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Seasonal Occurrence of Epifauna on Test Panels in Hampton Roads, Virginia[1, 2]

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ABSTRACT *A two-year study was made on settling patterns of some marine epifaunal invertebrates in the port of Hampton Roads, Virginia. Asbestos fiber test panels, submerged to a depth of 5 m from a pier at the Norfolk Navy Base, were used as substrates. The fouling assemblage consisted of species characteristic of the temperate North American Atlantic coast. Over half of the 41 species identified were either coelenterates or arthropods, although sponges, turbellarians, ectoprocts, polychaetes, mollusks, and ascidians were present as well. Four species,* Aselomaris michaeli, Clytia edwardsi, Obelia bicuspidata and O. commissuralis, *all hydroids, represent new distributional records for Virginia. The large annual range of water temperature results in distinct seasonal patterns of settlement. Attachment was heaviest from May to November and lightest from January to March. Barnacles* (Balanus improvisus) *were prevalent during spring and autumn, while ascidians* (Molgula manhattensis, Botryllus schlosseri) *and serpulids* (Hydroides hexagona) *were predominant in summer. Only* Balanus improvisus *occurred on the panels throughout the year.*

INTRODUCTION

Firm substrates immersed in seawater become overgrown by a variety of marine organisms. Such marine growth may reduce the efficiency of man-made structures, and considerable research has been directed toward protection of submerged objects. One of the most notable contributions on the subject to date is the monograph by Woods Hole Oceangraphic Institution (1952). Since the first use of test panels in the study of marine communities by Dahl (1893), artificial substrates have been widely used for qualitative and quantitative studies on marine fouling. Numerous

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studies have been conducted on the influence of factors such as light, temperature, salinity, depth, turbidity, currents, pollution, larval behavior, and tidal changes on fouling communities, as well as the effect of substrate composition, color, texture, and angle of suspension on settlement. Since Hewatt (1935) first demonstrated ecological succession in marine encrusting communities, additional investigations have been carried out, particularly on the Pacific and French Mediterranean coasts where the annual temperature ranges are minimal (Hedgpeth, 1957). Seasonal changes in community composition, growth, and fouling intensity are particularly noticeable in regions with considerable annual temperature ranges. Seasonal patterns of settling, resulting from reproductive cycles, were attributed by Coe and Allen (1937) to a complex of biotic and abiotic environmental factors.

In Chesapeake Bay, fouling organisms have received little attention except for problems relating to shell-fisheries and naval fouling. Visscher (1927) studied the organisms on ships' hulls at a number of ports, including those of Hampton Roads, Virginia. The surveys of Beaven (1947) and Andrews (1953) were based principally on oyster fouling. Maloney (1958) studied the seasons of attachment and growth rates of the important fouling species in the approaches to Hampton Roads. Our study was conducted from 15 May 1964 to 16 May 1966 to determine the types, relative numbers, and seasonal occurrence of epifaunal invertebrates which would settle on test panels in Hampton Roads.

HYDROGRAPHY OF HAMPTON ROADS

Hampton Roads covers about 65 km^2 at the confluence of Chesapeake Bay and its most southerly tributary, the James River. The harbor is relatively shallow and is characterized by extensive shoals along both shores. The channels are presently between 10.7 and 12.2 m deep, but are soon to be dredged to 13.8 m. The tidal range is about 0.8 m, and current velocities seldom exceed 1.7 knots. The bottom consists of mud, sand, and regions of shell, predominantly those of the oyster, *Crassostrea virginica*. The James River estuary is typical of a horizontal boundary estuary, with higher salinities on the right side of the river looking upstream. In the estuarine portion of the river, Pritchard (1952) found that the net motion of the surface water was about 0.25 knot downriver and approximately 0.2 knot upriver at a depth of 8.2 m. During ebb tide, he found the downriver current was relatively strong at the surface (up to 1.1 knots), but decreased with depth. During flood tide, the upriver current was relatively small at the surface (0.5-0.6 knot) but increased with depth, reaching a maximum of about 1.0 knot near a depth of 5.2 m.

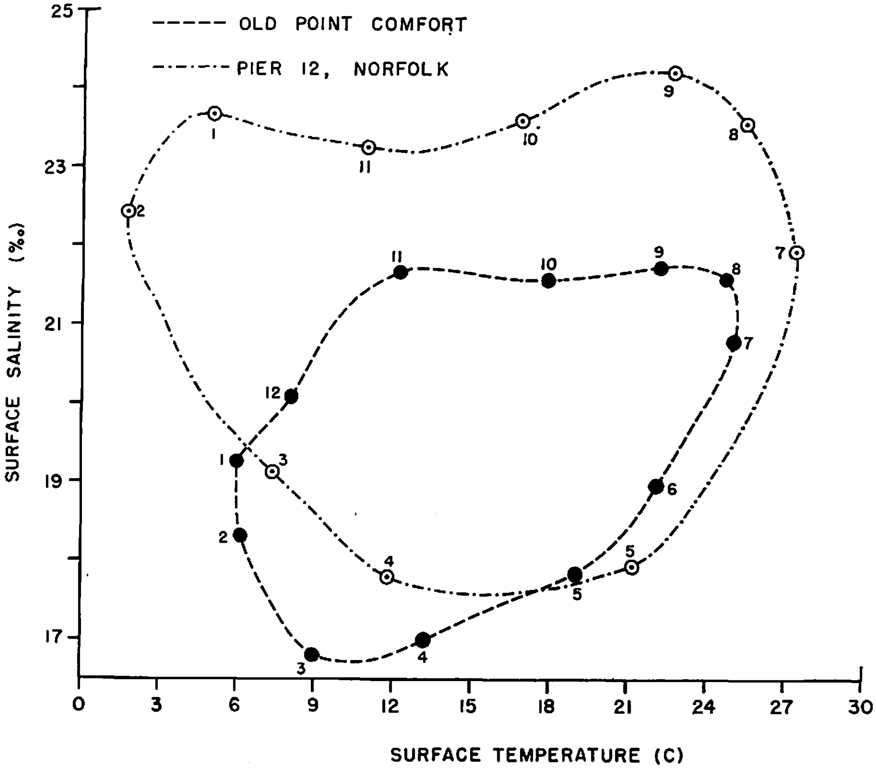
The area of investigation exhibits a wide range of hydrographical conditions from season to season (Fig. 1). Low salinity in spring was attributed to high river flow by Pritchard (1952), while decreased river flow in summer and autumn resulted in increased salinity. The summer and autumn of both 1964 and 1965 were rather exceptional for the James

River in that precipitation and runoff were below normal, resulting in higher salinities. During late 1965, drought conditions intensified in Virginia, and salinities in Hampton Roads, already above normal, remained high during autumn and early winter. Any effect on the benthos in the harbor is difficult to ascertain because of insufficient information from previous years.

MATERIALS AND METHODS

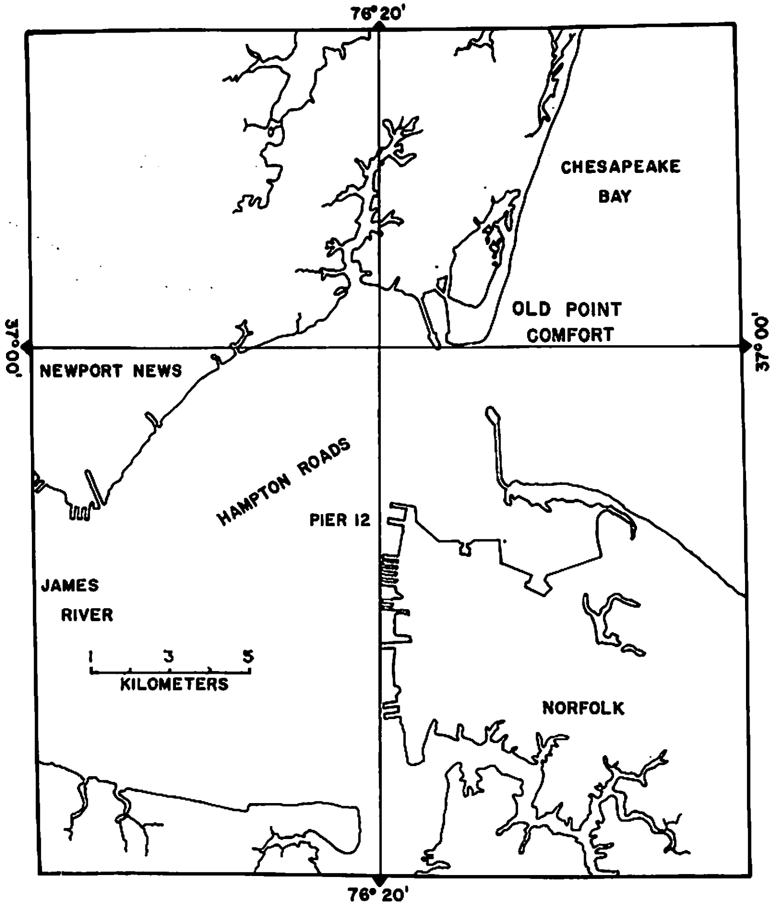
Asbestos fiber test panels, each 8 cm by 13 cm, were mounted in sets of five on a wooden crossbar, and submerged to a depth of 5 m from Pier 12 of the Norfolk Navy Base (Fig. 2). The panels were removed monthly, placed in polyethylene bags, and preserved by freezing. The panels were later thawed and examined under a dissecting microscope. Beginning 15

FIGURE 1. Temperature-salinity diagram for Pier 12 from May 1965 to April 1966, compared with data for Old Point Comfort compiled by U. S. Coast and Geodetic Survey (1960).



May 1965, panels were placed in seawater at the time of collection to prevent desiccation during transport to the laboratory. For examination, panels were placed in a small tray and covered with water. An acrylic plastic grid was used to facilitate enumeration. After identification or preservation of delicate and motile species, the panels were washed and oven dried for several hours to simplify examination of the various sessile forms. On each panel, 1.5 dm^2 was examined for identifications and counts.

FIGURE 2. Map of Hampton Roads, Virginia, showing the location of Pier 12 where panels were exposed.



Records of surface salinity and temperature were made periodically at Pier 12. Salinity samples were analyzed using an Industrial Instruments Inc., model RS-7A induction salinometer. Temperatures were measured with stem thermometers.

RESULTS

A total of 41 species of macroinvertebrates, belonging to eight phyla, was identified from the test panels (Table I). Analyzing the known ranges of these species showed that 38 also occur at Woods Hole, Massachusetts,

TABLE 1 Invertebrates collected from test panels at Pier 12 in Hampton Roads, Virginia.

	Months present (inclusive)
PHYLUM PORIFERA	
Class Demospongiae	
Halichondria bowerbanki	June-October
PHYLUM COELENTERATA	
Class Hydrozoa	
Aselomaris michaeli	September, October
Pennaria tiarella	June
Hydractinia echinata	June
Bougainvillia rugosa	May-October
Calyptospadix cerulea	September-November
Clytia edwardsi	September
Gonothyraea loveni	November-May
Obelia bicuspidata	June-September
Obelia commissuralis	October
Sertularia argentea	March-May
Schizotricha tenella	June-September
Class Anthozoa	
Diadumene leucolena	June-September
Aiptasiomorpha luciae	June-December
PHYLUM PLATYHELMINTHES	
Class Turbellaria	
Stylochus ellipticus	June-November
PHYLUM ECTOPROCTA	
Class Gymnolaemata	
Anguinella palmata	May-June
Aeverrillia armata	September
Membranipora tenuis	May-November
Electra crustulenta	April-November
PHYLUM ANNELIDA	
Class Polychaeta	
Nereis succinea	May-December
Lepidonotus sublevis	August-September
Sabellaria vulgaris	May-October
Hydroides hexagona	May-October
Polydora ligni	March-January
PHYLUM MOLLUSCA	
Class Pelecypoda	
Anadara transversa	June-September
Brachidontes recurvus	September
Anomia simplex	June-October
Crassostrea virginica	August-October
Class Gastropoda	
Crepidula fornicata	July-October
PHYLUM ARTHROPODA	
Class Pycnogonida	
Anoplodactylus parvus	June-November
Callipallene brevirostris	
Tanystylum orbiculare	
Class Crustacea	
Balanus eburneus	May, September
Balanus improvisus	all year
Ericthonius brasiliensis	June
Elasmopus pocillimanus	June-August
Caprella equilibra	May-January
Caprella geometrica	May-January
Neopanope texana sayi	May-October
PHYLUM CHORDATA	
Class Ascidiacea	
Botryllus schlosseri	April-November
Molgula manhattensis	May-November

while only 20 are known north of Cape Cod. To the south, 36 of these species range beyond Cape Hatteras, at least to Beaufort, North Carolina, or farther. Fifteen of the species occur both north of Cape Cod and south of Cape Hatteras.

Porifera

In Chesapeake Bay, most sponges are restricted to salinities of 15‰ or higher (Andrews, 1953). They are conspicuous and abundant epifaunal organisms in Hampton Roads, but were infrequent on the monthly test panels. *Halichondria bowerbanki,* the only species encountered, occurred as small growths from mid-June through October. At Hatteras Harbor, North Carolina, Wells, Wells and Gray (1964) reported attachment in spring and autumn for this species. *Microciona prolifera,* probably the most abundant sponge in Hampton Roads (Calder, 1966), was absent from the panels. Wells, *et al.* (1964) found *M. prolifera* to be 66% more numerous on fouled than fresh substrates, and noted that clean surfaces exposed for short periods of time may result in a distorted view of sponge setting. The paucity of sponges on our panels may have been due to the relatively short duration of exposure.

Coelenterata

Hydroids are of major importance in marine fouling because of their tendency toward rapid growth, proliferation, and formation of dense colonies. Five of the hydroids identified evidently have Chesapeake Bay as either their most northerly or southerly limit. *Aselomaris michaeli, Calyptospadix cerulea, Clytia edwardsi,* and *Gonothyraea loveni* are unreported farther south, while *Bougainvillia rugosa* is not known north of the bay. However, few areas along this coast have been thoroughly surveyed for hydroids, and present information may be an unsatisfactory indicator of their actual distribution. In Chesapeake Bay, little systematic work has been done on the hydroids since Clarke described several new species in 1882. Of 11 species found on the test panels, four were new records for the bay. Two of these, *Obelia bicuspidata* and *O. commissuralis,* are known both north and south of the region. Since the previous southern limit for *Clytia edwardsi* was Narragansett Bay, Rhode Island (Fraser, 1944), its known southward range has been extended considerably. It occurs northward to New Brunswick. Zoogeographically, the most interesting hydroid was *Aselomaris michaeli,* a species described by Berrill (1948) from the coast of Maine. Our report represents the first record of the species outside its type locality. Berrill believed it was either an extremely local species or had been extensively overlooked elsewhere, since he found it throughout the Boothbay Harbor region. The Hampton Roads record indicates that the species does extend south of Cape Cod and is not strictly a northern species, as Berrill suggested.

Six of the 11 species identified from the panels were thecate. *Bougainvillia rugosa,* most conspicuous of the athecates, was collected from early May through November from the supporting rope, and appeared periodically during this time on the test panels. During summer and autumn, *Obelia bicuspidata* and *Schizotricha tenella* were the predominant species, while *Gonothyraea loveni* was the commonest hydroid in winter. The remaining species were encountered sporadically but were never abundant.

Two anemones, *Diadumene leucolena* and *Aiptasiomorpha luciae,* were common on the panels, particularly during summer. They are also abundant in New England (Smith, 1964) and at Beaufort, North Carolina (Field, 1949).

Ectoprocta *Membranipora tenuis* and *Electra crustulenta* were the most prevalent ectoprocts on the panels, with *M. tenuis* being the more common except in spring and late autumn. *Aeverrillia armata,* a dendritic species which rivals the hydroids in tangling submerged objects, was rare on the panels, as was *Anguinella palmata,* the only other species observed.

Polychaeta During much of the year, sedentary polychaetes were the most abundant of the macrofauna on the test panels. *Sabellaria vulgaris* was prevalent on the panels during summer and early autumn. Andrews (1953) described it as one of the two commonest tube-building worms on oyster shells. In mid-summer, the serpulid *Hydroides hexagona* was a conspicuous member of the epibenthic community. It set in large numbers and grew rapidly, covering its substrate with a twisting mass of white calcareous tubes. Panels exposed from 2 August to 3 September 1965 bore tubes up to 5.0 cm in length. The most abundant polychaete on the panels at any given time of year was *Polydora ligni.* The material from which their tubes are constructed was an important component in the accumulated weight on the panels. This spionid is probably the most abundant polychaete in Chesapeake Bay (Wass, 1965).

Mollusca Andrews (1953) reported that 15 species of mollusks contribute to fouling in Chesapeake Bay. On the test panels in Hampton Roads, only *Anadara transversa* and *Anomia simplex* were common. *Crassostrea virginica,* a commercially important mollusk, was of minor importance on the panels. *Anadara transversa* appeared on test panels from mid-June through September 1965, but was never present in large numbers. *Anomia simplex* occurred on the panels from mid-June through October 1965. It is an important fouling organism since it attaches to most firm substrates and grows rapidly. Andrews (1953) noted that it reaches maximum size in two to four months. He stated that the life cycle is a short one, attachment occurring in summer and most individuals dying during the winter.

Arthropoda Barnacles are the most important arthropods in fouling submerged surfaces. Only two species, *Balanus eburneus* and *B. improvisus,* were observed in this study. *B. eburneus* occurred on the test panels periodically, but never in any abundance, since the panels were immersed to a depth of five meters. Zullo (1963) stated that it is seldom found subtidally, though it is common in lower intertidal regions of protected bays and inlets, particularly in waters of reduced salinity. In Chesapeake Bay, *B.*

eburneus fouls pilings extensively in the intertidal zone, but is of minor importance in oyster fouling (Andrews, 1953).

Balanus improvisus occurred on test panels at Pier 12 throughout the year, with marked fluctuations in numbers from month to month. Two peaks occurred, one in spring and one in autumn. The autumn set covered a longer time interval. Maloney (1958) obtained similar results in his study. Andrews (1953) reported that *B. improvisus* is responsible for nearly all oyster cultch fouling by barnacles. He stated that it is most abundant in waters below approximately 15 $^{0}/_{00}$ because of a reduction in competitors and predators. *B. improvisus* has a world wide distribution in temperate and tropical waters (Zullo, 1963).

Ascidiacea

Species of ascidians along the eastern United States are few in number but an abundance of individuals frequently occurs (Van Name, 1945). The number of species may be further reduced in Chesapeake Bay because most ascidians are unable to tolerate reduced salinities.

Botryllus schlosseri is known from Portland, Maine, and the western coast of Florida, but is rather discontinuous in distribution between these two locations (Van Name, 1945). Van Name noted that it is locally abundant from Massachusetts to New Jersey. It was not listed by McDougall (1943) for Beaufort, nor by Andrews (1953) for Chesapeake Bay. Subsequently, it was reported by Andrews to be rare on oyster beds in the lower bay, and by Wass on *Zostera* at Gloucester Point, Virginia (Wass, 1965). J. D. Andrews (personal communication) observed that *B. schlosseri* was a rare lower Bay form prior to the recent drought period. It is now a common species on oyster trays at Gloucester Point, and was common to abundant on test panels at Pier 12 from April to November. According to Van Name (1945), *B. schlosseri* was probably introduced from Europe on the bottom of ships. The taxonomy of this ascidian has been complicated by the great variability in color from colony to colony. Van Name stated that color is not to be relied on at all for distinguishing species in the Botryllidae.

Molgula manhattensis is by far the most abundant ascidian in Hampton Roads. Van Name (1945) reported that it is the commonest ascidian from Massachusetts to Chesapeake Bay or beyond. He noted that it is a shallow water species that will tolerate both highly polluted water and reduced salinities. Though it occurred from May to December on the panels, it was most abundant during summer.

Seasonal Fluctuations

In temperate regions, encrusting organisms characteristically exhibit seasonal fluctuations in attachment. Some of the salient seasonal changes on panels at Pier 12 are summarized below. Details are given in Table I for the periods of attachment.

January-March 1965. Balanus improvisus was the only organism present throughout the period. Amphipods, including caprellids, and *Polydora ligni* were observed only during January.

3 January-15 April 1966. Attachment during this interval was very light. Although amphipods, *Polydora ligni,* and *Gonothyraea loveni* set on occasion, only *Balanus improvisus* was present on every series.

April 1965. During April the water temperature began to rise. Barnacles increased in number and a moderate hydroid set occurred.

15 April-16 May 1966. Eight species were observed on this set compared with three on the 16 March-15 April 1966 set. *Balanus improvisus, Polydora ligni,* and *Botryllus schlosseri* were abundant, and *Electra crustulenta* was becoming numerous.

May 1965. The heavy spring set of *Balanus improvisus* and encrusting ectoprocts occurred during May, and the number of species increased markedly over previous months. Although *B. improvisus* was the dominant species numerically, it showed signs of being crowded by other organisms. Encrusting ectoprocts covered many small barnacles, and tunicates frequently covered both barnacles and ectoprocts.

15 May-15 June 1964. During this period barnacles were abundant and tunicates were moderate to heavy. A moderate attachment of encrusting ectoprocts occurred, with most colonies spread over the barnacle tests. The test panels were completely covered by a combination of *Balanus, Molgula,* and *Botryllus.*

June 1965. Balanus improvisus decreased considerably in number from the earlier 1965 set. *Hydroides hexagona* was becoming abundant, and tunicates were predominant. *Sabellaria vulgaris* appeared for the first time and two hydroids, *Pennaria tiarella* and *Hydractinia echinata,* were found only during this month.

15 June-15 July 1964. Maximum numbers of *Hydroides hexagona* were found on this set for 1964. Barnacles were greatly reduced in number.

July 1965. Tunicates, primarily *Molgula manhattensis,* and the serpulid *Hydroides hexagona* were prevalent during July. The sponge peak occurred from 1 to 14 July when the temperature increased from 25C to 28C.

15 July-15 August 1964. The largest number of species for any 1964 set was found during this time interval. *Molgula manhattensis* was abundant, but individuals were small in size and the total biomass was less than for the previous set. In 1964, sponges were found on the panels only during this period. *Hydroides hexagona* was decreasing in abundance, while hydroids were moderate.

August 1965. During August, temperatures slowly began to decline. *Hydroides hexagona* was still co-dominant with the tunicates, but numbers of this polychaete were fewer than on the July set. Most of the worm tubes were large, suggesting that setting had occurred most abundantly early in the month.

15 August-15 September 1964. A heavy hydroid set occurred during this period. Barnacles increased in number and a few *Crassostrea virginica* spat were identified. The panels were about 95% covered by a combination of tunicates, hydroids, and barnacles.

September 1965. The number of species remained high during the month, but numbers of individuals declined in all species except *Balanus improvisus, Molgula manhattensis,* and *Sabellaria vulgaris. S. vulgaris* reached maximum abundance during this period.

15 September-15 October 1964. Balanus improvisus and encrusting ectoprocts increased in numbers during this period. Although the number of species was not greatly reduced, numbers of individuals in most species decreased from the previous set.

October 1965. The peak autumn barnacle set characterized this exposure. Overall, the number of species and individuals was reduced from the September set.

15 October-16 November 1964. During this interval the autumn peak of *Balanus improvisus* occurred, and the species diversity dropped sharply. Encrusting ectoprocts were observed for the last time in 1964.

November 1965. The heavy barnacle set continued, although the numbers were reduced from the October exposure. *Gonothyraea loveni* appeared for the first time, while *Molgula manhattensis* and encrusting ectoprocts were observed for the last time.

16 November-16 December 1964. Only two species were found on this set, *Balanus improvisus* and *Polydora ligni.* Barnacles were less numerous than on the previous set.

December 1965. Gonothyraea loveni, Polydora ligni, and *Caprella equilibra* were present, but only *Balanus improvisus* was abundant.

Seasonal changes in the type and intensity of fouling on test panels resulted in the progression noted in Fig. 3. This is a consequence of environmentally influenced reproductive periods of the organisms involved, and does not represent the seral stages of ecological succession. The change from month to month is most clearly related to temperature.

DISCUSSION

There were relatively few species on the test panels compared to the diversity of benthic organisms found by Calder (1966) in adjacent waters. This is due in part to the brief duration of exposure and the habitat uniformity of a panel surface. Coe and Allen (1937) noted that test surfaces present very restricted attachment space compared with the variety of substrates in the vicinity.

The marked seasonal faunal changes on the test panels were most clearly related to temperature. During the summer months when the water temperature was above 20C, maximum numbers of species were found and the panels were heavily populated. Animals were scarce on the panels from January to mid-April when the temperature was below 10C. In Norway, Nair (1962) found the period of intense spawning to occur between April and October when the temperature was 4.8C or higher. Orton (1929) concluded that most marine invertebrates continue to reproduce as long as a certain temperature plateau, physiologically constant for each species, is maintained. As a result, reproductive periods are more likely to be prolonged in southern than in northern latitudes.

Types of seasonal attachment have been classified by Woods Hole Oceanographic Institution (1952) as follows:

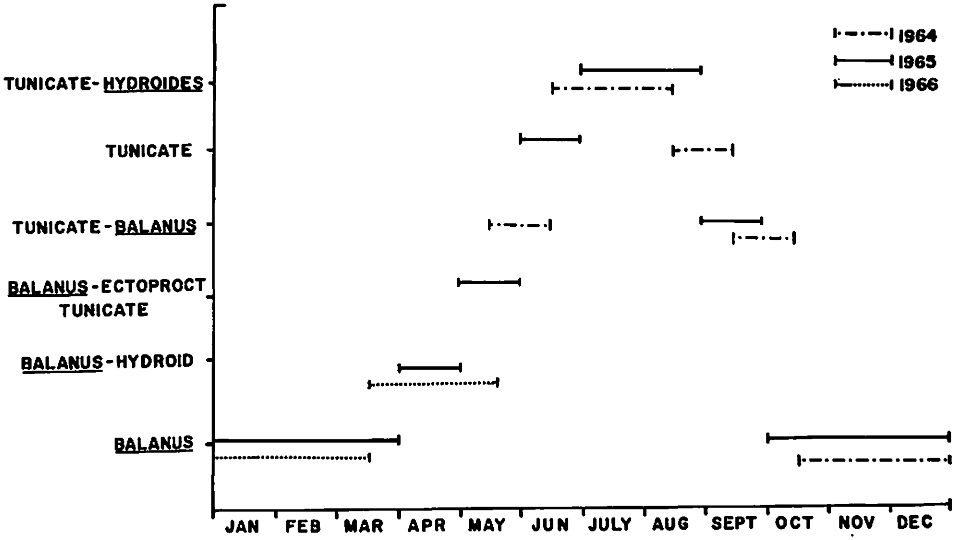
Type I. Continuous year around attachment and absence of a definite seasonal fluctuation. This occurs where seasonal differences are so slight that reproductive cycles are not influenced. This type of attachment occurs in the tropics.

Type II. Continuous attachment, but increased frequency of one period over another. This occurs in subtropical areas, and results from conditions which are more favorable at one season than another, although all seasons are compatible with reproduction.

Type III. Attachment during a definite period of the year only. This occurs in temperate regions, where the seasonal variations of temperature are marked. Reproduction is limited to that time of year when temperatures are compatible with spawning.

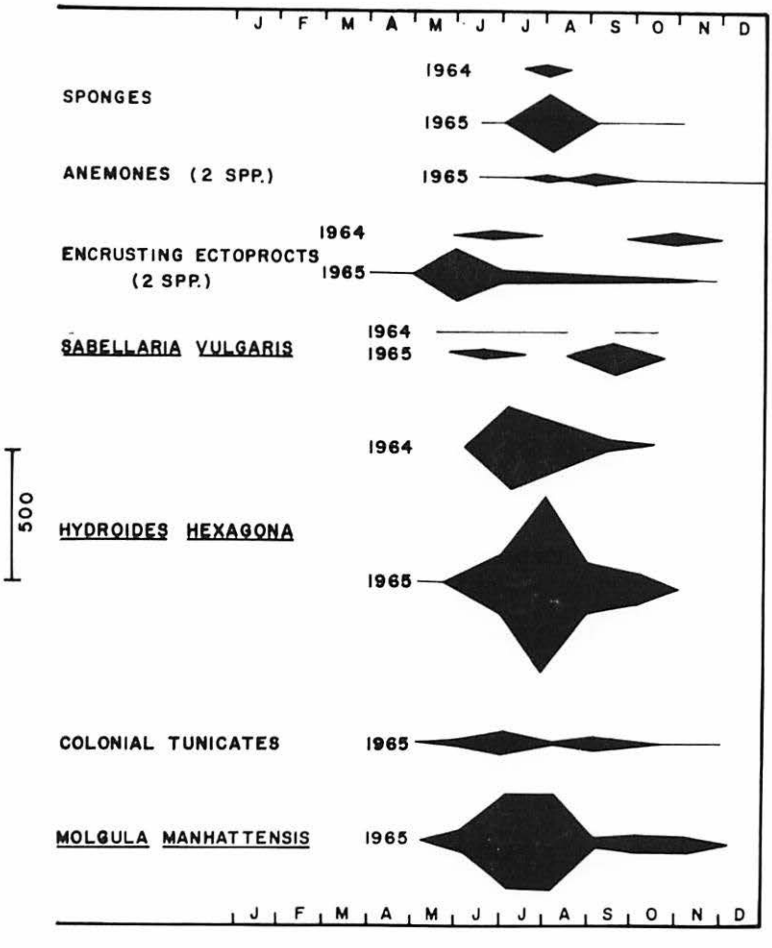
Type IV. Attachment during two separated periods of the year. This type also occurs in temperate regions. Spawning and subsequent attachment occur most frequently during spring and autumn in this type.

FIGURE 3. Seasonal changes in the dominant species on monthly test panels.



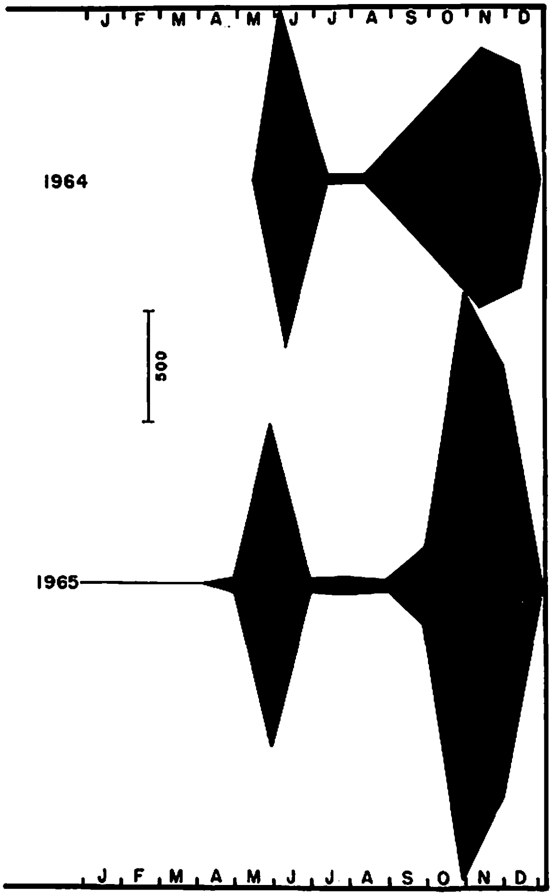
The Woods Hole Oceanographic Institution (WHOI) monograph emphasized that interpretation of seasonal fluctuations is complicated by inherent rhythms in the reproductive processes of organisms. Since these rhythms are influenced by environment, unfavorable conditions may interrupt them. Consequently, settling may be influenced by some earlier condition which affected the spawning period. In different parts of its range, a species may conform to different types of seasonal attachment. *Mytilus edulis,* for example, sets most heavily in spring and autumn on the Virginia coast, in late autumn at Beaufort (Wells and Gray, 1960), and in summer at Lamoine, Maine (Fuller, 1946).

FIGURE 4. Abundances of various fouling organisms per dm² of panel surface.



Six of the 10 species for which adequate quantitative data are available displayed Type III attachment (Fig. 4). *Electra crustulenta* and *Membranipora tenuis* approached Type IV in that both were numerous in late spring, but neither became abundant in autumn. Conversely, *Sabellaria vulgaris* reached peak attachment in early autumn, with a smaller peak in late spring and early summer. *Balanus improvisus* clearly showed Type IV attachment (Fig. 5). Maloney (1958) reported spring and autumn peaks for barnacles and encrusting ectoprocts, and summer peaks for jingle shells, colonial hydroids, and calcareous tubeworms. At Beaufort, McDougall (1943) found 10 of the 12 species for which he had quantita-

FIGURE 5. Numbers of *Balanus improvisus* per dm^2 of panel surface.



tive data showed two periods of attachment (Type IV), and Fuller (1946) encountered Type III attachment at Lamoine.

A comparison of the 1964 and 1965 sets at Pier 12 reveals distinct differences in population size for the two years, although the species composition and community structure were basically the same. Although these quantitative differences may be partly due to procedural differences, such year to year variations are well known in marine populations, but their causes are poorly understood (WHOI, 1952).

In addition to temperature, other factors of importance in determining the type and intensity of fouling include substrate texture, presence and type of "slime film," proximity of breeding populations, angle of the substrate, larval behavior, and light. Currents influence the settlement of encrusting organisms since the water velocity past a substrate may exceed the maximum rate at which the larvae can attach. Smith (1946) found this to be true for barnacle larvae, but he stated that once attachment has occurred, increasingly higher velocities could be tolerated, although growth rates were considerably reduced for the first two or three weeks. He stated that rarely under natural conditions do water currents alone prevent barnacle colonization of a surface, but that strong wave action may be an important factor. Doochin and Smith (1951) stated that currents play a role in barnacle attachment since the cyprids have a poor hold on the substrate until antennal cement is secreted to effect preliminary attachment. WHOI (1952) reported that exposed headlands usually support rich populations. Evidently, once the organisms attach, the currents become beneficial in transportation of food. Gentle water movement was reported by Knight-Jones and Crisp (1953) to encourage setting.

Weiss (1948) found that fouling was heavier in polluted than in purer water. This, according to Skerman (1958), is one of the factors involved in the intensification of fouling in port. Skerman believed that organic material in the form of sewage may provide an important food supply for encrusting organisms. Silt and suspended detritus may be incorporated in the slime film and promote *Balanus* settlement. Nair (1962) noted that turbid and polluted waters were dominated by mud tube dwellers, but he found encrustation reached a maximum in relatively clean waters. It appears from these reports that a certain amount of pollution with related dissolved and particulate organic and inorganic material may favor heavy set, at least for tolerant species, but too great a concentration may be detrimental. The type of pollutant would be of considerable importance in this respect also.

REFERENCES

Andrews, J. D. 1953. *Fouling organisms of Chesapeake Bay*. Chesapeake Bay Inst., Inshore Survey Program. Interim Report 17. 16 p.

Beaven, G. F. 1947. Observations on fouling of shells in the Chesapeake area. Convention address at Nat. Shellfisheries Assoc. 1947.

Berrill, N. J. 1948. The life cycle of *Aselomaris michaeli,* a new gymnoblastic hydroid. *Biol. Bull., 95,* 289-295.

Calder, D. R. 1966. Ecology of marine invertebrate fouling organisms in Hampton Roads, Virginia. M. A. Thesis, College of William and Mary, Williamsburg, Va. 66 p.

Clarke, S. F. 1882. New and interesting hydroids from Chesapeake Bay. *Mem. Boston Soc. Natur. Hist., 3,* 135-142.

Coe, W. R., and W. E. Allen. 1937. Growth of sedentary marine organisms on experimental blocks and plates for nine successive years. *Bull. Scripps Inst. Oceanog., Univ. Calif. Tech. Ser., 4,* 101-136.

Dahl, F. 1893. Untersuchungen über die Tierwelt der Unterelbe. *Jahresber. Komm. Wiss. Undersuch. Deut. Meere Kiel., 6,* 151-185.

Doochin, H., and F. G. W. Smith. 1951. Marine boring and fouling in relation to velocity of water currents. *Bull. Marine Sci. Gulf Caribbean, 1,* 196-208.

Field, L. R. 1949. *Sea anemones and corals of Beaufort, North Carolina.* Duke Univ. Marine Sta. Bull. No. 5. 39 p.

Fraser, C. M. 1944. *Hydroids of the Atlantic coast of North America.* Univ. Toronto Press, Toronto. 451 p.

Fuller, J. L. 1946. Season of attachment and growth of sedentary marine organisms at Lamoine, Maine. *Ecology, 27,* 150-158.

Hedgpeth, J. W. 1957. *Treatise on marine ecology and paleoecology,* v. 1. Geol. Soc. Amer. Mem. 67. 1296 p.

Hewatt, W. G. 1935. Ecological succession in the *Mytilus californianus* habitat as observed in Monterey Bay, California. *Ecology, 16,* 244-251.

Knight-Jones, E. W., and D. J. Crisp. 1953. Gregariousness in barnacles in relation to the fouling of ships' bottoms and to antifouling of ships and to antifouling research. *Nature, 171,* 1109-1110.

Maloney, W.E. 1958. *A study of the types, seasons of attachment, and growth of fouling organisms in the approaches to Norfolk, Virginia.* U. S. Navy Hydrographic Office, Tech. Rep. 47. 35 p.

McDougall, K. D. 1943. Sessile marine invertebrates of Beaufort, North Carolina. *Ecol. Monographs, 13,* 321-374.

Nair, N. B. 1962. Ecology of marine fouling and wood-boring organisms of western Norway. *Sarsia, 8,* 1-88.

Orton, J. H. 1929. Experiments in the sea on the growth inhibitive and preservative value of poisonous paints and other substances. *J. Marine Biol. Assoc.* U. K. *16,* 373-452.

Pritchard, D. W. 1952. Salinity distribution and circulation in the Chesapeake Bay estuarine system. *J. Marine Res.,* 11, 106-123.

Skerman, T. M. 1958. Marine fouling at the port of Lyttelton. *New Zealand J. Sci., 1,* 224-257.

Smith, F. G. W. 1946. Effect of water currents upon the attachment and growth of barnacles. *Biol. Bull., 90,* 51-70.

Smith, R. I. (Ed.). 1964. *Keys to marine invertebrates of the Woods Hole region.* Syst.-Ecol. Progr., Marine Biol. Lab., Woods Hole, Mass. No. 11. 208 p.

U. S. Coast and Geodetic Survey. 1960. *Surface water temperature and salinity, Atlantic coast, North and South America.* Coast Geod. Surv., Pub. 31-1. 76 p.

Van Name, W. G. 1945. The North and South American ascidians. *Bull. Amer. Mus. Natur. Hist., 84,* 1-476.

Visscher, J. P. 1927. Nature and extent of fouling of ships' bottoms. *Bull. U. S. Bur. Fisheries, 43,* 193-252.

Wass, M. L. 1965. *Check list of the marine invertebrates of Virginia.* Va. Inst. Mar. Sci. Spec. Sci. Rep. No. 24 (3rd Revision). 55 p.

Weiss, C. M. 1948. The seasonal occurrence of sedentary marine organisms in Biscayne Bay, Florida. *Ecology, 29,* 153-172.

Wells, H. W. and I. E. Gray. 1960. The seasonal occurrence of *Mytilus edulis* on the Carolina coast as a result of transport around Cape Hatteras. *Biol. Bull., 119,* 550-559.

Wells, H. W., M. J. Wells, and I. E. Gray, 1964. Ecology of sponges in Hatteras Harbor, North Carolina. *Ecology, 45,* 752-767.

Woods Hole Oceanographic Institution. 1952. *Marine fouling and its prevention.* U. S. Naval Inst., Annapolis, Md. 388 p.

Zullo, V. A. 1963. A preliminary report on systematics and distribution of barnacles (Cirripedia) of the Cape Cod region. Syst.-Ecol. Progr., Marine Biol. Lab., Woods Hole, Mass. 33 p.