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Behavioral Responses of Shiner Perch to Chlorinated Primary Sewage Effluent

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Toxicity bioassays of chlorinated primary sewage effluent from Seattle's West Point Sewage Treatment Plant have shown that the effluent is acutely toxic to shiner perch, Cymatogaster aggregata, and juvenile English sole, Parophrys vetulus, at about 15% effluent in seawater (v/v) and chronically toxic in concentrations of effluent as low as 0.5% (STOBER et al. 1978a). The actual impact of chlorinated sewage effluent in Puget Sound receiving waters is difficult to assess because fish and many invertebrates are capable of movement into or out of a discharge plume. If organisms are attracted to plumes of sewage effluent, the toxic effects in the field could approximate those seen in the laboratory. If, however, organisms avoid sewage plumes, the toxic effects may be minimized; but the plume must then be considered an uninhabitable area for those organisms demonstrating avoidance, and the ecological impacts caused by the plume must be assessed in a different manner. Thus, the behavioral responses (avoidance or attraction) of the resident species become important when considering the ecological impact of sewage discharges.

The object of this study was to determine the behavioral responses of a locally common marine fish (C. aggregata) to chlorinated primary sewage effluent in seawater.

MATERIALS AND METHODS

The behavioral responses of shiner perch to dilutions of chlorinated primary sewage effluent were tested in a behavior tank isolated in a 3 x 3 m metal shed. The test tank design was a modification (MELDRIM et al. 1974) of an avoidance tank first used by SHELFORD & ALLEE (1913) which employed a counter-flow water pattern. The test and control solutions entered from opposite ends of the tank and flowed toward a central drain (Fig. 1). The test tank had replicate sides which provided for simultaneous duplication of each test with reversal of test and

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control solutions to minimize any end-preference by the fish not related to the test/control solutions. The control and test solutions were prepared by a small diluter system, actively stirred in mixing tanks, and delivered to the test tank by pumps regulated by flow meters to deliver approximately 2 L/min. The water level in the test tank was maintained at a depth which allowed fish to swim freely over the central drain. The test tank was shielded on all sides and top by sheets of white plastic and indirectly lighted from above through the plastic blind. Fish movements were remotely monitored by closed-circuit television and video tape equipment with time-lapse capabilities.

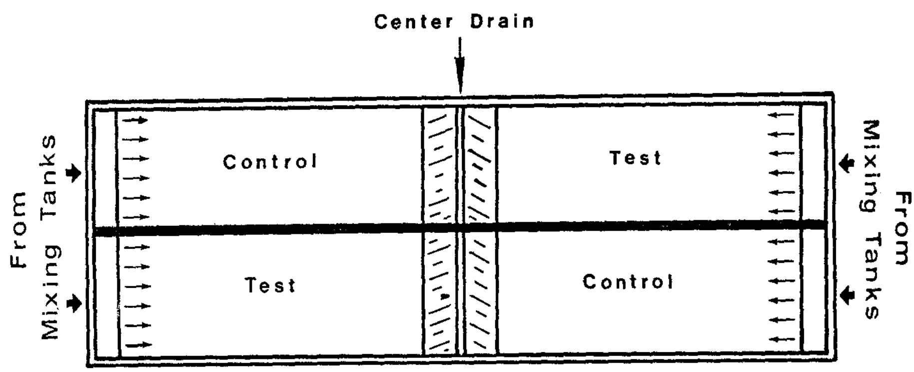

Fig. 1. Diagram of the fish behavior test tank.

Behavior tests were conducted by placing 5 shiner perch in each replicate side and determining the amount of time the perch spent in the test and control solutions after a 15-min acclimation period. Twenty duplicate tests were conducted with 0% effluent (control seawater in all four quadrants) and ten duplicated tests, each with 1, 5, 10, 15 and 20% v/v chlorinated effluent. Physical and chemical sampling for temperature, salinity, pH, ammonia, turbidity, and total residual chlorine was conducted prior to each test run. Ammonia was measured with an Orion specific ion meter and ammonia electrode. Total residual chlorine was measured as total residual oxidant (TRO) using a Wallace and Tiernan amperometric titrator, sensitive to 0.05 mg/L of oxidant.

Fish responses (avoidance or attraction) were tested for deviation from randomness by the Student t-test.

RESULTS

Shiner perch showed a statistical preference for

1, 5, ($p \leq 0.01$) and 10% ($p \leq 0.05$) chlorinated effluent, avoidance of 15 and 20% ($p \leq 0.01$) effluent, and random movement in the test tank when effluent was not present (0%) (Fig. 2).

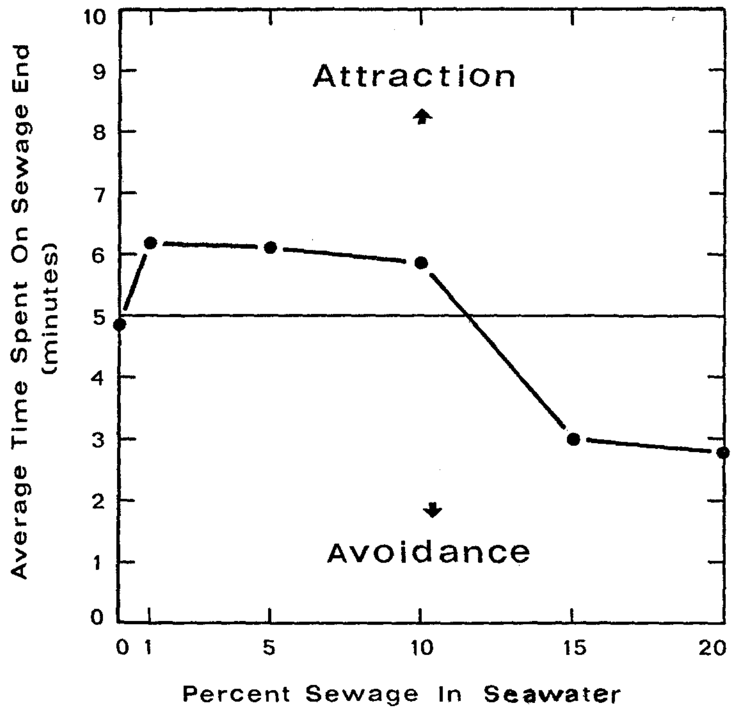

Fig. 2. Pattern of attraction and avoidance responses of shiner perch to dilutions of chlorinated primary sewage effluent.

Subjective analyses of shiner perch behavior from video tape recordings yielded similar conclusions. The perch generally moved freely and without hesitation on both ends of the test tank when effluent was not present. Addition of 1, 5, or 10% effluent caused fish to linger on the effluent end longer than normal. Shiner perch obviously avoided 15 or 20% effluent. These concentrations caused the perch to hesitate or turn away from the test/control solution interface at the center drain or caused them to return promptly to the clean seawater if they did venture into the effluent end.

Average temperature, salinity, pH, ammonia, turbidity, and total residual oxidant values are summarized in Table 1. The average total length of all shiner perch used in the behavior tests was 74.6 mm. As noted

Table 1. Average temperature, salinity, pH, ammonia, turbidity, and total residual oxidant in the control and test (effluent) ends of the chlorinated sewage effluent behavior tests with shiner perch.

Percent Chlorinated Effluent on Test End	Measurement Location	Temp. C^{o}	Salinity 0/00	Dissolved Oxygen ppm	pH	Ammonia mg/L	Turbidity JTU	Total Residual Oxidant mg/L
0	Control	9.8	29.8	9.6	8.0	0.0	0.5	0.00
	Test	9.8	29.8	9.6	8.0	0.0	0.5	0.00
1	Control	10.4	29.3	9.1	8.0	0.0	0.1	0.00
	Test	10.3	29.3	9.0	8.0	0.3	0.5	0.00
5	Control	10.1	28.1	8.8	8.1	0.0	1.0	0.00
	Test	10.1	28.0	8.4	8.0	1.3	4.5	0.02
10	Control	9.9	26.4	9.7	8.0	0.0	0.8	0.00
	Test	9.7	26.4	9.0	7.8	2.3	9.4	0.12
15	Control	10.9	25.1	9.2	8.1	0.0	0.8	0.00
	Test	10.7	25.0	8.1	7.8	3.6	15.6	0.19
20	Control	11.2	23.8	9.1	8.1	0.0	0.5	0.00
	Test	10.9	23.8	7.5	7.6	4.9	24.0	0.20

in Table 1, salinity values on both the control and test ends decreased with an increasing concentration of effluent. The effluent was essentially a freshwater discharge, thus resulting in a reduction of salinity on the test end. The equivalent reduction of salinity on the seawater control end was due to the addition of an equivalent amount of freshwater to maintain an equal density interface at the center drain. Preliminary tests revealed that density differences greater than a few tenths ppt salinity resulted in unacceptable mixing of the test and control solutions with a resulting lack of a distinct interface at the center drain. Additionally, equal salinities on each end were desirable to minimize behavior responses due to osmotic stress.

DISCUSSION

Shiner perch avoided levels of chlorinated sewage which would have been lethal to them in 96 h. However, they were attracted to effluent concentrations which have been shown to produce sublethal damage to the integrity of the gills (STOBER et al. 1978a) and changes in blood chemistry and blood cell morphology of coho salmon, *Oncorhynchus kisutch*, (BUCKLEY et al. 1976).

Chlorine may be partly responsible for the attraction-avoidance pattern exhibited by shiner perch. Other studies conducted at our West Point Bioassay Laboratory have shown shiner perch to be attracted to heated seawater (Δt 4-8° above ambient) chlorinated to 0.01 to 0.1 mg/L TRO, but repelled by chlorine concentrations >0.175 mg/L TRO (STOBER et al. 1978b). Shiner perch were attracted to concentrations of effluent containing an average of 0.00 to 0.12 mg/L TRO, but were repelled by concentrations of effluent averaging 0.19 and 0.20 mg/L TRO (Table 1).

Similar behavior experiments with coho salmon in chlorinated seawater have shown that coho salmon significantly avoid all concentrations of chlorine as low as 0.002 mg/L TRO in seawater (STOBER et al. 1978b). Thus, if chlorine in the sewage effluent is primarily responsible for the behavior responses of shiner perch discussed above, then coho salmon might be expected to avoid most chlorinated sewage effluents. However, this hypothesis must be tested to be confirmed as other workers have reported highly variable behavior test results, depending on such factors as species, type and concentration of chlorine (total, free, combined, etc.), temperature and characteristics of the dilution water (SPRAGUE & DRURY 1969, LARRICK et al. 1978, TEPPEN et al. 1978).

The effects of other components of sewage on behavior are presently unknown. Both ammonia and turbidity increased with increasing sewage concentrations, while dissolved oxygen and pH decreased. Additional behavior tests will be required to partition the effects of these components.

The variability observed in fish behavioral responses to chlorine and chlorinated sewage effluent may provide a partial answer to the differences in fish distribution sometimes observed in discharge areas (TSAI 1975).

TSAI (1973) studied the effects of sewage discharges of 149 sewage treatment plants and found major reductions in fish life and species diversity indices below the outfalls. No fish were found in water with total chlorine of 0.37 mg/L. The species diversity index went to zero at 0.25 mg/L. Turbidity also had a major impact.

Similar effects of sewage have been observed in seawater. In Galveston Bay, Texas, BECHTEL & COPELAND (1970) made a correlation of fish species diversity with percent wastewater. They found species diversity index values as low as 0.02 in areas receiving up to 88% effluent by volume to 2.2 in less polluted areas of the Bay. In Puget Sound, MILLER et al. (1977) have noted differences in frequency and relative abundance of deep water demersal fishes in the vicinity of the West Point sewage outfall which may be associated with the wastewater discharge. Specifically, they reported the apparent replacement of slender sole, *Lyopsetta exilis*, by rex sole, *Glyptocephalus zachirus*, a greater abundance of ratfish, *Hydrolagus colliei*, and a reduction in both diversity and species richness. These differences may partially be the result of differential avoidance/attraction responses to the chlorinated effluent by the various fishes normally associated with this environment.

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