International Council for the Exploration of the Sea

C.M.1977/E:11
Fisheries Improvement Committee

Avoidance by herring of suspended sediment from dredge spoil dumping

by

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SUMMARY

Laboratory behavioural tests with herring show that schooling fish avoid suspended sediments. For a fine sediment of 4.5 μ median particle diameter the threshold concentration is 19±5 mg/ℓ and for a coarser sediment containing 30% sand is 35±5 mg/ℓ. Sediment treated with 1 ppm of either a polychlorinated biphenyl or hexadecane did not alter the threshold avoidance suggesting that adsorbed xenobiotic molecules do not influence avoidance behaviour of herring.

INTRODUCTION

Increased industrialization of the Maritime Provinces of Eastern Canada and the resultant need to increase or maintain navigable depths for shipping has led to an increase in dredging activity within the area. Dredge spoil disposal in Canada is now controlled under legislation of the Ocean Dumping Control Act of 1975 (Anon. 1975). Each dumping action requires a permit as internationally agreed at the London Convention of 1972. One purpose of this legislation is to protect fisheries from pollution resulting from the disposal of dredged soil.

Part of the Maritime Provinces herring catch is taken in a shore-based weir fishery (see Miller and Iles 1975). This fishery is possible because herring come close inshore to feed -- during the summer and fall, particularly July to September in the Bay of Fundy. It is the purpose of this report to present some laboratory experiments which seek to answer the question: "Do young herring avoid suspended sediments as might occur following dumping of dredge spoil near a weir?".

MATERIALS AND METHODS

Fish were obtained from local weirs and maintained in large tanks supplied with running sea water as reported previously (Wildish et al. 1976). Care in handling the fish from the weir to the holding tank reduced scale loss and consequent mortalities. The herring were fed daily on thawed, frozen brine shrimp.

The experimental apparatus, protocol and analysis were as reported previously with the following differences. Flows of sea water into each of the interconnected circular arenas (A and B) were adjusted between 7-9 ℓ/min. This connection between each side was limited to 10 x 10 cm to minimize leakage. The toxicant supply line and small head tank were eliminated because sediments rapidly plugged the lines. Known wet weights of sediment were made into a slurry of known volume and injected with a 100-mℓ syringe fitted with a 1-mm diameter polyethylene tube directly into the side preferred in the control period. The timing and volume of the injection were adjusted to give a rapid steady-state concentration for 1 hr during the treatment period.

Control and treatment observations at 5-min intervals were made as previously with a half-hour interval between the two sets of observations. Samples of outlet water from A and B were taken to determine the concentration of suspended sediment in the water. This was achieved by measuring light scattering of the particles at 500 nm in a Beckman Model 25 Spectrophotometer. The values given are as wet weight of sediment in mg/ℓ.

Sediment-sorting characteristics and organic carbon content of the sediments were determined by standard techniques as previously (Akagi and Wildish 1975). Wet sediments were treated with a mixture of polychlorinated biphenyls (Aroclor 1242, 1254, and 1260) or hexadecane in acetone.

RESULTS

Some characteristics of the two sediments employed for this work are shown in Table 1.

Table 1. Sediment sorting characteristics and Walkley-Black organic carbon as % dry weight of sediment.

Number	Source	Md ø (μ)	QD ø	Skq ø	% carbon
I	Digdeguash estuary	7.94 (4.5)	0.79	-0.13	3.11
II	Pottery Creek	6.68 (10)	2.57	-0.69	1.30

Sediment I, a sublittoral deposit, contained little sand, whereas Sediment II, from an intertidal deposit, contained approximately 30%, and is poorly sorted.

Typical results from the treatment period of an experiment are shown in Table 2. During the control period $\bar{p}$ = 0.25±0.6, and for the treatment period $\bar{p}$ = 0.58±.07. This indicates that the herring preferred side B in the control period and that in the treatment period side A was slightly preferred. Differences of $\bar{p}$ are significant only at a 95% probability because of high variance in the data. Overall observed concentration during treatment was 52.2 mg/ℓ.

Table 2. Results of a single experiment with 60 g of Sediment I and herring of 3.3-6.4 g, 9.8-11.7 cm. Water temperature = 1.8°C, flow 8.1 ℓ/min.

Time (min)	Volume (mℓ) slurry added	Concentration (mg/ℓ) expected	found	Fish A	B
-1	90	0	0		
0	34	84.2	73.6	4	6
5	34	"	42.6	7	3
10	34	"	38.8	1	9
15	34	"	46.5	5	5
20	34	"	58.1	1	9
25	34	"	54.3	8	2
30	34	"	46.5	9	1
35	34	"	46.5	7	3
40	34	"	54.3	7	3
45	34	"	58.1	8	2
50	34	"	50.4	6	4
55	34	"	50.4	7	3
60	0	"	58.1	5	5

Because it was possible that injection caused some movement away from that side, blank runs were made with sea water in the syringe. Tests during the course of this work were run in which controls were compared with blank treatment periods. Results of 17 tests show that in only two of these was the blank treatment significantly different from the control at a probability level of 99%. Both results involved avoidance with differences of $\bar{p}$ up to 0.18.

Avoidance by herring of a fine sediment in sea water (Table 3) shows that the threshold lies within a concentration range of 19±5 mg/ℓ. Concentrations above 200 mg/ℓ could not be tested in our apparatus because of leakage from one side of the maze to the other.

Table 3. Proportion, $\overline{p}$, of 10 herring in arena A during control and treatment periods with Sediment I.

Observed concentration (mg/ℓ)	Control $\overline{p}$	± S.E.	Treatment $\overline{p}$	± S.E.	Significance
1.5	0.65	0.03	0.58	0.05	ND
4.9	0.35	.04	0.54	.03	ND
12.0	0.89	.01	0.82	.03	ND
14.0	0.36	.07	0.78	.04	****
17.0	0.60	.03	0.50	.03	ND
17.0	1.00	0	0.85	.02	***
19.0	0.70	.06	0.24	.05	****
21.9	0.36	.04	0.60	.04	***
52.2	0.25	.06	0.58	.07	**
66.5	0.58	.05	0.32	.04	***
74.4	0.35	.06	0.88	.03	****
130.0	0.46	.03	0.68	.04	****
195.0	0.38	.05	0.82	.03	****

A coarser sediment suspended in sea water (Table 4) also caused avoidance although the threshold occurred at a higher concentration (35±5 mg/ℓ).

Table 4. Proportion, $\overline{p}$, of herring in arena A during control and treatment periods with Sediment II.

Observed concentration (mg/ℓ)	Control $\overline{p}$	± S.E.	Treatment $\overline{p}$	± S.E.	Significance
21.1	0.31	.03	0.17	.04	*
25.6	0.35	.05	0.48	.04	ND
30.2	0.26	.04	0.45	.05	*
34.8	0.35	.04	0.48	.04	ND
41.4	0.24	.03	0.60	.05	****
67.8	0.36	.05	0.66	.04	***

Treatment of fine Sediment I with PCB (Table 5) did not cause a more marked avoidance and the threshold remained the same.

Treatment of Sediment I with hexadecane (Table 6) also did not cause a marked change of threshold, although at one concentration (18.7 mg/ℓ) a significant avoidance was found.

Table 5. Proportion, p, of herring in arena A during control and treatment periods with Sediment I containing 1 mg/ℓ PCB.

Observed concentration (mg/ℓ)	Control $\bar{p} \pm$ S.E.		Treatment $\bar{p} \pm$ S.E.		Significance
14.2	0.56	.05	0.53	.04	ND
20.5	0.20	.04	0.31	.07	ND
22.0	0.69	.05	0.45	.04	**
44.6	0.21	.04	0.48	.05	***
74.8	0.51	.05	0.22	.04	***
101.3	0.18	.04	0.77	.04	****
112.0	0.47	.03	0.12	.04	****

Table 6. Proportion, $\bar{p}$, of herring in arena A during control and treatment periods with Sediment I containing 1 mg/ℓ of hexadecane.

Observed concentration (mg/ℓ)	Control $\bar{p} \pm$ S.E.		Treatment $\bar{p} \pm$ S.E.		Significance
10.7	0.22	.05	0.19	.05	ND
14.7	0.25	.04	0.31	.05	ND
16.7	0.43	.05	0.59	.06	ND
17.2	0.22	.05	0.28	.04	ND
17.2	0.44	.04	0.65	.05	**
18.7	0.21	.04	0.55	.04	****
19.6	0.34	.06	0.55	.04	**
36.9	0.52	.07	0.25	.04	**
40.2	0.66	.05	0.30	.06	***
63.4	0.12	.03	0.55	.05	****
75.4	0.28	.05	0.73	.02	****

DISCUSSION AND CONCLUSIONS

In order to determine whether the concentration thresholds determined are likely to cause avoidance under field conditions, it is necessary to know concentrations of suspended sediments. Brown (1975) records concentrations of 100 mg/ℓ within 122 m of the dredge at the surface and bottom concentrations of 50-1000 mg/ℓ persisting for up to 549 m from the dredge. These concentrations and some background levels 1-2 m from the bottom in the southwestern part of the Bay of Fundy (Wildish et al. 1977a) are greater than the observed avoidance thresholds.

The present results have not, however, shown whether the particles themselves or leachates from freshly disturbed sediments, are involved. In this regard it has previously been shown that humic substances are avoided by herring (Wildish et al. 1977b). This question deserves further attention.

ACKNOWLEDGMENTS

We thank Joan Mitchell for technical assistance and Brenda McCullough for typing the manuscript.

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