.1	13	140	Total Animals
ANNELIDA					
Cistenides gouldii	6	14	9	2	31
Polydora ligni	6	3	3	0	12
Polydora websteri	5	2	5	0	12
Neanthes succinea	1	0	1	0	2
Capitellides jonesi	0	1	0	0	1
Glycera americana	1	0	0	0	1
Hypsicomus elegans	0	0	1	0	1
Mediomastus californiensis	0	1	0	0	1
Nereis pelagica	0	1	0	0	1
Polydora socialis	0	0	1	0	1
Polyodontes lupina	0	0	1	0	1
Total annelids	19	22	21	2	64
ARTHROPODA					
Corophium acherusicum	18	9	7	0	34
Oxyurostylis smithi	4	2	1	0	7
Callinectes sapidus	1	2	1	1	5
Cymadusa compta	0	0	0	1	1
Total arthropods	23	13	9	2	47
COELENTERATA					
Actiniidae	1	0	1	1	3
Edwardsia sp.	0	0	1	0	1
Total coelenterates	1	0	2	1	4
TOTAL ALL PHYLA					
Individuals	254	232	277	37	800
Species	15	13	17	7	24

Community structure was significantly altered ($\alpha = 0.05$) by 141 µg PCP/L (field) and 140 µg/L (laboratory). Average number of species per aquarium was less in aquaria that received the highest concentration of PCP than in control aquaria; number of individuals was significantly less only in the laboratory-developed communities (Table 3).

Effects of PCP on annelids were species dependent. Numbers of polychaetes exposed to the highest concentration of PCP significantly decreased in laboratory communities, whose numbers were dominated by spionid species, but not in field communities, where only one spionid occurred. Species of Spionidae, in earlier studies on developing benthic communities, were particularly sensitive to 161 µg PCP/L (TAGATZ et al. 1978).

Mollusks exposed to the highest concentration of PCP were significantly affected in communities developed in the field (primarily Enis minor) and laboratory (primarily E. minor and Mulinia lateralis)

TABLE 3

Average density of animals and number of species (in parentheses) per aquarium, collected from control aquaria and aquaria exposed to PCP for 7 days. Only the more abundant phyla are listed.

Phylum and Category	Field control / Lab. control	PCP µg/L 0.9 / 1.1	13 / 13	141 / 140
FIELD				
Annelida	8.2 (3.5)	7.7 (2.7)	12.0 (3.7)	11.5 (3.7)
Mollusca	9.0 (3.5)	7.0 (3.5)	10.0 (4.7)	0.2* (0.2*)
Arthropoda	8.2 (3.7)	6.7 (2.2)	2.5 (1.5)	1.2 (0.7)
All phyla	26.2 (11.2)	21.7 (8.7)	25.2 (10.7)	13.2 (5.0*)
LABORATORY				
Annelida	4.7 (3.0)	5.5 (3.0)	5.2 (2.7)	0.5* (0.2*)
Mollusca	46.7 (3.0)	40.7 (2.5)	51.5 (2.5)	6.2* (2.0)
Arthropoda	5.7 (1.5)	3.2 (1.7)	2.2 (1.2)	0.5 (0.5)
Chordata	6.0 (1.0)	8.5 (1.0)	9.7 (1.0)	1.7 (0.7)
All phyla	63.5 (8.7)	58.0 (8.2)	69.2 (8.0)	9.2* (3.7*)

*Significantly less than control at 5% level.

Ninety-six percent of E. minor (10 to 26 mm long) from field aquaria and 97 percent of those (7 to 28 mm) from laboratory aquaria were dead when collected at the end of the test (Table 4). An advantage of exposing an already established community to a toxicant is that

TABLE 4

Number and length (mm) of dead Ensis minor from field- and laboratory-developed communities exposed for one week to PCP.

	PCP, µg/L							
	Field				Laboratory			
Category	0	0.9	13	141	0	1.1	13	140
No. dead	0	1	3	26	3	7	5	119
% dead	0	6	12	96	3	6	5	97
Avg. size	-	15	18	16	16	15	17	14
Range	-	-	15-20	10-26	11-18	11-21	13-21	7-28

resultant deaths in some taxa, such as mollusks, can readily be enumerated to document toxicant effect. Earlier stages of mollusks may be more sensitive, since TAGATZ et al. (1978) found a significant reduction in numbers of E . minor and M. lateralis in benthic communities exposed during early development to as little as 15.8 µg PCP/L.

Abundance of arthropods (primarily amphipods) and chordates (all the tunicate, Molgula manhattensis) in communities treated with PCP did not significantly differ from that in control communities. However, number of amphipods decreased somewhat in the highest concentration, and in earlier studies, decreased significantly when exposed to a higher concentration, 161 µg PCP/L (TAGATZ et al. 1978).

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