plastic bags or hermetically sealed tin cans should not be used on semipreserved fishery products.

3. We can control botulism by maintaining the temperature of the product below 38F during all periods of storage and distribution, including the consumer stage of handling and storage. The lowest temperature at which the botulinus Type E organism has been known to produce toxin is 38F.

4. We can sometimes use chemicals to control the growth of botulinus bacteria in fishery products. Chemicals, of course, are applicable only to certain types of speciality and preserved products. Salt concentrations in the neighborhood of 8 to 10% inhibit the growth of the botulinus bacteria. Significant quantities of acids in a product also prevent the growth of this organism.

We must remember that everyone in the fish-processing industry, in the Gulf area as well as in the other parts of the United States and the world, must be aware of the dangers of botulism. We must be familiar with the growth characteristics of the botulinus organism producing the deadly toxin. A single outbreak of botulism attributable to fishery products can result in tragic deaths, destroy the public's faith in the products involved, and damage the entire fishing industry for many years.

Notes on the Ecology of DONAX DENTICULATUS (Linne)

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Abstract

Donax denticulatus (Linne) is a burrowing clam found in the intertidal zone of sandy beaches in Jamaica. It lives only in the saturated region of the wash zone, and migrates synchronously with the tides to maintain this zonation. Its distribution is influenced by the size and sorting of the beach sands, the organic content of the sands, and the degree of exposure of the beach to direct wave action. Enormous populations sometimes develop and different populations show wide variations in densities and maximum sizes of individuals. Chance settling of the planktonic larvae and high mortality in the first four months of life determine the density of populations. Maximum sizes of individuals depend on their growth rates, determined by the availability of food as suspended particulate organic matter. The most thriving populations occur near the mouths of rivers.

INTRODUCTION

Donax denticulatus (Linné) is a common bivalve found in the intertidal zone of sandy beaches in Jamaica. It is particularly interesting because of its special adaptations for living on wave swept beaches and also because of the enormous populations which frequently develop. Hitherto, there has been no comprehensive investigation of the biology of any one species of *Donax*. This present study is therefore aimed at discovering as much as possible about the ecology of *D. denticulatus*, and elucidating those features of its morphology responsible for its great success on the beach.

HABITS AND DISTRIBUTION

The members of the superfamily Tellinacea, to which *Donax* belongs, are characterized by having a large, anteriorly displaced foot and two separate and mobile siphons posteriorly. On the beach, the animal lives buried in the sand with its foot extended to act as an anchor, and its two siphons also extended and lying flush with the surface of the sand. Normally, the clams are confined almost entirely to the saturated region of the wash zone, although occasionally, in very rough seas, the pattern of zonation may be disrupted for a few days.

On the beaches of Jamaica, *D. denticulatus* is almost unchallenged in its occupancy of the saturated zone. The mole crab, *Emerita portoricensis* (Schmidt), and the spionid worm, *Scolelepis squamata* (Müller) occupy parts of this zone, but the former has its greatest density higher on the beach and the latter lower on the beach than do the clams.

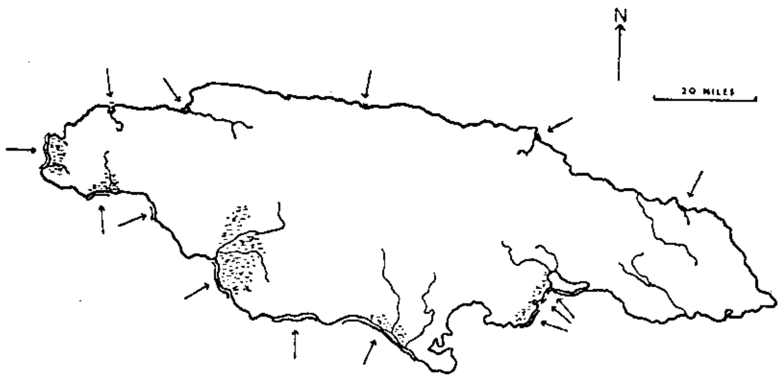

FIG. 1. Map of Jamaica showing distribution of *D. denticulatus*.

As the tide rises and falls, *D. denticulatus* migrates up and down the beach to maintain its position in the saturated zone. Mori (1950) and Turner and Belding (1957) have attributed this migratory habit of *Donax* to an intrinsic timing mechanism which triggers one type of behavior on the flood tide and another on the ebb tide, although in the case of *D. denticulatus* migration seems to be entirely due to mechanical processes.

Donax denticulatus occurs in Jamaica in at least twenty different localities. A distribution map reveals two important features (Fig. 1). First, the clam is more common on the south coast, where the beaches are mostly made up of alluvial deposits, than on the north coast and offshore cays, where the sand is of the coarse algal type. Second, populations are frequently found near the mouth of a river or swamp.

There are three factors which determine this distribution. These are:

(1) Size and sorting of the sand grains on the beach

D. denticulatus cannot maintain a footing in coarse sand which tends to be loose, nor in fine sand which is firm and tight. There is therefore an optimum range of sand grain size between these two extremes in which populations are supported (Fig. 2). This range, measured as a size-sorting index, is between 0.2 and 0.4. (Size-sorting index is a product of median diameter and coefficient of sorting.) Most algal sands have a size-sorting index of more than 0.6, hence the absence of the clams on most of the north coast and offshore cays.

(2) Organic content of the sand

The sands in which *D. denticulatus* lives must be low in organic content.

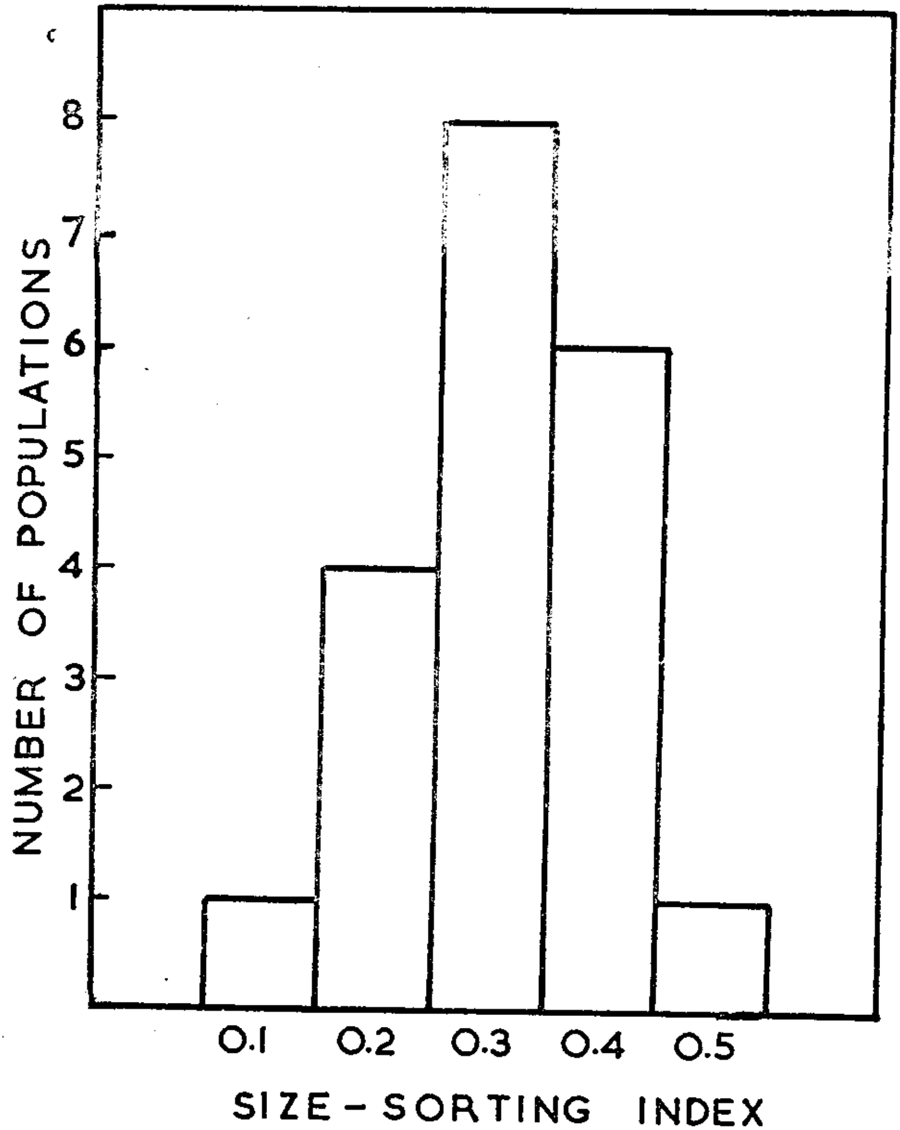

FIG. 2. The distribution of populations of *D. denticulatus* with respect to size-sorting index of beach sands.

In twenty sands analysed, the average percentage of organic matter was 0.12% with only five samples exceeding 0.2%. *Donax* populations are unable to tolerate the presence of decaying organic matter such as dead algae.

(3) Wave action

D. denticulatus can live only on beaches which are exposed to the open sea and have a constant wave action. Associated with good wave action is the slope of the beach, which determines to some extent the exposure of the beach to the direct action of the waves. The beaches which support populations in Jamaica are all steep and have a slope of between one in six and one in ten.

LIFE HISTORY

Once a population has become established on a beach, its history may show several variations from others. In the first place, there is a wide range of population densities. On some beaches, the clams occur in densities greater than 4,000 per linear meter of beach, while on others they are as low as 10 per meter. Secondly, there are great differences in the sizes to which the clams of different localities grow. On some beaches, adult individuals are as large as 23 mm in length; on others, they are dwarfed and seldom attain a length of 15 mm. To investigate the reasons for such variations, I have followed the history of two populations situated in the vicinity of Kingston harbor. Three aspects of their life history seem responsible for the differences.

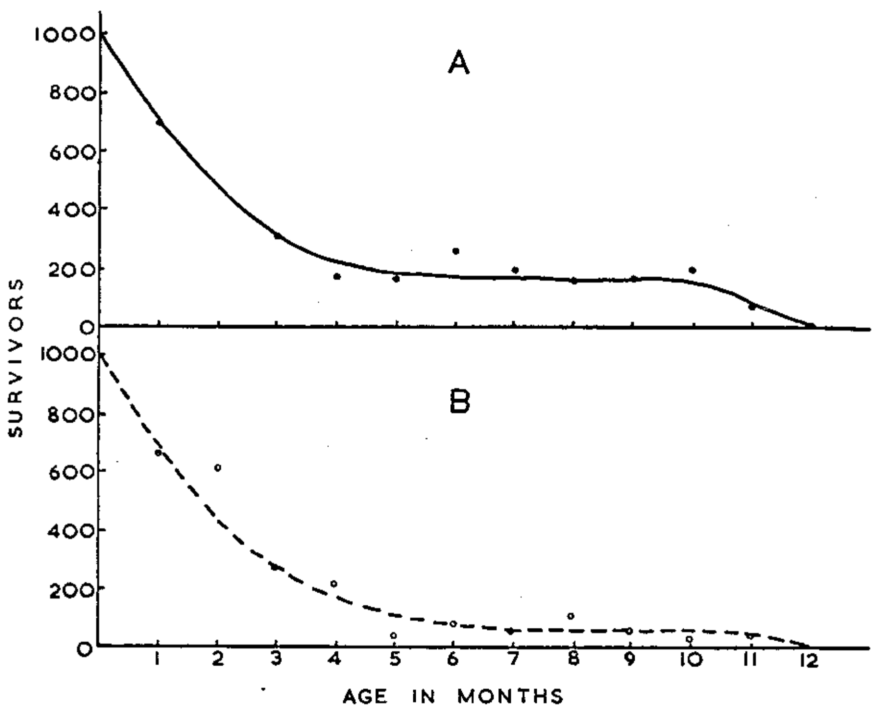

FIG. 3. Survival curves of two populations of *D. denticulatus* from localities A and B.

(1) Settling of spats

Donax has a planktonic larval life of at least two weeks, during which time the larvae may be carried some distance from the parent population to settle elsewhere among another population. In this way, mass spawning in one area may result in dense settling in another. In November, 1963, shortly after Hurricane Flora passed near Jamaica, there was a phenomenal settling of more than 25,000 spats per meter of beach in one of the populations under study. Hitherto this population had had a density of only 600 per meter of beach. This large settling could not have been the result of breeding of the previous population. Simultaneously, the large nearby spawning population was not being replaced by newly settled spats as might be expected. There was every indication that due to prevailing currents, one population was being greatly increased at the expense of the other. Chance settling was therefore responsible for the setting up of a large population in one locality and the decline of another nearby.

(2) Mortality among spats

D. denticulatus has a life span of from ten to twelve months. For the first four months of life, there is a high mortality rate and at least 70% of the spats die off. From five months onwards, there is little mortality until at ten months when they begin to spawn and subsequently die (Fig. 3).

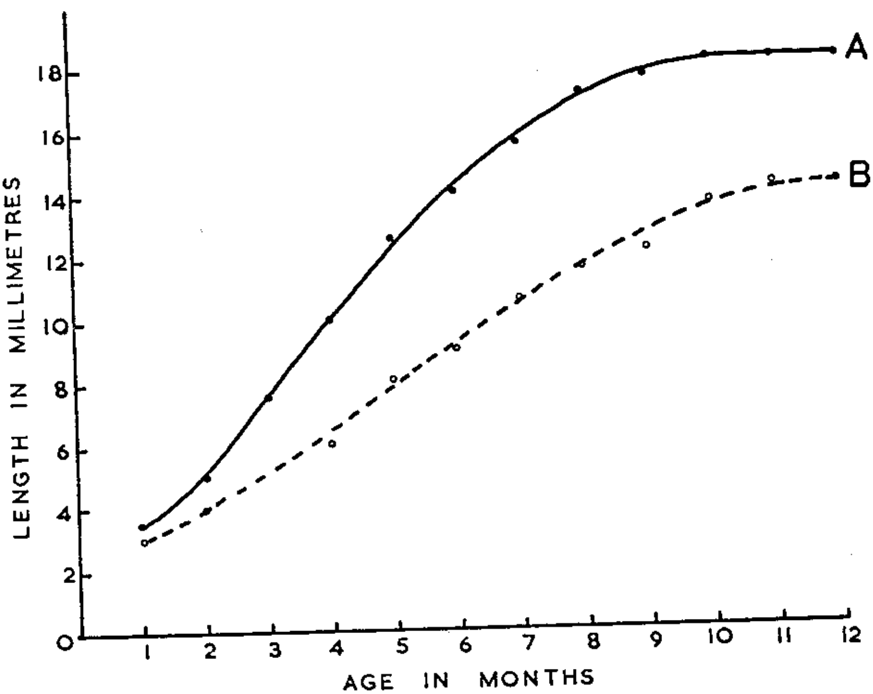

FIG. 4. Graphs showing differences in growth rate of clams from localities A and B.

The spats are susceptible to reduced salinities and high seas, two conditions which are common on the beaches where the clams occur. In some cases, mortality within the first four months of life has contributed to a sudden collapse of a large population. Following Hurricane Flora, during which the salinity of one locality fell to nine parts per thousand, there was 100% mortality of the spats settled up to two months prior to the rains. Had it not been for a few surviving adults which spawned and produced new spats, this population would almost certainly have been exterminated. With so many populations occurring near the mouths of rivers and the presence of frequent heavy rains in Jamaica (Goodbody, 1961), periodic collapse of populations must be regarded as a common occurrence and a major factor in determining the density of populations.

(3) Growth rates

In the two populations under study, there are marked differences in the maximum sizes of the individuals. This has been found to be due to differences in the growth rates of the clams (Fig. 4). Morphological features have shown that, unlike the other Tellinacea which are deposit feeders (Yonge, 1949), *Donax* is a suspension feeder, feeding on particulate organic matter suspended in the sea water. Using a measure of the suspended organic matter as a measure of the available food, I have found that the differences in growth rates of the clams are correlated with the amount of available food (Fig. 5). In places where much organic matter is in suspension, the clams tend to grow faster and bigger. It is not surprising, therefore, that the most thriving populations are to be found near the mouths of rivers where the food content is high.

In conclusion, it is interesting to note that *Donax* has been the basis of small fisheries in several parts of the world. With a more thorough understanding of the environmental factors which affect the clam, this hitherto spasmodic fishery may be able to proceed on a more scientific basis.

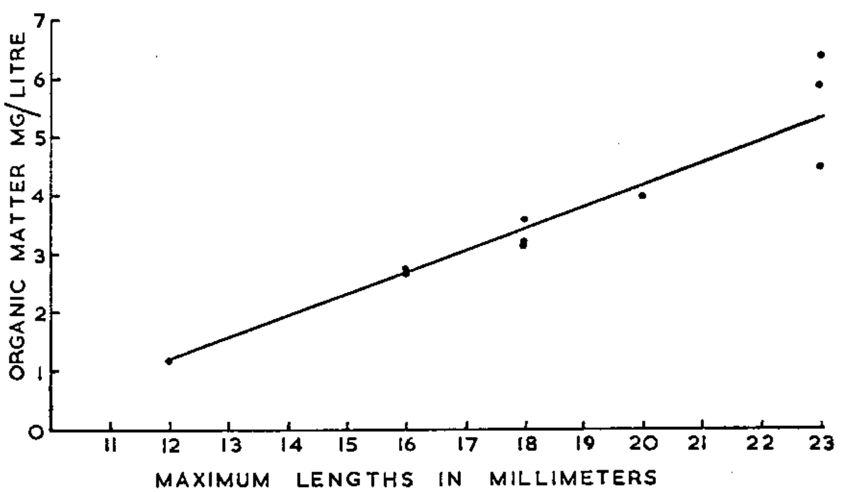

FIG. 5. Graph showing correlation between the amount of suspended organic matter in the sea water and the maximum sizes to which the clams grow.

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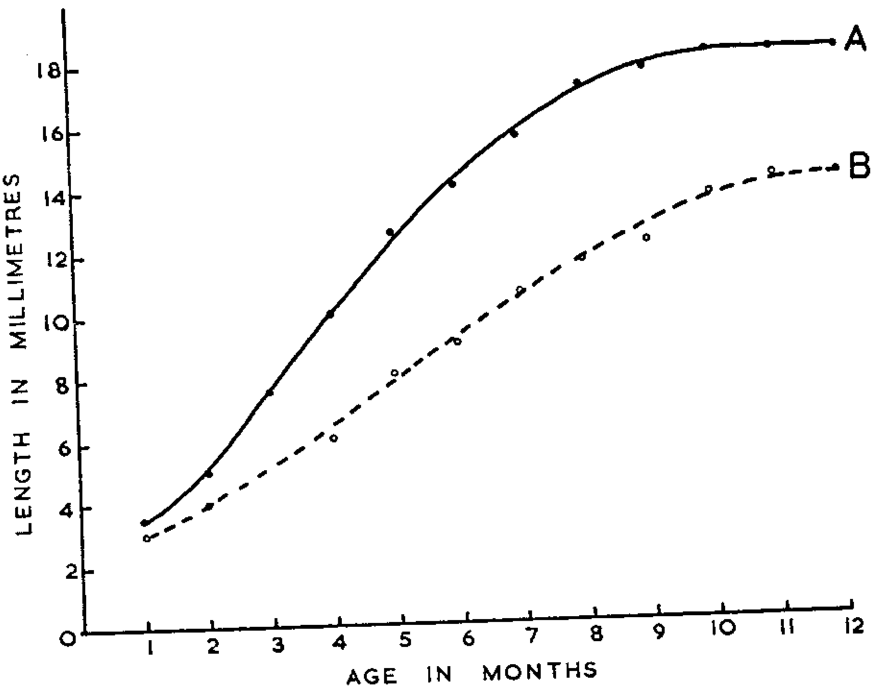

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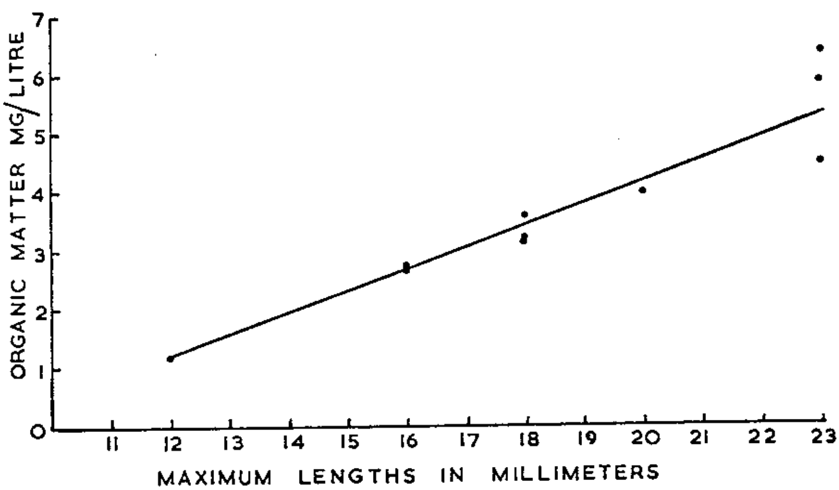

FIG. 5. Graph showing correlation between the amount of suspended organic matter in the sea water and the maximum sizes to which the clams grow.

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Physical Parameters of Maracaibo Estuary and Their Ecological Implications

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Abstract

The system formed by Lake Maracaibo and the Gulf of Venezuela is the site of a new flourishing fish industry, and at the same time the route for oil tankers. Alterations in the estuary to improve navigation could permanently damage the fishery.

Studies are being made in our laboratory to determine the physical parameters of this estuary. The yearly distribution of organisms and chlorinities, and the circulation of masses of water have permitted the separation of several ecological regions. Effects of substratum and tidal system are being studied. We hope to predict how alterations in the physiography will reflect on the hydrography, indicating how the distribution of organisms will be altered.

INTRODUCTION

THE OBJECTIVE OF THIS PAPER is to present some of the recent research on the physical parameters in the Maracaibo estuary and their bearing on the distribution and reactions of the communities. This is part of a project done for the Instituto Nacional de Canalizaciones.

Lake Maracaibo (Fig. 1) is the second largest estuary on the southern part of the Caribbean, the Orinoco River being the largest. The fresh water of Lake Maracaibo mixes with the sea water of the Gulf of Venezuela in Tablazo Bay. In the southern part of the bay Lake Maracaibo discharges through the Maracaibo Strait. The Limon River discharges into the northwestern part of Tablazo Bay..

The Maracaibo area is the site of most of the oil industry in Venezuela and tankers continually cross the water of the bay. To facilitate navigation,