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Study and control of marine fouling organisms, Naval Base, Norfolk, Virginia

Morris L. Brehmer
Virginia Institute of Marine Science

Maynard M. Nichols
Virginia Institute of Marine Science

Dale R. Calder
Virginia Institute of Marine Science

CONTRACT REPORT
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STUDY AND CONTROL OF MARINE FOULING ORGANISMS, NAVAL BASE, NORFOLK, VIRGINIA

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Morris L. Brehmer, Ph.D.
Maynard M. Nichols, Ph.D.
Dale R. Calder, M. A.

SUMMARY AND RECOMMENDATIONS

The Virginia Institute of Marine Science investigated the biology and distribution of marine organisms responsible for condenser fouling of deep-draft vessels. Physical studies of Hampton Roads and adjacent parts of Chesapeake Bay were conducted in the prototype and in the hydraulic model at Vicksburg, Mississippi, to determine the net current patterns and transport mechanisms of the area. Control and removal methods were evaluated.

The biological program included 1) identification of marine organisms removed from ship heat exchangers by Naval personnel, 2) a monthly sampling program on the shoals and bars in the vicinity of the Naval Base, 3) monthly and special interval monitoring of the Pier 12 berthing areas and approaches, 4) sub-contracting for and evaluating removal operations, and 5) setting plate studies at Pier 12 and on the shoals of Hampton Roads and Lower Chesapeake Bay. The physical program centered around tracer dye and current drogue studies in the Hampton Roads area and in VIMS' hydraulic model of the James River which is located at the U. S. Army, Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Biological studies indicated that the silvery hydroid, Thuiaria argentea, and the fleshy bryozoan, Alcyonidium verrilli, were primarily responsible for vessel operational difficulties. The monthly sampling program revealed that these colonial animals were developing on the

shoals and bars of Hampton Roads and Lower Chesapeake Bay. These shallow areas are frequently subjected to wave action of sufficient force to break up or dislodge colonies from the substrate and permit transport by currents. Setting plate data indicated that no set was occurring at Pier 12 and that the occurrence of colonies in the berthing areas was entirely due to transport and deposition.

Physical studies in Hampton Roads and in the model verified that the deeper waters have a net "upstream" flow and the surface layer has a net "downstream" flow. Also, current velocities in the pier basins are much lower than those of the access channels or the adjacent waters. This results in a very high deposition rate in the protected area as the silt, clay, and plant and animal forms transported into the basin in suspension "settle out" under the condition of reduced velocities. Once deposited, the probability of resuspension and transport out of the area is reduced by the bottom profile created by the dredged basins.

Once dislodged from the substrate, fragments of or entire colonies of organisms capable of fouling condensers may be transported in suspension in the water column or they may be carried along with the bed load just off the bottom. Because of the tidal current characteristics of the estuary, an extremely large area of Hampton Roads and Lower Chesapeake Bay serves as a source for organisms which might be deposited in the pier basins. Colonies originating from any point within five miles of the pier and held in suspension on either a flood or ebb tide would be deposited in the basins due to the reduced velocities within the area if that water mass entered the basins. Colonies settling out and becoming associated with the bed load outside Hampton Roads or being

dislodged from beds in Chesapeake Bay would be carried back into Hampton Roads by the net "upstream" currents of the area. The large area involved and the complexity of the deposition processes made chemical control of the organisms on the growing areas completely unfeasible. Also, since the fouling problems resulted from transport and deposition rather than from setting and growth in the basins, chemical control was impractical, even in limited areas.

Efforts were directed towards the evaluation of removal methods to eliminate the organisms responsible for condenser fouling of deep-draft vessels. Utilization of readily available commercial crab dredge gear appeared to offer the most efficient and economical method. Sub-contracts were let to a local commercial fisherman to remove the colonies from the berthing and access areas under supervision of Institute personnel.

Post-removal evaluations by both sample dredgings and by reports from Engineering Officers of deep-draft vessels returning to Pier 12 indicated that the density of colonies in the berthing areas had been reduced to levels which did not cause operational difficulties. The cost of a removal operation was less than $1,000.

The data derived from the research and monitoring program performed under this contract indicate:

1. Consideration should be given to an investigation of the methods for decreasing the high rate of sedimentation in the berthing areas and access channel. The high rate of siltation augments the problems created by colonies of marine animals by decreasing the clearance between the bottom and

the sea water intake ports of the vessel, thus increasing the probability that colonies will be drawn into the heat exchangers.

2. The agencies responsible for maintenance of the pier area should monitor the density of the colonies in the berthing sites. Monitoring should be conducted particularly after periods of gale-force winds which produce waves capable of dislodging or fragmenting colonies on the growing areas.
3. The Naval Base should develop the capability for removing organisms from limited areas with commercial crab dredges or have a stand-by contract with a commercial fisherman to perform the service when conditions warrant.

STUDY AND CONTROL OF MARINE FOULING ORGANISMS

Introduction

The Virginia Institute of Marine Science entered a contract (NBy46710) with the U. S. Navy, Atlantic Division, Bureau of Yards and Docks, in 1962 to study the biology, distribution, and control of marine organisms that had been responsible for the fouling of seawater systems of vessels operating in the Hampton Roads area. Special attention was given to the Naval Base berthing areas adjacent to the Norfolk Reach Channel.

The field program was initiated during the winter of 1962 and continued through 1966. The study was designed to gain specific information on the current directions and velocities in Hampton Roads which affect transport and deposition of both sediments and passive marine forms. The biological program was designed to determine the setting and growing areas of the marine animals responsible for operational difficulties.

Preliminary studies showed that the fleshy bryozoan, Alcyonidium verrilli, and the silvery hydroid, Thuiaria argentea, were primarily responsible for condenser fouling. The field investigations indicated that the organisms were setting and growing in areas other than at the berthing sites and that they were being dislodged and carried from the growing areas to the pier basins by currents. Efforts were then concentrated on current studies and on life history studies of the sessile animal community. Methods of control or removal of organisms deposited in the berthing areas were also investigated.

PHYSICAL DESCRIPTION OF HAMPTON ROADS

Hampton Roads, Virginia, is a part of one of the most complex estuarine systems of the world. It comprises the lower part of the James River, the most southerly tributary of Chesapeake Bay. The sedimentary and biological characteristics of Hampton Roads are dependent upon the entire Bay and other tributary streams, on the off-shore characteristics of the Atlantic Ocean, and on the 400-mile long James River upstream from the Roads.

Chesapeake Bay, which serves as a source for most of the water entering Hampton Roads, is one of the largest estuaries in the world. It ranges from five to twenty-five miles in width and is approximately 165 miles long. The drainage area covers approximately 67,000 square miles. The mean freshwater discharge through the system is approximately 80,000 c.f.s. The tributaries include the Susquehanna, Potomac, Rappahannock, York, and the James rivers. The streams south of the Patapsco River and Baltimore Harbor have sufficient salinity in their downstream area to support estuarine and marine flora and fauna.

The James River is tidal from its mouth at Hampton Roads to the Fall Line at Richmond, a distance of approximately 95 miles. The average saltwater intrusion extends to Jamestown Island, 35 miles upstream from the mouth, but the transition zone may shift fifteen miles upstream or downstream with extremes in freshwater run-off.

Hampton Roads covers approximately 25 square miles at the confluence of the James River and Chesapeake Bay. The area is characterized by

extensive shoal areas along both shores. Navigation channels are maintained at 45 feet through Hampton Roads to Newport News and to Norfolk. The tidal range is approximately 2.5 feet and current velocities seldom exceed 1.7 knots.

The physical-chemical characteristics of the Hampton Roads area for the period May 1965 through May 1966 are given in Appendix A.

PHYSICAL ASPECTS OF FOULING PROBLEM

The purpose of this phase was to determine the character of the local pattern of circulation and siltation at Pier 12. It was believed that currents supply the pier basins with silt and fouling organisms from Hampton Roads harbor and vicinity. Deposition of silt raises the substrate level of fouling organisms and brings them within close reach of vessel intake ports. This section of the report provides information of potential use to engineers for improving berthing arrangements at Pier 12.

Observations

The path of water movement in the pier basins and vicinity was traced by use of current drogues and dye. Similar observations were made in a hydraulic model at Vicksburg, Mississippi. In addition, net non-tidal flow was calculated from extensive measurements of the U. S. Coast and Geodetic Survey at anchor stations throughout Hampton Roads. Cores of bottom muds were examined for their texture and composition. Rates of filling were determined from periodic soundings made by engineers of the Naval Base.

Circulation

Circulation in the vicinity of the piers consists of a two-way movement induced by fluctuations of the tide. Within one tidal cycle water reaches the pier from a wide area which extends, on the ebb, "upstream" to the mouth of the Nansemond River and, on the flood, "downstream" to Thimble Shoals. Although most of the tidal flow sweeps past the pier in the Norfolk Reach Channel, small eddies develop about the pier structures at certain phases of the tide. Figure 1 presents the pattern of bottom

circulation depicting the predominant flow at maximum flood current and at maximum ebb, as well as selected phases when the flow leads into the basins for short periods of 1-2 hours. Inasmuch as these inward flows are repeated over many cycles, they lead to a net transport of silt and fouling organisms into the pier basins.

Current velocities in the pier basins are greatly reduced by comparison to flow in the access channel. Water movement of the inner reaches, especially near corners of the pier, is more sluggish than elsewhere. The slow movement provides a good settling environment for suspended materials carried into pier and slack water permits very fine-grained material to settle out. Once deposited, a greater movement is required to remove the mud from the basin floor than is required to maintain it in suspension. Deposition is active in the basins at velocities less than 0.1 knot. Flows greater than 0.1 knot would be required to maintain most of the material in suspension for deposition elsewhere.

The location of the pier--at the confluence of the Elizabeth River with the mouth of the James River estuary--favors high rates of sediment deposition. Current velocities near the bottom off Sewells Point reach more than 1 knot, but in the access channel off Pier 12 velocities are less than 0.5 knot. In these areas also, the bottom character changes from scour, off Sewells Point, to fill, just south of Pier 12 in the Elizabeth River where deposition averages 0.8 foot per year.

The quantity of material introduced into the pier basins depends on the net non-tidal flow; that is, the residual flow after the flood and ebb motion of the tidal flow is averaged out over many tidal cycles. U. S. Coast and Geodetic Survey measurements indicate a pronounced net seaward

(north) flow of the near-surface water in the access channel and a very slight net seaward flow near the bottom. It seems probable that the net flow is part of a harbor-wide two-layered estuarine system with a small net upstream flow (south) in the access channel off the pier most of the time. This current, typically enriched with suspended materials near the bottom, supplies coarse-grained sediment and organic debris from seaward reaches off the mouth of the harbor, whereas the near-surface current, draining the Elizabeth River, supplies very fine-grained sediment and water rich with planktonic organisms.

Sediment also enters the pier by diffusion along the pier-channel boundary at all depths. Since velocities in the channel maintain higher suspended concentrations than quiet waters of the pier basin, a gradient exists which necessitates an inward transport of suspended materials by eddy and molecular processes. Flocculation and subsequent settling out are not of major importance in the pier basins. The pier is a considerable distance from entering rivers; salinity is intermediate (12-25 ‰) and there is no sharp fresh-salt water interface.

Sedimentation

Bottom "muds" on the pier basin floor consist of silty clay rich in diatoms. These microscopic plants make up about 30% of the mud, whereas common quartz constitutes 30% and clay minerals 40%. In addition, there are small proportions of shell fragments, mica, cinder, organic detritus, and microfauna of Foraminifera and ostracods. Interestingly, many of the forams are fossil specimens of Miocene age. Presumably, they were derived from the harbor by scour of the channel floor or perhaps by erosion of former spoil deposits near the harbor mouth.

A comparison of bottom soundings taken in 1961 and again in 1963, 18 months later, shows that filling in the basins varies from place to place. Figure 2 presents the pattern of fill above the 40-foot depth. Greatest shoaling is concentrated in the inner reaches of the north pier basin and substantial quantities are evident along sides of the south basin. In addition, a shallow sill extends southward across the north basin in a pattern that suggests deposition from flood currents directed upstream along the access channel.

In summary, bottom muds consist of a mixture of sediment introduced into the pier basins from both upstream and downstream sources at late phases of the tide.

Considerations for Improvement

To retard the high rate of siltation in the pier basins, consideration should be given to eliminating the exchange of silt-laden water between the access channel and the pier basins near the bottom. Attention should be directed to the relative depth of the access channel in relation to the depth of the pier basins. Siltation might be retarded by maintaining the access channel 5-10 feet deeper than the pier basin and by maintaining a natural sill across the entrance of the basins. These measures would assist in retaining sediment-charged bottom water in the main access channel.

Enclosure of the pier basins by gates would obviously minimize siltation; however, deposition might continue around exterior parts of the structures. Siltation could be minimized by structures designed to provide a free flow through the pier basins sufficient to keep the sediment in suspension and carry it elsewhere.

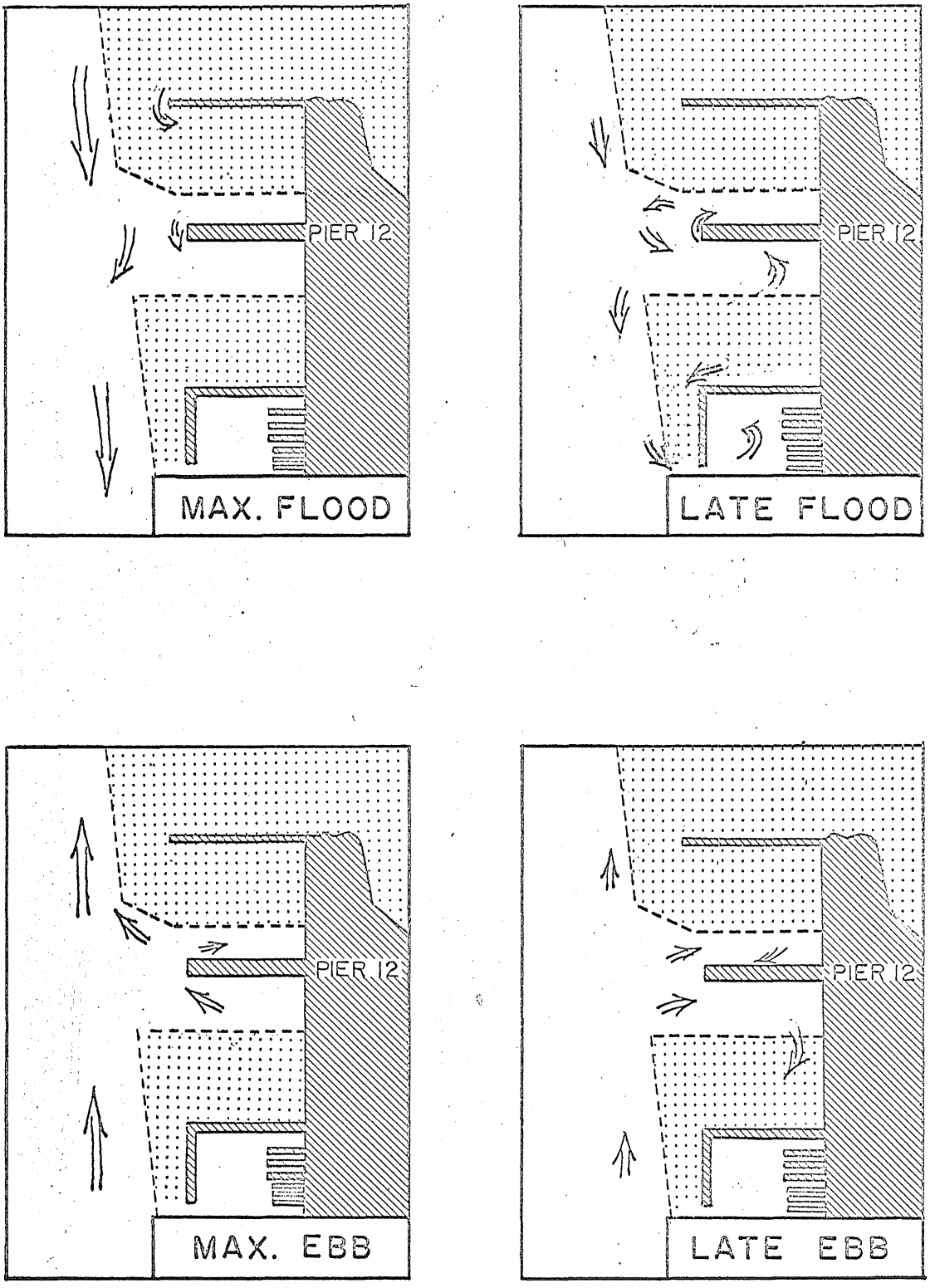

Figure 1. Circulation pattern at Pier 12 and vicinity for different phases of the tide. Length of arrow represents relative current velocity near the bottom.

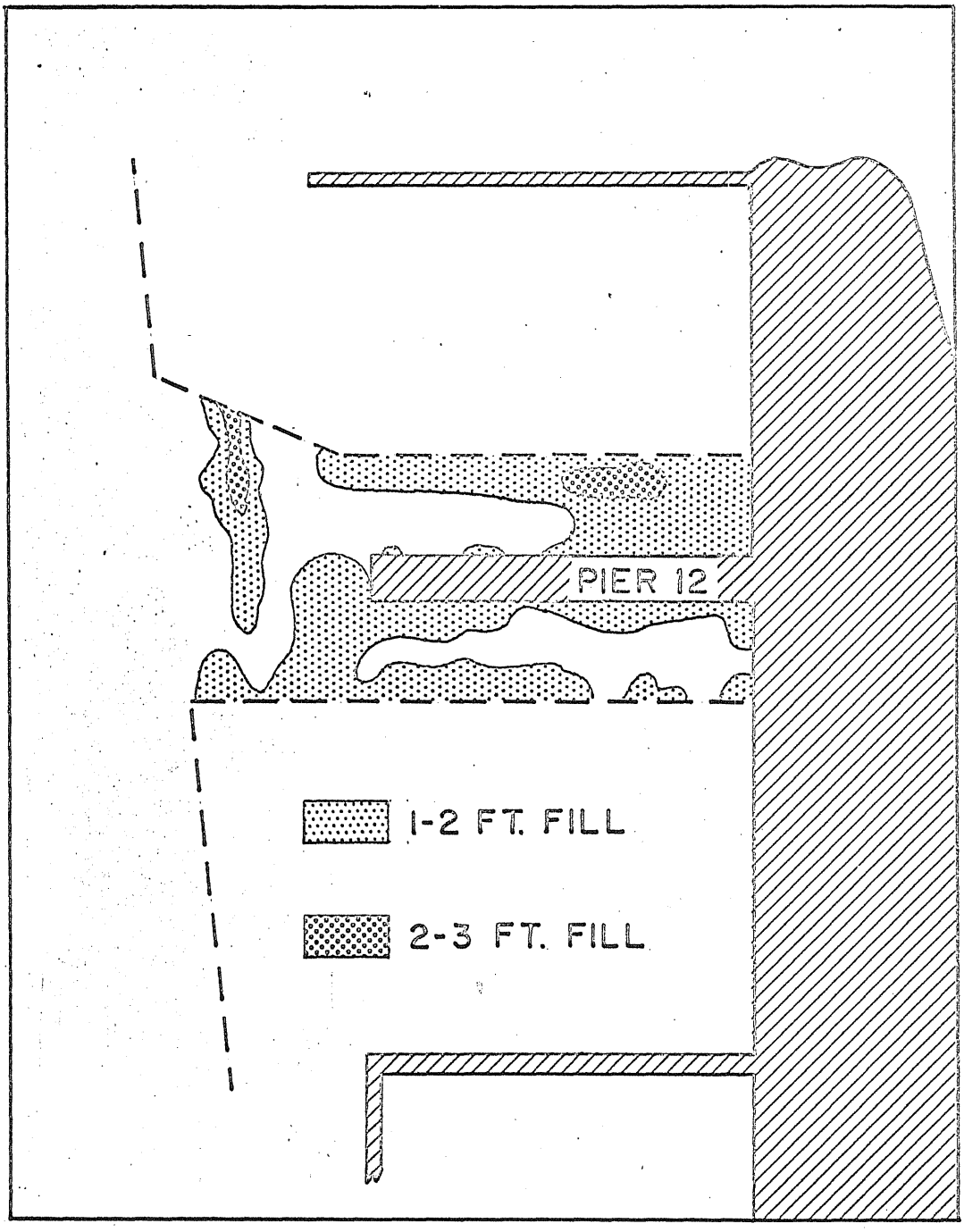

Figure 2. Distribution of siltation rates in pier basins during an 18-month period, 1961-1963.

BIOLOGICAL STUDIES

Preliminary biological studies indicated that the two organisms primarily responsible for shipboard condenser fouling were the silvery hydroid (Thuiaria argentea) and the fleshy bryozoan (Alcyonidium verrilli). In addition, samples of marine organisms recovered from the heat-exchange systems of deep-draft vessels contained occasional specimens of sargassum weed (Sargassum sp.), red algae (Agardhiella type), blue mussel shells (Mytilus edulis), crabs, and fish. The latter five groups or species did not constitute a sufficient volume to produce operational difficulties.

The "stringy, grass-like" colony of the silvery hydroid may grow to a height of 10 to 12 inches and occupy a volume of several cubic inches. The colonies consist of many individuals (hydranths) located alternately on a common stem. The hydranths die during the summer but the remaining stems are extremely resistant to decomposition and may be observed throughout the year. In early fall, new growth begins and proceeds rapidly. The colony reaches maximum size in late winter or early spring through asexual reproduction.

Sexual structures (gonangia) appear in mid-autumn and reach maximum abundance in early winter. Planula larvae are produced in and released from the gonangia and, after a free-swimming period, settle on a firm substrate, such as shell or rocks, and develop into the hydranth form. New colonies then develop by asexual reproduction. Stolons which develop at base buds form additional stalks to give the colony its typical "bushy" appearance.

Colonies of the silvery hydroid may also be distributed by fragmentation. Stalks bearing individuals may become dislodged from the original set and carried by currents to a new location. In this condition, the colony survives, continues to grow, and is capable of sexual and asexual reproduction as long as the polyps are free to feed.

The fleshy bryozoan, Alcyonidium verrilli, develops into a yellowish or tan colony which may occupy a cubic foot of volume. The colony consists of many thousands of very small animals imbedded in a common gelatinous matrix.

The morphological characteristics of the adult animal (zooid) imbedded in the gelatinous matrix can only be examined under magnification. The lophophore (part bearing feeding structures) normally withdraws behind a pleated collar when the animal is disturbed. After a few minutes of rest, the "neck," mouth parts, and tentacles extend through the collar and feeding commences.

The portion of the adult animal permanently imbedded in the gelatinous sheath contains the circulatory, digestive, and sexual reproductive systems encased in a cuticular body wall.

Sexual reproduction apparently occurs in the late spring. The newly-hatched larvae form a bivalve-type shell and spend several weeks as a free-swimming stage feeding on minute organisms. The mature larvae settle on a firm substrate, such as shell, rock, or hydroid stems, and metamorphose into the adult form which produces new zooids by budding.

New colonies may also be established by fragmentation. If pieces of an established colony are broken off by wave action or by mechanical means, they may be carried into areas unsuitable for larval setting, be

mechanically anchored by silt or possibly held in place by lack of current action, and proceed to develop large colonies by asexual reproduction.

Both of the animal forms primarily responsible for operational difficulties of deep-draft naval vessels require a silt-free substrate for initial set and growth. Core samples and dredging data for the berthing areas indicate a high rate of siltation which results in unsuitable setting areas for the larval stages. Samples of organisms dredged from alongside the piers also indicated that the colonies were not attached to shell or other forms of suitable substrate. The colonies were, however, increasing in size after being deposited in the area by asexual reproduction.

POPULATION STUDIES

A review of the ecology of the silvery hydroid and fleshy bryozoan indicated that the colonies were developing in Chesapeake Bay or in Hampton Roads, being dislodged by wave action, and being transported into the pier area by currents. A monthly sampling program was initiated to evaluate the populations on the shoals and shell areas which serve as setting and growing areas for the organisms.

The initial field sampling program involved a monthly survey of twelve stations, six in Hampton Roads and six in Chesapeake Bay. The number of stations was later reduced to seven by eliminating all but the Thimble Shoal station in Chesapeake Bay (Figure 3). The stations were designated as follows:

Station 1 . . . . . Pier 12, Naval Base
Station 2 . . . . . Newport News Middle Ground
Station 3 . . . . . Hampton Bar
Station 4 . . . . . Sewells Point
Station 5 . . . . . Sewells Point Spit
Station 6 . . . . . X-Ray Station
Station 7 . . . . . Thimble Shoal.

The stations were occupied monthly through the 1966 growing season. A modified oyster dredge was pulled along the bottom for five minutes at each station in qualitative studies on the epifauna. The dredged organisms were examined, identified, recorded, and disposed of on station. Only specimens of interest or those requiring laboratory examination were retained.

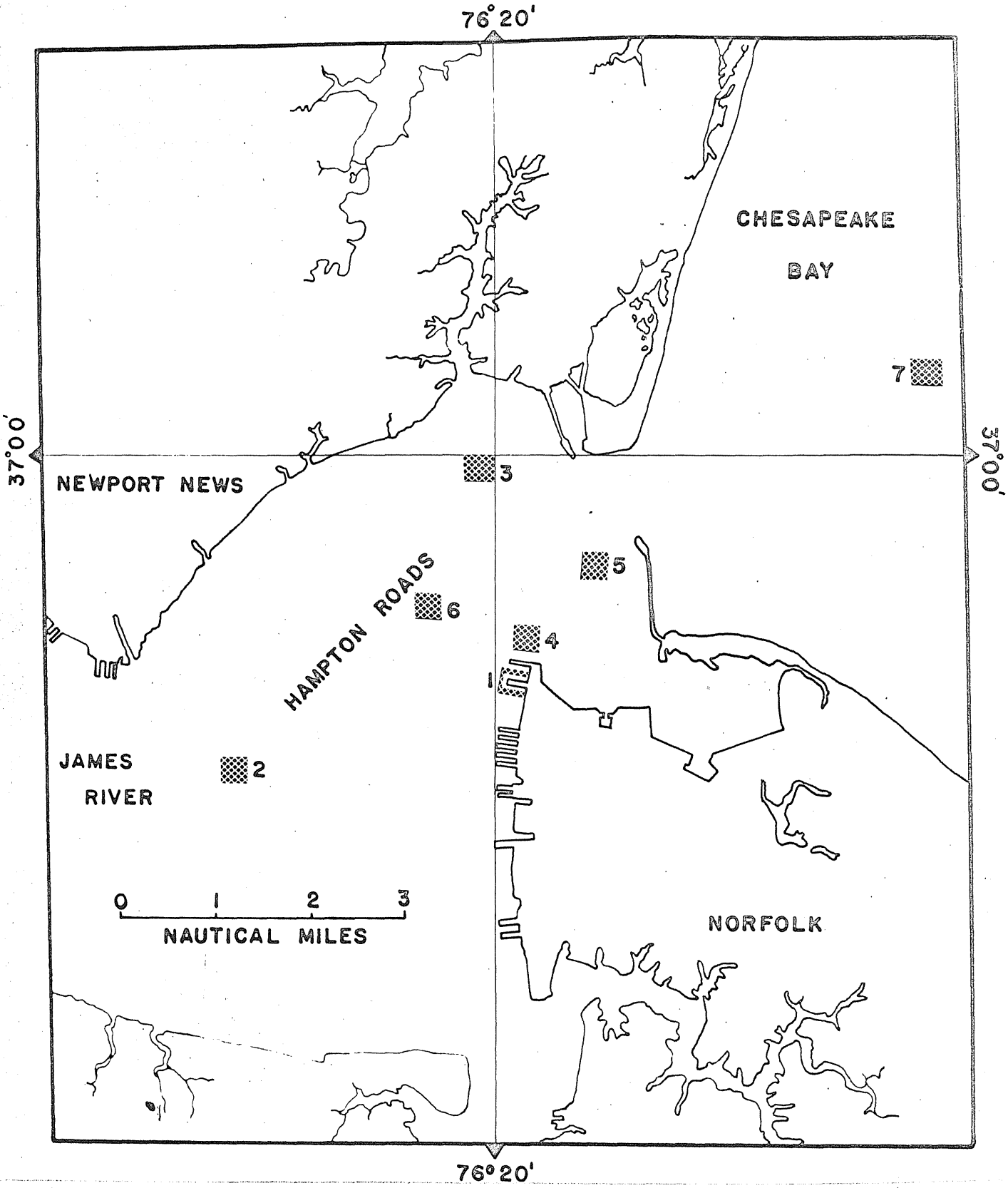

Figure 3. Chart of Hampton Roads and adjacent waters, showing the stations occupied in the study.

Test panel studies were conducted at Pier 12, Naval Base, and at irregular intervals due to recovery problems at Newport News Middle Ground, Hampton Bar, Sewells Point Spit, and Thimble Shoal to determine the seasonal abundance of fouling organisms in the Hampton Roads area.

The panels consisted of rectangular asbestos fiber plates mounted in sets of five on a wooden support and submerged with a concrete block. The sets were exposed for a month, removed and returned to the laboratory, and the attached organisms were identified and enumerated. From 1 June 1965 to 2 August 1965, panels were replaced twice monthly at Pier 12 since a heavy set of tunicates during this period hindered analyses of the fauna on panels exposed for one month.

RESULTS

The dredging and panel studies proved conclusively that the two organisms primarily responsible for the fouling of shipboard seawater systems were not setting and growing in the berthing areas. Hydroids, such as Bougainvillia rugosa, were recovered from the panels but not from condenser cleanings. The large population of the tunicate, Molgula manhattensis, that developed on the panels and on the supporting structures of the pier during the summer months contributes to the sedimentation problem in the berthing areas but does not interfere with vessel operations. Barnacles and the other marine filter-feeding organisms also settle and grow on the supporting structures and increase the rate of sedimentation by bio-deposition of suspended solids.

A summary of the monthly dominance changes in the faunal forms found on the test panels is given in Figure 4.

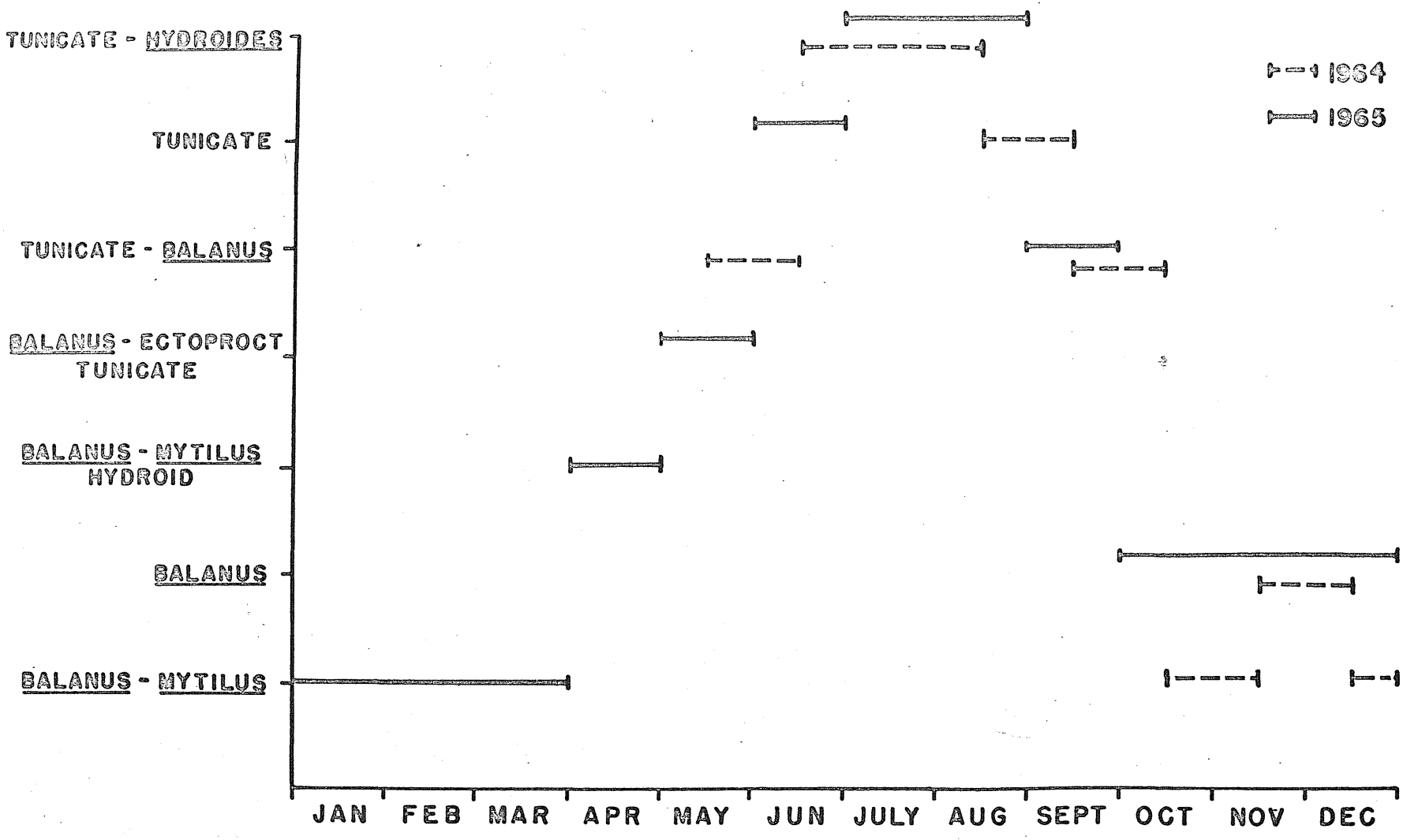

Figure 4. Monthly dominance changes on test panels at Pier 12.

The dredge sampling program indicated that the major growing area for the silvery hydroid was on Newport News Middle Ground. This area was at one time an excellent oyster ground but the shellfish population has been destroyed by disease and predators. The area is shelly and presents an ideal substrate for setting of the larval stages. The water depth is less than 20 feet and therefore frequently subjected to wave action. Small populations of the hydroid were recovered at the other six sampling stations but the densities never approached those found on the Newport News Middle Ground area.

The largest attached populations of the fleshy bryozoan were found on Sewells Point Spit and on Hampton Bar. Both these areas are characterized by a hard bottom, with sufficient shell present to provide an ideal substrate for setting and growth. No conclusive explanation can be given for the absence of heavy populations of silvery hydroids on these areas since the substrate is similar to that at the Newport News Middle Ground beds. Since the hydroid is less abundant in very shallow waters, this may explain the paucity of colonies in these areas.

The fleshy bryozoan population on the bars in Chesapeake Bay appears to fluctuate widely between years. Heavy concentrations were not encountered outside of Hampton Roads during the period of this contract but fishermen and crabbers describe populations of previous years which hampered their operations.

Operations such as the dredge and test panel sampling program result in the recovery of specimens representing most epifaunal groups indigenous to an area. Although forms other than the silvery hydroid and the fleshy bryozoan were not found to produce condenser fouling problems, the organisms

were identified and recorded to aid in describing the community. Tables 1-8 list the species of organisms collected, the sampling area, and the method of collection.

TABLE 1

SPECIES OF PORIFERA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Cliona sp.	2-5, 7	dredge
Halichondria bowerbanki	1-5	test panel, dredge
Microciona prolifera	1-7	dredge
Lissodendoryx isodictyalis	1-3, 5	dredge

TABLE 2

SPECIES OF HYDROZOA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Aselomaris michaeli	1	test panel
Bougainvillia rugosa	1,2	test panel, dredge
Calyptospadix cerulea	1	test panel
Eudendrium album	2	dredge
Hydractinia echinata	1	test panel
Pennaria tiarella	1	test panel
Tubularia crocea	1-4	test panel, dredge
Campanularia gelatinosa	5	dredge
Clytia edwardsi	1	test panel
Gonothyraea loveni	1,5	test panel, dredge
Obelia bicuspidata	1,3	test panel, dredge
Obelia commissuralis	1,5	test panel, dredge
Opercularella pumila	5	dredge
Sertularia cornicina	3	dredge
Thuiaria argentea	1-7	test panel, dredge
Schizotricha tenella	1-5	test panel, dredge

TABLE 3

SPECIES OF ANTHOZOA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Leptogorgia virgulata	2	dredge
Diadumene leucolena	1,2,5	test panel, dredge
Aiptasiomorpha luciae	1-3	test panel, dredge
Ceriantheopsis americanus	1-3	dredge

TABLE 4

SPECIES OF ECTOPROCTA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Alcyonidium verrilli	1-7	dredge
Victorella pavida	1,5	test panel, dredge
Amathia vidovici	1-5	dredge
Amathia convoluta	2	dredge
Aeverrillia armata	1-6	dredge
Membranipora tenuis	1-6	test panel, dredge
Electra crustulenta	1-6	test panel, dredge
Schizoporella unicornis	5,7	dredge

TABLE 5

SPECIES OF POLYCHAETA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Lepidonotus sublevis	1,2,4	test panel, dredge
Sabellaria vulgaris	1,2,5	test panel, dredge
Fabricia sabella	1	test panel
Hydroides hexagona	1-6	test panel, dredge
Polydora ligni	1-7	test panel, dredge

TABLE 6

SPECIES OF MOLLUSCA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Nucula proxima	2	dredge
Yoldia limatula	7	dredge
Anadara transversa	1-3,5,6	test panel, dredge
Anadara ovalis	2,6	dredge
Brachidontes recurvus	1	test panel
Mytilus edulis	1,6	test panel, dredge
Anomia simplex	1-7	test panel, dredge
Crassostrea virginica	1,5,7	test panel, dredge
Laevicardium mortoni	2	dredge
Mercenaria mercenaria	2,5,6	dredge
Tellina agilis	2	dredge
Macoma tenta	2,5	dredge
Tagelus divisus	2	dredge
Ensis directus	2	dredge
Mulinia lateralis	1,2	dredge
Lyonsia hyalina	2,5	dredge
Bittium sp.	2	dredge
Crepidula fornicata	1-3,5	test panel, dredge
Polinices duplicatus	3	dredge
Eupleura caudata	2,3,5	dredge
Urosalpinx cinerea	1,2,4,5	dredge
Anachis avara	1-5	dredge
Mitrella lunata	2	dredge
Busycon canaliculatum	1,6	dredge
Nassarius vibex	1-7	dredge
Mangelia sp.	2	dredge
Haminoea solitaria	2	dredge
Retusa canaliculata	1,2	dredge
Corambella depressa	-	dredge
Unident. nudibranchs	-	test panel, dredge

TABLE 7

SPECIES OF ARTHROPODA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Pycnogonida		
Anoplodactylus parvus	1	test panel
Callipallene brevirostris	1,3	test panel, dredge
Tanystylum orbiculare	1	test panel
Cirripedia		
Balanus eburneus	1	test panel
Balanus improvisus	1-5,7	test panel, dredge
Isopoda		
Cyathura burbancki	2	dredge
Amphipoda		
Ericthonius brasiliensis	5	test panel
Elasmopus pocillimanus	1	test panel
Caprellidae	1-5,7	test panel, dredge
Decapoda		
Palaemonetes pugio	2,7	dredge
Crangon septemspinosa	1-5,7	dredge
Upogebia affinis	2	dredge
Euceramus praelongus	2	dredge
Pagurus longicarpus	1-5,7	dredge
Callinectes sapidus	1,2,4-6	dredge
Xanthidae	1-6	dredge
Libinia dubia	1,3,5-7	dredge
Stomatopoda		
Squilla empusa	1	dredge

TABLE 8

SPECIES OF TUNICATA COLLECTED IN HAMPTON ROADS

Species	Station	Collection Method
Perophora viridis	2,3	dredge
Botryllus schlosseri	1-6	test panel, dredge
Symplegma viride (?)	1,4	test panel, dredge
Molgula manhattensis	1-6	test panel, dredge

CONTROL AND REMOVAL STUDIES

Methods for the control and/or removal of fouling organisms from the berthing areas were investigated.

Preliminary data, confirmed by later detailed studies, indicated that the two forms primarily responsible for operational difficulties of deep-draft vessels were setting and growing on the shoals of Hampton Roads or Chesapeake Bay, were dislodged by wave action, and then carried into the berthing areas by currents. The physical studies indicated that the berthing areas were natural areas of deposition and that the current velocities were further decreased by the submerged structures and channel characteristics. Fouling organisms once deposited inside the Norfolk Reach Channel would have a low probability of being removed by natural hydraulic forces and would, in fact, be anchored in place by sediment depositions. The organisms have the capability for enlarging the colony size by asexual division once they are redeposited in a new area.

Chemical treatment was investigated as a means of halting new growth of newly deposited colonies. Preliminary studies indicated that the two organisms were quite resistant to commonly used control agents. The studies were discontinued when it became apparent that the chemical screening program that would be required was beyond the scope of the contract. The feasibility of chemical control was also doubtful because (1) the colonies are extremely resistant to decomposition and would continue to hamper vessel operations even after complete treatment, and (2) *in situ* growth appeared to account for only a very small percentage of the biomass of organisms present.

Efforts were concentrated on techniques which would physically remove the colonies from the operational areas. A small oyster-type dredge which could be towed with a small boat had been utilized to sample the epifaunal community of shoals and bars in estuaries. Personal observations of commercial fishing operations indicated that the standard size dredge used to harvest oysters and hibernating blue crabs frequently collected large quantities of the silvery hydroid and the fleshy bryozoan. When collected during fishing operations, extra effort was required to sort the shellfish from the "grass and pussly," the local names for the two organisms.

Permission was obtained to utilize and evaluate a commercial crab dredging unit in the Pier 12 area. Deep-draft naval vessels had encountered operational difficulties after a period of gale-force winds had apparently dislodged a large number of colonies and they had been deposited in the berthing areas by currents. A commercial crab dredging vessel equipped with two dredges was employed to dislodge and recover the organisms, and then transport them away from the area for disposal. The operation was supervised by Institute personnel.

Although the operation was hampered by the presence of paint cans, line, cable, and other man-made detritus which reduced the efficiency of the dredges, the 16 hours of effort yielded approximately 15 cubic yards of material. Samplings with the small dredge indicated that the density of colonies was greatly reduced and no vessel operational difficulties were reported.

A second evaluation of the efficiency of commercial crab dredging gear in removing condenser fouling organisms from limited areas was made

after the USS ENTERPRISE CVA(N)65 reported difficulties after being berthed at Pier 12. Three days of effort were required to reduce the population of organisms from the Norfolk Reach Channel to the bulkhead at the head of the pier. After the operation was completed, the USS ENTERPRISE returned to the pier, was berthed for several days, and returned to sea. After clearing the Thimble Shoals Channel, the vessel notified the Command that she had experienced no operational difficulties from marine fouling organisms while in port or while departing for sea duty. This information confirmed previous observations, indicating that commercial crab dredging equipment could be utilized to remove marine organisms responsible for operational difficulties of deep-draft vessels from limited areas.

A third removal program was initiated and evaluated in February 1966. The results were again very satisfactory and information received indicated that operations of deep-draft vessels using Pier 12 were not hampered by fouling organisms. The monitoring program was continued through the contract period but the data did not indicate the need for another removal operation during this time.

The Virginia Institute of Marine Science sub-contracted for the construction of a small sampling dredge which can be operated from an 18 to 20-foot boat. This has now been transferred to the Public Works Center, Naval Base. The Institute also recommended that the Naval Base make arrangements with a commercial crab dredger to remove the colonies of organisms from the berthing areas when the sampling program indicated that the density had reached levels which might produce difficulties for deep-draft vessels.

In conclusion, an efficient, economical method for the removal of condenser fouling organisms from limited areas, such as berthing sites and access channels, was demonstrated and verified.

APPENDIX A

PHYSICAL AND CHEMICAL CHARACTERISTICS OF JAMES RIVER AT 36°57.4'N - 76°22.5'W (Mid-Channel off Pier 12) FROM MAY 1965-MAY 1966*

Legend

Depth	- Sample depth at slack before flood tide
Temp	- Water temperature
Salinity	- ‰ or g kg^{-1}
DO	- Dissolved oxygen
Alk	- Alkalinity
pH	- Hydrogen ion concentration
SS	- Suspended solids
LOI	- Loss on ignition
FR	- Fixed residue
TOT. P.	- Total phosphorus
SRP	- Soluble reactive phosphorus
PRP	- Particulate reactive phosphorus
SUP	- Soluble unreactive phosphorus
PUP	- Particulate unreactive phosphorus
NO_2.N	- Inorganic nitrogen as nitrite
NO_3.N	- Inorganic nitrogen as nitrate
OPN	- Organic particulate nitrogen
Chl.a	- Chlorophyll a

*Data not collected under contract but included to describe the environment.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF JAMES RIVER
AT 36°57.4'N - 76°22.5'W (Mid-Channel off Pier 12)
FROM MAY 1965-MAY 1966

Date	Depth (M)	Temp (C)	Salinity (‰)	DO (mgl^{-1})	ALK ($meql^{-1}$)	pH	SS (mgl^{-1})	LOI (mgl^{-1})	FR (mgl^{-1})
20 V 65	1	20.4	18.47	7.43	1.63	7.4	16.4	8.2	8.2
	3	20.2	18.95	7.47		7.7			
	5	19.6	20.20	7.98		7.8			
	7	19.6	20.04	7.39	1.58	7.7	21.2	10.4	10.8
22 VI 65	1	21.9	19.69	7.06	1.58	7.6	7.2	2.6	4.6
	3	21.7		6.76		7.5			
	5	21.5	21.46	6.46		7.4			
	7	21.9	22.22	6.40	1.66	7.3	10.0	2.4	7.6
14 VII 65	1	26.0	21.29	7.07	1.59	7.7	16.5	8.8	7.7
	3	25.8	21.35	6.73		7.7			
	5	25.6	21.69	6.28		7.6			
	7	25.5	22.79	5.96	1.68	7.5	11.6	9.8	1.8
12 VIII 65	1	25.2	23.56	6.26	1.76	7.8	8.4	1.2	7.2
	3	25.2	23.73	6.22		7.9			
	5	24.9	24.40	5.58		7.9			
	7	24.7	24.61	6.04	1.81	7.9	20.2	4.2	16.0
15 IX 65	1	25.2	23.82	5.99	1.75	7.9	28.5		
	3	25.1	23.87	5.97		7.8			
	5	25.1	24.01	5.97		7.6			
	7	25.7	24.15	5.85	1.81	6.6	33.9		
15 X 65	1	18.8	23.70	7.11	1.66		10.4	4.1	6.3
	3	18.8	23.91	7.15					
	5	18.8	23.98	7.07					
	7	18.7	24.09	7.03	1.69		12.0	5.0	7.0
29 XI 65	1	11.2	23.50	8.72	1.62	8.0	11.14	4.0	7.14
	3	11.3	24.03	8.54		8.0			
	5	11.4	24.53	8.32		7.45			
	7	11.2	24.36	7.16	1.65	6.7	10.14	2.57	7.57
14 XII 65	1	9.0	24.19	5.39	1.80		16.00	6.91	9.09
	3	8.8	24.22	8.41					
	5	8.7	24.27	4.98					
	7	8.9	24.24	6.40	1.82		21.00	4.75	16.25
13 I 66	1	5.9	23.79	9.82	1.64		15.11	2.89	12.22
	3	5.8	23.92	9.84					
	5	5.8	24.03	9.70					
	7	5.8	24.05	9.76					
	9	5.7	24.03	9.84	1.70		24.00	3.75	20.25
13 III 66	1	6.8	16.39	10.33	1.40	8.05	26.67	7.34	19.33
	3	6.8	16.78	10.58		7.95			
	5	6.8	17.70	10.56		7.85			
	7	6.8	17.33	10.45	1.42	6.70	33.00	10.67	22.33

Date	Depth (M)	Temp (C)	Salinity (‰)	DO (mgl^{-1})	ALK ($meql^{-1}$)	pH	SS (mgl^{-1})	LOI (mgl^{-1})	FR (mgl^{-1})
11 IV 66	1	11.2	19.75	10.38	1.54	8.05	27.33	16.33	11.00
	3	11.1	19.86	10.13		8.00			
	5	11.1	20.06	10.08		7.95			
	7	11.2	20.34	10.04		7.80			
	9	11.0	20.69	10.04	1.49	7.80	31.67	12.34	19.33
11 V 66	1	16.4	17.26	8.52	1.40		22.00	7.33	14.67
	3	16.2	17.62	8.34					
	5	16.0	19.02	8.10					
	7	16.0	19.57	7.85					
	9	16.0	19.76	7.89					
	11	15.6	19.86	7.85	1.50		21.50	6.25	15.25

Date	Depth (M)	TOT. P (ug.at l^{-1})	SRP (ug.at l^{-1})	PRP (ug.at l^{-1})	SUP (ug.at l^{-1})	PUP (ug.at l^{-1})	NO_2.N (ug.at l^{-1})	NO_3.N (ug.at l^{-1})	OPN (ug.at l^{-1})	Chl.a (ugl^{-1})
20 V 65	1	0.97	0.03	0.15	0.38	0.41	0.23		4.82	4.23
	7	0.68	0.10	0.06	0.17	0.35	0.19			3.04
22 VI 65	1	2.04	1.25		0.13	0.89	0.54	10.1		4.06
	7	1.50	0.70	0.15	0.37	0.28	0.43	4.8	2.80	2.70
14 VII 65	1	1.83	0.40	0.10	0.30	1.03	0.03	5.0	0.40	11.20
	7	1.93	0.56	0.14	0.44	0.79	0.04	4.4	3.20	4.23
12 VIII 65	1	2.13	1.10	0.00	0.40	0.63	0.06	<1.00	2.53	4.91
	7	2.13	1.06	0.00	0.49	0.58	0.04	<1.00		5.25
15 IX 65	1	2.60	1.85	0.01	0.39	0.35	0.50	1.40	2.38	2.70
	7	2.54	1.85	0.00	0.30	0.39	0.49	1.45	6.02	2.60
15 X 65	1	2.66	1.90	0.20	0.42	0.14	0.80	5.12	0.80	2.87
	7	2.58	1.90	0.20	0.33	0.15	0.80	5.70	2.04	2.53
29 XI 65	1	2.15	1.10	0.12	0.50	0.43	0.15	1.00		7.35
	7	1.90	0.95	0.12	0.47	0.36	0.20	0.80		6.04
14 XII 65	1	1.90	0.52	0.20	0.43	0.75	0.03	0.79		14.09
	7	1.93	0.55	0.20	0.47	0.71	0.04	0.82	4.90	13.84
13 I 66	1	2.01	0.95	0.18	0.41	0.42	0.10	1.45	0.80	7.63
	9	2.08	0.92	0.20	0.44	0.52	0.06	1.45	11.00	6.10
13 III 66	1	1.90	0.16	0.12	0.31	1.31	1.43	19.20	2.31	22.54
	7	1.98	0.11	0.16	0.34	1.37	1.20	20.00	14.19	11.28
11 IV 66	1	2.23	0.15	0.08	0.32	1.68	0.60	2.80	17.13	21.60
	9	2.43	0.15	0.12	0.28	1.88	0.47	2.00	8.58	13.36
11 V 66	1	1.41	0.20	0.05	0.40	0.76	0.53	8.20	6.60	11.28
	11	1.33	0.20	0.08	0.24	0.81	0.39	3.80	8.63	8.65