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Distribution and Hydrodynamic Properties of Fouling Organisms in the Pier 12 Area of the Norfolk Area Station

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DISTRIBUTION AND HYDRODYNAMIC PROPERTIES OF FOULING ORGANISMS IN THE PIER 12 AREA OF THE NORFOLK NAVAL STATION

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INTRODUCTION

Fouling of deep draft naval vessels, in particular aircraft carriers, in the area of the Norfolk Naval Station has been a reoccurring problem since the early 60's. The principal agents of fouling have been the hydroid, Sertularia argentea and the fleshly bryozoan, Alcyonidium verrilli. The particular fouling problem encountered in the Norfolk area is not the typical case of the organisms growing attached to ship hulls but is basically a problem of sea suction and subsequent clogging of screen grates and condenser tube sheets.

To date all efforts to solve the problem have proven ineffective, partly because there has never been a clear understanding of the life history and hydrodynamic behavior of either the hydroid or bryozoan. In order to develop and make sound judgement of alternative solutions to the hydroid and bryozoan fouling problem, it is necessary to understand as completely as possible the biological and physical behavior of these organisms. This paper presents our current state of the art knowledge about hydroid and bryozoan properties as they relate to fouling of naval vessels.

THE ORGANISMS

The hydroid, Sertularia argentea, is the commonest winter hydroid in the Chesapeake Bay region. Each colony of animals is generally attached to a hard substrate, rocks, shells, piling, etc., by a stolon. Colonies can obtain lengths over 10 inches and be quite plumose, encompassing a volume equivalent to a 10 to 12 inch sphere. The integrity of the colony is maintained by a very tough chitinous polymucosaccharide sheath that is resistant to decay and breakage.

This hydroid may have an annual life cycle in the Bay area. In the early and late winter adult colonies reproduce sexually, producing a swimming larval phase that eventually sets on a suitable substrate. The newly set colonies grow until spring. When the Bay waters start to warm they become dormant and remain in a dormant state over summer. In the fall when Bay waters cool, growth ensues and, by early winter, colonies mature and reproduce sexually completing the life cycle.

Sertularia is widely distributed in the Bay and can be found growing in every major tributary. It is an estuarine species and tends to be found attached and growing at salinities of 10 to 25 percent. However, we really do not know if there are specific areas around the Bay that are major production points. In the winter when storms generate a lot of wave action the hydroid is broken free of its attachment and drifts with the currents, in a manner very similar to tumble weed. It is the movement and concentration of these loose adult colonies that creates the fouling problems for deep-draft vessels.

The bryozoan, Alcyonidium verrilli, is the most common winter bryozoan in the Chesapeake Bay region. Colonies of animals can be attached to a variety of hard substrates intruding the sheath of Sertularia. Colonies can obtain sizes larger than spheres 18 inches in diameter. The colonies are very fleshly and given structural support by a fiberous connective tissue. Unlike the hydroid, the bryozoan is prone to decay once it dies and does not tend to accumulate in the sediments.

We do not know what the life history of Alcyonidium is in the Bay area, but it is most likely an annual and follows a similar pattern to Sertularia. The bryozoan differs from the hydroid in that it is more a marine species and seems to be found growing at salinities of 20 percent or higher.

Waves and currents are also responsible for the disattachment of the bryozoan. Once free to move, they tend to concentrate in areas of reduced currents or in areas protected from wave action.

HYDRODYNAMIC PROPERTIES

The hydrodynamic properties of the fouling organisms were examined in a hydraulic flume which has a 14.6m (48 ft) by 0.9m by 0.9m (3 ft) test section. The current speed in the test section may be adjusted from 2 cm/sec[1] to 85 cm/sec. The overall uniformity of current speed versus depth is within 2-3 percent.

Once the current speed has been properly adjusted, the fouling organisms were released at the head of the test section. Movement patterns and speed were recorded. Settling velocities were determined in standing water. All tests were run in fresh water. Hydrodynamic properties of both 10 percent formaldehyde preserved and freshly collected specimens were examined.

In general it was found that both the hydroid and bryozoan were negatively buoyant and sank. The larger the colony the greater the settling or fall velocity (Table 8-1). Density was found to be approximately 1.128 g/cc for hydroids and 1.187 g/cc for bryozoans. The critical roll velocity for bryozoans seems to be about 8 cm/sec. For hydroids the critical roll velocity ranges from about 4.5 to 8 cm/sec depending on the size and condition of the colony (alive or dead). When a colony of hydroids is actively feeding it is very plumose and would present maximum surface area for movement by weaker currents. Table 8-1 summarizes the measured hydrodynamic properties of the fouling organisms.

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[1] cm/sec x 0.03281 = ft/sec
cm/sec x 0.1943 = knots
ft/sec x 0.5921 = knots

TABLE 8-1. SUMMARY OF THE HYDRODYNAMIC PROPERTIES OF THE HYDROID *SERTULARIA ARGENTIA* AND THE BRYOZOAN *ALCYONIDIUM VERRILLI*

Critical Roll or Transport Velocity Test on Smooth Floor

Hydroids

Flume Velocity		Comments*
0.05 ft/sec	1.52 cm/sec	No motion
0.07	2.13	Large plumose live col. move and stopped
0.08	2.43	No movement of dead col.
0.09	2.74	No movement of dead col., liv col. waving
0.10	3.04	Live col. waving
0.12	3.65	Move and stop large col.
0.14	4.26	Moving of large col.
0.17	5.18	Dead col. start moving
0.25	7.62	Rolling of col. starts
0.26	8.00	Rolling of preserved col.

Bryozoans

Flume Velocity		Comments**
0.18	5.48	No motion
0.20	6.09	Waving
0.22	6.70	Waving
0.23	7.01	Waving
0.25	7.62	Large col. move & stop
0.28	8.53	Large and small col. move
0.32	9.75	Some rolling of larger col.
0.48	14.63	Large col. roll, small col. slide or roll

* Large Hydroid colony is > 50 g
** Large Bryozoan colony is > 150 g

Density

Hydroid

$$\frac{152.3\ g}{135\ cc} = 1.128\ g/cc$$

Bryozoan

$$\frac{296.9\ g}{250\ cc} = 1.187\ g/cc$$

TABLE 8-1. SUMMARY OF THE HYDRODYNAMIC PROPERTIES OF THE HYDROID *SERTULARIA ARGENTIA* AND THE BRYOZOAN *ALCYONIDIUM VERRILLI* (Cont'd)

Critical Lift Velocity, on Irregular Floor, Into Water Column

Hydroids and Bryozoans	25/cm/sec / 0.82 ft/sec

Settling or Fall Velocity

Hydroids		
wet weight live colonies		
158 g	3.42 cm/sec	0.11 ft/sec
50	2.71	0.09
29	3.71	0.12
7	1.27	0.04
wet weight preserved colonies		
40 g	5.9 cm/sec	0.19 ft/sec
20	4.5	0.15
10	3.6	0.12
5	3.0	0.10
Bryozoans		
wet weight live colonies		
278 g	6.9 cm/sec	0.23 ft/sec
130	6.5	0.21
45	8.1	0.27

TABLE 8-1. SUMMARY OF THE HYDRODYNAMIC PROPERTIES OF THE HYDROID SERTULARIA ARGENTIA AND THE BRYOZOAN ALCYONIDIUM VERRILLI (Cont'd)

Colony Velocity at Various Flume Velocities

Flume Velocity 0.23 ft/sec 7.01 cm/sec

Hydroids

Live colony Velocity cm/sec

wt.	Trial A	Trial B	Trial C	$\bar{X}$	SD
72.6 g	6.47	6.15	6.47	6.36	0.18
30.3	6.83	7.03	6.91	6.92	0.10
28.9	5.49	5.35	4.86	5.23	0.33
25.4	5.69	6.31	5.67	5.89	0.36
19.6	7.24	6.83	6.65	6.90	0.30
11.9	5.08	4.73	5.42	5.08	0.34
5.1	6.99	5.69	6.15	6.28	0.66

Flume Velocity 0.31 ft/sec 9.44 cm/sec

Hydroids

Live Colony Velocity cm/sec

wt.	Trial A	Trial B	Trial C	$\bar{X}$	SD
72.6 g	9.46	9.25	8.98	9.23	0.24
30.3	9.46	9.46	9.11	9.34	0.20
28.9	7.55	8.66	7.45	7.89	0.67
25.4	7.32	8.78	8.78	8.30	0.84
11.9	9.54	8.09	8.61	8.41	0.28

Bryozoans

Live Colony Velocity cm/sec

wt.	Trial A	Trial B	Trial C	$\bar{X}$	SD
117.5g	3.00	3.21	3.12	3.18	0.16
80.5	3.73	4.73	3.62	4.02	0.61
48.0	4.10	3.97	4.17	4.08	0.10
25.0	5.17	4.56	4.92	4.88	0.31
13.7	3.30	4.39	3.61	3.76	0.56

TABLE 8-1. SUMMARY OF THE HYDRODYNAMIC PROPERTIES OF THE HYDROID <u>SERTULARIA</u> <u>ARGENTIA</u> AND THE BRYOZOAN <u>ALCYONIDIUM</u> <u>VERRILLI</u> (Cont'd)

Colony Velocity at Various Flume Velocities (Cont'd)

Flume Velocity 0.61 ft/sec 18.59 cm/sec

Hydroids

Live Colony Velocity cm/sec

wt.	Trial A	Trial B	Trial C	$\bar{X}$	SD
177.0 g	11.71	12.18	10.25	11.38	1.01
56.0	17.32	17.83	17.08	17.41	0.38
53.5	13.67	14.47	12.95	13.69	0.76
22.7	18.09	17.57	--	17.83	0.34
12.7	17.57	17.08	17.83	17.49	0.38
6.4	16.18	18.64	18.36	17.73	1.35

Bryozoans

Live Colony Velocity cm/sec

wt.	Trial A	Trial B	Trial C	$\bar{X}$	SD
364.0 g	11.60	11.50	11.71	11.60	0.11
108.5	9.39	10.08	11.18	10.22	0.90
51.5	10.42	12.30	12.95	11.89	1.31
25.9	8.98	10.80	7.93	9.20	1.39
13.5	8.98	13.08	10.25	10.77	2.10

DISTRIBUTION OF FOULING ORGANISMS AT PIER 12

The distribution of fouling organisms around Pier 12 at the Norfolk Naval Base is quite variable and dynamic. Controlling factors are thought to be tidal currents and wind setup circulation. Once in the Pier 12 berthing area, sedimentation and burial of organisms play a role in keeping the organisms in the berth.

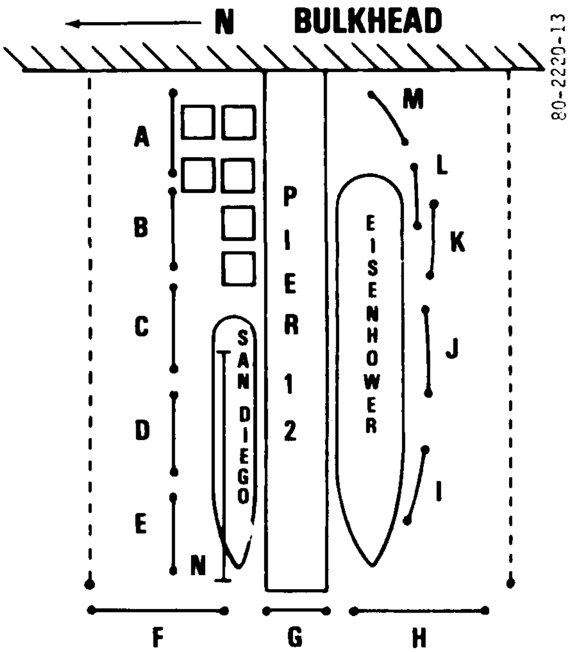
Detailed surveys were conducted in the berthing area on April 1, April 15, and May 12 using a 2 ft oyster dredge dragged for a known distance in order to get quantitive estimates of fouling organisms' densities. Results of these surveys are presented in Tables 8-2, 8-3, and 8-4. There appears to have been a substantial decline in hydroid density from April 1 to April 15 (3941 kg to 1215 kg) in the south berth of Pier 12. The mechanism that moved the hydroids out of the berth is most likely wind-driven circulation. It is also likely that a portion of the hydroids were buried in the berth. There was an increase in the percentage of buried hydroids with each survey period (70% buried April 1, 93% April 15, and 96% May 12). Navy divers have reported finding hydroids buried at least 3 ft below the sediment surface. The oyster dredge we used effectively samples only to sediment depths of 6-8 in. Therefore, while the surface concentrations of hydroids may appear to decline, there may be a net accumulation of hydroids when episodes of high sedimentation occurred.

A gradient of fouling organisms exists in the berthing area with highest densities occurring 400-500 ft from the bulkhead. It seems that the animals tend to pile up in this area on entering the berth. The highest percentages of live animals, an indication of recent recruitment, also occur in this area.

DISTRIBUTION OF FOULING ORGANISMS AROUND PIER 12 AND HAMPTON ROADS

The density of hydroids and bryozoans in Hampton Roads from April 1 to 15 was variable. While no direct comparison can be made with densities in the berthing area, because the area covered by the oyster dredge out in Hampton Roads could not quantified, there were areas, in particular Middle

TABLE 8-2. HYDROID DISTRIBUTION PIER 12
APRIL 1, 1980



Drag	Hydroids Amount	% Live	% Buried
A	2.8 kg*	10	90
B	1.0	40	60
C	4.8	40	60
D	0.4	0	100
E	2.0	40	60
F	0.7	10	90
G	0.1	10	90
H	0.2	0	100
I	0 5	0	100
J	1.3	0	100
K	3.0	0	100
L	8.0	100	0
M	1.7	100	0
N**	3.2	70	30

Drag is 2 ft wide and was towed for 200 ft so area covered was 400 ft^2

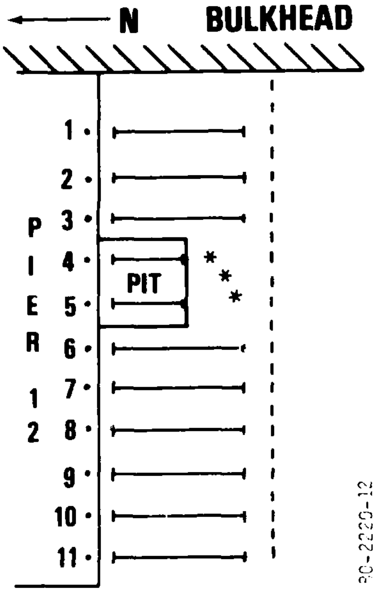
*1 kg wet weight $\approx$ 1 gallon

Total amount in pier area
North side 3634 kg - 7.60 g/ft^2
South side 3941 kg - 7.25 g/ft^2

Drag	Bryozoans Amount	% Live	% Buried
A	0	-	-
B	0	-	-
C	0	-	-
D	0	-	-
E	0	-	-
F	0	-	-
G	0	-	-
H	0	-	-
I	0.3	0	100
J	0	-	-
K	0	-	-
L	2.5	100	0
M	0	-	-
N	0	-	-

** Taken April 2 after San Diego left, 500 ft Drag of 8.0 kg.

TABLE 8-3. HYDROID DISTRIBUTION SOUTH SIDE PIER 12
APRIL 15, 1980



Hydroids

Drag	Amount	% Live	% Buried	Amt for Pier Seg
1	2.2 kg*	30	70	181.2
2	2.2	5	95	181.2
3	1.3	1	99	107.1
4**	2.4	10	90	199.4
5***	2.0	10	90	166.2
6	1.2	10	90	98.8
7	0.6	0	100	49.4
8	0.4	1	99	33.0
9	0.5	1	99	41.2
10	0.3	1	99	24.7
11	0.2	10	90	16.5
			TOTAL	1215.3 kg

Drag is 2 ft wide and was towed for 300 ft so area covered was 600 ft^2

* 1 kg wet weight $\approx$ 1 gallon

** Drag length in pit 130 feet

***Hydroid density in this area taken as average of drag 3 and 6

Bryozoans

Drag	Amount	% Live	% Buried
1	0.1 kg	30	70
2	0.1	5	95
3	0.05	1	99
4	0.9	5	95
5	0	-	-
6	0.1	90	10
7	0	-	-
8	0	-	-
9	0	-	-
10	0	-	-
11	0	-	-

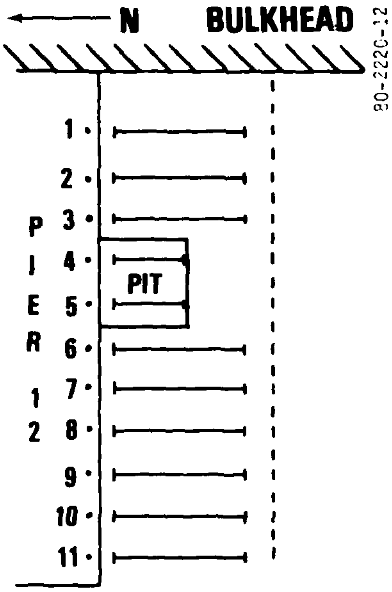
Total volume of Hydrozoans in pier area:

- pit 366 kg
- total pier 1215.3 kg
- 30% of all Hydroids in pit
- density in pit 5 x's higher than rest of pier area

Total volume of Bryozoans in pier area:

- pit 96.9 kg
- total pier 141.9 kg
- 68% of all bryozoans in pit
- density in pit 25 x's higher than rest of pier area

TABLE 8-4. HYDROID DISTRIBUTION PIER 12
MAY 12, 1980



Hydroids

Drag	Amount	% Live	% Buried	Amt for Pier Seg
1	0.9 kg*	10	90	74.1
2	2.5	20	80	205.9
3	1.5	10	90	123.6
4**	2.3	0	100	191.1
5**	2.2	0	100	182.8
6	0.3	0	100	24.7
7	0.2	0	100	16.47
8	0.3	0	100	24.7
9	0.3	0	100	24.7
10	3.3	0	100	271.8
11	1.1	0	100	90.6
			TOTAL	1230.5 kg

Drag is 2 ft wide and towed for 300 ft, area covered was 600 ft^2

* 1 kg wet weight ∿ 1 gallon

** Drag length in pit 130 ft area covered 260 ft^2

Bryozoans

Drag	Amount	% Live	% Buried	Amt for Pier Seg
1	6.7	100	0	551.9
2	0.2	0	100	16.5
3	0.1	0	100	8.2
4**	0	-	-	0
5**	0.4	0	100	33.2
6	1.5	0	100	123.6
7	0	-	-	0
8	0	-	-	0
9	0	-	-	0
10	0	-	-	0
11	0	-	-	0
				733.41 g

Ground (Figure 8-1 and Table 8-5), where it was felt that densities of hydroids exceeded densities in the Pier 12 area. It must be kept in mind that the hydroid, Sertularia argentea and the bryozoan, Alcyonidium verrilli are very abundant over the entire lower Bay during the winter months.

The origin of the hydroids and bryozoans that eventually enter Pier 12 is unknown. Current and circulation patterns in Hampton Roads are very complex, and it may be that only hydroids produced in a certain part of the James River or lower Bay serve as the primary source of fouling organisms to the pier. It is definite that the fouling organisms are not produced in the Pier 12 berths. The pier area acts only as a sink and catches drifting organisms.

RESOLUTION OF THE FOULING PROBLEM

The resolution of fouling problem at Pier 12 can only be engineered with a clear understanding of how the organisms get to the Pier 12 area and the mechanisms involved. It appears that fouling organism movement is related to extreme weather conditions. However we have no data on currents in the pier area during or after extreme weather. Where the organisms originate may also be a key to solving the problem, if there are definable areas in Hampton Roads that serve as primary sources for the organisms in Pier 12. When and at what rate the organisms grow would be helpful in predicting when to expect fouling. Correlation of the historic record of fouling incidents, biological properties (growth distribution), and hydrodynamic properties with meteorological and hydrographic conditions is necessary to predict the fate and movement of hydroids.

The solution to the fouling problem will not be simple. The organisms are too common and widely distributed to be eliminated from the Bay. Dredging the berths deeper and raking can only be considered temporary solutions. The permanent solution must be engineering and based on understanding of the dynamic processes that move the organisms in the Pier 12 area.

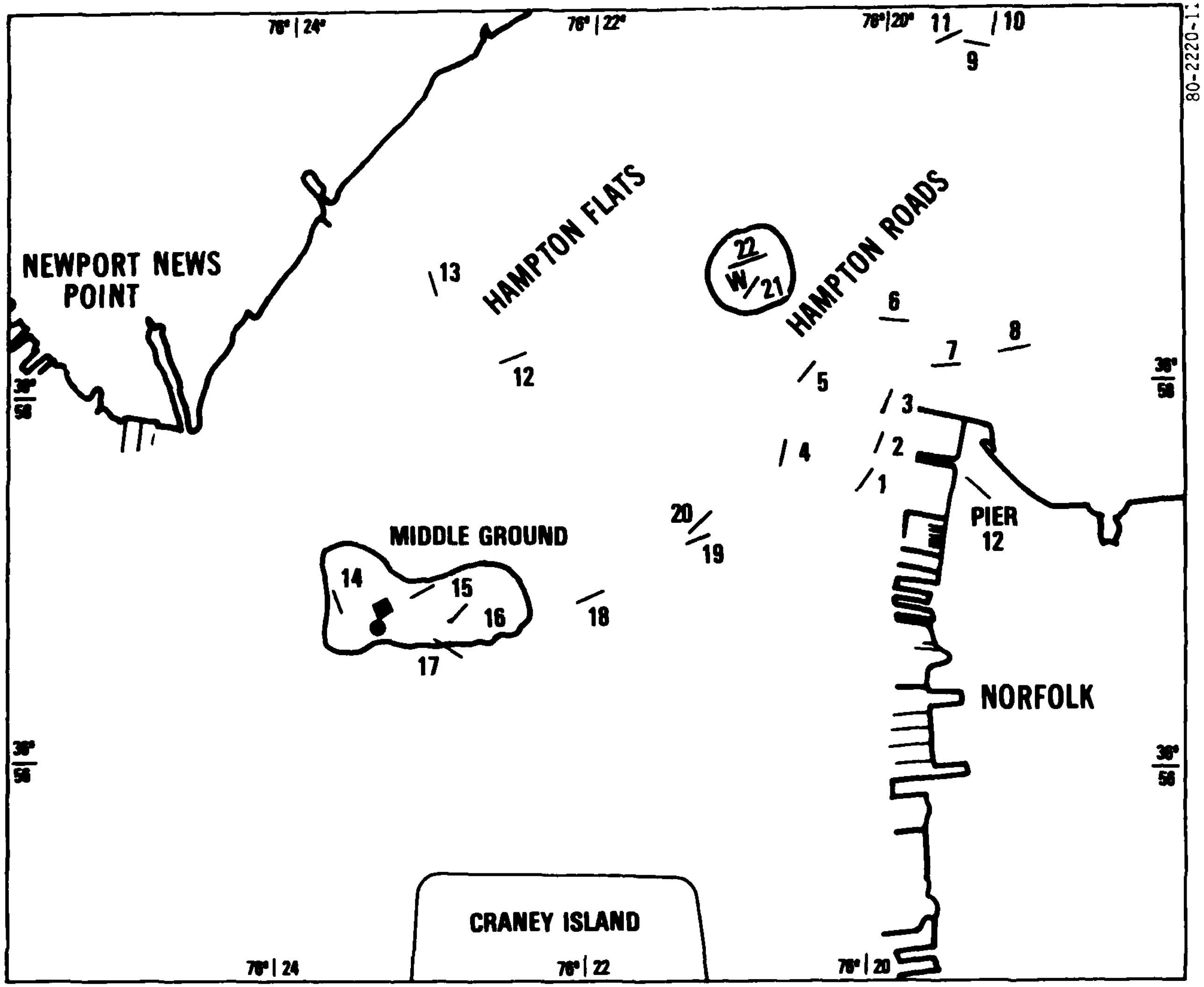


Figure 8-1. Distribution of Fouling Organisms in Hampton Roads from April 1 to 15, 1980. Quantities Collected are Given in Table 5.

TABLE 8-5. HYDROID DISTRIBUTION AROUND PIER 12
AND HAMPTON ROADS - APRIL 1 to 15, 1980

Drag*	Amount	% Live	% Buried	Comments
1	0.2 kg	50	50	No shell
2	0.9	100	0	No shell
3	0.6	100	0	Attached and growing on shells
4	2.0	50	50	No shell
5	3.0	100	0	No shell
6	0.5	100	0	Attached and growing on shells
7	3.0	100	0	Attached and growing on shells
8	0.0	--	--	Just shells
9	3.0	100	0	Mud
10	5.3	100	0	Mud
11	5.0	90	10	In dredged pit - mud
12	0.4	100	0	Attached and growing on shells
13	0.1	100	0	Attached and growing on shells
14	5.2	70	30	Shells, not attached
15	3.5	90	10	Shells, not attached
16	2.7	90	10	Attached and growing on shells
17	12.0	90	10	Attached and growing on shells
18	6.7	100	0	No shell
19	0.7	5	95	Mud
20	0.8	10	90	Mud
21	0.4	100	0	Attached and growing on shells
22	2.0	90	10	Attached and growing on shells

Bryozoans found only at the following:

3	0.2	100	0	Not attached to shells
9	0.9	100	0	Mud
10	2.3	100	0	Mud
11	2.0	90	10	Mud
17	0.3	90	10	Not attached to shells

Drags were approximately two minutes. Area covered was variable so amounts are not strictly quantitive.

* Location of Drags are numbered on Figure 8-1.