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TECHNICAL REPORT

A STUDY OF THE TYPES, SEASONS OF ATTACHMENT, AND GROWTH OF FOULING ORGANISMS IN THE APPROACHES TO NORFOLK, VIRGINIA

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ABSTRACT

This report describes a marine biological fouling program conducted near Thimble Shoal Channel in lower Chesapeake Bay. The results of 12 months' (April 1956 to April 1957) fouling data on mine case test panels are presented.

Observations of water temperature, salinity, currents, transparency, and underwater visibility were taken in conjunction with the monthly observations of the fouling complex. Additional data from tide stations for past years were analyzed to determine whether the environmental factors for 1956-57 were within the range of averages. Apparently this was not an unusual year. Therefore, the results of this study are considered reliable.

Fouling organisms began to attach in May and reached peak attachment in August. In general, attachment was limited to periods when the water temperature was above 65°F. Growth of the organisms, following the period of peak attachment, continued at a rapid rate from August to October. Attachment of fouling organisms from October through April was practically nil. However, growth continued from October through April, but at a reduced rate.

Test panels accumulated a total of 31 ounces of growth (wet weight in air) per square foot per year. The predominant fouling organisms were barnacles, calcareous tubeworms, hydroids, bryozoans, jingle shells, and tunicates. Attachment periods and growth of each of these organisms are described in detail, and the possibility of using this information to determine the length of time an object has been submerged is discussed. The results thus obtained will be verified or modified as additional information is obtained from the second 12 months' data at the same location.

ACKNOWLEDGMENT

Acknowledgment is made of the efforts of the Harbor Defense Unit, Norfolk in providing the necessary services and facilities which made possible the collection of the data reported herein. In addition to performing its primary function, the Harbor Defense Unit, Norfolk has demonstrated its value as a "Pilot Unit" for making an operational evaluation of marine biological fouling to promote better understanding of military oceanography and improve harbor defense procedures.

ERRATA

6 August 1958

1. Page 11, par. 3, last sentence should read, "Size determinations become less reliable with time, however, and the sizes determined for the 10- and 11-month panels may not be representative."

2. Page 23, par. 5, first sentence should read, "Total wet weight of fouling accumulated at the rate of 31 ounces per square foot per year for the period April 1956 to April 1957."

FOREWORD

This developmental report describes the methods, results, and conclusions from the first year's data obtained from a cooperative program between the U. S. Navy Hydrographic Office and the Mine Hunting Unit (now a part of the Harbor Defense Unit) at Norfolk, Virginia. Additional reports will follow describing the second year's data and a second test site.

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A STUDY OF THE TYPES, SEASONS OF ATTACHMENT, AND GROWTH OF FOULING ORGANISMS IN THE APPROACHES TO NORFOLK, VIRGINIA

I. INTRODUCTION

In April 1956 the Division of Oceanography initiated a study to determine the biological fouling complex and the rate of fouling on test panels near the bottom in the entrance to Chesapeake Bay. Specific objectives of the study were: 1) to assess the predominant foulers, their seasons of attachment, and their rates of growth in the channel approaches to Chesapeake Bay, and 2) to determine the feasibility and value of this type of data collection in other harbors and approaches. In addition, the information might be used to determine the length of time objects had been on the bottom where time of submergence was unknown.

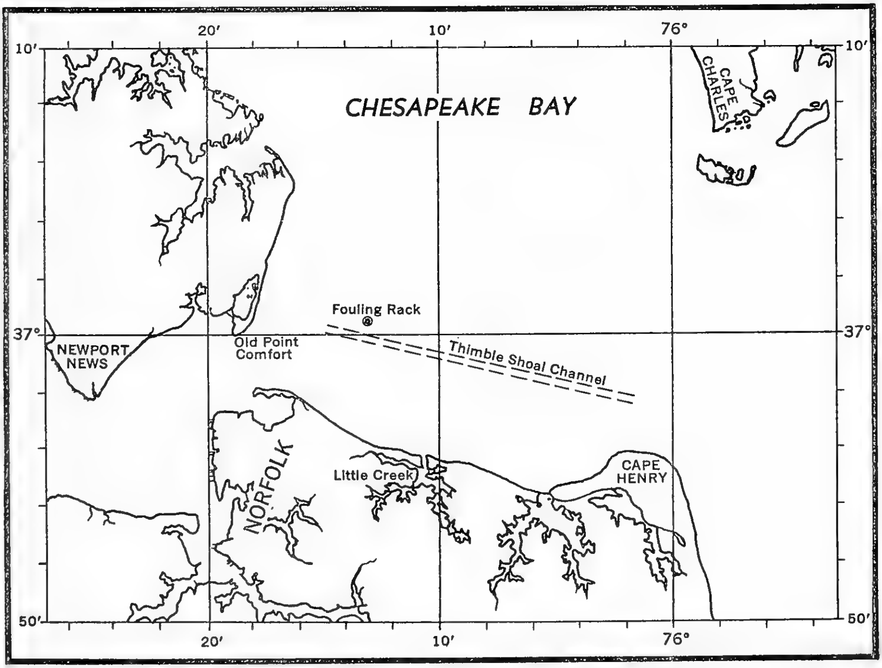


FIGURE 1. FOULING RACK LOCATION CHART

In April 1957 the collection of a 12-month series of data was completed. The study was continued for another year at the present location (Fig. 1) to verify the first year's data. In addition, another rack of test panels was submerged at a location farther out in the channel to ascertain the type of spatial variation to be expected. The results reported here will be substantiated or modified based on these additional data.

II. METHODS AND MATERIALS

Figure 1 shows the test location in Chesapeake Bay. The following considerations were used in the selection of the site. The site had to be close enough to the channel to be representative of the type of fouling occurring in the channel. However, ship traffic precluded locating it directly in the channel. The site had to be somewhat protected so that a small diver's boat (a converted LCM) could operate at the location in rough weather. It also had to be located in a depth of water which would not be unduly restrictive on diver descent and ascent. The location chosen was near a shoal-marker buoy at the edge of Thimble Shoal Channel in 38 feet of water.

A fouling rack, designed and built by personnel of the Mine Hunting Unit, was constructed so as to have sufficient weight and stability to remain in place on the bottom under conditions of strong current flow, such as occur in this area. The rack was designed to hold 13 fouling test panels in a vertical position suspended 3 feet off the bottom. The test panels were attached to the rack by means of hooks which permitted easy removal and replacement by suited divers wearing heavy gloves. Figure 2 is a sketch illustrating the construction of the rack. Figure 3 is a view of the rack prior to placement at the test location.

The test panels, which had been cut out of mine cases, were curved steel plates 15 1/4 inches by 8 inches by 1/8 inch, weighing 68 ounces and having a total surface area of 1.7 square feet. The panels were painted with standard black enamel which is used routinely on ground mines. Holes were drilled through the panels to permit suspension from the hooks on the rack.

The rack was submerged, and 12 test panels were attached by a diver. The location was visited at regular monthly intervals, and test panels were removed and replaced according to a schedule designed to expose them for various lengths of time from 1 to 12 months. Figure 4 shows the panel manipulation schedule and the exposure

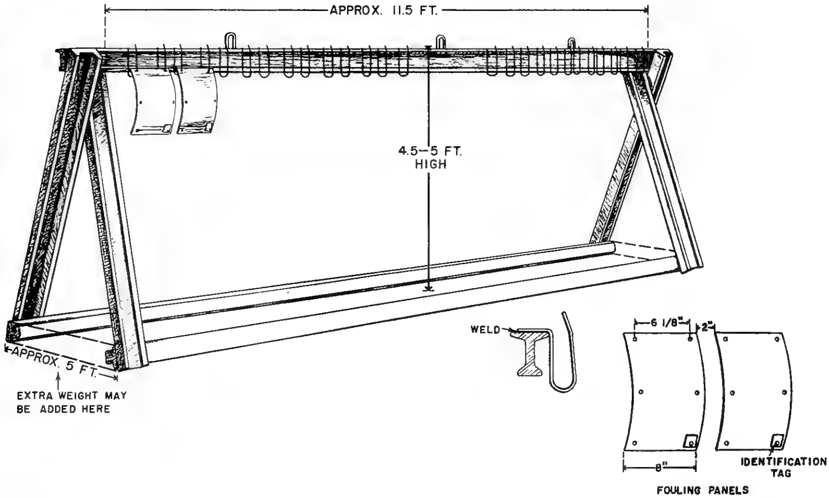


FIGURE 2. SKETCH OF BIOLOGICAL FOULING RACK

NOTE:
Additional rails were welded to the bottom of the legs to add stability.

FIGURE 3. BIOLOGICAL FOULING RACK AS ORIGINALLY CONSTRUCTED

POSITION OF PANELS IN RACK												DATES
1st Pos.	2nd Pos.	3rd Pos.	4th Pos.	5th Pos.	6th Pos.	7th Pos.	8th Pos.	9th Pos.	10th Pos.	11th Pos.	12th Pos.	
1	2	3	4	5	6	7	8	9	10	11	12	17 APRIL 1956
1 13												16 MAY 1956
13 14	**2** 15											19 JUNE 1956
14 NO NO.		**3** 16										13 JULY 1956
NO NO. 17	**15** 18		**4** 19									15 AUGUST 1956
17 20				**5** 21								13 SEPTEMBER 1956
20 22	**18** 23	**16** 24			**6** 25							9 OCTOBER 1956
22 26						**7**						14 NOVEMBER 1956
26 27	**23** 28		**19** 29				**8**					11 DECEMBER 1956
27 30		**24** 31						**9**				9 JANUARY 1956
30 32	**28** 33			**21**					**10**			13 FEBRUARY 1957
32 34										**11**		19 MARCH 1957
34	**33**	**31**	**29**		**25**						**12**	16 APRIL 1957

LEGEND

INSERTION OF TEST PANEL

REMOVAL OF TEST PANEL

NUMBERS DENOTE IDENTIFICATION TAG NUMBER ATTACHED TO EACH TEST PANEL.

FIGURE 4. TEST PANEL INSERTION AND REMOVAL SCHEDULE

periods. Observations of water temperature, salinity, currents, transparency, and underwater visibility were made at the rack location during each monthly visit.

Test panels were identified by a number engraved on a plastic tag attached to each panel. Before immersion each test panel was weighed in sea water and in air. At the termination of its exposure period, each panel was again weighed in sea water and in air. Immediately after removal, each test panel was examined and an estimate made of the percent of surface of both concave and convex sides covered by various fouling organisms. The panels were photographed, packed in preservative, and returned to the Hydrographic Office for careful examination to determine the type and number of foulers.

The various large forms, such as tunicates, bryozoans, and colonial hydroids on each panel were counted and the maximum and average height and diameter were determined. Smaller forms were counted by means of a random strip sampling technique. A template designed to expose a unit of surface area of the panel was laid across portions of the panel showing representative fouling types; numbers and sizes of the various organisms within the unit area were then determined. By this method, the total number of organisms on the panel was computed along with the maximum and average sizes of each form. The examination was performed on both the concave and the convex sides. Following this identification and counting procedure, the panels were allowed to dry thoroughly over a period of days and were again photographed. Specific identification of most organisms has not yet been made.

III. RESULTS

In April 1957, one complete year of fouling data, indicating the seasonal progression and degree of fouling, was accumulated.

A. Environment

The fouling rack is situated in a typical estuarine location. Currents are tidal, the flood setting westward and the ebb eastward. The surface current is strong, averaging 1.5 knots at maximum flood and ebb. The current near the bottom at the fouling rack is somewhat weaker, averaging 0.5 knot but at times attaining 1.0 knot at maximum flood or ebb. During all seasons a positive salinity gradient exists between the surface and the bottom. The strength of this gradient depends primarily on the stage of the tide. Strong gradients occur during flood and somewhat weaker gradients during ebb. Salinities ranged from 19‰ to 27‰ (parts per thousand) throughout the year. Negative temperature gradients or isothermal conditions occur during summer. These conditions depend almost completely upon the meteorological conditions. During periods of slight winds or calms the surface is strongly heated, and a sharp temperature gradient develops between the surface and depths of 5 to 10 feet. Following periods of moderate or strong winds, the temperature structure is either isothermal from surface to bottom or shows an isothermal layer overlying a moderate negative gradient extending to near the bottom. During winter the temperature gradient is weakly positive.

The transparency of the water is generally low. Secchi disc measurements, taken with a white (Secchi) disc approximately 12 inches (30 cm.) in diameter, range from 1/2 to 3 feet. Water transparency measurements with a white light hydrophotometer indicate that throughout the year the light transmission at the surface ranges from 20 to 40 percent of light transmission in air, whereas at 5 feet above the bottom the transmission ranges from about 5 to 15 percent of that in air.

The question immediately arises as to whether the 1956-57 period was typical wi.h regard to environmental factors. Biological activity is dependent to a large degree on water temperature. A preliminary means of determining how closely the test period approximated an average year is to compare observed sea surface temperatures at the test site with average temperature data for the surrounding area. The Coast and Geodetic Survey has compiled surface temperature observations for the tide gage station at Old Point Comfort for the years 1943 to 1945 and 1948 to 1954. Monthly mean maximum, mean, and mean minimum temperatures for the tide gage station are shown in Figure 5 along with the observed sea surface temperatures at the fouling rack location. The figure indicates that temperatures at the test location during the test period were within the average range for the area, although during the first part of the period they were consistently lower than the mean, and during the latter part of the period they were consistently higher than the mean. On the basis of water temperature, therefore, biological activity in 1956-57 was probably close to average. The collection of an additional year of data will serve to indicate the validity of this conclusion. The plot of mean and observed salinities, shown in Figure 6, also indicates that this element varied within the average range for the test period.

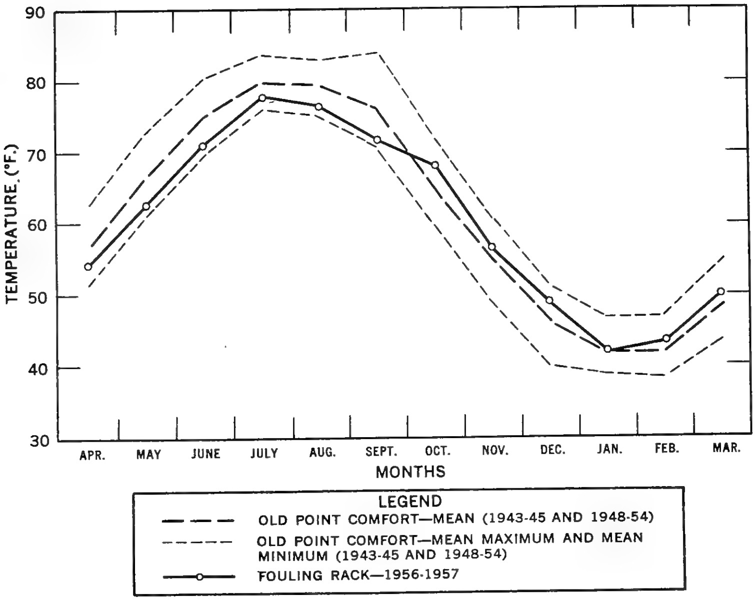


FIGURE 5. SEA SURFACE TEMPERATURES

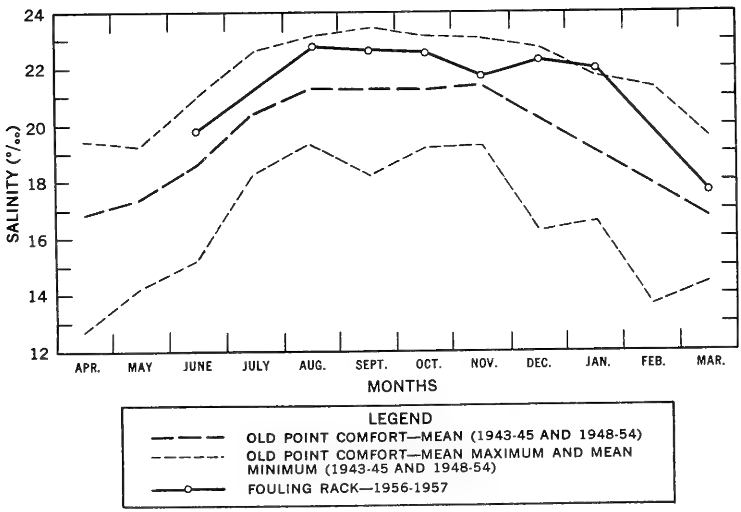


FIGURE 6. SEA SURFACE SALINITIES

B. Weight

The weight of the fouling complex on each panel was determined in an effort to make a quantitative estimate of the rates of setting and growth of organisms. Panels exposed for 1-month periods can be considered to represent primarily the setting rate of organisms, although some growth also occurs during the month. Panels exposed for longer periods (2 months, 3 months, etc.) are considered to represent the accumulation resulting from both setting and growth. Figure 7 shows the wet weight (in air) in ounces of the fouling on 1-month, 2-month, and 3-month panels. The weight of the fouling on 1-month panels indicates that little or no biological attachment occurred from October through April. Organisms began to set in May and reached peak setting in August. The weight of fouling on 2- and 3-month panels indicates that setting and subsequent growth of organisms were most rapid during the period August to October. Surface water temperatures near the fouling rack increased in May to 67°F. and decreased in October to 65°F. (Fig. 5). Attachment in this area appeared to be limited generally to the period when temperatures were above 65°F. The curves showing the weight of fouling on panels exposed for 2 and 3 months indicate that growth proceeded at a rapid rate after attachment had reached its peak. The sharp drop of the curves after October is significant because it indicates lack of subsequent growth following cessation of attachment in September and October.

Figure 8 is a plot of accumulated wet weight (in air) of fouling on panels exposed for increasing lengths of time and the cumulative weight of fouling on panels exposed for 1-month periods. The accumulated weight curve exhibits a typical sigmoid shape resulting from both attachment and growth. New attachment began in May. Both attachment and growth went on at an accelerated rate from July to September. New attachment decreased sharply in September, whereas growth continued at a relatively rapid rate for the remainder of the test year. New attachment declined to practically nil from October through April.

C. Organisms

1. Barnacles

Barnacles were the first macroscopic organisms to appear on the panels after the start of the test in April. Figure 9A is a plot of the number of individuals, their average diameter, and average height on the monthly panels from April 1956 through March 1957. Barnacle

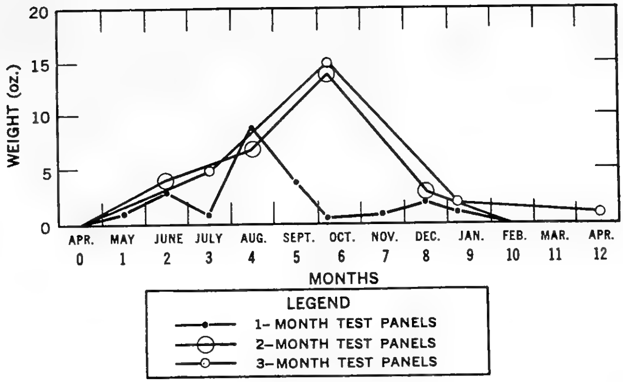


FIGURE 7. TOTAL WET WEIGHT (IN AIR) OF FOULING

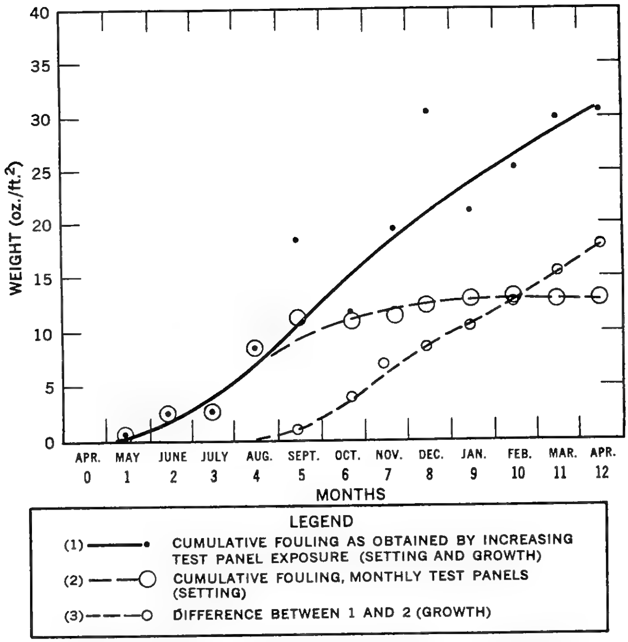


FIGURE 8. ACCUMULATED WET WEIGHT (IN AIR) OF FOULING

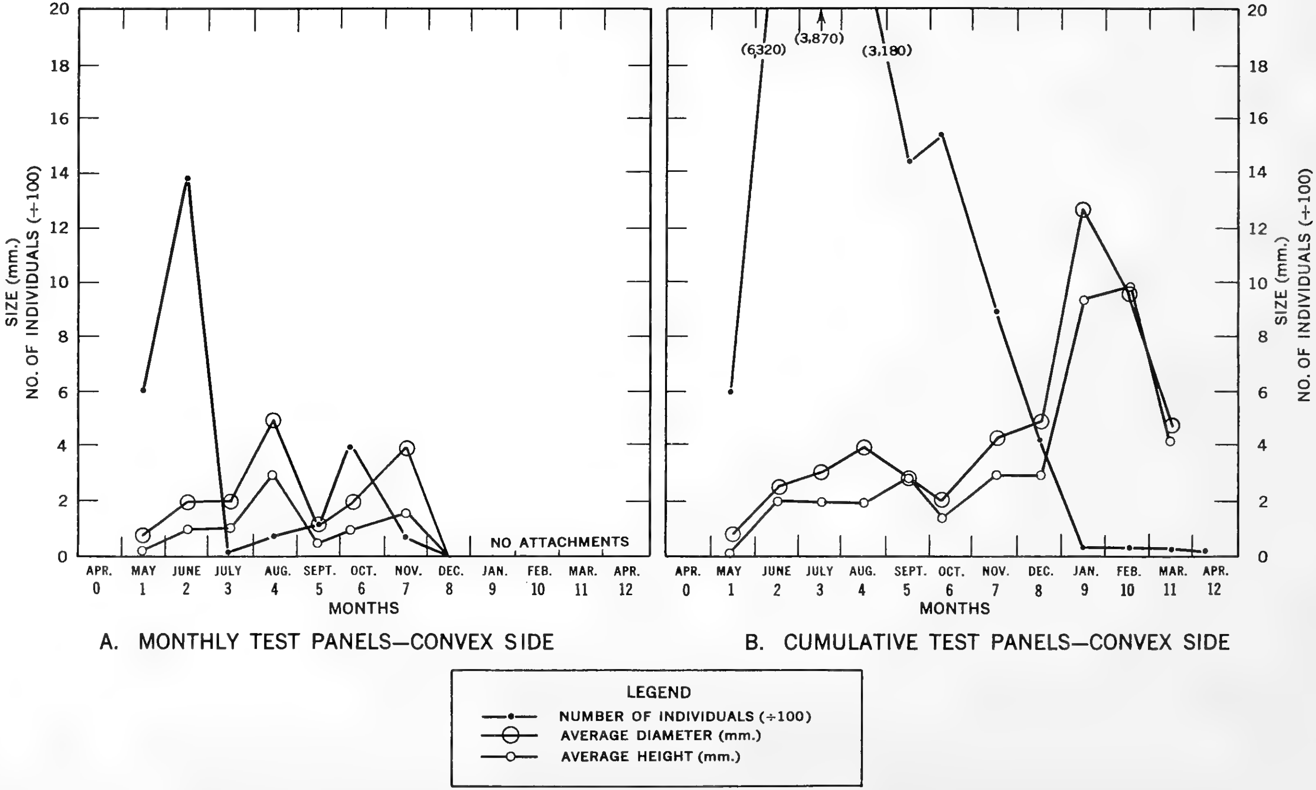


FIGURE 9. BARNACLE FOULING

attachment began in April, reached its yearly maximum in June, decreased markedly during July, and reached a secondary maximum in October. Barnacles did not appear on the panels from December through March. Andrews (1953) gives the peak setting period for one species of barnacle (Balanus improvisus) as May and August or September. The presence of the primary and secondary maxima has three possible explanations: 1) two separate spawnings of the original spawning stock occurred; 2) the secondary maximum represents a second generation resulting from the individuals setting in May and June; 3) the two maxima indicate two different species having different breeding seasons. The first setting was composed of Balanus improvisus, and although this species has been identified in the second setting, no other species was positively determined to be present in the second set.

A possible indication of the competition between individuals for both food and space may be gained by comparing the size curve with the curve representing the number of individuals. During the short time available for individuals to grow (1 month), the average size attained was much greater during the period of minimum attachment than during periods of maximum attachment.

Figure 9B shows plots of number and size of barnacles attaching to panels exposed for progressively longer periods. On these panels barnacles appeared in great numbers during May and June but correspondingly fewer were found on panels exposed for progressively longer periods. This rapid decrease in numbers with time probably indicates that the numbers of dead barnacles increase as the numbers of succeeding foulers increase. After the 7th month most observed barnacles were dead. Many others were overrun by bryozoans and colonial hydroids making a count of individuals difficult. Barnacles which were not overrun by other fouling forms continued to increase in size. Size determinations of dead organisms become less reliable with time, however, and the sizes determined for the 10- and 11-month panels may not be representative.

Plots were made of sizes and numbers of barnacles only on the convex side of panels. However, the trends of numbers and size on the concave side were similar to those on the convex side.

2. Colonial Hydroids

The number of colonies and the average length of colonial hydroids are plotted in Figure 10. Figure 10A shows the results obtained from

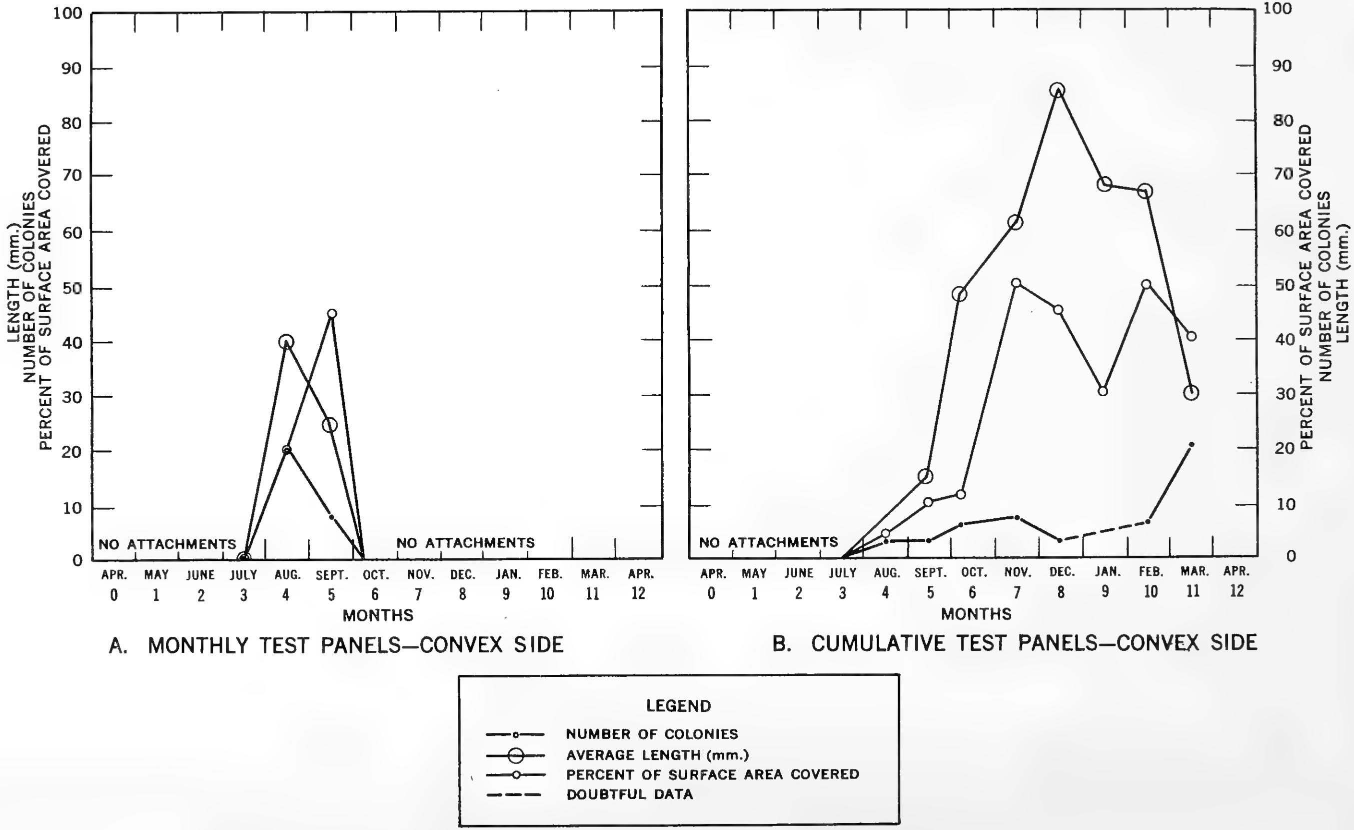


FIGURE 10. COLONIAL HYDROID FOULING

the convex side of the 1-month panels. Colonial hydroids appeared only from July though September, reaching their maximum attachment rate in August. These organisms did not appear on monthly panels exposed from October through June. Figure 10B shows the numbers and lengths of colonial hydroids attaching to the convex side of panels exposed for progressively longer periods of time. As with the monthly panels, colonial hydroids appeared first between July and August. The number of colonies remained fairly constant, indicating that setting took place only over a relatively short period of time, a fact agreeing with data from the monthly panels. The growth, in terms of the average length of the colonies, showed a rapid increase from August through December with a sharp decline following. This is in agreement with the report of Andrews (1953), which indicates that hydroids attain dense woolly growth during late autumn and winter and disappear during spring. Colonial hydroids were equally numerous on both convex and concave sides.

3. Calcareous Tubeworms

Figure 11 shows the number of individuals and length of tubes of calcareous tubeworms on the monthly and cumulative panels. Tubeworm setting, as indicated by plots of the monthly panels (Fig. 11A), began in late June or early July and continued through October. The greatest intensity of setting occurred in August; tubeworms did not attach from November through June. The cumulative panels (Fig. 11B) indicate that the number of individuals attaching to panels increased until September and then remained essentially constant until December. The rapid decrease in numbers of organisms occurring after December may be attributed to the difficulty experienced in counting them when the total mass of fouling became large. Probably, the actual numbers of tubeworms remained constant at about 700 per panel. More complete information probably will be forthcoming from additional data. Tubeworms, as indicated by the average length on the cumulative panels, made their most rapid growth during the period July to September and exhibited virtually no additional growth from October through March.

4. Encrusting Bryozoans

Plots of the total number and average diameter of encrusting bryozoans on monthly and cumulative panels are shown in Figure 12. The monthly panels, which indicate the degree of setting, showed two periods of peak bryozoan activity (Fig. 12A). The first and greater occurred during July, while the second and somewhat more moderate

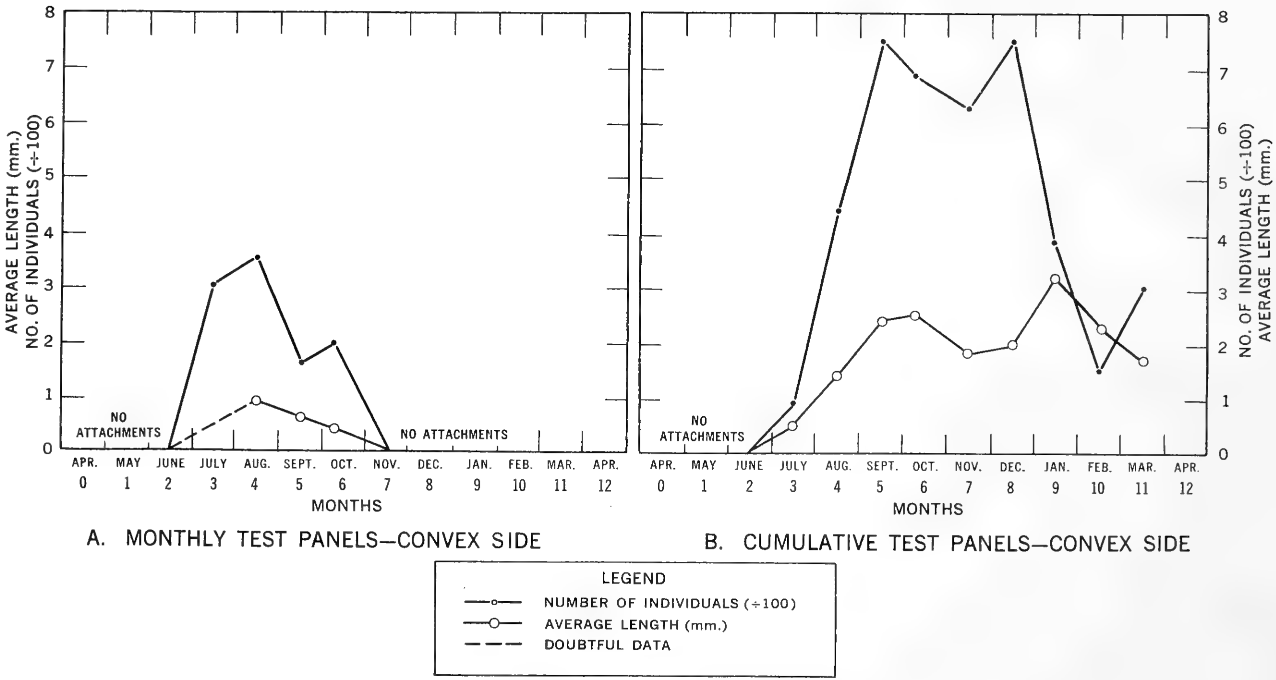


FIGURE 11. CALCAREOUS TUBEWORM FOULING

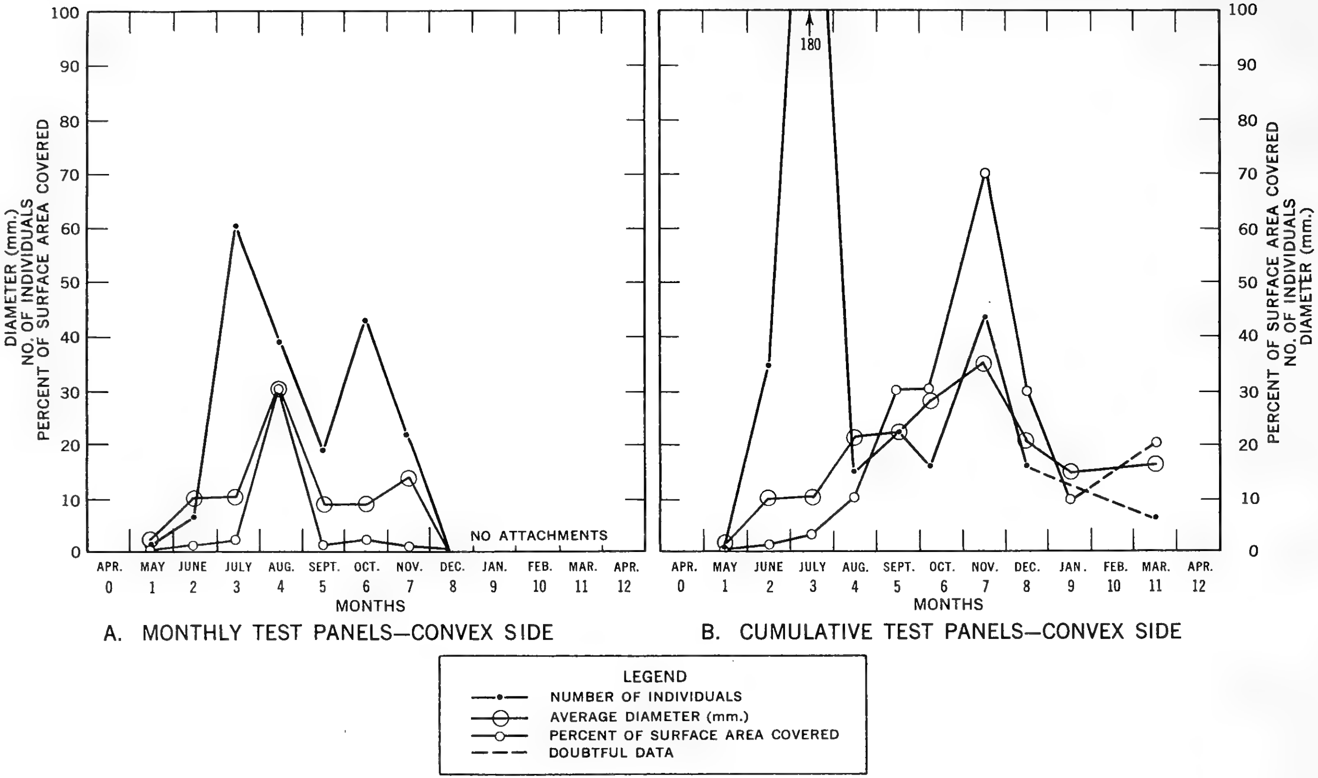


FIGURE 12. ENCRUSTING BRYOZOAN FOULING

occurred during October. Bryozoans did not attach during the period December through March. The monthly panels also showed a 1-month lag between the maximum average size and maximum number of individuals, indicating that growth was more rapid when competition was less. The cumulative panels also indicate two periods of maximum setting activity (Fig. 12B). The first occurred, as with the monthly panels, during July; however, the second period, indicated by these data, was during November. The trend of the average size curve on the cumulative data plot indicates that bryozoans continued to grow at a relatively constant rate from the time setting first began in June until November. The drop in average size in December is interpreted as further evidence of a new set resulting in a "statistically" smaller average size.

5. Jingle Shells

Figure 13 illustrates number and average diameter of jingle shells attaching to the monthly and cumulative panels. The plot of monthly data (Fig. 13A) indicates that jingle shells appeared first during late July or early August in great numbers. Setting continued through October. They did not appear on monthly panels from November through June. The average diameter curves show that jingle shells grew most rapidly during the period of peak attachment. The cumulative panel data (Fig. 13B) indicate, as did the monthly panels, that maximum setting occurred in August. The decrease in number of individuals with increasing exposure time is interpreted as indicating mortality. It appears that jingle shells were gradually replaced or overrun by other forms. Andrews (1953) reports that Anomia (jingle shells) reach full size and die during winter. The size plot shows the growth rate of individuals and indicates an initial increase of size of attaching individuals followed by a period of steady growth of the surviving individuals.

Jingle shells exhibited a definite preference for the concave side of the panels, as generally 5 to 10 times more individuals were found on the concave side than on the convex.

6. Tunicates

Neither solitary nor colonial tunicates appeared on 1-month panels. One small colony was found on a 2-month panel exposed during March and April. Colonial tunicates in significant numbers first appeared on panels exposed for 3-month periods. Both solitary and colonial forms were noted on panels exposed for 4-month periods,

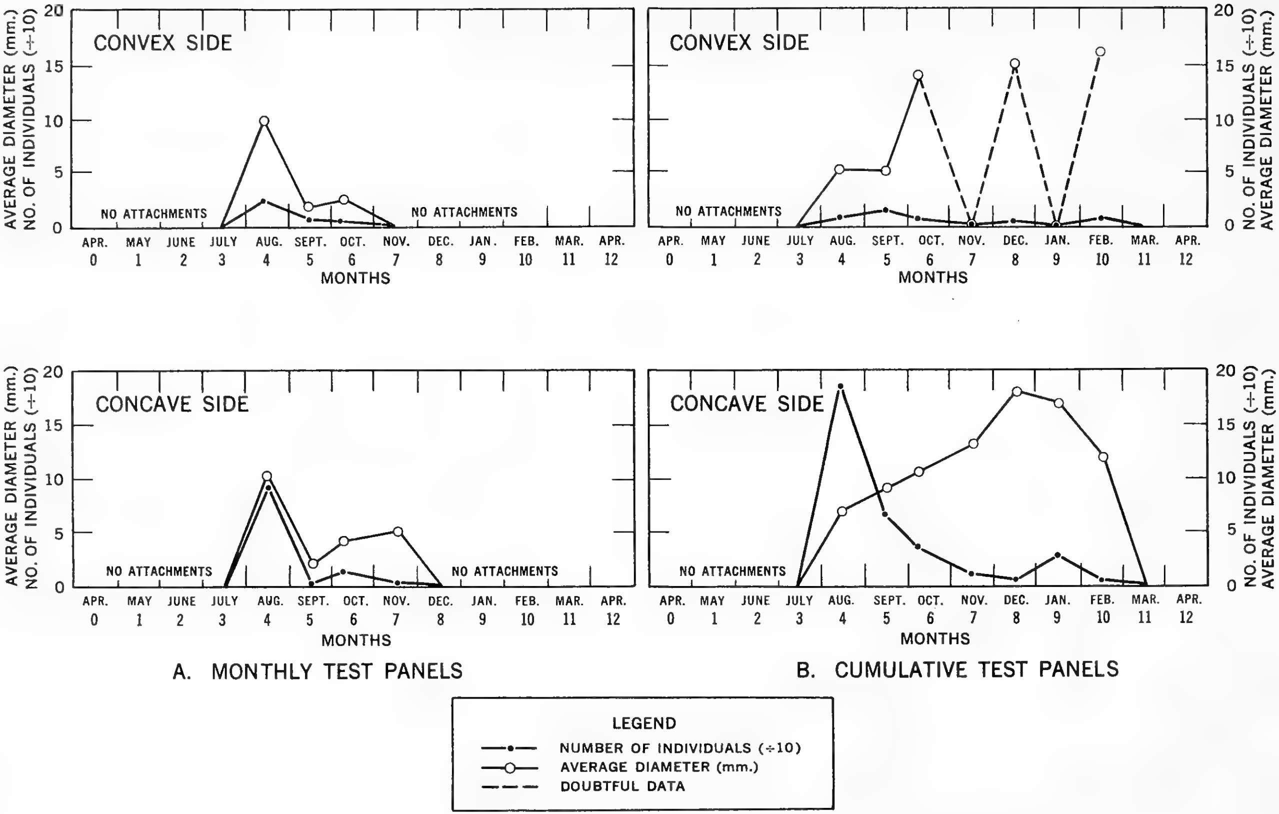


FIGURE 13. JINGLE SHELL FOULING

whereas only solitary forms were found on panels exposed for periods of 5 and 6 months. This is interpreted to mean that tunicates require a particular substratum for optimum setting, and a 1-month or probably 2-month exposure period does not allow sufficient time for development of this substrate.

Tunicates apparently set in greatest numbers during autumn or early winter. They exhibited no apparent preference for the concave or convex side of the panel.

7. Amphipods

Amphipods appeared on the monthly panels in quantity from July through December and in consistently greater numbers on the cumulative panels as the total mass of fouling became greater. Amphipods apparently flourish as the density of hydroids increases. Amphipods did not appear on the monthly panels from January through March, probably because of lack of suitable habitat.

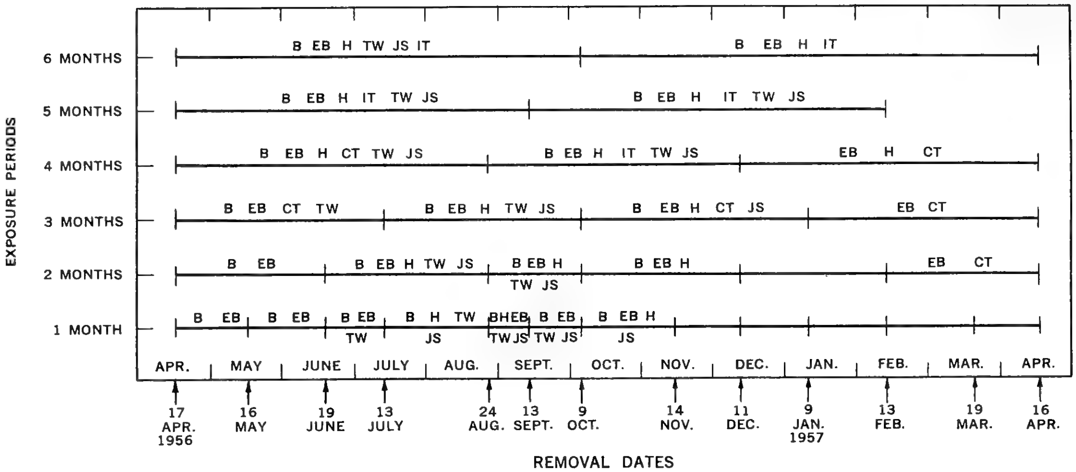
IV. DISCUSSION

The results of the first year's exposure of test panels in Thimble Shoal Channel have provided relatively detailed and apparently consistent information on the total fouling complex and the seasonal variation of set and growth which occurred during the 1956-57 period.

In this region of lower Chesapeake Bay the test panels accumulated a total of .31 ounces of growth (wet weight in air) per square foot per year. The fouling complex consisted predominantly of barnacles, calcareous tubeworms, hydroids, bryozoans, jingle shells, and tunicates. Oysters, sponges, mussels, and sea anemones were also observed in the fouling complex. For purposes of this study, the discussion will be restricted to the predominant, permanently attaching forms.

Figure 14 shows graphically the exposure period of each panel and the predominant forms attaching to it. The 1-month panels show the times of attachment of the various forms, whereas the 2-, 3-, 4-, 5-, and 6-month panels serve to indicate cumulative fouling, succession of the various forms, and probably most important, as a cross check on the data obtained from the monthly panels.

As an example of the consistency between monthly panels and panels exposed for longer periods of time, consider the distribution of tubeworms. These organisms were observed first in June but were not observed on panels after October. These relatively sharp beginning



LEGEND

B—BARNACLES
EB—ENCRUSTING BRYOZOANS
H—HYDROIDS
TW—TUBEWORMS
JS—JINGLE SHELLS
CT—COLONIAL TUNICATES
IT—INDIVIDUAL TUNICATES

NOTE:

The fouling organisms indicated are those found on the test panels at the end of the submersion period.

FIGURE 14. EXPOSURE PERIODS AND PREDOMINANT FOULING ORGANISMS OCCURRING ON MONTHLY AND CUMULATIVE TEST PANELS

and cutoff points of tubeworm setting are further verified by the 2-, 3-, 4-, 5-, and 6-month panels. Tubeworms did not appear on the 2-month panel exposed from April to June, but did appear on the 3-month panel exposed from April to July. Tubeworms appeared also on the 4-, 5-, and 6-month panels whose exposure periods began in April. They did not appear on the 2-, 3-, and 6-month panels whose exposure periods began in October, but did appear on the 4- and 5-month panels whose exposure periods started prior to October. Thus, tubeworm setting appears to be definitely restricted to the period June through October. Similar consistency is indicated by this diagram for the setting periods of barnacles, jingle shells, hydroids, and bryozoans.

Figure 15 is a simplified setting period diagram of these forms in this area. The data, of course, are applicable strictly to the 1956-57 season; however, the occurrence of the various organisms are expected to follow this general sequence every year with some variation in the beginning and cutoff points.

Growth, as indicated by the size of various organisms, offers a possiblility for determining the length of time an object has been submerged. Shelled forms such as barnacles, mussels, tubeworms, and jingle shells and colonial encrusting forms such as bryozoans offer the best possibilities for making such estimates. Figures 16 and 17 are plots of the average and maximum sizes of jingle shells and tubeworms for increasing exposure periods. The average and maximum sizes shown on these figures are actually means of the measurements from the various panels. That is, the values plotted for the 1-month exposure period represent the means of the average and maximum sizes of organisms on all panels exposed for 1 month during and subsequent to setting of the organism. Likewise, the values plotted for the 2-month panels represent mean values of the average and maximum sizes of organisms on all panels exposed for 2 months during and subsequent to setting of these organisms. The mere fact a panel was exposed for 3 months does not mean it necessarily represents a 3-month growth period for a particular organism. For example, from Figures 14 and 15 it can be seen that the 3-month panel, April to July, actually represents a 1-month period of tubeworm setting and growth. The 4-month panel, April to August, represents a 2-month period of tubeworm setting and growth and a 1-month period of jingle shell and hydroid setting and growth. These facts were considered in determining the values plotted in Figures 16 and 17. Jingle shells (Fig. 16) show fairly smooth growth curves for 7 months, the longest period of jingle shell growth during this test.

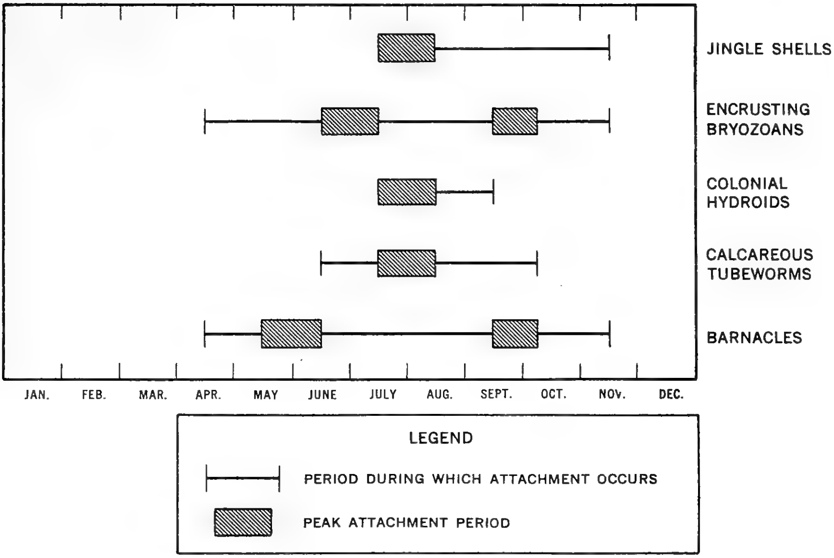


FIGURE 15. SETTING PERIODS OF PREDOMINANT ATTACHING ORGANISMS

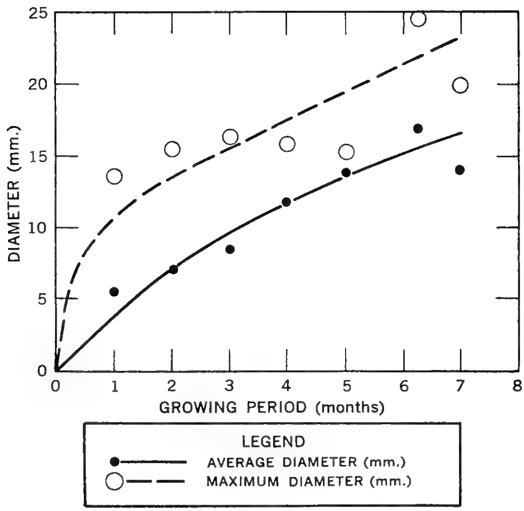


FIGURE 16. JINGLE SHELL GROWTH

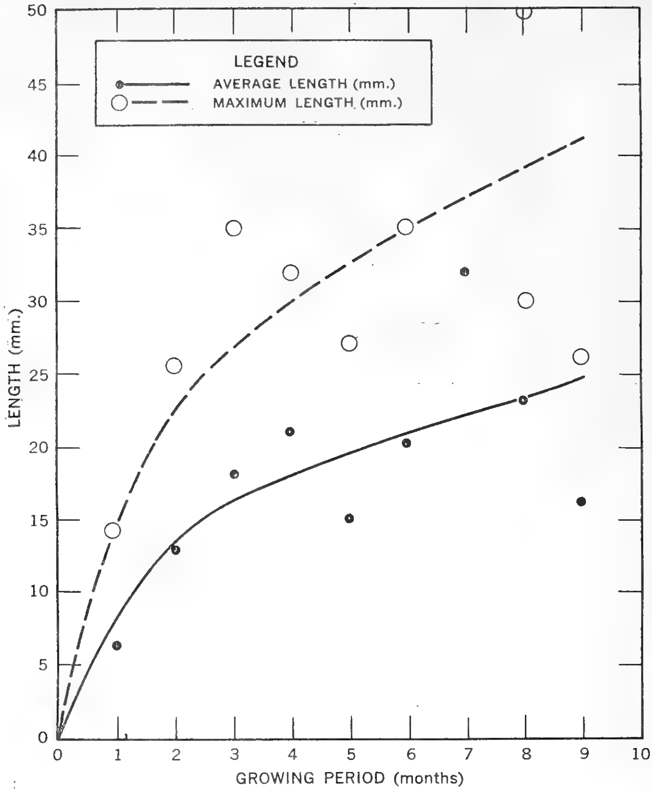


FIGURE 17. CALCAREOUS TUBEWORM GROWTH

The curves of average and maximum lengths of tubeworms (Fig. 17) are somewhat more irregular, although the average curve shows a definite increase and then a gradual leveling off with time. The wide variation in these plots results from the extreme difficulty encountered in measuring the length of the tubes which are typically meandering or convoluted.

Figures 18 through 20 are photographs of panels after thorough drying. The sequence of pictures of the 1-month panels (Fig. 18) shows quite clearly the seasonal progression of biological activity. Photographs of the convex side only are shown; the concave side of the panels indicated the same progression, but generally was more susceptible to silting. In some panels as much as 3/4 of the concave side became covered with a layer of silt 1/8 inch thick.

The part of Figure 19 showing photographs of the 2-month panels reveals in even more vivid fashion the biological sequence. The April to June panel shows barnacles almost exclusively with a few grasslike hydroids. On the June to August panel many tubeworms and encrusting bryozoans overlie barnacles. A few hydroids also appear on this panel. The August to October panel shows a thick matlike growth of colonial hydroids together with encrusting bryozoans. Barnacles occur beneath the hydroids and bryozoans. Only an occasional tubeworm appears on this panel. The October to December panel contains a few barnacles, hydroids, and bryozoans. Tubeworms do not appear on this panel. The December to February and February to April panels show no attachments; however, silt appears on these panels, indicating the probable presence of an underlying substrate of bacterial or protozoan slime which is thought to be the basic stratum upon which further attachment occurs. The 3-month panels (Fig. 19) serve to confirm the biological attachment progression displayed by the 1- and 2-month panels. With increased exposure time (Figs. 19 and 20), the growth becomes more luxuriant, the gross appearance of the panels becomes less dissimilar, and detailed size and count analyses become much more difficult.

Table I contains a complete list of the fouling organisms observed on the test panels of this study.

V. CONCLUSIONS

The analysis of a 1-year fouling study in Thimble Shoal Channel near Norfolk, Virginia has served to provide valuable preliminary data on the type, seasons of attachment, and growth of attaching fouling organisms in that area.

Total wet weight of fouling accumulated at the rate of about 30 ounces per square foot per year for the period April 1956 to April 1957. For comparison, Ayers (1951) reports an accumulation of fouling on the bottom in the approaches to New York Harbor of 19.2 to 76.8 ounces wet weight per square foot per year.

Important foulers are jingle shells (Anomia simplex), barnacles (Balanus improvisus), encrusting bryozoans, hydroids, and calcareous tubeworms. Lesser components of the complex include oysters, algae, amphipods, sponges, and tunicates.

Table I

Fouling organisms observed and periods of attachment at the fouling test site

Organism	Period of Attachment
Barnacles (*Balanus improvisus*)	April to November
Simple Hydroids (probably *Thuiaria*)	April to August
Colonial Hydroids (probably *Sertularia*)	July to September
Colonial Hydroids (probably *Tubularia*)	July to September
Calcareous Tubeworms (Serpulidae)	June to October
Encrusting Colonial Bryozoans (probably *Acanthodesia*)	April to November
Erect Bryozoans (probably *Bugula*)	
Jingle Shells (*Anomia simplex*)	July to November
Colonial Tunicates (probably *Perophora*)	Autumn
Solitary Tunicates (probably *Molgula*)	Autumn
Oysters (*Crassostrea virginica*)	July to September
Mussels (*Mytilus*)	minor occurrence
Anemones	attachment slight
Slipper Limpet	minor occurrence
Snails	attachment slight
Encrusting Sponges	minor occurrence
Clams	attachment slight
Mud Crabs	minor occurrence
Flatworms	minor occurrence
Amphipods (*Caprella*)	minor occurrence

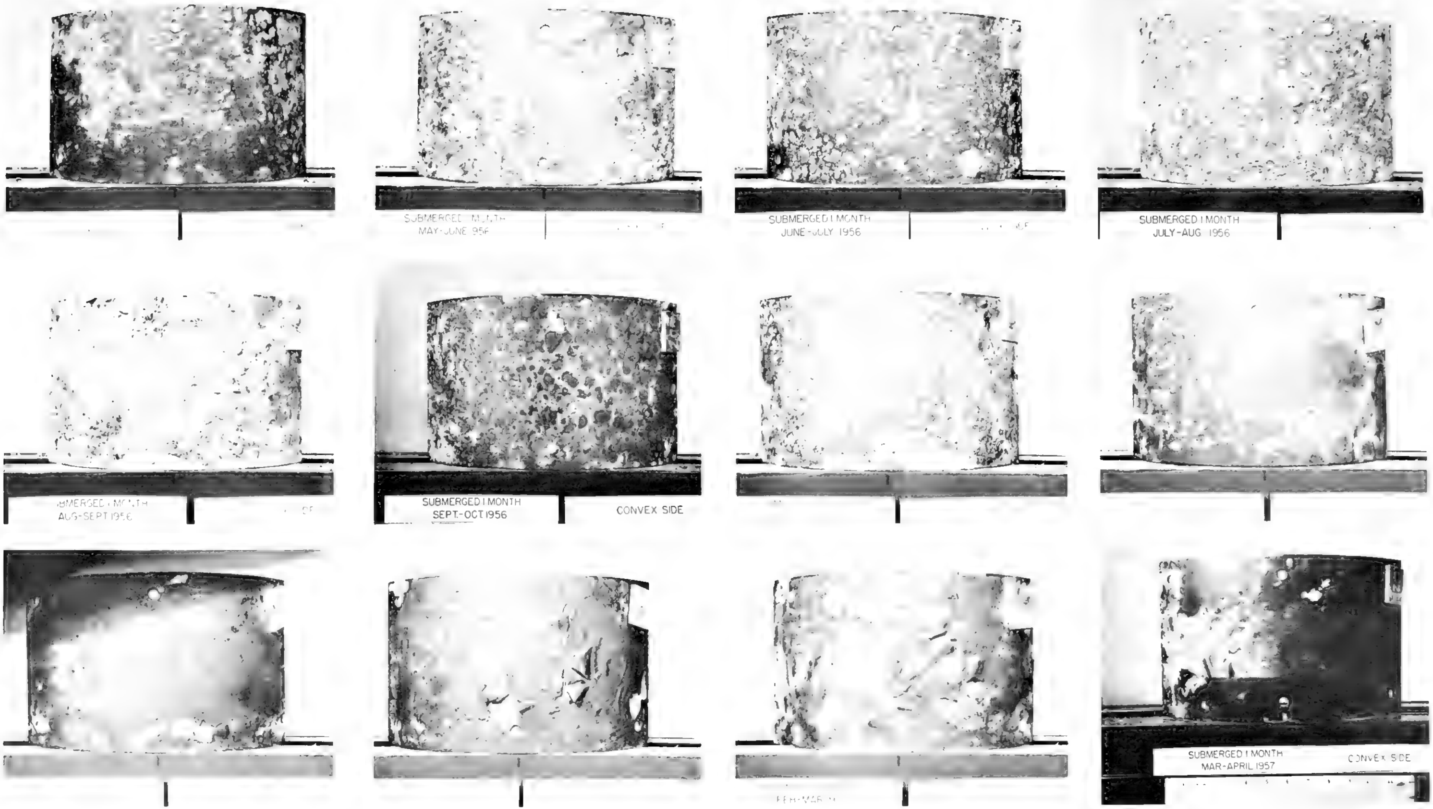


FIGURE 18. PANELS EXPOSED FOR 1-MONTH PERIODS FROM APRIL 1956 TO APRIL 1957

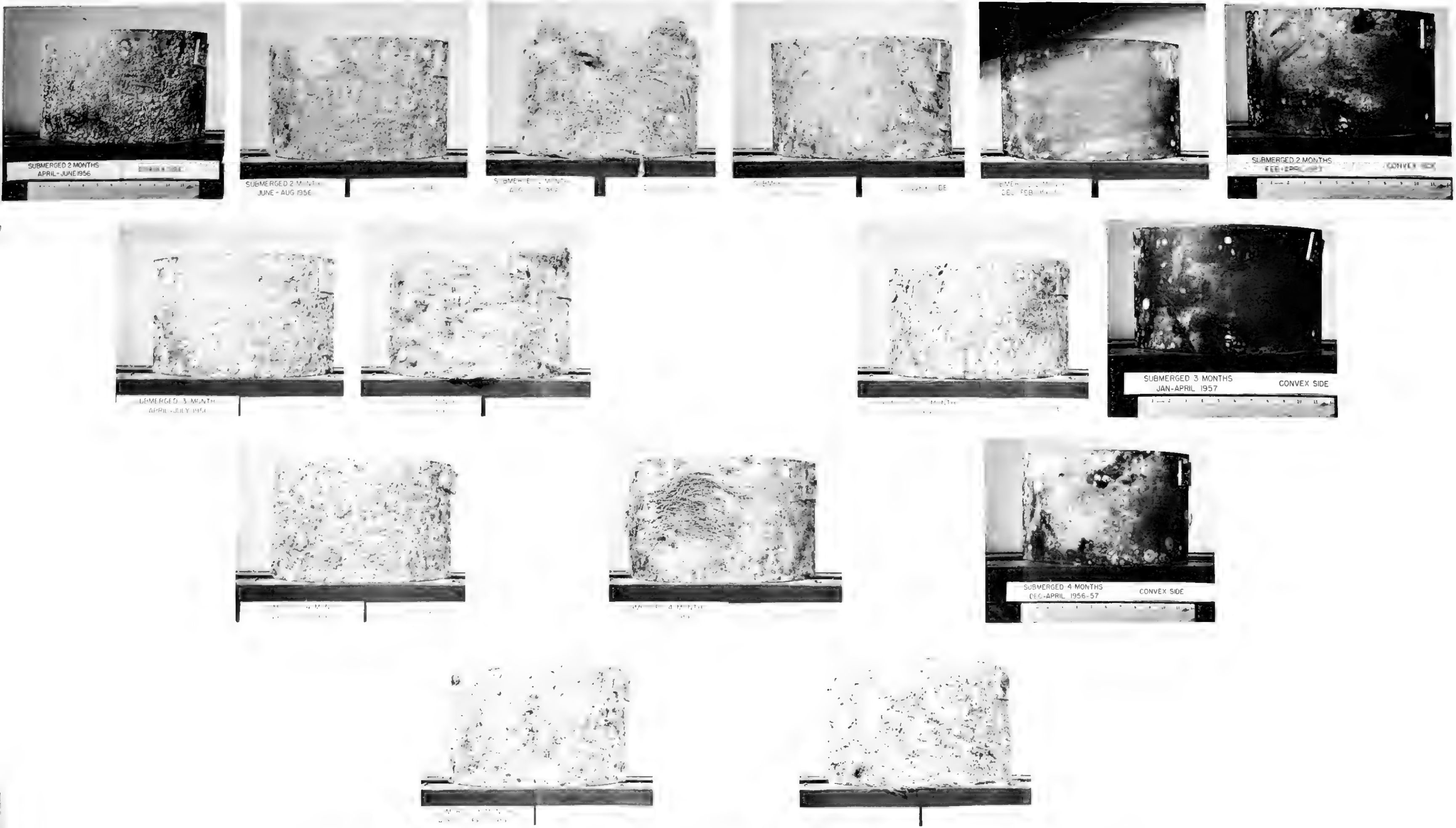


FIGURE 19. PANELS EXPOSED FOR PERIODS GREATER THAN ONE MONTH FROM APRIL 1956 TO APRIL 1957

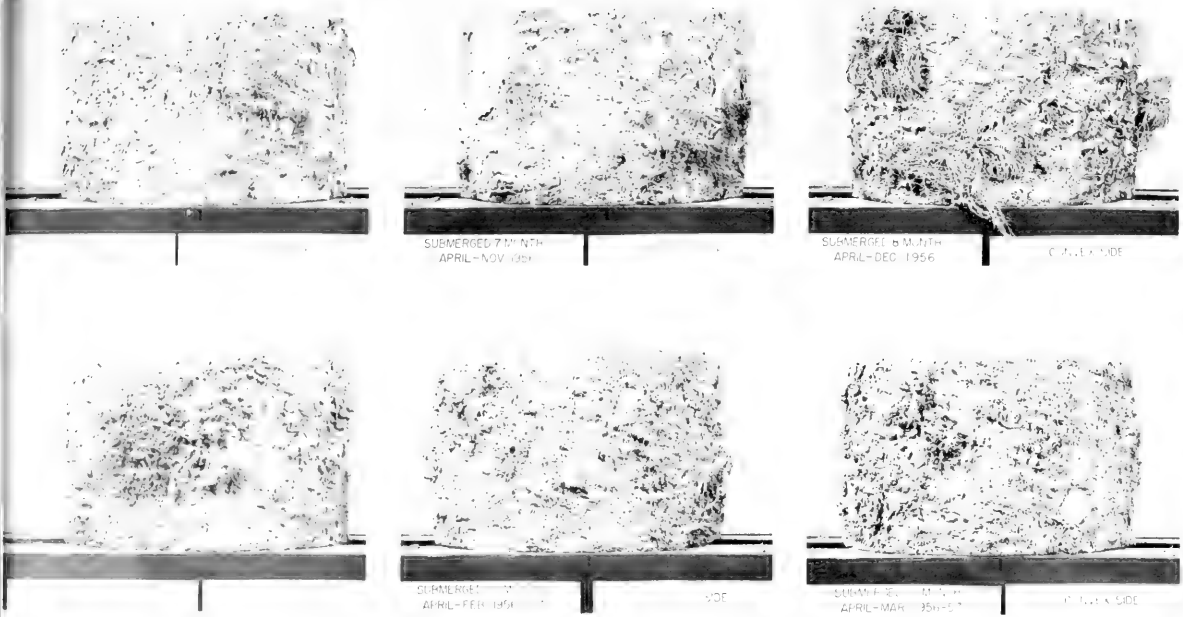
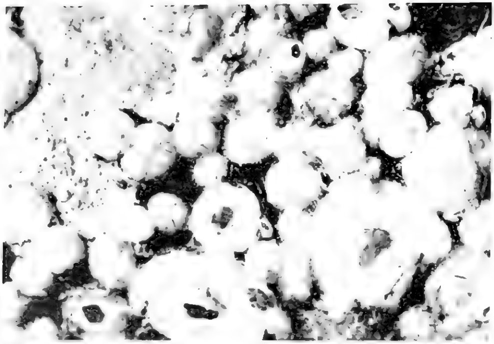
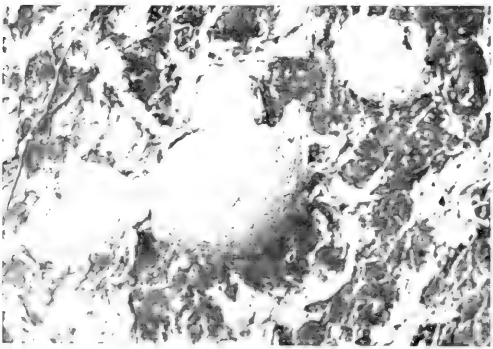


FIGURE 20. PANELS SHOWING GROWTH RESULTING FROM EXPOSURE PERIODS FROM 6 TO 11 MONTHS

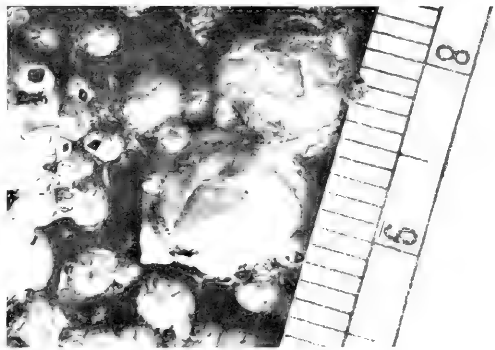


A. AN ENCRUSTING BRYOZOAN (UPPER LEFT) ENCROACHING ON A BARNACLE COMMUNITY

B. COLONIAL HYDROIDS



C. SOLITARY TUNICATE (CENTER)



D. BARNACLES (SCALE IN INCHES)

FIGURE 21. CLOSE-UP VIEWS OF SOME COMMON FOULING ORGANISMS OCCURRING ON TEST PANELS

The period of biological attachment extends from April to December with maximum activity occurring from July to October.

The gross appearance of the test panels reveals relatively large differences from month to month as the season progresses. Biological activity is practically nil from the latter part of December to the latter part of April.

Detailed analysis of the various organisms occurring on the panels indicate the following attachment periods:

Encrusting bryozoans	- April to November
Barnacles	- April to November
Tubeworms	- June to October
Hydroids (colonial)	- July to September
Jingle shells	- July to November

The growth of tubeworms, as indicated by average length of tubes and of jingle shells as indicated by average diameter of shell, show a relatively smooth, progressive increase with increase in exposure during the growing period. These two organisms offer a possibility for determining the length of time an object to which they have attached has been in place on the bottom. Figure 21 shows a closeup view of some of these common fouling organisms. Further study and more detailed statistical measuring procedure are required to establish definite growth curves for these and other forms such as barnacles, bryozoans, and hydroids. These studies will be continued as the project moves into its second year.

The information obtained from the study during the first year of operation has already demonstrated some important applications to various harbor activities. The results of this study demonstrate the advisibility and feasibility of initiating similar fouling studies in all major harbor areas.

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