AROCLOR® 1254: EFFECT ON COMPOSITION OF DEVELOPING ESTUARINE ANIMAL COMMUNITIES IN THE LABORATORY*

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ABSTRACT

Aroclor® 1254, a polychlorinated biphenyl, affected the composition of communities of estuarine animals that developed from planktonic larvae in salt water that flowed through 10 control aquaria and 10 aquaria contaminated with 0.1, 1 or 10 µg/ℓ of this PCB. Communities that developed in control aquaria and aquaria that received 0.1 µg/ℓ of PCB in water for four months were dominated (>75%) by arthropods, primarily the amphipod Corophium volutator. In aquaria receiving 1 and 10 µg/ℓ, the number of arthropods decreased and the number of chordates, primarily the tunicate Molgula manhattensis, increased; over 75% of the animals in 10 µg/ℓ aquaria were tunicates. Numbers of phyla, species, and individuals (particularly amphipods, bryozoans, crabs, and mollusks) were decreased in this PCB, but there was no apparent effect on the abundance of annelids, brachipods, coelenterates, echinoderms or nemerteans. The Shannon-Weaver index of species diversity was not altered by Aroclor 1254.

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INTRODUCTION

Polychlorinated biphenyls (PCBs) have been manufactured for various uses (Broadhurst, 1972) for over 40 years, but their occurrence in aquatic ecosystems was not confirmed until 1966 (Anonymous, 1966). Since then, PCBs have been detected in estuarine organisms from 5 of 15 of the coastal United States (P. A. Butler, 1973). One PCB, Aroclor 1254, was discovered in the water, sediment and biota of Escambia Bay, Florida (Duke et al., 1970).

Chronic and acute toxicity experiments conducted at the Gulf Breeze Laboratory have established that Aroclor 1254 is toxic to some estuarine organisms. A concentration of 100 µg/ℓ of Aroclor was acutely toxic (48 to 96 hours) to pink shrimp, Penaeus duorarum, and oysters, Crassostrea virginica, but not to pinfish, Lagodon rhomboides (Duke et al., 1970). Chronic toxicity was up to 100 times greater than acute toxicity. In exposures lasting more than two weeks, 1 µg/ℓ of Aroclor 1254 killed pink shrimp (Nimmo et al., 1971a), whereas 5 µg/ℓ killed pinfish and spot, Leiostomus xanthurus (Hansen et al., 1971) and significantly reduced oyster growth rate (Parrish et al., 1972), but it was not lethal to blue crabs, Callinectes sapidus (Duke et al., 1970). Aroclor 1254 is, therefore, toxic to certain estuarine species exposed separately. However, its effect on communities of estuarine animals is not known. This study reports experiments that determined the effect of this chemical on development of estuarine animal communities in the laboratory.

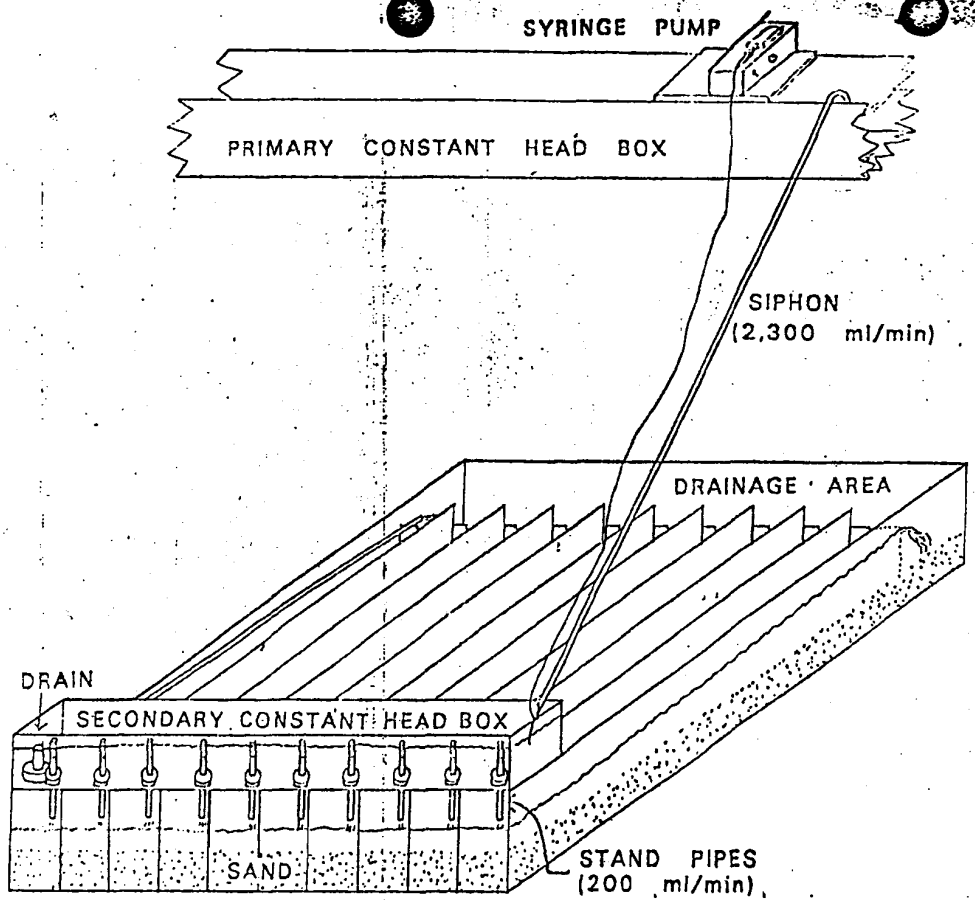
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MATERIALS AND METHODS

I investigated the effect of Aroclor 1254 on development of estuarine communities by comparing the number, species, and diversity of animals that grew from planktonic larvae in apparatuses continuously contaminated with 0.1, 1 or 10 $\mu g/\ell$ of PCB for four months, 18 May to 25 September 1970, with animals from an identical apparatus that was not contaminated.

The apparatus used in this investigation is illustrated in Fig. 1 (only one of four identical apparatuses is shown). Sea water with its natural component of plankton was pumped from the estuary adjacent to the laboratory into the primary constant head box. Salinity of the water ranged from 10 to 34 °/oo (average, 29.7 °/oo) and temperature ranged from 22 to 33 C (average, 28.5 C). In contaminated apparatuses Aroclor 1254 was added to water after it was siphoned, at the rate of 2,300 ml/min, from the primary into the secondary constant head box; the control apparatus received the same flow of water. Water then flowed from the secondary constant head box to each of 10 adjacent aquaria-10 replicates for each treatment. (Treatment includes control and contaminated apparatuses). Flow rate through each aquarium was maintained at 200 ml/min each by adjusting the height of a 2.7 mm diameter hole in each of the 10 standpipes in the secondary constant head box. Each aquarium was 44 cm long, 9 cm wide and 14 cm high. Water depth in each aquarium was maintained at 8 cm. PCB-free sand was placed in each aquarium to a depth of 6 cm.

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SYRINGE PUMP
PRIMARY CONSTANT HEAD BOX
SIPHON
(2,300 ml/min)
DRAINAGE AREA
DRAIN
SECONDARY CONSTANT HEAD BOX
SAND
STAND PIPES
(200 ml/min)

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Figure 1 -- Apparatus used to test the effect of Aroclor 1254 on composition of estuarine animal communities.

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Planktonic larvae colonized this sand and the walls of the aquaria. The siphon and constant head boxes were cleaned weekly so that all aquaria received planktonic larvae from a common source-the incoming water. Water leaving each aquarium flowed through a V-shaped opening and into a common drain for the apparatus.

Aroclor 1254, dissolved in polyethylene glycol 200, was metered by a syringe pump into the water as it entered the secondary constant head box of each experimental apparatus. The same amount of polyethylene glycol (2 ml/day, 0.68 mg/ℓ) was metered into the control apparatus. Solvent-induced effect was not expected because: (1) polyethylene glycol 200 did not affect development of two species of crabs at this concentration (Epifanio, 1971) (2) concentrations up to 1% ($v/_v$) were not lethal to grass shrimp, Palaemonates pugio, or sheepshead minnows, Cyprinodon variegatus, in 96 hours in static tests (Hansen, unpublished data) and (3) the toxicity of 5 ug/ℓ of Aroclor 1254 to brown shrimp, Penaeus aztecus, and pinfish was not increased by increasing the concentration of solvent up to 100 times (0.1 to 10.0 mg/ℓ) (Hansen, unpublished data).

Concentrations of Aroclor in test water and sediment were determined by gas chromatography. Methods of analysis for water are described by Nimmo et al. (1971a) and for sediment by Nimmo et al. (1971b), except that an OV-101 column was used. Recovery rates were above 70%, but data in this report do not include a correction factor for recovery. Water from the secondary constant head box of each

apparatus was analyzed twice a month (Table 1). Concentrations throughout this box were uniform; water from each standpipe, analyzed once during the 10 μg/ℓ exposure, averaged 7.9 μg/ℓ (range 6.8 – 8.7). Sediment cores from 4 of 10 aquaria from each apparatus were analyzed at the end of the exposure (Table 1).

At the end of the four-month exposure, animals were scraped from the sides of the aquaria and the contents of the aquaria siphoned into a 1 mm mesh sieve. During the last three months of the experiment, animals that left or were lost from the aquaria or were cleaned from the secondary constant head box and the drainage area were also collected in a 1 mm mesh sieve. Animals retained by the sieve were placed in fingerbowls of seawater relaxed with $MgCl_2$, preserved in 50% isopropanol and identified.

To determine effect of Aroclor 1254 in each treatment, an index of species diversity as well as the number and percent occurence of various species in each treatment (contaminated and control aquaria) were compared. A species diversity index provides a numerical means of assessing community structure that is independent of sample size, expresses the relative importance of each species and is dimensionless. Modifications of the Shannon-Weaver (1963) formula, $H' = -\sum_{i=1}^{s} p_i \log p_i$, where p_i is the proportion of the i^{th} species in the collection and s = the number of species, have been used in freshwater (Wilhm and Dorris, 1968) and saltwater (Bechtel and Copeland, 1970) to assess effects of pollution on natural communities. In unpolluted

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areas, many species of animals are abundant and diversity is high, but pollution can decrease diversity by making a few species very abundant and all others rare. In this study, the Shannon-Weaver formula ($\log_2$) was used to determine the usefulness of the species diversity index in assessing the effect of Aroclor 1254 on community structure in laboratory experiments.

Pooled data from each Aroclor concentration and control were compared statistically using the χ^2 test for independent samples. Data from each of the 10 aquaria receiving one treatment were compared with data from 10 aquaria receiving a different treatment using the Mann-Whitney "U" test (Siegal, 1956). Differences were considered real at $\alpha = 0.01$.

RESULTS

A large number and variety of animals were found in all aquaria (Tables 2 & 3). Of the 67 species from nine phyla, 27 were mollusks (15 pelecypods and 12 gastropods), 23 annelids, 6 arthropods, 3 chordates, 2 coelenterates, 2 echinoderms, 2 nemerteans, 1 brachiopod and 1 bryozoan. Arthropods were most abundant (3,842) of the 5,897 animals followed by chordates (1,302), annelids (448), mollusks (219) and animals from other phyla (86). The two most abundant animals were the amphipod, Corophium volutator (3,770), and the tunicate, Molgula manhattensis, (1,164).

Species composition and abundance of individual species varied

among the 40 aquaria. The number of species in each aquarium ranged from 5 to 23 (average 13). Annelids and mollusks were present in all aquaria. Animals from other phyla were present in from 1 to 36 aquaria (Table 3). Seventeen species were found in all treatments and 26 were in only one.

Aroclor 1254 prevented animals of certain phyla from colonizing (Table 3). Although nine phyla were found, the number of phyla represented in any aquarium ranged from three to seven. The number of phyla in the control, 0.1 and 1 $\mu g/\ell$ aquaria averaged 5.7, 5.4 and 5.7, respectively. Fewer phyla, average 4.1, were in aquaria contaminated with 10 $\mu g/\ell$ of Aroclor because fewer aquaria contained arthropods, and none contained bryozoans.

The total number of species found in each apparatus ranged from 25 to 52 but the percentage of species in each phylum was similar in all four treatments (Table 4). In each apparatus, more species of mollusks were found than species from any other phylum. The relative numbers of molluscan species were similar for all treatments (40 - 44 percent). The number of annelid species was only slightly less (29 - 35 percent). Although fewer arthropods and chordates were found, the relative numbers of each were similar in all treatments.

The number of species in each aquarium of an apparatus was altered by Aroclor 1254 (Tables 2 & 5). The total number of species and the number of species from each phylum in the ten

control, 0.1 and 1 µg/ℓ contaminated aquaria were similar. However, there were significantly fewer species and the species composition differed in the ten aquaria contaminated by 10 µg/ℓ of the PCB. The greatest shifts in species composition were found in arthropods, bryozoans, and mollusks. Although there were significant reductions in the number of molluscan species in the 10 µg/ℓ aquaria, there was no difference in the gastropod - pelecypod ratio.

The total number of animals in each aquarium did not differ significantly among the four treatments; whereas the number and percentage occurrence of species was markedly different (Tables 2 & 6). Arthropods (primarily the tube-dwelling amphipod, Corophium volutator) were the dominant animals in the control (76 percent) and 0.1 µg/ℓ PCB (84 percent) aquaria. In these aquaria, chordates (primarily Molgula manhattensis) were secondarily abundant. Arthropods were also abundant (55 percent) in aquaria that received 1 µg/ℓ but a significant decrease in their abundance and an increase in abundance (31 percent) of chordates occurred. Dominance was different in aquaria contaminated by 10 µg/ℓ; 80 percent of the animals were chordates. This difference from communities dominated by arthropods in control aquaria and in aquaria contaminated by 0.1 µg/ℓ of Aroclor 1254 to communities dominated by chordates in aquaria receiving the highest concentration of this PCB was the most striking PCB-

induced effect in this experiment.

The abundance of animals of other phyla, although less striking, was also altered by PCB. There were more mollusks in the control aquaria than in treated aquaria, but the percentage of their occurrence was not different in the PCB environments. Colonies of the encrusting bryozoan, Membranipora tenuis, were not counted, and therefore their numbers are not adequately represented in Table 6. However, their exclusion from the ten aquaria contaminated with 10 µg/ℓ was significant. Abundance of polychaetes was not altered by any of the three concentrations of PCB.

The Shannon-Weaver (1963) index of species diversity calculated for each aquarium did not differ among the control and three contaminated apparatuses (Table 7). Species diversity is a function of two components, richness (numbers of species (Table 5) and equitability or relative number of each species (Table 7) (Lloyd and Ghelardi, 1964). In my study, species diversity is not correlated ($r = 0.094$) with richness of species, but is correlated ($r = 0.882$) with relative abundance of each species: $J' =$ calculated diversity ÷ maximum diversity (Pielou, 1966). (Maximum diversity is defined as species diversity where all species are equally abundant.) Equitability did not differ between treatments because communities in this study were usually dominated by one species and were not rich in species. Therefore, the effect of Aroclor was not on species diversity but on species composition.

Conclusions based on abundance and diversity of animals collected at the end of the four-month exposure were corroborated by the abundance and diversity of animals that migrated from and were washed from each apparatus during the exposure (Table 8). The total number of animals and species from aquaria with 10 µg/ℓ was markedly lower than those from the other aquaria. Arthropods were abundant in collections from the effluents of control aquaria and aquaria with 0.1 and 1 µg/ℓ but rare from the aquaria with 10 µg/ℓ. The effect of Aroclor on crabs collected from the aquaria could not be assessed at the end of the exposure because only two were found in all aquaria. However, presence of exoskeltons in seven of 10 control, six of 10 0.1 µg/ℓ and eight of 10 1µg/ℓ aquaria and absence of exoskeltons in the 10 µg/ℓ aquaria strongly suggests that crabs were sensitive to highest concentration of Aroclor 1254. This sensitivity was substantiated by collections of crabs from the effluents of the aquaria. Eurypanopeus sp., Neopanope sp., Pinnixa sp., and portunids were abundant in effluents of control, 0.1 and 1 µg/ℓ aquaria but absent from the effluent of the 10 µg/ℓ aquaria. The bryozoan, M. tenuis, was absent in the effluent from the 10 µg/ℓ aquaria, but present in the effluent from the other aquaria. Mollusks were most abundant in effluent from the 10 control aquaria.

DISCUSSION AND CONCLUSIONS

The polychlorinated biphenyl, Aroclor 1254, influenced the composition of animal communities that developed from planktonic larvae in sea water which entered the test aquaria. The primary influence was that the dominant species in the control aquaria was the amphipod, C. volutator, and the dominant species in aquaria receiving 10 µg/ℓ PCB was the tunicate, M. manhattensis. Also, there were fewer species and the number of animals was markedly but not significantly fewer in the 10 µg/ℓ aquaria. The abundance of arthropods, chordates, bryozoans and mollusks differed significantly but abundance of annelids, brachiopods, coelenterates, echinoderms or nemerteans apparently did not differ.

Differences in community structure that were apparent at the lowest concentration (0.1 µg/ℓ) became more pronounced as the concentration of Aroclor 1254 increased to 10 µg/ℓ. Control aquaria were dominated by arthropods (76 percent), with lesser numbers of animals from eight other phyla. Aquaria contaminated by 0.1, 1 or 10 µg/ℓ contained fewer mollusks than did control aquaria; however, the percentage occurrence of mollusks was not altered by the PCB. Aquaria receiving 1 µg/ℓ or 10 µg/ℓ had more tunicates and fewer arthropods than did control aquaria. Aquaria receiving 10 µg/ℓ were dominated by tunicates (80 percent) with lesser numbers of five other phyla; only 1% of the animals were arthropods. Animals most reduced in numbers at the highest PCB concentration included

the amphipod, C. volutator; the xanthid crabs, Eurypanopeus depressus and Neopanope texana; the bryozoan, M. tenuis; the gastropod, Bittium varium; and the pelecypods, Abra aequalis and Tellina alternata.

Few of these changes could have been predicted from information from current literature, because only one species in this study had been challenged previously with PCB and only a few are phylogenetically related to previously challenged species. Arthropods, particularly amphipods and crabs, were sensitive to Aroclor 1254 in this experiment and in the experiments by Nimmo et al. (1971a) in which pink shrimp were killed by 1 µg/ℓ. Juvenile blue crabs appeared resistant to 5 µg/ℓ (Duke et al., 1970). In my experiment, the numbers of xanthid crabs was reduced by 10 µg/ℓ indicating that larval stages may be particularly sensitive to PCBs. Sensivity of crab larvae has been shown with the insecticides dieldrin (Epifanio, 1971) and mirex (Bookhout et. al., 1972). Aroclor 1254 was lethal to two estuarine fishes at 5 µg/ℓ (Hansen et. al., 1971) but in this study lower chordates (tunicates) seemed unaffected and were most abundant in the PCB-stressed communities. Lethal effects of PCBs on mollusks are not known. However, growth of oysters was reduced significantly without mortality by 5 µg/ℓ of Aroclor 1254 (Parrish et al., 1972). In my experiment fewer mollusks occurred in all exposure concentrations possibly because the larval stages are sensitive or because

of factors other than the presence of Aroclor. Studies on protozoans (Cooley, Keltner, and Forester, 1972) provided the only other data I am aware of on the sensitivity of estuarine animals of other phyla to PCBs.

The Shannon-Weaver species diversity index has been used as an indicator of the effects of some types of pollution on animal communities in estuaries, but in this experiment, the index was not decreased even though composition of the communities were greatly altered. This species diversity index did not decrease as the concentration of PCB increased because the index was proportional to the relative number of each species present in the aquaria, and communities that developed at each treatment concentration were dominated by one species of animal. If Aroclor 1254 affected the composition of established communities in an estuary as it did the developing communities in this experiment, this species diversity index could not be used to estimate effects of this pollutant in the environment.

One purpose of this experiment was to determine whether the effect of a toxicant on developing estuarine animal communities can be investigated in the laboratory. Preliminary experiments at this laboratory indicated that the structure of communities of organisms setting in aquaria was altered by presence of the insecticide Dursban® (J. I. Lowe, personal communication[2]). My analysis of his data indicated that replicate aquaria were necessary to separate the effects of a toxicant from the effects

of an efficient predator or from the effects of an animal with great reproductive capacity. The use of ten replicate aquaria for each treatment in my experiment readily separated the effect of Aroclor 1254 from other factors that might influence community structure. My experiment also showed that small aquaria can be used, provided that larger animals can emigrate before they drastically affect community structure and thus mask effects of the toxicant. Emigrating animals must be caught and enumerated so the effects on them can be assessed.

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[2] Mr. Jack I. Lowe, Environmental Protection Agency, Gulf Breeze Fla. 32561

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LITERATURE CITED

Anonymous. 1966. Report of a new chemical hazard. New Sci. 32, 612.

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contrib. Mar. Sci. 15: 103-133.

Bookhout, C. G., A. J. Wilson, Jr., T. W. Duke and J. I. Lowe. 1972. Effects of Mirex on the larval development of two crabs. Water, Air, and Soil Pollut. 1: 165-180.

Broadhurst, M. G. 1972. Use and replaceability of PCBs. Environ. Health Perspectives. 2: 81-102.

Butler, P. A. 1973. Organochlorine residues in estuarine mollusks -- 1965-1972. Pestic. Monit. J. 6(4).

Cooley, N. R., J. M. Keltner, Jr. and J. Forester. 1972. Mirex and Aroclor® 1254: Effect on and accumulation by Tetrahymena pyriformis strain W. J. Protozool. 19: 636-638.

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Duke, T. W., J. I. Lowe and A. J. Wilson, Jr. 1970. A polychlorinated biphenyl (Aroclor 1254®) in the water, sediment and biota of Escambia Bay, Florida. Bull. Environ. Contam. Toxicol. 5, 171-180.

Epifanio, C. E. 1971. Effects of dieldrin in seawater on the development of two species of crab larvae, Leptodius floridanus and Panopeus herbstii. Mar. Biol. (Berlin) 11(4): 356-362.

Hansen, D. J., P. R. Parrish, J. I. Lowe, A. J. Wilson, Jr. and P. D. Wilson. 1971. Chronic toxicity, uptake and retention of Aroclor® 1254 in two estuarine fishes. Bull. Environ. Contam. Toxicol. 6, 113-119 (1971).

Lloyd, M. and R. J. Ghelardi. 1964. A table for calculating the equitability component of species diversity. J. Anim. Ecol. 33: 217-225.

Nimmo, D. R., R. R. Blackman, A. J. Wilson, Jr. and J. Forester. 1971a. Toxicity and distribution of Aroclor® 1254 in the pink shrimp Penaeus duorarum. Mar. Biol. (Berlin) 11(3): 191-197.

Nimmo, D. R., P. D. Wilson, R. R. Blackman and A. J. Wilson, Jr. 1971b. Polychlorinated biphenyl absorbed from sediments by fiddler crabs and pink shrimp. Nature, London 231: 50-52.

Parrish, P. R., J. I. Lowe, A. J. Wilson, Jr. and J. M. Patrick, Jr. 1972. Effects of Aroclor® 1254, a PCB, on oysters, Crassostrea

virginica (Bivalvia: Protobranchia: Ostreidae). ASB Bull. 19(2): 90.

Pielou, E. C. 1966. The measure of diversity in different types of biological collections. J. Theor. Biol. 13: 131-144.

Shannon, C. E. and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana.

Siegal, S. 1956. Non parametric statiestics for the behavioral sciences. 312 p. McGraw-Hill Book Co., Inc. New York.

Wilhm, J. L. and T. D. Dorris. 1968. Biological parameters for water quality criteria. BioScience 18(6): 477-481.

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Table 1. Range and average concentration of Aroclor® 1254 in water and sediment from experimental and control apparatuses. Water was analyzed twice monthly and sediment was analyzed at the end of the four month experiment. Limit of quantification was 0.1 µg/l in water and 0.015 mg/kg (dry weight) in sediment. Correction for recovery (>70%) is not included.

Concentration in water, µg/l			Concentration in sediment, µg/g	
Nominal	Measured		Measured	
	Average	Range	Average	Range
Control	None		None	
0.1	<0.1	<0.1 - 0.1	0.1	0.05 - 0.18
1.0	0.6	0.48 - 0.72	0.36	0.25 - 0.42
10.0	6.7	5.2 - 7.8	2.0	1.5 - 2.5

Table 2. Animals collected from control aquaria and from aquaria contaminated for four months with Aroclor® 1254. Ten aquaria were used for each treatment. Number of animals and number of aquaria from which they were collected are listed.

TAXON	Control		Aroclor 1254						Total Animals
			0.1 µg/l		1 µg/l		10 µg/l		
	Animals	Aquaria	Animals	Aquaria	Animals	Aquaria	Animals	Aquaria	
Annelida									
Armandia agilis	8	5	11	4	3	2	0	0	22
Capitella capitata	34	10	30	6	34	9	23	8	121
Cirratulus sp.	1	1	0	0	1	1	0	0	2
Dasybranchus sp.	0	0	0	0	1	1	0	0	1
Eupomatus dianthus	6	3	8	6	11	6	9	6	34
E. protulicola	8	4	13	9	5	4	17	9	43
Heteromastus filiformis	0	0	0	0	2	1	0	0	2
Laeonereis culveri	1	1	0	0	0	0	0	0	1
Lumbrineris parvapedata	1	1	0	0	0	0	0	0	1
Marphysa sanguinea	1	1	0	0	0	0	0	0	1
Mediomastus californiensis	0	0	0	0	0	0	1	1	1
Neanthes succinea	8	6	11	7	12	6	9	7	40
Notomastus hemipodus	0	0	0	0	1	1	0	0	1
Pedarke, near guanica	1	1	1	1	0	0	0	0	2
Polydora websteri	28	10	35	10	51	8	22	4	136
Polydora sp.	2	2	1	1	1	1	0	0	4
Prinospio sp.	1	1	2	1	0	0	0	0	3
Spiophanes bombyx	1	1	0	0	0	0	0	0	1
Streblespio benedicti	6	4	7	4	3	3	0	0	16
Capitellidae sp.	0	0	0	0	0	0	3	1	3
Spionidae sp.	6	1	0	0	0	0	0	0	6
Unidentified sp. #1	2	2	0	0	2	1	1	1	5
Unidentified sp. #2	1	1	0	0	1	1	0	0	2

MONS 063994

Table 2. (Continued)

TAXON	Control		Aroclor 1254						Total Animals
			0.1 µg/l		1 µg/l		10 µg/l		
	Animals	Aquaria	Animals	Aquaria	Animals	Aquaria	Animals	Aquaria	
Arthropoda									
Balanus sp.	6	4	2	2	9	6	2	1	19
Corella sp.	0	0	11	1	3	3	0	0	14
Corophium volutator	1338	10	1693	10	736	10	3	3	3770
Neocamops texana	2	2	0	0	0	0	0	0	2
Upogebia	0	0	0	0	0	0	1	1	1
Decapod larvae, unident. sp.	0	0	0	0	4	3	0	0	4
Pycnogonidae, unident. sp.	0	0	3	1	28	6	1	1	32
Brachiopoda									
Glottidia pyramidata	1	1	0	0	0	0	0	0	1
Chordata									
Bostrichobranchus pilularis	100	1	2	2	3	1	29	5	134
Branchiostoma caribaeum	2	1	1	1	0	0	0	0	3
Molgula manhattensis	91	7	141	10	434	9	499	10	1164
Coelenterata									
Leptomedusae*, unident. sp.	5	5	4	4	8	8	7	7	24
Zoantharia, unident. sp.	0	0	0	0	5	3	0	0	5

MCNS 063995

Table 2. (Continued)

TAXON	Control		Aroclor 1254						Total Animals
			0.1 µg/l		1 µg/l		10 µg/l		
	Animal	Aquaria	Animal	Aquaria	Animal	Aquaria	Animal	Aquaria	
Echinodermata									
Hemipholis elongata	4	2	17	4	15	6	0	0	1
? Amphioplus sp.	1	1	0	0	0	0	0	0	36
Ectoprocta									
Membranipora tenuis*	6	6	6	6	4	4	0	0	16
Mollusca									
Abra aequalis	15	8	11	6	5	5	0	0	31
Amygdalum papyria	10	6	4	3	0	0	6	6	20
Anachis translirata	2	2	0	0	0	0	0	0	2
Andara transversa	6	4	4	4	3	3	6	5	19
Barnea costata	5	4	1	1	1	1	1	1	8
Bittium varium	16	7	4	4	7	4	1	1	28
Caecum pulchellum	0	0	2	2	0	0	0	0	2
Crassostrea virginica	4	3	5	4	4	3	4	4	17
Crepidula fornicata	0	0	0	0	0	0	3	3	3
Epitonium humphreysi	0	0	0	0	1	1	0	0	1
Laevicardium mortoni	9	5	3	3	2	2	4	3	16
Lyonsia hyalina	2	1	1	1	1	1	0	0	4
Mactra fragilis	0	0	1	1	1	1	0	0	2
Mitrella lunata	2	2	0	0	1	1	0	0	3
Modiolus americanus	1	1	0	0	1	1	1	1	3
M. demissus	1	1	1	1	2	1	0	0	4

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Table 2. (Continued)

TAXON	Control		Aroclor 1254 0.1 µg/ℓ		Aroclor 1254 1 µg/ℓ		Aroclor 1254 10 µg/ℓ		Total Animals
	Animal	Aquaria	Animal	Aquaria	Animal	Aquaria	Animal	Aquaria	
Mollusca (Continued)									
Mulinia lateralis	5	3	0	0	1	1	0	0	6
Musculus lateralis	7	4	3	2	2	1	3	2	15
Nassarius albus	1	1	0	0	2	2	0	0	3
N. vibex	0	0	0	0	1	1	0	0	1
Ostrea equestris	1	1	0	0	1	1	0	0	2
Retusa canaliculata	1	1	0	0	0	0	0	0	1
Rissoina catesbyana	1	1	0	0	0	0	0	0	1
Tagelus divisus	0	0	1	1	1	1	0	0	2
Tellina alternata	9	7	3	3	7	7	1	1	20
Eolidacea, unident. sp.	1	1	0	0	0	0	0	0	1
Gastropoda, unident. sp.	2	1	0	0	0	0	0	0	2
Nemertinea									
Oerstedia dorsalis	2	2	0	0	0	0	0	0	2
Unidentified sp.	1	1	0	0	0	0	0	0	1

*Colonies: Counted as one animal.

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Table 3. Number of control and experimental aquaria that contained animals, by phylum. Ten aquaria were used for each control and contaminated apparatus. Experimental aquaria were contaminated continuously with Aroclor 1254 for four months.

Phylum	Control Aquaria	Aroclor 1254 Aquaria		
		0.1 ppb	1.0 ppb	10.0 ppb
Annelida	10	10	10	10
Arthropoda	10	10	10	4
Branchiopoda	1	0	0	0
Chordata	7	10	9	10
Coelenterata	5	4	9	7
Echinodermata	3	4	6	0
Ectoprocta	6	6	4	0
Mollusca	10	10	10	10
Nemertea	3	0	0	0
Total phyla in apparatus	9	7	7	6
Average number of phyla per aquarium	5.7	5.4	5.7	4.1

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Table 4. Number of species, by phylum, that developed from planktonic larvae in control apparatus and in apparatuses contaminated continuously for four months with 0.1, 1 or 10 µg/ℓ of Aroclor 1254. Each apparatus consisted of 10 aquaria.

	Control		Aroclor 1254					
			0.1 µg/ℓ		1 µg/ℓ		10 µg/ℓ	
Taxon	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Annelida	18	34.6	10	29.4	14	32.6	8	32.0
Arthropoda	3	5.8	4	11.8	4	9.3	4	16.0
Chordata	3	5.8	3	8.8	2	4.6	2	8.0
Mollusca	21	40.4	14	41.2	19	44.2	10	40.0
Other phyla	7	13.4	3	8.8	4	9.3	1	4.0
TOTAL	52	100.0	34	100.0	43	100.0	25	100.0

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Table 5. Number of species, by phylum, that developed from planktonic larvae in 10 control aquaria and 10 aquaria in each apparatus contaminated continuously for four months with 0.1, 1 or 10 µg/ℓ of Aroclor 1254.

Taxon	Control		Aroclor 1254					
			0.1 µg/ℓ		1.0 µg/ℓ		10.0 µg/ℓ	
	Average number per aquarium	Range	Average number per aquarium	Range	Average number per aquarium	Range	Average number per aquarium	Range
Annelida	5.7	2-10	5.1	3-7	4.5	2-6	3.9	3-5
Arthropoda	1.6	1-2	1.4	1-3	2.8	2-4	0.6	0-3
Chordata	0.9	0-3	1.3	1-2	1.0	0-2	1.5	1-2
Mollusca	6.3	2-10	3.6	1-7	3.9	1-6	2.7	1-5
Other phyla	1.8	0-3	1.4	0-3	2.1	1-4	0.7	0-1
TOTAL	16.3	7-23	12.8	9-18	14.3	7-18	9.4	5-15

MDNS 064000

Table 6. Average number per aquarium and average percent frequency per aquarium of animals, by phylum (range in parentheses), that developed from planktonic larvae in 10 control aquaria and 10 aquaria that for four months received 0.1, 1 or 10 µg/l of Aroclor 1254.

Phylum	Control		Aroclor 1254					
			0.1 µg/l		1 µg/l		10 µg/l	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Annelida	11.6 (3-23)	6.5 (1.8-21.4)	11.9 (4-21)	5.8 (1.3-42.8)	12.8 (7-22)	9.0 (3.9-38.5)	8.5 (5-16)	12.9 (5.3-66.7)
Arthropoda	134.6 (6-406)	75.8 (12.7-94.0)	170.9 (14-528)	83.6 (28.6-96.2)	78.0 (8-199)	54.9 (20.5-86.9)	0.7 (0-4)	1.1 (0-2.8)
Chordata	19.3 (0-112)	10.9 (0-64.7)	14.4 (1-52)	7.0 (0.6-19.4)	43.7 (0-130)	30.8 (0-59.1)	52.8 (3-160)	80.4 (25.0-88.6)
Mollusca	10.1 (3-18)	5.7 (0.7-28.6)	4.4 (1-10)	2.2 (0.8-12.2)	4.4 (1-9)	3.1 (1.3-33.3)	3.0 (1-6)	4.6 (1.9-9.0)
Other phyla	2.0 (0-4)	1.1 (0-7.1)	2.7 (0-11)	1.4 (0-6.5)	3.2 (1-7)	2.2 (0.9-7.7)	0.7 (0-1)	1.0 (0-3.5)
TOTAL	177.6 (14-432)	100.0	204.3 (49-589)	100.0	142.1 (24-239)	100.0	65.7 (12-186)	100.0

MONS 064001

Table 7. Shannon-Weaver index of species diversity and index of species richness in the ten control aquaria and ten aquaria contaminated with 0.1, 1 or 10 µg/l of Aroclor 1254.

	Control			Aroclor 1254								
				0.1 µg/l			1.0 µg/l			10.0 µg/l		
	Mean	Range	Std. Error	Mean	Range	Std. Error	Mean	Range	Std. Error	Mean	Range	Std. Error
Species diversity	1.80	0.57-2.83	0.24	1.42	0.36-3.17	0.26	2.07	0.94-3.26	0.20	1.62	1.03-2.19	0.13
Equitability (J)	0.47	0.14-0.89	0.07	0.38	0.10-0.81	0.07	0.55	0.25-0.86	0.06	0.53	0.26-0.94	0.06

MONS 064002

Table 8. Species and total number of animals collected from the effluents of 10 control aquaria and 10 aquaria contaminated for four months with 0.1, 1 or 10 µg/ℓ Aroclor 1254.

Taxon	Control	0.1 µg/ℓ	1 µg/ℓ	10 µg/ℓ
Annelida				
Eupomatus dianthus	1	1	0	0
E. protulicola	0	1	1	0
Neanthes succinea	1	2	2	0
Total	2	4	3	0
Arthropoda				
Balanus sp.	10	2	2	1
Caprella sp.	0	8	4	0
Clibanarius tricolor	0	1	0	0
Corophium volutator	7	15	32	1
Eutypanopeus depressus	5	2	5	0
Neopanope texana	10	6	3	0
Pagurus longicarpus	1	0	0	0
Pinnixa chaetopterа	1	0	0	0
Upogebia affinis	1	1	0	0
Decapod zoea, unident. sp.	0	0	1	0
Portunidae, unident. sp.	2	1	0	0
Pycnogonidae, unident. sp.	0	0	3	0
Total	37	36	50	2
Chordata				
Bostrichobranchus pilularis	3	0	0	0
Branchiostoma caribaeum	1	0	1	0
Molgula manhattensis	72	103	304	35
Total	76	103	305	35
Coelenterata				
Leptomedusae*, unident. sp.	1	1	1	1
Echinodermata				
Hemipholis elongata	1	0	3	0
Ectoprocta				
*Membranipora tenuis**	1	1	1	0
Mollusca				
Anadara ovalis	1	0	0	0
A. transversa	12	0	4	1
Bittium alternata	0	1	0	0
B. varium	3	0	1	0
Crassostrea virginica	2	0	1	1
Doridella obscura	12	1	2	1
Laevicardium mortoni	1	0	0	0
Mitrella lunata	2	0	2	2

MCNS 064003

Table 8. (Continued)

Taxon	Control	0.1 µg/l	1 µg/l	10 µg/l
Mollusca (Continued)				
Musculus lateralis	1	0	1	0
Nassarius albus	2	0	0	0
Tagelus divisus	1	2	0	0
Kolidacea, unident. sp.	1	1	1	3
Total	38	5	12	8
TOTALS: Animals	156	150	375	47
Species	27	18	20	10

*Colonies: Counted as one animal.

MONS C64004