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# The effect of Tropical Storm Agnes on the benthic fauna of eelgrass, Zostera marina, in the lower Chesapeake Bay

Robert J. Orth

# The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System

The Chesapeake Research Consortium, Inc.

# THE EFFECTS OF TROPICAL STORM AGNES ON THE CHESAPEAKE BAY ESTUARINE SYSTEM

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THE CHESAPEAKE RESEARCH CONSORTIUM, INC.

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# Preface

During June 1972 Tropical Storm Agnes released record amounts of rainfall on the watersheds of most of the major tributaries of Chesapeake Bay. The resulting floods, categorized as a once-in-100-to-200-year occurrence, caused perturbations of the environment in Chesapeake Bay, the nation's greatest estuary.

This volume is an attempt to bring together analyses of the effects of this exceptional natural event on the hydrology, geology, water quality, and biology of Chesapeake Bay and to consider the impact of these effects on the economy of the Tidewater Region and on public health.

It is to be hoped that these analyses of the event will usefully serve government agencies and private sectors of society in their planning and evaluation of measures to cope with and ameliorate damage from estuarine flooding. It is also to be hoped that the scientific and technical sectors of society will gain a better understanding of the fundamental nature of the myriad and interrelated phenomena that is the Chesapeake Bay ecosystem. Presumably much of what was learned about Chesapeake Bay will be applicable to estuarine systems elsewhere in the world. Most of the papers comprising this volume were presented at a symposium held May 6-7, 1974, at College Park, Maryland, under the sponsorship of the Chesapeake Research Consortium,Inc., with support from the Baltimore District, U.S. Army Corps of Engineers (Contract No. DACW 31-73-C-0189). An early and necessarily incomplete assessment, *The Effects of Hurricane Agnes on the Environment and Organisms of Chesapeake Bay* was prepared by personnel from the Chesapeake Bay Institute (CBI), the Chesapeake Biological Laboratory (CBL), and the Virginia Institute of Marine Science (VIMS) for the Philadelphia District, U.S. Army Corps of Engineers. Most of the scientists who contributed to the early report conducted further analyses and wrote papers forming a part of this report on the effects of Agnes. Additional contributions have been prepared by other scientists, most notably in the fields of biological effects and economics.

The report represents an attempt to bring together all data, no matter how fragmentary, relating to the topic. The authors are to be congratulated for the generally high quality of their work. Those who might question, in parts of the purse, the fineness of the silk must keep in mind the nature of the sow's ears from which it was spun. This is not to disparage the effort, but only to recognize that the data were collected under circumstances which at best were less than ideal. When the flood waters surged into the Bay there was no time for painstaking experimental design. There were not enough instruments to take as many measurements as the investigators would have desired. There were not enough containers to obtain the needed samples or enough reagents to analyze them. There were not enough technicians and clerks to collect and tabulate the data. While the days seemed far too short to accomplish the job at hand, they undoubtedly seemed far too long to the beleaguered field parties, vessel crews, laboratory technicians, and scientists who worked double shifts regularly and around the clock on many occasions. To these dedicated men and women, whose quality of performance and perseverance under trying circumstances were outstanding, society owes an especial debt of gratitude.

It should be noted that the Chesapeake Bay Institute, the Chesapeake Biological Laboratory, and the Virginia Institute of Marine Science, the three major laboratories doing research on Chesapeake Bay, undertook extensive data-gathering programs, requiring sizable commitments of personnel and equipment, without assurance that financial support would be provided. The emergency existed, and the scientists recognized both an obligation to assist in ameliorating its destructive effects and a rare scientific opportunity to better understand the ecosystem. They proceeded to organize a coordinated program in the hope that financial arrangements could be worked out later. Fortunately, their hopes proved well founded. Financial and logistic assistance was provided by a large number of agencies

that recognized the seriousness and uniqueness of the Agnes phenomenon. A list of those who aided is appended. Their support is gratefully acknowledged.

This document consists of a series of detailed technical reports preceded by a summary. The summary emphasizes effects having social or economic impact. The authors of each of the technical reports are indicated. To these scientists, the editors extend thanks and commendations for their painstaking work.

Several members of the staff of the Baltimore District, U.S. Army Corps of Engineers, worked with the editors on this contract. We gratefully acknowledge the helpful assistance of Mr. Noel E. Beegle, Chief, Study Coordination and Evaluation Section, who served as Study Manager; Dr. James H. McKay, Chief, Technical Studies and Data Development Section; and Mr. Alfred E. Robinson, Jr., Chief of the Chesapeake Bay Study Group.

The editors are also grateful to Vickie Krahn for typing the Technical Reports and to Alice Lee Tillage and Barbara Crewe for typing the Summary.

The Summary was compiled from summaries of each section prepared by the section editors. I fear that it is too much to hope that, in my attempts to distill the voluminous, detailed, and well-prepared papers and section summaries, I have not distorted meanings, excluded useful information or overextended conclusions. For whatever shortcomings and inaccuracies that exist in the Summary, I offer my apologies.

Jackson Davis
Project Coordinator

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- -- Reserve Training Center
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Environmental Protection Agency

U. S. Office of Emergency Preparedness

State of Maryland, Department of Natural Resources

Commonwealth of Virginia, Office of Emergency Preparedness

TABLE OF CONTENTS

C. Water Quality Effects



D. Biological Effects

# THE EFFECT OF TROPICAL STORM AGNES ON THE BENTHIC FAUNA OF EELGRASS, *ZOSTERA MARINA*, IN THE LOWER CHESAPEAKE BAY[1]

Robert J. Orth[2]

*ABSTRACT*

Tropical Storm Agnes caused major changes in the macroinvertebrate assemblages of both epifauna and infauna in eelgrass, *Zostera marina*, beds. Species abundance and density of infauna declined by one-third to one-half of values found prior to Agnes. Typical members of the infaunal community such as the amphipods, *Ampelisca* spp. and *Lysianassa alba*, the polychaetes *Sabella microphthalma* and *Exogone dispar*, ostracods and gastropods were either absent or rare following Agnes. Epifaunal density was much higher than that recorded before Agnes but the number of species was reduced. This high density was attributed to several species, e.g. *Molgula manhattensis*, which appeared to occupy space left open by the absence of typical members of this community, e.g. *Paracereceis caudata* and *Bittium varium*. The abnormally low salinities following Agnes affected various species in different ways. Some species were totally eliminated, severely reduced in abundance or, in a few euryhaline species, not affected at all. In some populations it appeared that adults survived but juveniles suffered high mortalities. Recovery and reestablishment by many species will be complicated by the disappearance of eelgrass in some portions of the Bay.

## *INTRODUCTION*

The eelgrass, *Zostera marina*, ecosystem in the Chesapeake Bay is highly productive, furnishing shelter and food for young fishes and blue crabs and providing an essential habitat for many invertebrate species. The invertebrate fauna normally associated with *Zostera* beds is among the most diverse and dense in the Chesapeake Bay (Marsh 1973; Orth 1973).

In June 1972 freshwater runoff from Tropical Storm Agnes caused a drastic reduction in salinity in the shallows where *Zostera* grows throughout the lower Bay. The *Zostera* beds and associated fauna experienced a salinity reduction of as much as 10% or 50% of their normal values. Salinity remained low for periods ranging from one to two months (see papers in this symposium concerning salinity changes in the lower Bay).

The objective of this report is to document the major changes in the *Zostera* community related to the apparent salinity stress following Agnes.

## *MATERIALS AND METHODS*

Two study sites (Fig. 1) in the York River were chosen at which baseline data already existed. Mumfort Island was the site of a study of epibiota by Marsh

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(1970) during 1967-1968 and a study of infauna by Orth (1971) in 1970. Sandy Point at the mouth of the river was also sampled during the infaunal study in 1970.

Infaunal samples were taken approximately every two months beginning in August 1972 and continuing through July 1973 at Sandy Point. Epifaunal samples were taken in March and July 1973 at Sandy Point and in July, October and December 1973 at Mumfort Island. A large epifaunal collection was taken from artificial *Zostera* in August 1972 at Sandy Point and from Brown's Bay in the Mobjack Bay in November and December 1973 and January 1974. Artificial eelgrass, consisting of polypropylene plastic strands, was placed in the York River immediately after Agnes. Fauna associated with artificial *Zostera* resembled that from real *Zostera*.

Methods of sampling epifauna and infauna were identical to those employed by Marsh (1970) and Orth (1971). Ten infaunal samples were taken randomly with a Plexiglas corer (area of 0.007 $m^2$); epifaunal samples were taken by clipping plants at the base and placing them in cloth bags with a 0.5 mm nylon mesh bottom. Where epifaunal and infaunal samples were taken together, the epifaunal sample was taken first, followed by the infaunal sample. The latter were washed through a 1.0 mm mesh screen. Epifauna and sediment was stripped from blades of eelgrass and washed through a 0.5 mm mesh screen. Cleansed plants were oven-dried at 80$^{o}$C for 48 hours and weighed. Abundance of non-colonial species was expressed as numbers of individuals per gram dry weight of *Zostera*.

## *RESULTS*

### *Infauna*

Post-Agnes infaunal samples show some changes in numerically dominant species (Fig. 2, Table 1). Epifaunal species found in the sediments in winter when *Zostera* is scarce (Orth 1973) are excluded from this analysis. Samples taken after Agnes at Sandy Point were compared with those taken at Sandy Point and Back River in 1970. Samples at Sandy Point (B) and Back River (A) were very similar in species composition in 1970 (Orth 1973).

Table 1. Species recorded in infaunal collections in 1970 but not present or rare after Agnes at Sandy Point.

| |
|---|
| *Prionospio heterobranchia* (Polychaeta) |
| *Exogone dispar* (Polychaeta) |
| *Lysianassa alba* (Amphipoda) |
| *Cylindroleberis mariae* (Ostracoda) |
| *Sarsiella zostericola* (Ostracoda) |
| *Anadara transversa* (Bivalvia) |
| *Acteocina canaliculata* (Gastropoda) |
| *Triphora perversa* (Gastropoda) |
| *Mangelia plicosa* (Gastropoda) |
| *Acteon punctostriatus* (Gastropoda) |

The eurytopic species, *Heteromastus filiformis, Scoloplos robustus, Streblospio benedicti, Eteone heteropoda, Edotea triloba, Polydora ligni, Nereis succinea, Spiochaetopterus oculatus, Glycinde solitaria,* and *Peloscolex gabriellae* (Fig. 2), seemed least affected by Agnes. Their abundances were similar to those recorded in 1970. These species are widely distributed throughout the estuary (Boesch 1971) in a wide range of sediment types. Their euryhalinity presumably allowed them to tolerate salinity stress imposed by Agnes.

Species apparently most affected by Agnes were those which brood their young or are more stenohaline (Table 1). The amphipods *Ampelisca abdita, A. vadorum* and *Lysianassa alba*, the isopod *Cyathura burbancki*, and the polychaetes *Sabella microphthalma, Exogone dispar* and *Prionospio heterobranchia*, numerically dominant species in 1970, were rare or absent following Agnes (Table 1, Fig. 2). *Macoma balthica* and *M. mitchelli*, normally restricted to the mesohaline and oligohaline zones (Wass 1972), were found at the mouth of the York River in 1973 for the first time (Orth 1971). At Mumfort Island, *M. balthica* had densities up to $14/m^2$ in 1970; in July 1973 they reached $514/m^2$.

At Sandy Point numbers of species and faunal densities were reduced following Agnes (Fig. 3). The high density in March 1973 was similar to that of March 1970 (at Station B, *Polydora ligni* made up 47% of the total in the Post-Agnes data and 36% prior to Agnes).

Recovery of species associated with *Zostera* was interrupted by the dramatic decline of *Zostera* in the York River and other areas of the lower Bay in August 1973. This was apparently due to the influx of the migratory cownose ray *Rhinoptera bonasus*, which uprooted vast areas of *Zostera* (Orth 1975).

Infaunal samples collected in November and December 1973 and January 1974 in Mobjack Bay, one of the few places where *Zostera* was still dense, revealed densities of *Ampelisca vadorum, Cyathura burbancki, Acteocina canaliculata* and *Sabella microphthalma* similar to those recorded in 1970. Other species (Table 1) have been found only rarely if at all.

### *Epifauna*

Although quantitative sampling did not commence until March 1973, qualitative observations made during July and August 1972, a large qualitative sample taken from a plot of artificial *Zostera* in August 1972, and the absence of epifauna usually taken in infaunal samples during the winter months confirmed the patterns observed in the quantitative data. Changes in epifauna after Agnes are represented by taxonomic groups.

*Anthozoa*. *Aiptasiomorpha luciae*, the only anemone collected in 1968, was present from late March to early December, with peak densities in late summer and fall. This species was present on the artificial *Zostera* in August 1972 and appeared unaffected by Agnes. One year after Agnes, *A. luciae* was rare, with densities (0.3-1.8 ind./g *Zostera*) far below those recorded by Marsh for these same times of year. Adults apparently survived the Agnes freshet but subsequent recruitment was poor, perhaps because of poor survival of juveniles or reproductive failure. This pattern was common to several species discussed below.

*Turbellaria*. *Euplana gracilis* and *Stylochus ellipticus* were the most abundant flatworms in 1968. They were very abundant in August 1972 on artificial *Zostera* and again in 1973. As suggested by Andrews (1973) these species appeared unaffected by Agnes.

*Rhynchocoela*. *Zygonemertes virescens* and *Tetrastemma elegans* were common previously and both species were found in August 1972. In July through December 1973, densities were similar or higher than those recorded by Marsh in 1968.

<u>*Polychaeta*</u>. *Nereis succinea*, found throughout the year, was most abundant from June to October during Marsh's study. After Agnes, *N. succinea* was extremely abundant on the artificial *Zostera*, and was found throughout 1973, being most abundant during the summer with densities higher than previously recorded (Table 2).

*Platynereis dumerilii* was found on artificial *Zostera* after Agnes. In 1973 it was absent in summer but occurred in high densities in the fall. Marsh reported a summer increase in 1968.

*Polydora ligni* was also present on artificial *Zostera* and was dense at several locations during 1973 (Table 2). The seasonal abundance pattern differed from that found by Marsh. However, *Polydora* populations vary greatly in space and time. Large numbers were found on *Zostera* in Mobjack Bay in January 1974. Marsh found none in January 1968.

No other polychaete species were found on artificial *Zostera* after Agnes and only three other species have since been collected on *Zostera*. *Podarke obscura* and *Hydroides dianthus* were recorded frequently by Marsh but have not occurred since Agnes. *Sabella microphthalma* was found throughout the year in 1968. None were recorded after Agnes on artificial *Zostera*, but densities in July and October 1973 were similar to those of Marsh for this same period in 1968. *Brania clavata*, another polychaete abundant from April to October 1968 was infrequent in very low densities and not until December 1973 was it recorded in high densities. This apparently reflected gradual recovery of the populations.

Less abundant species found by Marsh, but not recorded after Agnes, were *Nereiphylla fragilis*, *Exogone dispar*, *Pista palmata*, *Odontosyllis fulgurans*, and *Lepidonotus variabilis*.

<u>*Prosobranchia*</u>. *Bittium varium* was one of the most numerically dominant species in the *Zostera* community prior to Agnes. It was abundant on artificial *Zostera* after Agnes and was observed frequently on live eelgrass during July and August 1972. In 1973, few *Bittium* were recorded from samples taken in March and July but they increased in abundance in October and November 1973 (Table 3) the decline in *Bittium* populations during late 1972 and early 1973 probably resulted from juvenile or larval mortality during the Agnes freshet. Egg capsules are deposited in May and June (Marsh 1970), with the new year class constituting an increasing proportion of the population from June through fall (Fig. 4). A random sample of *Bittium* taken in August 1972 revealed the almost complete absence of young, suggesting they were largely killed by the salinity reduction. Adults die in the fall, and the few surviving juvenile *Bittium* comprised the small spring and summer 1973 populations. Infaunal samples taken in the winter (1972-1973), when *Bittium* is normally found in the sediment, contained few live snails, another indication that young had suffered high mortalities in the summer. Repopulation during the summer of 1973 appeared successful. In July 1973, 18% of all *Bittium* were 1.5-2.0 mm and in October 1973 the entire sample (592 individuals) consisted of individuals less than 3.5 mm. Densities on *Zostera* were similar to those recorded for the same periods by Marsh. Infaunal samples taken January 1974 in Mobjack Bay revealed an abundance of *Bittium* in the sediments.

*Crepidula convexa* was abundant throughout 1968 and on artificial eelgrass after Agnes. In the summer and fall 1973, *Crepidula* reached a density, in some samples, 200 times that found during the same period in 1969 (Table 3). Blades of *Zostera* were covered with *Crepidula*. *Crepidula*, apparently unaffected by Agnes, was able to exploit space made vacant by the demise of other dominant species.

Table 2. Number of individuals per gram dry weight of *Zostera* for three species of polychaetes found on *Zostera* before and after Agnes. Mean and range for each sampling period for Marsh's three stations (pre-Agnes) and for replicates taken after Agnes at each station listed (SP - Sandy Point; MI - Mumfort Island; BB - Brown's Bay).

| Species | Post-Agnes | | | | | Pre-Agnes | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Nereis succinea* | 1972 | Aug | (SP) | abundant | | 1967 | Nov | 0.8 | (0.02- 2.3) |
| | 1973 | March | (SP) | 0.08 | (0 - 0.5) | | Dec | 0.3 | (0.09- 0.7) |
| | | July | (SP) | 10.1 | (7.8 -12.6) | 1968 | Jan | 0.2 | (0.02- 2.3) |
| | | July | (MI) | 9.1 | (8.3 - 9.9) | | March[1] | 0.1 | (0.1 - 0.2) |
| | | Oct | (MI) | 11.1 | (8.2 -13.9) | | June[2] | 4.7 | (1.2 - 11.0) |
| | | Nov | (BB) | 0.1 | (0 - 0.2) | | July | 2.9 | (1.7 - 4.7) |
| | | Dec | (MI) | 0.6 | | | Aug | 1.2 | (0.4 - 2.0) |
| | | Dec | (BB) | 0.3 | (0.1 - 0.5) | | Oct | 6.0 | (3.3 - 7.7) |
| | 1974 | Jan | (BB) | 0.03 | (0 - 0.08) | | Nov | 0.5 | (0.07- 1.0) |
| | | | | | | | Dec | 0.2 | (0.08- 0.4) |
| *Platynereis dumerilii* | 1972 | Aug | (SP) | present | | 1967 | Nov | 2.0 | (0.2 - 5.7) |
| | 1973 | March | (SP) | 0 | | | Dec | 0.7 | (0.2 - 2.0) |
| | | July | (SP) | 0.2 | (0 - 0.4) | 1968 | Jan | 0.8 | (0.1 - 2.4) |
| | | July | (MI) | 0 | | | March[1] | 0.03 | (0 - 0.1) |
| | | Oct | (MI) | 4.2 | (2.8 - 5.6) | | June[2] | 4.7 | (1.2 - 11.0) |
| | | Nov | (BB) | 2.4 | (1.8 - 2.9) | | July | 2.9 | (1.7 - 4.7) |
| | | Dec | (MI) | 1.5 | | | Aug | 1.2 | (0.4 - 2.0) |
| | | Dec | (BB) | 3.8 | (3.4 - 4.1) | | Oct | 7.1 | (4.5 - 10.1) |
| | 1974 | Jan | (BB) | 2.8 | (2.2 - 3.4) | | Nov | 0.5 | (0.07- 1.0) |
| | | | | | | | Dec | 0.2 | (0.08- 0.4) |
| *Polydora ligni* | 1972 | Aug | (SP) | present | | 1967 | Nov | 0 | |
| | 1973 | March | (SP) | 2.2 | (1.7 - 3.2) | | Dec | 0 | |
| | | July | (SP) | 77.6 | (46.8 -96.1) | 1968 | Jan | 0 | |
| | | July | (MI) | 5.4 | (4.4 - 6.3) | | March[1] | 0.2 | (0.07- 0.4) |
| | | Oct | (MI) | 9.3 | (7.9 -10.7) | | April | 56.4 | (13.0 - 86.5) |
| | | Nov | (BB) | 3.5 | (0.9 - 6.0) | | May | 48.6 | (0.3 -144.9) |
| | | Dec | (MI) | 0 | | | June[2] | 0.3 | (0.05- 0.9) |
| | | Dec | (BB) | 16.9 | (14.5 -19.3) | | July | 0.02 | (0 - 0.05) |
| | 1974 | Jan | (BB) | 11.8 | (9.9 -13.7) | | Aug | 0 | |
| | | | | | | | Oct | 7.9 | (0.8 - 13.7) |
| | | | | | | | Nov | 0.02 | (0 - 0.07) |
| | | | | | | | Dec | 0 | |

[1]represents first sampling period for that month.

[2]represents second sampling period for that month (see Marsh 1970 for sampling dates)

Table 3. Number of individuals per gram dry weight of *Zostera* for *Bittium varium* and *Crepidula convexa*. Mean and range of each sampling period given.

| Species | Post-Agnes | | | | | Pre-Agnes | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Bittium varium* | 1972 | Aug | (SP) | abundant | | 1967 | Nov | 3.7 | ( 1.9- 6.5) |
| | 1973 | March | (SP) | 0.08 | ( 0 - 0.5) | | Dec | 5.5 | ( 3.5- 9.3) |
| | | July | (SP) | 9.0 | ( 4.7- 14.7) | 1968 | Jan | 3.5 | ( 0.8- 8.2) |
| | | July | (MI) | 1.7 | ( 1.5- 1.8) | | March[1] | 0.8 | ( 0.3- 1.4) |
| | | Oct | (MI) | 61.6 | ( 58.8- 64.4) | | June[2] | 23.6 | (12.1- 40.0) |
| | | Nov | (BB) | 66.5 | ( 62.0- 71.0) | | July | 60.1 | (14.4-121.2) |
| | | Dec | (MI) | 1.1 | | | Aug | 66.2 | (27.1-124.7) |
| | | Dec | (BB) | 11.1 | ( 10.4- 12.7) | | Oct | 96.3 | (39.3-203.1) |
| | 1974 | Jan | (BB) | 7.0 | ( 5.2- 8.7) | | Nov | 43.8 | (33.2- 60.1) |
| | | | | | | | Dec | 57.8 | (46.3- 71.8) |
| *Crepidula convexa* | 1972 | Aug | (SP) | abundant | | 1967 | Nov | 14.1 | ( 8.3- 22.9) |
| | 1973 | March | (SP) | 4.3 | ( 0.7- 6.8) | | Dec | 10.6 | ( 6.1- 13.1) |
| | | July | (SP) | 119.5 | ( 72.8-164.7) | 1968 | Jan | 11.6 | ( 4.9- 22.0) |
| | | July | (MI) | 108.5 | ( 96.0-121.0) | | March[1] | 3.0 | ( 1.3- 5.7) |
| | | Oct | (MI) | 851.8 | (817.6-886.0) | | June[2] | 8.1 | ( 4.2- 13.2) |
| | | Nov | (BB) | 164.3 | (108.2-220.4) | | July | 18.2 | (11.3- 24.8) |
| | | Dec | (MI) | 40.0 | | | Aug | 38.4 | (10.0- 46.1) |
| | | Dec | (BB) | 40.0 | ( 39.6- 40.3) | | Oct | 12.3 | ( 6.6- 21.8) |
| | 1974 | Jan | (BB) | 34.1 | ( 23.5- 44.6) | | Nov | 10.5 | ( 6.7- 17.6) |
| | | | | | | | Dec | 9.1 | ( 5.7- 15.5) |

[1]represents first sampling period for that month.
[2]represents second sampling period for that month (see Marsh 1970 for sampling dates).

Only two other prosobranch species were collected after Agnes but their densities on *Zostera* were low compared to *Bittium* and *Crepidula*. Populations of adult *Mitrella lunata* were found in August 1972. Few were found in the sediments in the winter where they had occurred previously, and low densities occurred in summer 1973. Densities remained depressed, at least to January 1974. This suggests heavy juvenile mortality after Agnes.

Epifaunal populations of *Urosalpinx cinerea* were apparently decimated after Agnes (Andrews 1973). Few individuals were seen in the 1972-1973 collections made from *Zostera* blades; however, the density of *Urosalpinx* in infaunal samples was similar to those recorded previously.

*Opisthobranchia.* The abundance of most opisthobranchs was severely reduced after Agnes. Four pyramidellids were recorded before Agnes, with *Odostomia impressa* the most common. Only one specimen of *O. bisuturalis* was found after Agnes and *O. impressa* was rare (only nine specimens have been recorded in all epifaunal collections since Agnes).

*Elysia catula*, a saccoglossan occurring throughout the year in Marsh's 1968 study, has not been found since Agnes. Collections by R. Vogel (personal communication) verify that not only *E. catula* but also *Doris verrucosa*, a dorid nudibranch previously less common than *Elysia*, have not been found in the York River since Agnes. *Tenellia fuscata*, *Ercolania vanellus*, and *Cratena pilata* appeared unaffected by Agnes (R. Vogel, personal communication). *Doridella obscura*, another dorid nudibranch, was very abundant on the artificial *Zostera* after Agnes and occurred at densities of 11-18 ind./g eelgrass during the summer of 1973. *Doridella*, present in Marsh's study at lower densities, is very euryhaline and might have responded to the increase in available space, as did *Crepidula convexa*.

*Bivalvia.* *Anadara transversa* occurred in almost every collection by Marsh, but after Agnes only one specimen was found at Mumfort Island in October 1973 and at Sandy Point in July 1973. *A. transversa* was also absent from infaunal samples where it occurred previously. Andrews (1973) also found this species rare after Agnes.

*Amygdalum papyria*, a relatively euryhaline species not recorded by Marsh, was found on artificial *Zostera* and at Sandy Point in July 1973 and also at Mumfort Island in October and December 1973.

*Urochordata.* *Molgula manhattensis* was one of the few extremely abundant species after Agnes (Table 4). After Agnes, recruitment of *Molgula* was suppressed for two months by fluctuating salinities, after which it recovered quickly as salinities became more favorable (Andrews 1973). The cause for this increase in abundance on *Zostera* is unknown, but may be a result of increased survival of juveniles because of reduced predation or reduced competition from other sessile fauna.

*Botryllus schlosseri* and *Perophora viridis*, two colonial ascidians found by Marsh, have not been seen since Agnes.

*Cirripedia.* *Balanus improvisus*, a very euryhaline species, was found throughout 1968, with peak abundances in May and early June. Competition for space and predation appear to be factors that lead to reduction in their numbers under normal conditions. After Agnes, *Balanus* was present on artificial *Zostera* and more abundant one year after Agnes than in 1968 (Table 4). Whether this was because of reduced predation (*Stylochus* was still abundant and found in many empty barnacle tests), relaxed competition for space, or simply unusually successful recruitment is unknown.

Isopoda. *Paracerceis caudata*, previously one of the numerically dominant members of the *Zostera* community, has been absent since Agnes. Present throughout the year in Marsh's study, numerous *Paracerceis* were observed during 1970 and 1971 on *Zostera* blades. It appears that *Paracerceis* populations were eliminated, at least in the York River-Mobjack Bay area.

Two other isopod species, *Erichsonella attenuata* and *Idotea baltica*, were present in densities similar to those found by Marsh. These species seemed unaffected by Agnes. Abundant *Idotea*, including ovigerous females and juveniles, were observed just after Agnes.

Amphipoda. Amphipods, normally abundant and diverse on *Zostera*, were comparatively depauperate after Agnes. Only three species were found on artificial *Zostera* in August 1972, and only ten species have been recorded from August 1972 to October 1973, compared with 23 species recorded by Marsh. The group is now less diverse (Fig. 5); data on number of species in November and December 1973 are similar to 1968 data, but the species composition in these two periods of 1973 compared to 1968 are different. The dominant species, *Cymadusa compta*, *Ampithoe valida*, *Elasmopus laevis*, *Caprella penantis*, and *Paracaprella tenuis*, were present before and after Agnes, but the rarer species, such as *Colomastix halichondriae*, *Rudilemboides nageli*, *Melita* spp., and *Stenothoe* spp. were absent from all collections.

*Cymadusa compta* and *Ampithoe valida* [reported by Marsh as *A. longimana*, which is found in higher salinities (Bousfield 1973)], were the most abundant species recorded by Marsh in 1968 and both were found after Agnes in similar densities (Table 5). *Cymadusa compta* was extremely abundant on the artificial *Zostera* in August 1972 with many ovigerous females present.

*Elasmopus laevis* and *Gammarus mucronatus* were also present during Marsh's study. *Elasmopus* was found in York River collections made in July 1972 but was absent from artificial *Zostera* in August 1972 and has not re-occurred there. It was found in the Mobjack Bay in November and December 1973 and January 1974. *Gammarus mucronatus* was very abundant just after Agnes and in March 1973, but has since been rare. *Caprella penantis* and *Paracaprella tenuis* were rare after Agnes in the York River but found in Mobjack Bay from November 1973 to January 1974 at moderate to high densities.

## *DISCUSSION*

The macroinvertebrate community associated with *Zostera* was severely affected by the salinity stress following Agnes. Though quantitative data are not available for the periods just prior to and immediately after Agnes, qualitative observations together with existing background quantitative data reflected a major disturbance during this period. Later quantitative samples also support this conclusion. Many of the numerically dominant species, as well as less abundant species, were either rare or absent immediately after Agnes. A few species, e.g. *Crepidula* and *Molgula*, became more abundant than prior to the influx of Agnes. Of course, the degree to which the effects of Agnes were responsible for observed population changes is questionable. Little is known about physiological tolerances of Chesapeake Bay organisms. Even less is known about importance of biological interactions and func-

Table 4. Number of individuals per gram dry weight of *Zostera* for *Balanus improvisus* and *Molgula manhattensis*. Mean and range of each sampling period given.

| Species | Post-Agnes | | | | | Pre-Agnes | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Balanus improvisus* | 1972 | Aug | (SP) | abundant | | 1967 | Nov | 0.3 | (0.02- 0.5 ) |
| | 1973 | March | (SP) | 0.05 | ( 0 - 0.3 ) | | Dec | 1.4 | (0.1 - 3.9 ) |
| | | July | (SP) | 30.0 | ( 15.3- 46.5 ) | 1968 | Jan | 0.7 | (0.3 - 1.8 ) |
| | | July | (MI) | 4.6 | ( 1.4- 7.8 ) | | March[1] | 0.07 | (0 - 0.2 ) |
| | | Oct | (MI) | 24.5 | ( 22.6- 26.4 ) | | May | 18.5 | (0.7 -50.0 ) |
| | | Nov | (BB) | 26.5 | ( 14.5- 38.4 ) | | June[1] | 9.2 | (0.8 -23.0 ) |
| | | Dec | (MI) | 6.3 | ) | | July | 0.04 | (0 - 0.1 ) |
| | | Dec | (BB) | 17.7 | ( 13.8- 21.5 ) | | Oct | 0.2 | (0.04- 0.7 ) |
| | 1974 | Jan | (BB) | 1.3 | ( 0.8- 1.7 ) | | Nov | 0.1 | (0 - 0.2 ) |
| | | | | | | | Dec | 0.03 | (0 - 0.08) |
| *Molgula manhattensis* | 1972 | Aug | (SP) | | | 1967 | Nov | 0.4 | (0 - 1.2 ) |
| | 1973 | March | (SP) | 0 | | | Dec | 0 | |
| | | July | (SP) | 154.8 | ( 87.2-232.8 ) | 1968 | Jan | 0 | |
| | | July | (MI) | 158.2 | (127.8-188.5 ) | | March[1] | 0 | |
| | | Oct | (MI) | 37.1 | ( 33.8- 40.3 ) | | June[2] | 1.3 | (0.03- 3.9 ) |
| | | Nov | (BB) | 0.9 | ( 0.1- 1.6 ) | | July | 7.7 | (0.2 -22.1 ) |
| | | Dec | (MI) | 0 | ) | | Aug | 0.5 | (0.1 - 1.3 ) |
| | | Dec | (BB) | 0.7 | ( 0.5- 0. ) | | Oct | 2.6 | (1.6 - 3.5 ) |
| | 1974 | Jan | (BB) | 0.03 | ( 0 - 0.08) | | Nov | 0.06 | (0 - 0.2 ) |
| | | | | | | | Dec | 0.03 | (0 - 0.08) |

[1]represents first sampling period for that month.
[2]represents second sampling period for that month (see Marsh 1970 for sampling dates).

Table 5. Number of individuals per gram dry weight of *Zostera* for *Cymadusa compta* and *Ampithoe valida* (and *longimana*). Mean and range for each sampling period given.

| Species | Post-Agnes | | | | | Pre-Agnes | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Cymadusa compta* | 1972 | Aug | (SP) | very abundant | | 1967 | Nov | 3.9 | ( 0.5 - 10.7) |
| | 1973 | March | (SP) | 0.9 | ( 0.7- 2.0) | | Dec | 1.0 | ( 0.4 - 1.8) |
| | | July | (SP) | 1.9 | ( 1.4- 2.3) | 1968 | Jan | 2.7 | ( 1.8 - 4.0) |
| | | July | (MI) | 5.2 | ( 5.0- 5.3) | | March[1] | 0.8 | ( 0.3 - 1.5) |
| | | Oct | (MI) | 4.5 | ( 4.4- 4.5) | | June[2] | 0.3 | ( 0.04- 0.5) |
| | | Nov | (BB) | 9.9 | ( 6.2-13.6) | | July | 3.4 | ( 1.5 - 4.8) |
| | | Dec | (MI) | 6.1 | | | Aug | 2.1 | ( 0.3 - 3.0) |
| | | Dec | (BB) | 23.7 | (23.4-24.0) | | Sept | 5.2 | ( 0.3 - 13.1) |
| | 1974 | Jan | (BB) | 13.0 | ( 8.5-17.4) | | Oct | 39.1 | ( 2.7 - 79.5) |
| | | | | | | | Nov | 2.5 | ( 0.2 - 5.0) |
| | | | | | | | Dec | 1.4 | ( 0.2 - 2.3) |
| *Ampithoe valida* & *longimana* (*valida* at Mumfort Island only) | 1972 | Aug | (SP) | Present | | 1967 | Nov | 1.1 | ( 0.6 - 2.8) |
| | 1973 | March | (SP) | 0.2 | ( 0 - 1.0) | | Dec | 2.2 | ( 1.4 - 3.9) |
| | | July | (SP) | 0.3 | ( 0 - 0.6) | 1968 | Jan | 2.5 | ( 1.4 - 3.1) |
| | | July | (MI) | 18.1 | (16.5-19.6) | | March[1] | 1.2 | ( 0.5 - 2.6) |
| | | Oct | (MI) | 4.3 | ( 3.6- 4.9) | | June[2] | 1.2 | ( 0.3 - 2.2) |
| | | Nov | (BB) | 0.6 | ( 0.2- 0.9) | | July | 16.9 | ( 7.0 - 35.6) |
| | | Dec | (MI) | 3.1 | | | Aug | 5.6 | ( 1.4 - 12.4) |
| | | Dec | (BB) | 5.9 | ( 3.4- 8.3) | | Sept | 3.2 | ( 0.2 - 7.6) |
| | 1974 | Jan | (BB) | 4.6 | ( 2.2- 7.0) | | Oct | 69.7 | (15.0 -150.2) |
| | | | | | | | Nov | 3.7 | ( 2.0 - 6.3) |
| | | | | | | | Dec | 0.8 | ( 0.4 - 1.2) |

[1]represents first sampling period for that month.
[2]represents second sampling period for that month (see Marsh 1970 for sampling dates).

tional roles of species in communities.

The effects of Agnes on species in the *Zostera* community were of several types:

1) Species which may have suffered some mortality but became more abundant after Agnes, e.g. *Molgula manhattensis, Crepidula convexa.*

2) Species totally eliminated, severely reduced, or with poor recovery, e.g. *Ampelisca* spp., *Lysianassa alba, Paracerceis caudata, Podarke obscura, Elysia catula.*

3) Species whose adult populations survived but the juveniles suffered high mortalities resulting in reduced populations later, e.g. *Bittium varium.*

4) Species unaffected, e.g. *Heteromastus filiformis, Polydora ligni, Cymadusa compta, Erichsonella attenuata.*

The *Zostera* community in the Chesapeake Bay is a diverse assemblage of species in a wide variety of taxonomic groups. However, after Agnes both the epifauna (Fig. 6) and infauna (Fig. 3) were less diverse than previously. This was a result of the loss of a few numerically dominant species and many of the less abundant ones. No comparably catastrophic environmental stresses on the *Zostera* community have occurred for at least 10-15 years, thus allowing the development of high species diversity.

The biotic interactions (intra- and interspecific competition, predation, etc.) on the species associated with *Zostera* are not known but experimental manipulation of dominant species may provide an insight to some of the biological control mechanisms operating in the *Zostera* community. Agnes provided a natural experiment on community, selectively removing some dominant members and reducing the abundance of others. The observations, keeping in mind the noted limitations, suggest some interesting interrelationships. However, these are mostly correlative and further experimentation needs to be carried out for verification.

*Crepidula convexa* and *Molgula manhattensis* were found in far greater abundance than recorded prior to Agnes (Tables 4 & 5). *Crepidula* broods its young and *Molgula* has short-lived planktonic larvae, yet both were recruited successfully after Agnes. This may have been due to increased larval survival resulting from a depression of planktonic predators, a relaxation of predation on newly settled juveniles, or to space left open by eliminated competition.

*Bittium varium,* a usually abundant herbivorous grazer reduced by Agnes, may play a major role of keeping space open on the *Zostera* blade by grazing on space-consuming algae and eliminating newly settled larvae by its grazing action.

Whether and when the *Zostera* community returns to pre-Agnes conditions of high species diversity, depends on potential recruitment from refuge populations of species almost totally eliminated (in this context, species which disperse via planktonic larvae, or swimming juvenile or adult stages, would be expected to reestablish faster than those which brood their young and disperse by crawling), the ability of those species reduced in abundance to increase their populations and the absence of any major disturbance, either man-made or natural. Reestablishment of these species in *Zostera* will be complicated by the absence of *Zostera* in areas where it normally occurs. The mass destruction of *Zostera* by the cownose ray, *Rhinoptera bonasus,* has eliminated much of the *Zostera* in the lower Bay, thus removing, at least temporarily, an important habitat for many species.

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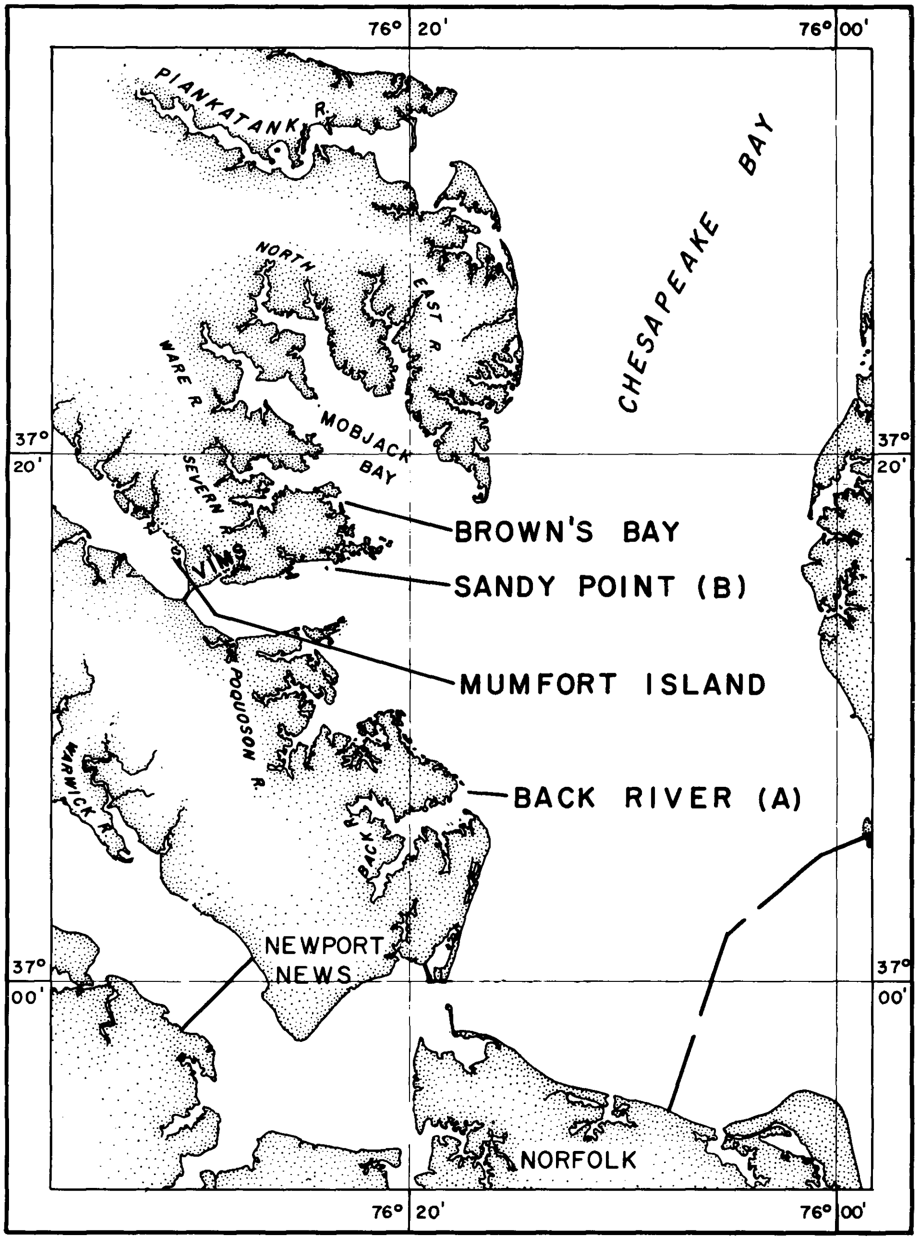


Figure 1. Map of Chesapeake Bay, York River, and Mobjack Bay showing sampling locations.

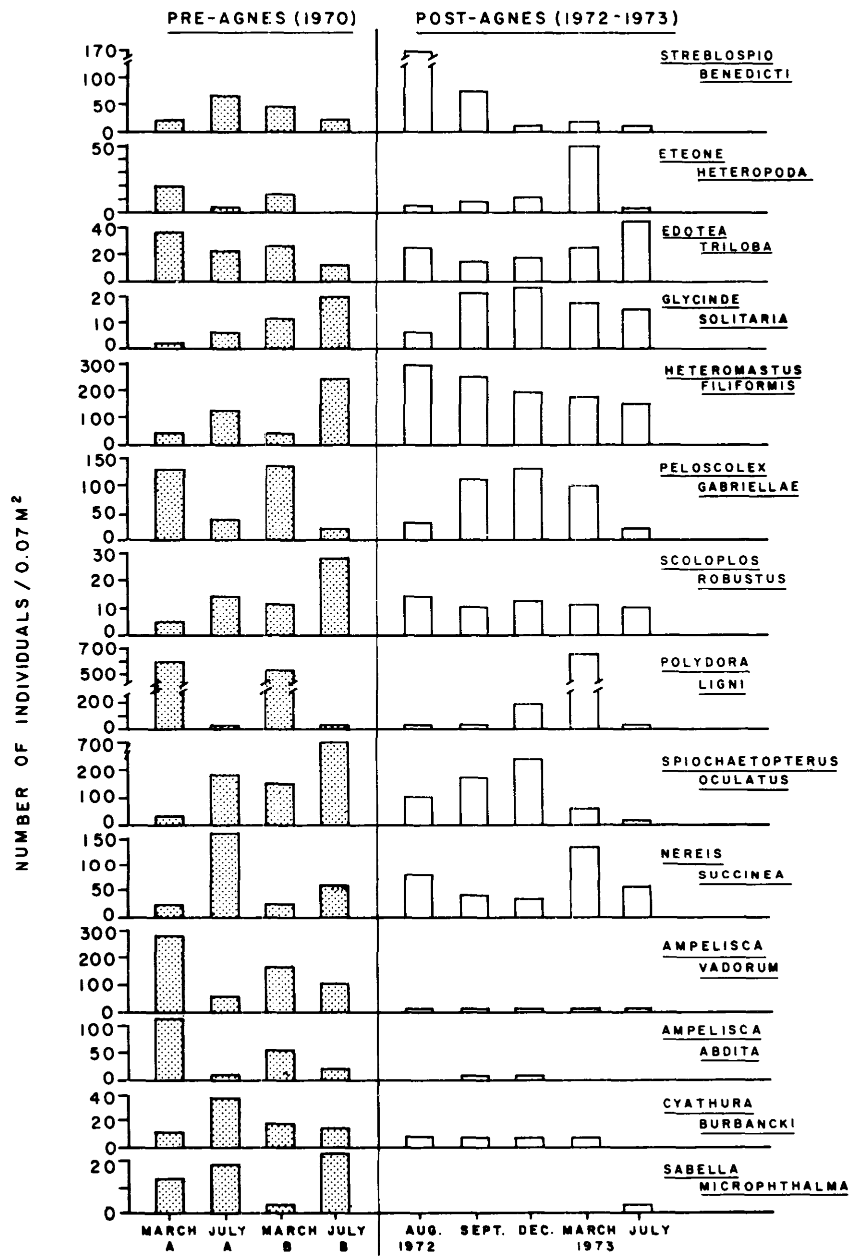


Figure 2. Densities of infaunal species found prior to and after Agnes. Pre-Agnes data from Orth (1971) for two selected stations A and B. Post-Agnes data collected at station B (Sandy Point).

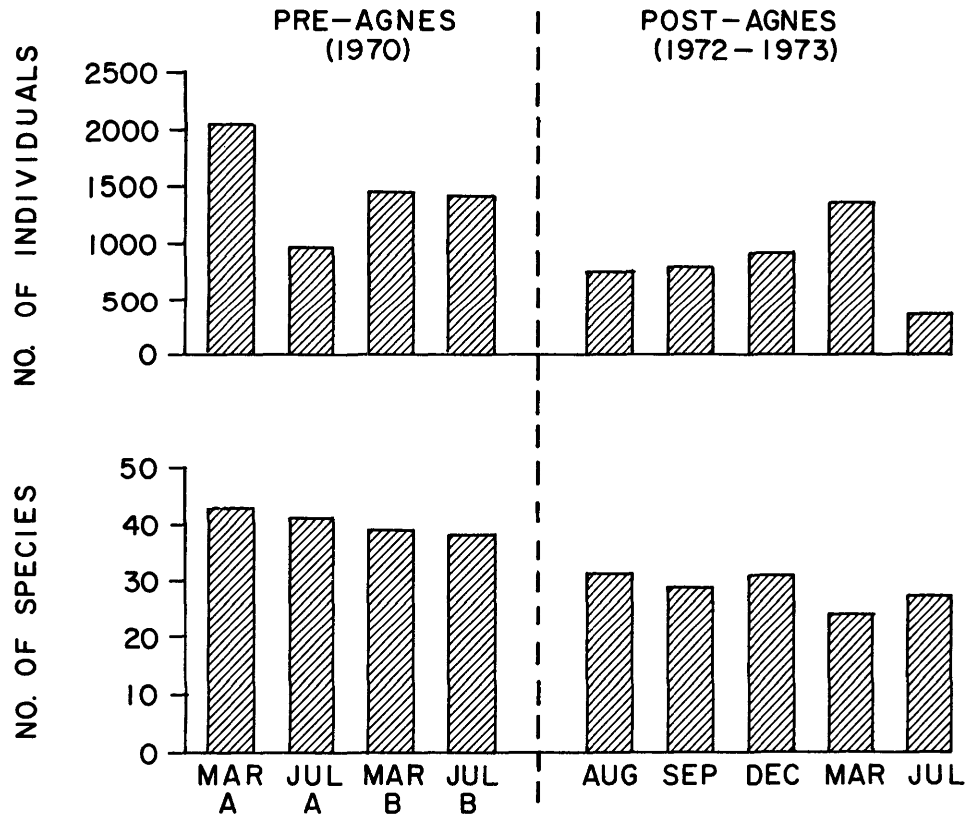


Figure 3. Total number of species and individuals found in 10 cores ($0.07\ m^2$) at stations A and B in 1970 and at station B in 1972-1973.

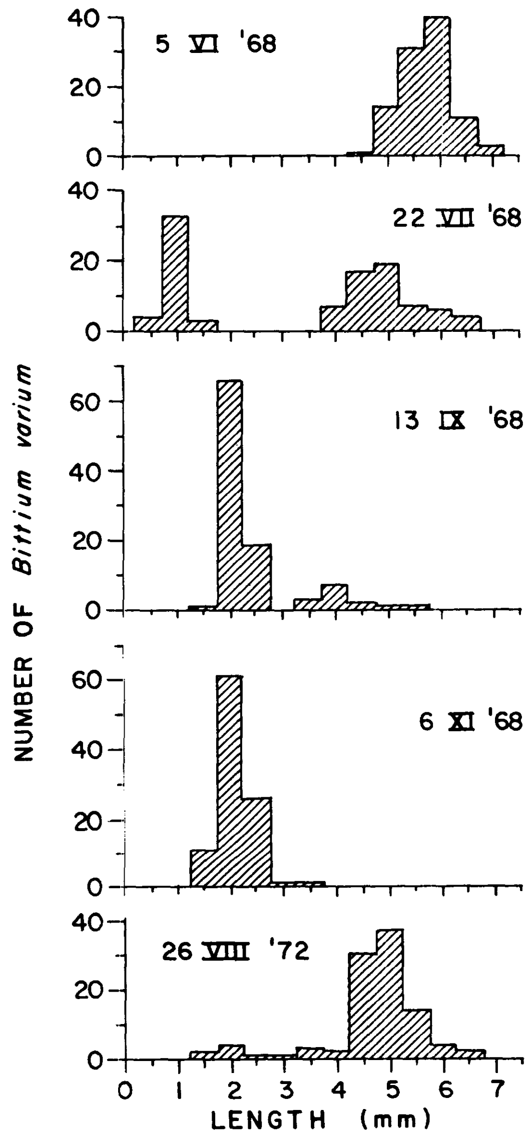


Figure 4. Length x frequency histograms of 100 *Bittium varium* selected randomly from Mumfort Island (Marsh's station C) on each of four sampling dates in 1968 and similar sample taken from artificial eelgrass in August, 1972, at Sandy Point.

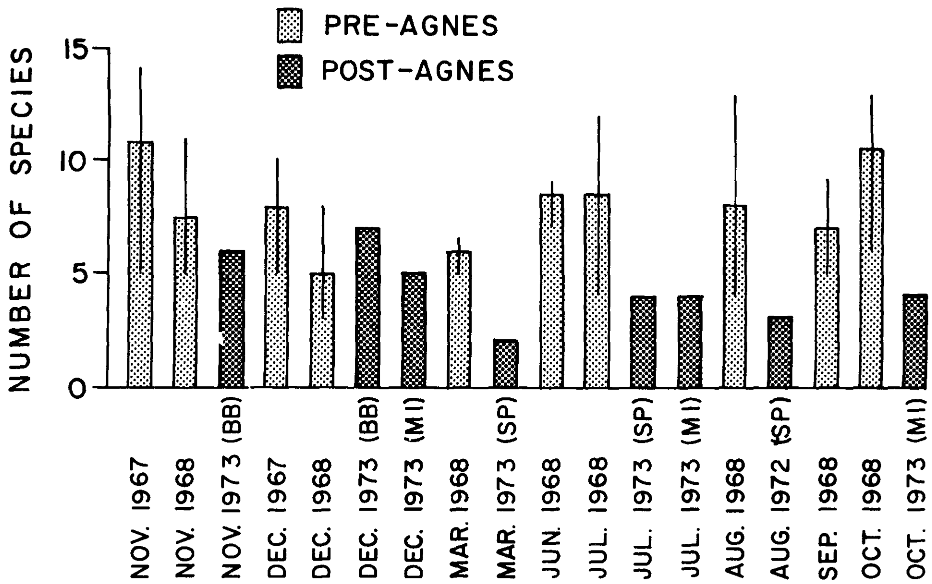


Figure 5. Number of amphipod species found before and after Agnes. Pre-Agnes data from Marsh at Mumfort Island. Mean and range of three stations sampled by Marsh in 1967 and 1968 for number of epifaunal amphipod species and total number of amphipod species found after Agnes at selected areas (BB-Browns Bay; MI-Mumfort Island; SP-Sandy Point).

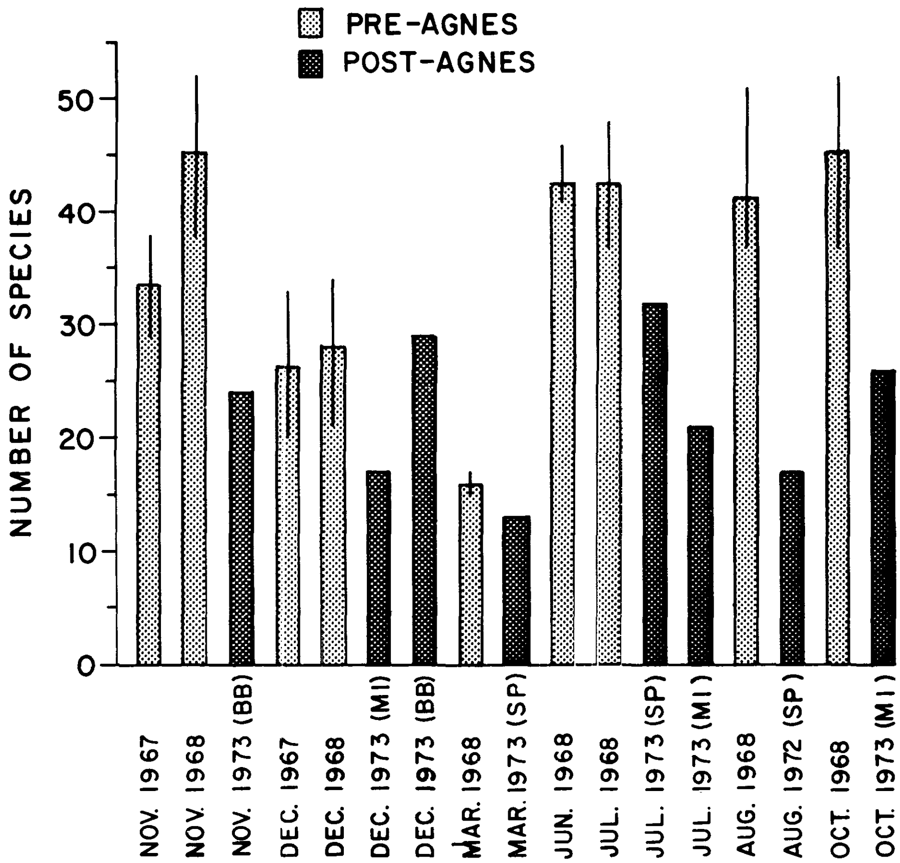


Figure 6. Mean and range for number of epifaunal species found by Marsh at three stations at Mumfort Island, 1967, 1968, and total number species found at several locations after Agnes.