STUDIES ON FOULING INVERTEBRATES IN THE INDIAN RIVER

1. SEASONALITY OF SETTLEMENT

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ABSTRACT—Settlement of fouling invertebrates was monitored over a period of 1 year. The effectiveness of the sampling methods used is discussed. Invertebrates that established themselves in the cooler months were generally widely distributed forms while those that were found in the warmer seasons were usually stenothermic tropical forms.

The seasonal settlement of invertebrates on hard surfaces, commonly known as fouling has not received much attention in the coastal waters of the southeastern United States. Fouling assemblages have been studied in Beaufort, North Carolina (Sutherland, 1974; Sutherland and Karlson, 1973; Maturo, 1959; McDougall, 1943); Ponce de Leon Inlet in northeast Florida (Richards and Clapp, 1944); and Biscayne Bay in southeast Florida (Moore, Albertson, and Miller, 1974; Moore and Frue, 1959; Smith, Williams, and Davis, 1950; Weiss, 1948). This paper reports the first such investigation conducted in the Indian River estuary of the central east coast of Florida, a region which encompasses the zoogeographic transition zone between tropical and warm temperate shelf waters (Briggs, 1970).

Experiments were designed to: (1) determine if a single 225 cm^2 surface area adequately samples the settlement of fouling invertebrates quantitatively and qualitatively; (2) specify time periods for settlement surfaces to be submerged for identification and enumeration of dominant fouling invertebrates and; (3) observe the seasonal settlement of fouling invertebrates on short term collection surfaces.

METHODS

Studies were conducted in the Link Port canal, located on the west bank of the Indian River estuary about 6 km north of Fort Pierce, Florida. Collections were made from September 1974 to September 1975. The canal is 5-6 m deep and bulkheaded with concrete and steel.

The substrata used as settlement surfaces were Italian quarry tiles. Surfaces larger than 225 cm^2 were fabricated from 15 cm × 15 cm tiles, glued together with epoxy cement. Tiles were cemented to 30 cm pieces of 1.2 cm (½ in) polyvinylchloride (PVC) pipe with silicone rubber cement, and hung vertically from bars constructed from 10 cm diameter (4 in) PVC pipe which were suspended from a stationary barge.

Racks of 225 cm^2 tiles were submerged 10 cm below the surface for 2-week and 4-week periods throughout the study (September 1974-September 1975) to determine seasonal settlement of fouling invertebrates. At the end of each period, fouled tiles were retrieved and replaced with clean tiles. All sessile invertebrates were counted. In the case of colonial invertebrates, numbers of colonies were recorded. Numbers of animals on 2-week and 4-week tiles were compared to determine which period provided the best estimate of settlement. Surface temperatures and salinities were measured when tiles were collected.

The efficiency of sampling fouling invertebrates was determined by submerging five replicate tiles of 225 cm^2 each at a 10 cm depth for 4 weeks in July 1975. Species were recorded from all tiles and sampling efficiency was estimated by calculating Pk values according to Gaufin, Harris, and Walter (1956), where Pk is the average probability that a species will be found in the K-th sample of a set of K_n samples but in no previous sample.

To verify if the area of tile surface adequately sampled settlement of fouling invertebrates, pairs of 56, 112, 255, 337 and 450 cm^2 square tiles were suspended in the water at a depth of 10 cm for 4 weeks in July 1975. Numbers of species of each tile were counted, means determined and species-area curves drawn.

RESULTS AND DISCUSSION

Species-area curves (Fig. 1) show that few additional species are collected on tiles larger than 225 cm^2. Sampling efficiency (Pk values) tests indicate that a single tile estimates 85% of probable number of species collected and 65% of the potential coverage (Table 1). The use of a second tile contributes an additional 9% in probable number of species collected but these species consist of small actinarians and sponges which only account for another 2% coverage.

The same species of organisms were found on 2-week tiles as on 4-week tiles

Table 1. Probable percentage of fouling species present at study site that would be collected as additional plates are used. Per cent coverage column indicates the total per cent coverage of the plate by fouling organisms as less common species are added. These data are based on 4-week tiles.

No. tiles	Probable percentage of available species collected	% coverage
1	85	65
2	94	67
3	97	70
4	98	71
5	99	72

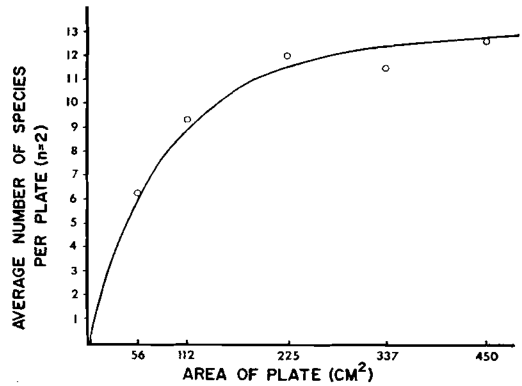

Figure 1. Species-area curve comparing the number of species found on pairs of 56, 112, 225, 337 and 450 cm^2 plates, curves fitted by eye.

but crowding on the 4-week tiles made enumeration of organisms more difficult.

Fouling organisms and their settlement times are summarized in Table 2 and from the data in Table 3. Barnacles were most common in the fall and the spring with maximum settlement peaks in May and November and a lesser one in June. *Balanus eburneus* was the numerically dominant species. *Balanus amphitrite* was observed frequently but in lower densities. A few specimens of *B. trigonus* and *B. improvisus* were found in the spring months.

Serpulid polychaetes, *Spirorbis* spp. and

Table 2. Fouling animals that settle year round or only during the winter months

Organism	Settlement at Link Port	Distribution	Author
Perophora viridis	Common early spring, summer	Massachusetts to Caribbean	Van Name, 1945
Balanus eburneus	Common all year	Massachusetts, South America	Pilsbry, 1916
Balanus amphitrite	Common all year	Massachusetts, Brazil	Pilsbry, 1916
Hydroides spp.	Very common spring, summer, all year, rare winter	——	——
Spirorbis spp.	All year, most common fall and winter	——	——
Bugula neritina	Common in winter, spring	North Carolina, Brazil	Maturo, 1957
Bugula stolonifera	Common in winter, early spring	Massachusetts, Brazil	Maturo, 1966
Conopeum tenuissimum	Common in winter, fall	New England, Florida, Gulf of Mexico	Winston, 1976 Cook, 1968
Hippoporina verrilli	Common in late fall, early winter	Massachusetts, Gulf of Mexico	Maturo and Schopf, 1968
Ascidia curvata	Rare in summer	Florida, Caribbean	Van Name, 1945
Diplosoma macdonaldi	Common in spring, summer, occasional in winter	South Carolina to Brazil	Van Name, 1945
Symplegma viride	Common in spring, summer	North Carolina to Caribbean	Van Name, 1945
Schizoporella floridae	Common late spring, summer	North Carolina to Gulf of Mexico	Maturo, 1968
Branchiomma nigromaculata	Abundant in summer	Caribbean	Jones, 1962

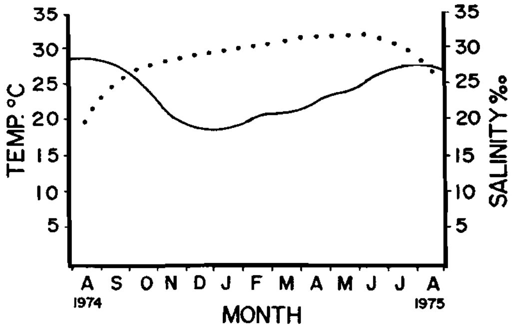

Figure 2. Average monthly temperature and salinity at Link Port from August 1974-September 1975. Dotted line is salinity; solid line is temperature.

Hydroides spp., were more numerous during the warmer months. Neither species group occupied more than 1% of the available space except in September when they covered over 10% of the tile surfaces. Numerically, however, they often exceeded 800 per tile (225 cm^2). The sabellid polychaete, *Branchiomma nigromaculata*, was found most often between barnacle plates and worm tubes in late spring and summer.

Erect bryozoans were observed mainly in the cooler months. *Bugula stolonifera* was most abundant in the early part of the winter and *B. neritina* settled more frequently in late winter and early spring. The dominant encrusting bryozoans were *Hippoporina verrilli*, *Conopeum tenuissimum*, and *Schizoporella floridae*. *Hippoporina verrilli* was abundant in the late autumn months, whereas *C. tenuissimum* was collected in greatest numbers in the winter. *Schizoporella floridae* was most common in the late spring and summer. Small numbers of *Watersipora subovoidea* colonies were found in the late spring.

Colonial ascidians were numerous in the spring and summer. *Diplosoma macdonaldi* and *Symplegma viride* were most abundant in the late spring and summer months and they often covered up 20 to 40% of the tiles. *Perophora viridis* occupied smaller portions (less than 10%) although its stolons often spread over large areas of the tiles. *Ascidia curvata*, a solitary ascidian, was found in small densities during the summer months. Oysters and the ascidian, *Styela plicata*, both very common on the Link Port seawall year round, were not observed on any of the short term settlement tiles.

The fouling invertebrates studied can be roughly divided into two groups. One group is comprised of animals that settled either all year round or only during the cooler months of late fall, winter, or early spring (Table 2). These animals were predominantly widely distributed forms, suggesting that they have wide temperature tolerances (Southward, 1958; Vernberg and Vernberg, 1972). The other group, which consists of narrowly distributed, stenothermic tropical forms, is found only during the warmer months of the year (Table 2) when water temperatures are probably more favorable for their settlement.

Many environmental factors affect the establishment of fouling organisms (Sutherland and Karlson, 1973; Maturo, 1959). For example, at Link Port settlement ceases for many animals such as tropical ascidians in late summer or early fall before water temperatures begin to fall (Table 2). Salinities are lowest at this time of year (Fig. 2), indicating that reduced salinities may limit the settlement of some of these organisms. As seen in Table 3, the time variability of the appearance of certain species is high. Since the order of larval recruitment can affect which species monopolizes the fouling community during its initial stages of development (Sutherland, 1974), and understanding of the effects of environmental components on the settlement of fouling organisms is important.

The influence of environmental factors on spawning and settlement of fouling organisms would be better understood if continuous monitoring of environmental parameters could be coupled with such data as appearance of planktonic larvae, success of settlement, growth rates, and interactions between fouling organisms. Future studies

Table 3. Summary of sessile animals found on 2-week tiles. Specimens/m². (Extrapolated from 225 cm² tiles.)

Organism	30 Sept	14 Oct	28 Oct	12 Nov	27 Nov	10 Dec	20 Dec	6 Jan	20 Jan	4 Feb	22 Feb	6 Mar	25 Mar
Balanus spp.	3285	1372	0	0	266	0	0	0	0	177	1731	2708	4084
Spirorbis sp.	0	0	0	11466	36640	16516	1731	22910	3552	3374	7104	3640	12432
Hydroides spp.	1110	222	2907	0	0	0	0	0	0	177	310	0	0
Branchiomma nigromaculata	0	0	0	0	0	0	0	0	0	0	0	0	0
Hippoporina verrilli	0	0	2619	4884	799	0	0	0	0	0	0	0	0
Conopeum tenuissimum	0	0	44	0	133	0	0	310	44	177	0	0	88
Schizoporella floridae	0	0	0	0	0	0	0	0	0	0	0	88	222
Watersipora subovoidea	0	0	0	0	0	0	0	0	0	0	0	0	0
Bugula neritina	0	0	0	0	44	44	0	355	88	440	2264	399	1820
Bugula stolonifera	0	0	0	0	0	88	0	1998	133	1465	4795	0	399
Diplosoma macdonaldi	0	0	0	0	132	3418	0	6393	1776	9358	266	0	0
Symplegma viride	0	0	0	0	0	0	0	0	0	0	0	0	0
Perophora viridis	0	0	0	0	0	0	0	0	0	0	222	0	488

Summary of dominant sessile animals found on 2-week tiles. Specimens/m²

Organism	8 Apr	24 Apr	6 May	21 May	4 June	18 June	1 July	28 July	13 Aug	27 Aug	11 Sept
Balanus spp.	1908	5687	44	18292	0	482	44	754	355	532	355
Spirorbis spp.	11366	14563	12565	4662	1721	2797	2619	13320	22200	101587	390720
Hydroides spp.	2886	3418	2042	32323	310	1465	444	754	310	2752	488
Branchiomma nigromaculata	0	0	0	9723	0	0	0	0	0	1554	0
Hippoporina verrilli	0	0	0	444	0	0	0	0	0	0	0
Conopeum tenuissimum	177	0	0	0	0	0	0	0	0	0	0
Schizoporella unicornis	177	666	355	488	177	444	88	0	88	0	0
Watersipora subovoidea	0	0	0	577	0	0	0	0	0	0	0
Bugula neritina	2752	2974	888	310	355	133	0	0	0	0	0
Bugula stolonifera	222	0	0	0	0	0	0	0	0	0	0
Diplosoma macdonaldi	0	7281	6970	44400	35164	32323	20956	3330	1554	9190	3463
Symplegma viride	133	133	44	310	710	621	44	133	44	133	440
Perophora viridis	177	254	222	310	133	532	44	0	0	0	0

will stress these as well as the effects of predation on the fouling community.

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Literature Cited

Briggs, J. C. 1970. Tropical shelf zoogeography. Proc. Calif. Acad. Sci. 7: 131-138.

Cook, P. 1968. Polyzoa from West Africa. The Malacostega Part I. Bull. Brit. Mus. Nat. Hist. 16: 115-160.

Gaufin, A., E. Harris, and H. Walter. 1956. A statistical evaluation of stream bottom sampling data obtained from three standard samplers. Ecology 37: 643-648.

Jones, M. L. 1962. On some polychaetous annelids from Jamaica, the West Indies. Bull. Am. Mus. Nat. Hist. 124: 169-212.

McDougall, D. K. 1943. Sessile marine invertebrates of Beaufort, N. C. Ecol. Monogr. 13: 323-374.

Maturo, F. 1957. A study of the bryozoa of Beaufort, North Carolina and vicinity. J. Elisha Mitchell Scientific Soc. 73: 11-68.

———. 1959. Seasonal distribution and settling

rates of estuarine Bryozoa. Ecology 40: 116-127.
———. 1966. Bryozoa of the southeast coast of the United States. Bugulidae and Beaniidae (Cheilostomata: Anasca). Bull. Mar. Sci. 16: 556-583.
———. 1968. The distributional pattern of the Bryozoa of the east coast of the United States exclusive of New England. Atti. Soc. It. Sc. Nat. e Museo Civ. St. Nat. Milano 108: 261-284.
———, and T. Schopf. 1968. Ectoproct and Entoproct type material: re-examination of species from New England and Bermuda named by A. E. Verrill, J. W. Dawson and E. Desor. Postilla, No. 120: 1-95.
Moore, H. B., and A. C. Frue. 1959. The settlement and growth of *Balanus improvisus*, *B. eburneus* and *B. amphitrite* in the Miami area. Bull. Mar. Sci. 9: 421-440.
———, H. Albertson, and S. Miller. 1974. Long-term changes in the settlement of barnacles in the Miami area. Bull. Mar. Sci. 24: 86-100.
Pilsbry, H. 1916. The sessile barnacles (Cirripedia) contained in the collections of the U.S. National Museum; including a monograph of the American species. U. S. Nat. Mus. Bull. 93: xi + 366.
Richards, B. R., and W. F. Clapp. 1944. A preliminary report on the fouling characteristics of Ponce de Leon Tidal Inlet, Daytona Beach, Florida. J. Mar. Res. 5: 189-195.
Smith, F., R. Williams, and C. Davis. 1950. An ecological survey of the subtropical inshore waters adjacent to Miami. Ecology 31: 119-146.
Southward, A. J. 1958. Note on the temperature tolerances of some intertidal animals in relation to environmental temperatures and geographical distribution. J. mar. biol. Ass. U. K. 37: 49-66.
Sutherland, J. 1974. Multiple stable points in natural communities. Amer. Nat. 108: 859-873.
———, and R. Karlson. 1973. Succession and seasonal progression in the fouling community at Beaufort, N. C. 3rd Int. Cong. Mar. Corros. and Foul., Northwestern Univ. Press, pp. 906-929.
Van Name, W. 1945. The North and South American Ascidians. Bull. Am. Mus. Nat. Hist. 84: 1-476.
Vernberg, W. B., and F. J. Vernberg. 1972. Environmental physiology of marine animals. Springer-Verlag, New York, 346 pp.
Weiss, C. M. 1948. The seasonal occurrence of sedentary marine organisms in Biscayne Bay, Florida. Ecology 29: 153-172.
Winston, J. E. 1976. Experimental culture of the estuarine ectoproct *Conopeum tenuissimum* from Chesapeake Bay. Biol. Bull. 150: 318-335.

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