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

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Fenvalerate [cyano (3-phenoxyphenyl) methyl 4-chloro-alpha-(1-methylethyl) benzeneacetate] is a synthetic pyrethroid, a broad spectrum insecticide used primarily to protect cotton. It has low solubility in seawater (24 µg/L), strongly adsorbs to sediment and particulate matter in water, has a half-life of 24 days in estuarine sediment in laboratory systems, and has an octanol/water partition coefficient of 1.6×10^6 (R.L. GARNAS, Gulf Breeze, ERL, personal communication).

Acute toxicity tests conducted at the Gulf Breeze Environmental Research Laboratory indicated that fenvalerate was extremely toxic to various aquatic organisms. Acute toxicity (96-h LC50) in flowing seawater to mysid shrimp (Mysidopsis bahia) was 0.008 µg/L (nominal concentration); to pink shrimp (Penaeus duorarum), 0.84 µg/L (measured concentration); and to four species of fish (Mugil cephalus, Menidia menidia, Opsanus beta, and Cyprinodon variegatus), from 0.31 to 5.4 µg/L (measured) (S.C. SCHIMMEL, personal communication). MCLEESE et al. (1980) also found crustaceans to be very sensitive to fenvalerate. They reported 96-h LC50's (measured concentrations, static tests) of 0.14 µg/L for the lobster, Homarus americanus, and 0.04 µg/L for the sand shrimp, Crangon septemspinosa. Oyster larvae (Crassostrea virginica) were less sensitive, the 48-h EC50 value (nominal concentration, static test) for abnormal shell development being greater than 1,000 µg/L (P.W. BORTHWICK, personal communication).

To obtain additional information on the effects of fenvalerate on the estuarine environment, we conducted studies on the responses of laboratory- and field-colonized benthic communities exposed to this toxicant.

METHODS

Laboratory-Colonized Communities

The effect of fenvalerate on colonization was determined in the laboratory by comparing numbers and species of estuarine animals that grew from planktonic larvae in aquaria treated with fenvalerate for 8 weeks (June 16 to August 11, 1980) with those of animals that grew in untreated aquaria. Larvae entered the aquaria as

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plankton in continuously supplied unfiltered seawater. We used four acrylic plastic apparatuses (Figure 1), each consisting of a central constant-head box positioned atop six aquaria (40 cm long, 10 cm wide, and 12 cm high). Aquaria were filled to a depth of 5 cm with clean silica sand (particle size, 0.2 to 0.8 mm) dredged at least a year previously from Santa Rosa Sound, Florida. Water in aquaria was maintained at 3 cm above the sand.

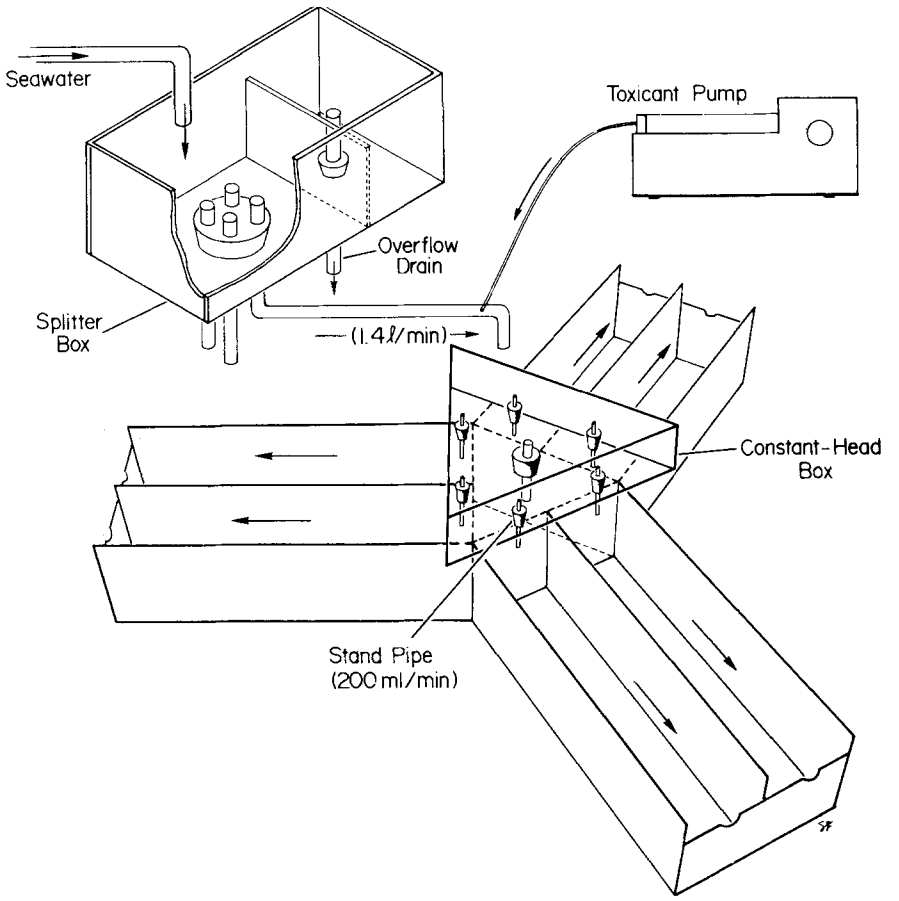

Figure 1. Apparatus used to test the effect of fenvalerate on development of estuarine macrobenthic communities in the laboratory.

Seawater with its constituent plankton was pumped from Santa Rosa Sound to a splitter box where four adjacent glass tubes supplied water at a rate of 1.4 L/min to the four constant-head boxes that supplied water to the aquaria (Fig. 1). Flow to each aquarium was maintained at 200 mL/min by adjusting the height of a glass standpipe (2.2-mm interior diameter) in the constant-head box. Water flowed from each aquarium through a notched end-opening; large predators, such as crabs, escaped through these openings before they could affect community structure. Salinity and

temperature of incoming seawater were recorded continuously and averaged 26.5 ppt (14.5 to 34.0 ppt) and 28° C (24 to 31° C). Photoperiod was 12 h.

Technical grade fenvalerate (100%) dissolved in a stock solution consisting of 15% acetone and 85% triethylene glycol was metered by syringe pump into and mixed with the seawater entering the center of the constant-head box of each apparatus receiving fenvalerate. The same amount of carrier solvent (10 ml/day, 5 mg/L) was metered into the control apparatus. Nominal concentrations of fenvalerate in seawater were 0.01, 0.1 and 1.0 µg/L. Samples of water were taken from constant-head boxes once a week for chemical analyses for fenvalerate concentration.

After 8 weeks, animals were collected by siphoning the contents of the aquaria into a 1-mm mesh sieve, after which they were perserved and identified.

Field-Colonized Communities

The effect of fenvalerate on benthic animal communities colonized in the field was determined by placing sand-filled aquaria in the field to be colonized by naturally occurring animals for 7 weeks and 5 days (Sept. 3 to Oct. 27, 1980), bringing the established communities into the laboratory, and then exposing them to fenvalerate for 1 week (Oct. 28 to Nov. 4). Abundance of living animals in contaminated and control aquaria was compared.

Thirty-two aquaria were placed by SCUBA divers in 3 meters of water at a site in Santa Rosa Sound adjacent to our laboratory. Aquaria, 32 cm x 32 cm x 6 cm deep, were constructed of acrylic plastic and filled with sand from the source described previously. They were numbered for identification and grouped by fours (in the form of squares). The aquaria, positioned in the substratum so that their surfaces were level with the surrounding sand, were covered with 1/4-inch (6.4 mm) hardware cloth to exclude large predators, such as crabs. Salinity of the water entering our laboratory during colonization averaged 25.5 ppt (22 to 29 ppt); temperature, 26° C (19 to 30° C).

After colonization in the field, the aquaria were collected by divers and covered with acrylic plastic for immediate transfer to the laboratory. Temperature and salinity in field and laboratory at transfer did not differ. In the laboratory, groups of four aquaria were placed in eight acrylic plastic boxes that when filled resulted in a 3-cm layer of water over the sand. Two boxes served as eight replicate aquaria for the control and for each of the three fenvalerate exposures (0.1, 1.0 and 10.0 µg/L, nominal concentrations). Each group of eight replicates contained an aquarium that had been randomly selected from each of the eight field groups of four aquaria. Toxicant concentrations were one order of magnitude higher than those tested against laboratory-developed communities because of shorter exposure time and older

animals, which are usually less sensitive to toxicants than early developmental stages.

Unfiltered seawater was delivered continuously at 2 L/min. to the center of each box, water flowed from the box through notched openings on all sides. Plankters in the seawater could serve as food during exposure; we believe that few or none were retained by the 1-mm mesh sieve used in harvesting at the end of 1-week treatment.

Fenvalerate (dissolved as previously described) was metered by syringe pump for 7 days and mixed with the seawater entering the center of each box. Aquaria used as the control received the same amount of carrier solvent (10 mL/day, 3.5 mg/L) as the aquaria receiving toxicant. Water samples were taken from each box after 3 and 6 days for determination of fenvalerate concentrations. Salinity during exposure averaged 26.5 ppt (24 to 29 ppt); temperature, 19° C (17 to 22° C).

After 1 week exposure to the toxicant, the communities were harvested. Animals retained by a 1-mm mesh sieve were preserved and identified.

Statistical and Chemical Analyses

Results are presented as pooled data from each fenvalerate 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 ($\alpha = 0.05$).

Fenvalerate concentrations were determined with a gas chromatograph equipped with a Ni^{63} electron-capture detector. The toxicant was extracted from 1 L water samples with two 100-mL portions of petroleum ether. The extract was dried by passage through glass wool into a 250 mL Kuderna-Danish concentrator and then evaporated on a steam table to 20 mL, using a Snyder Column, followed by nitrogen evaporation to 2 mL. A control sample fortified with fenvalerate was analyzed concurrently to evaluate the integrity of the results. The mean recovery for fortified seawater samples exceeded 90%.

RESULTS

Laboratory-Colonized Communities

Fenvalerate was not detected (limit of detection, 0.15 µg/L) in samples of water that contained nominal concentrations of 0.01 and 0.1 µg/L. Concentrations measured in water from aquaria that contained 1.0 µg/L, nominal, averaged 1.1 µg/L and ranged from 0.77 to 1.5 µg/L. Data are presented as nominal concentrations.

A total of 1,758 animals representing 35 species of 6 phyla were collected from laboratory-colonized aquaria (Table 1). The

chordate, Molgula manhattensis, was most abundant; other dominant phyla consisted of approximately equal numbers of arthropods, mollusks, and annelids.

TABLE 1

Animals in laboratory-colonized benthic communities collected from control aquaria and from aquaria exposed to fenvalerate for 8 weeks. Replicates were pooled.

Taxon	Control	Fenvalerate, µg/L 0.01	0.1	1.0	Total animals
CHORDATA					
Molgula manhattensis	238	289	278	99	904
ARTHROPODA					
Corophium acherusicum	102	139	0	0	241
Balanus amphitrite	4	9	8	7	28
Neopanope texana	0	1	0	0	1
Total arthropods	106	149	8	7	270
MOLLUSCA					
Acteocina canaliculata	20	15	28	16	79
Diastoma varium	15	16	29	15	75
Mulinia lateralis	11	12	5	10	38
Laevicardium mortoni	6	8	7	0	21
Amygdalum papyrium	2	0	2	4	8
Crassostrea virginica	2	0	1	0	3
Mitrella lunata	0	1	1	0	2
Tagelus divisus	0	0	1	1	2
Anomalocardia auberiana	1	0	0	0	1
Cyrtopleura costata	0	0	1	0	1
Mangelia quadrata	0	1	0	0	1
Total mollusks	57	53	75	46	231
ANNELIDA					
Capitella capitata	15	21	10	11	57
Armandia agilis	13	7	17	4	41
Neanthes succinea	10	15	9	6	40
Mediomastus californiensis	5	10	5	10	30
Polydora websteri	8	3	9	9	29
Hydroides protulicola	2	2	1	1	6
Polydora ligni	3	2	0	0	5
Capitellides jonesi	0	0	2	1	3
Capitomastus aciculatus	0	0	1	2	3
Prionospio cirrifera	0	1	1	1	3
Cistenides gouldii	1	0	0	0	1
Dasybranchus lumbricoides	0	1	0	0	1
Dasybranchus lunulatus	0	1	0	0	1
Gyptis vittata	0	0	1	0	1
Hydroides dianthes	0	0	1	0	1
Nereis pelagica	0	1	0	0	1
Prionospio cirrobranchiata	1	0	0	0	1

TABLE 1
(Continued)

Taxon	Control	Fenvalerate, µg/L 0.01	0.1	1.0	Total animals
Prionospio heterobranchia	1	0	0	0	1
Total annelids	59	64	57	45	225
COELENTERATA					
Actinaria	23	32	34	35	124
ECHINODERMATA					
Leptosynapta inhaerens	0	1	2	1	4
Total All Phyla					
Individuals	483	588	454	233	1758
Species	21	23	24	18	35

Total abundance of animals, but not number of species, was decreased significantly by 1.0 µg fenvalerate/L, and arthropod abundance and species by 0.1 µg/L (Table 2). No Corophium acherusicum (89% of the total arthropods collected) occurred in 0.1 or 1.0 µg/L; number was not affected by 0.01 µg/L. The number of tunicates, Molgula manhattensis, in aquaria containing the highest toxicant concentration was less than one-half that in the control or in lower concentrations. However, statistical differences were not real because of the high variability in abundance of this species among aquaria (21 to 89 in the control, 9 to 25 in the highest concentration). Numbers of individuals and species of mollusks, annelids, and coelenterates in contaminated aquaria did not significantly differ from those in the control. Few echinoderms were collected.

TABLE 2

Average density of animals and number of species (in parentheses) per aquarium collected from laboratory-colonized benthic communities in control aquaria and aquaria exposed to fenvalerate for 8 weeks.

Phylum	Control	Fenvalerate, µg/L 0.01	0.1	1.0
Chordata	39.7 (1.0)	48.2 (1.0)	46.3 (1.0)	16.5 (1.0)
Arthropoda	17.7 (1.5)	24.8 (2.2)	1.3* (0.8*)	1.2* (0.7*)
Mollusca	9.5 (3.5)	8.8 (3.3)	12.5 (4.3)	7.7 (3.5)

TABLE 2

(Continued)

Phylum	Control	Fenvalerate, µg/L 0.01	0.1	1.0
Annelida	9.8 (4.5)	10.7 (5.0)	9.5 (5.2)	7.5 (4.3)
Coelenterata	3.8 (1.0)	5.3 (1.0)	5.7 (1.0)	5.8 (1.0)
Echinodermata	0 (0)	0.2 (0.2)	0.3 (0.3)	0.2 (0.2)
All phyla	80.5 (11.5)	98.0 (12.7)	75.7 (12.7)	38.8* (10.7)

*Significantly less than control at the 5% level.

Field-Colonized Communities

Concentrations of fenvalerate in samples of water that contained a nominal concentration of 10.0 µg/L averaged 3.2 µg/L (1.3 to 4.2); in water that contained 1.0 µg/L, 0.74 µg/L (0.66 to 0.80). In water containing 0.1 µg/L, nominal, one sample was 0.16 µg/L and the others <0.15 µg/L, the limit of detection. Data are presented as nominal concentrations.

A total of 1,462 animals representing 59 species of 7 phyla were collected from field-colonized aquaria (Table 3). Annelids were particularly abundant; other dominant phyla were Mollusca, Chordata, Rhynchocoela, and Arthropoda.

TABLE 3

Animals in field-colonized benthic communities collected from control aquaria and from aquaria exposed to fenvalerate for 7 days. Replicates were pooled.

Taxon	Control	Fenvalerate, µg/L 0.1	1.0	10.0	Total animals
ANNELIDA					
Capitella capitata	229	436	191	61	917
Cistenides gouldii	3	4	13	9	29
Armandia agilis	1	6	7	1	15
Loimia viridis	2	4	3	3	12
Podarke, near guanica	3	4	2	3	12
Dasybranchus lunulatus	1	1	2	4	8
Unidentified polychaete	4	1	3	0	8
Spiophanes bombyx	2	2	2	0	6
Hydroides protulicola	0	4	0	1	5
Dispio uncinata	1	1	2	0	4

TABLE 3

Continued

Taxon	Control	Fenvalerate, µg/L 0.1	1.0	10.0	Total animals
Amphinome rostrata	0	0	1	2	3
Axiothella mucosa	1	1	0	0	2
Nerine agilis	1	0	1	0	2
Notomastus hemipodus	2	0	0	0	2
Poecilochaetus sp.	0	1	1	0	2
Ancistrosyllis bassi	1	0	0	0	1
Arenicola cristata	0	0	0	1	1
Glycera dibranchiata	1	0	0	0	1
Gyptis vittata	1	0	0	0	1
Haploscoloplos robustus	1	0	0	0	1
Laeonereis culveri	0	1	0	0	1
Laonice cirrata	0	1	0	0	1
Macroclymine elongata	0	1	0	0	1
Nereiphylla fragilis	1	0	0	0	1
Ninoe nigripes gracilis	0	1	0	0	1
Pareurythoe americana	0	0	0	1	1
Polydora ligni	0	1	0	0	1
Travisia carnea	1	0	0	0	1
Total annelids	256	470	228	86	1040
MOLLUSCA					
Diastoma varium	10	10	13	10	43
Mitrella lunata	6	8	7	5	26
Laevicardium mortoni	8	7	4	6	25
Anomalocardia auberiana	5	5	3	5	18
Crassostrea virginica	2	9	3	2	16
Triphora nigrocincta	2	5	5	1	13
Acteocina canaliculata	1	2	2	3	8
Persicula sp.	2	4	0	2	8
Morula didyma	2	1	3	1	7
Mangelia stellata	1	1	2	1	5
Marginella carnea	0	2	1	0	3
Tellina alternata	1	0	1	1	3
Ensis minor	0	1	0	1	2
Polinices duplicatus	0	1	1	0	2
Crepidula maculosa	1	0	0	0	1
Crepidula plana	0	0	1	0	1
Geukensia demissa	0	1	0	0	1
Noetia ponderosa	0	0	1	0	1
Pinna sp.	0	0	1	0	1
Thais haemastoma floridana	0	0	0	1	1
Total mollusks	41	57	48	39	185
CHORDATA					
Branchiostoma caribaeum	64	46	14	4	128
RHYNCHOCOELA					
Cerebratulus lacteus	26	15	20	11	72

TABLE 3
Continued

Taxon	Control	Fenvalerate, µg/L 0.1	1.0	10.0	Total animals
ARTHROPODA					
Corophium acherusicum	15	3	0	0	18
Acanthohaustorius millsi	3	3	0	0	6
Ampelisca vadorum	2	0	1	0	3
Ampelisca verrilli	2	0	0	0	2
Pinnixa cylindrica	2	0	0	0	2
Processa sp.	1	0	0	0	1
Total arthropods	25	6	1	0	32
COELENTERATA					
Actinaria	1	0	0	0	1
Echinoidea	0	0	1	0	1
ECHNODERMATA					
Ophiophragmus filograneus	2	0	0	0	2
Total All Phyla					
Individuals	415	594	313	140	1462
Species	40	35	31	25	59

Total number of species, but not total abundance, was decreased significantly by 10 µg fenvalerate/L (Table 4). Numbers and species of arthropods and numbers of the chordate, *Branchiostoma caribaeum*, were significantly less in all toxicant concentrations than in the control. Most of the dead lancelets, *B. caribaeum*, had decomposed by the end of the treatment period, but 19 that were intact averaged 25 mm total length (18 to 38 mm). Abundance of the annelid, *Capitella capitata*, in aquaria that contained 10 µg fenvalerate/L was 73% less than in control aquaria. However, high variability in its abundance among aquaria (0 to 164 in the control, 0 to 35 in the highest concentration) masked any statistical significance. Numbers of individuals and species of mollusks and nermerteans in contaminated aquaria did not differ significantly from those in the control. Few coelenterates and echinoderms were collected.

TABLE 4

Average density of animals and number of species (in parentheses) per aquarium collected from field-colonized benthic communities in control aquaria and aquaria exposed to fenvalerate for 7 days.

Phylum	Control	Fenvalerate, µg/L 0.1	1.0	10.0
Annelida	32.0 (3.2)	58.8 (4.4)	28.5 (3.4)	10.8 (2.8)
Mollusca	5.1 (3.8)	7.1 (5.1)	6.0 (4.4)	4.9 (3.8)

TABLE 4

Continued

Phylum	Control	Fenvalerate, µg/L 0.1	1.0	10.0
Chordata	8.0 (1.0)	5.8* (1.0)	1.8* (0.6)	0.5* (0.5*)
Rhynchocoela	3.2 (0.9)	1.9 (0.6)	2.5 (0.9)	1.4 (0.8)
Arthropoda	3.1 (1.9)	0.8* (0.5*)	0.1* (0.1*)	0* (0*)
Coelenterata	0.2 (0.2)	0 (0)	0.1 (0.1)	0 (0)
Echinodermata	0.1 (0.1)	0 (0)	0.1 (0.1)	0 (0)
All phyla	51.9 (11.1)	74.2 (11.6)	39.1 (9.6)	17.5 (7.8*)

*Significantly less than control at the 5% level.

DISCUSSION

Colonization in field- and laboratory-derived communities resulted in sufficient numbers of benthic macrofauna to allow determination of toxicant effects on a variety of taxa. Community structure was altered significantly in both studies by 0.1 and 1.0 µg fenvalerate/L. The two studies provided corroborating data on toxicant effects as well as data that were peculiar to one study. Abundance of amphipods was significantly altered in both laboratory and field situations. The lancelate, Branchiostoma caribaeum, very sensitive to fenvalerate in field-colonized communities, did not occur in laboratory-colonized communities.

High variability in abundance of Molgula manhattensis and Capitella capitata among aquaria indicated that although these systems provided conditions favorable for their colonization, assessing toxicant effects on these species would be difficult. Most of those collected were young individuals which may have resulted from spawning within aquaria. Both species are highly opportunistic, with ability to increase rapidly in unexploited habitat (GRAVE 1933, GRASSLE and GRASSLE 1974).

Abundance of mollusks and annelids was not significantly reduced by the highest concentrations of fenvalerate tested, 1.0 µg/L in laboratory-colonized communities and 10.0 µg/L in

field-colonized communities. Although a majority of the mollusks in field-colonized communities were dead when harvested (tabular data represent only surviving animals), death appeared to be field-related and not toxicant-related. Mortality among mollusks was approximately equal for the control (63% of those collected) and for the various toxicant concentrations (62 to 66%). In addition, the shells of most of the dead pelecypods and some of the gastropods in field-colonized aquaria bore round holes of the types produced by oyster drills (Thais sp.) or moon snails (Polinices sp.).

Of an overall total of 79 species, only 15 (19%) appeared in both field and laboratory communities. However, the more abundant species of Arthropoda, Annelida, and Mollusca usually were common to both situations. In an earlier study in which colonization of field and laboratory communities occurred simultaneously, 30% of the species were present in both, and the most abundant annelid and mollusk were the same (TAGATZ et al. 1981). Similarities between laboratory and field communities in the present study were less likely because the period of colonization and aquarium size differed.

The phylogentic groups that were sensitive or not sensitive to fenvalerate in our studies compare with those in acute tests with single species. Concentrations of the toxicant less than 1 µg/L were particularly toxic to crustaceans, Corophium acherusicum in community studies, and Mysidopsis bahia, Penaeus duorarum, Crangon septemspinosa, and Homarus americanus in acute tests (S.C. SCHIMMEL, personal communication; MCLEESE 1980). Of chordates, Branchiostoma caribaeum in community studies and Menidia menidia and Mugil cephalus in acute tests (SCHIMMEL, personal communication), also were sensitive to concentrations less than 1 µg/L. Mollusks were not adversely affected by 10 µg/L in our studies or by 1,000 µg/L in acute tests with Crassostrea virginica (P.W. BORTHWICK, personal communication).

Our studies and the acute toxicity tests cited earlier indicate that fenvalerate contamination, even at concentrations in water not detectable by our procedures, could be very hazardous to the saltwater environment and could adversely affect a wide variety of ecological relationships among benthic and water-column animals.

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