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Two New Species of *Stichopathes* (Zoantharia; Antipatharia) with Observations on Aspects of their Biology

by

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ABSTRACT

Two new distinct but similar species of Stichopathes are described along with observations on aspects of their biology. First discovered on the shelf slope south of La Parguera, Puerto Rico, both have since been found in Cozumel, Dominican Republic, St. Croix and Mona Island. The species are sympatric and have been observed at depths ranging from 15-70+m. The axial skeleton of the new species bear papillose spines as does the West Indian S. lutkeni Brook but are not coiled as in the latter species.

The two species can be readily distinguished by their color, species "A" being brown and species "B" yellow. Comparison of the axial skeleton of the two species shows differences in spine size, colony diameter near the point of attachment and ratio of colony length to diameter near base. Also the height of the oral cone of the zooids distinguishes one species from the other. Minor nematocyst size differences are also evident. Absorption spectra, under visible light, of methanol extracts of coenenchyme gave distinctly different peaks for the two species.

In addition to morphological differences, the two species also contrast in reproductive period, coenenchyme regeneration rate, average annual growth rate and incidence of parasitic infection of a lichomolgid copepod. Population

densities for species A and B have been observed up to 0.50 and 0.18 per m^2 respectively.

During three years of at least monthly visits to the study sites, no colonies of Stichopathes n. spp. less than about 20 cm long nor dead ones (despite the resistence of the axial skeleton to decay) were ever observed. This evidence, along with that of the species slow growth rate, indicate that the population turnover rate is low. On the other hand, the numbers of ova produced per polyp (estimated over 100) and the length of the breeding season (approximately 10 months) suggest that the species should be prolific. Possibly, high mortality of larvae is responsible for the apparent lack of planktonic larvae (evidenced by no settlement on collectors) as well as the very negligible recruitment rate observed. One explanation for larval mortality is the limited and specific nature of the attachment place of Stichopathes n. spp. In almost every instance, colonies observed were fastened to solid substrate and grew out from beneath an overhang.

Symbionts of the two species of Stichopathes include an undescribed species of Pontonides, an undescribed polychaete near Pilargidae (externally), an undescribed lichomolgid copepod and a mysostomid polychaete (internally).

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INTRODUCTION

The Antipatharia are colonial cnidarians with a black, spiny, scleroproteinaceous axial skeleton which may be bush or whip shaped. The polyps generally possess six unbranched, non-retractile tentacles and either six, ten or twelve mesenteries. Due to their apparent resemblance with the "cerinula" larvae of the cerianthids and because of the rudimentary condition of their septal musculature, the black corals were thought to be closely allied to the Ceriantharia by early workers (Brook, 1889; Van Beneden, 1897; Roule, 1904). Subsequent studies have shown that the antipatharian sperm and cnidom are very similar to those of Zoanthidea (Schmidt, 1974). Also these two orders exhibit the same chemical composition of the skeleton, as far as such structure is formed by the Zoanthidea.

Because they occur at depths greater than 15 m, it is only since the advent of SCUBA that in situ observations upon them became possible. Consequently, most of the literature on antipatharians is of taxonomic nature and based on dredged material that has been dried and accumulated in museums. To base classification principally on the dry axial skeletons and without any ecological information, can only lead to a very unsatis-

factory taxonomy of the group. This is particularly true of the Indivisae or unbranched Antipatharia. The Indivisae comprise two genera, Stichopathes Brook, with uniserial polyps and Cirripathes Blainville, with polyserial polyps. This division of the unbranched forms into two genera by Brook (1889) has been questioned by Pesch (1914) who claims having observed species which have uniserial polyp arrangement when young and polyserial when old. With few specimens at hand and no information on their ecology, Pesch could easily have failed to distinguish between the two genera. The writer, in the course of this study, has seen a considerable number of West Indian stichopathid colonies of different ages and also specimens of two species of Cirripathes and finds Brook's criteria acceptable.

Prior to this work, four species of Stichopathes had been reported from the West Indies. These are S. desbonii Duchassaing and Michelotti 1864, S. occidentalis Gray 1857, S. pourtalesi Brook 1889 and S. lutkeni Brook 1889. During the course of this investigation two undescribed Stichopathes, similar to one another but differing in color, were discovered on the shelf edge south of La Parguera, Puerto Rico. Their unbranched axial skeletons bear papillose spines similar to those of S. lutkeni but the distal colony is never an open

spiral as is characteristic of the latter species. The other three species have smooth spines and cannot be confused with the La Parguera species.

The two undescribed species from La Parguera seem to be closely related and are possibly sibling. For the most part they are sympatric.

The abundance of the two species within reasonable distance of the laboratory offers a unique opportunity to determine whether they are indeed distinct and new as well as to evaluate the taxonomic characters previously employed for the group. Of equal value in assessing the distinctiveness of the species would be that evidence obtained from in situ observations and laboratory studies.

The objectives of this thesis work were: to compare the anatomy and histology of the three different West Indian Stichopathes bearing papillose spines; to determine and compare sizes, growth rates, reproduction patterns, pigments and possible interspecific aggression for these; to determine population densities of the two La Parguera species; to investigate their symbionts and predators for indication of host specificity; and to describe the two La Parguera species should they prove to be new.

HISTORICAL RESUME

The antipatharians were first clearly differentiated from the gorgonians by Pallas in 1776. For those species possessing a spiny axial skeleton and non-spiculate coenenchyme, he erected the genus Antipathes. The former character has proved to be an essential ordinal character of all Antipatharia.

The first drawings of antipatharian zooids, those of Ellis and Solander (1786), show that while the Gorgonia zooid always has eight tentacles that of Antipathes, usually has six. Later it was observed that the tentacles of Antipathes were smooth instead of being pinnately branched as in Gorgonia.

Because of their smooth tentacles, the Antipathes were placed under the Actinoidea by Dana (1846). Considering them sufficiently different from actiniarians, Milne-Edwards erected a new suborder for the group "Zooantharia Sclerobasica." Lacaze-Duthier (1864) also noting distinctive anatomical features erected the order Antipatharia within the Zoantharia.

Similarities in the mesenteries, presence of ectodermal muscle fibers in the stomadeum and body wall, the thin mesoglea and the rudimentary septal

musculature led Brook (1889) to suggest that the Antipatharia and Ceriantharia were related and Van Beneden later combined them in the subclass Cerian-tipatharia.

Van Pesch (1914), who considered the ectodermal musculature of the antipatharians different from that of the cerianthids, decided that the recognition of the subclass Ceriantipatharia was premature because he thought proof of an interrelationship between Antipatharia and Ceriantharia would come only with knowledge of the developmental patterns of the septae. Schmidt (1974) had shown later that similarities of the sperm and cnidom put the Antipatharia closest to Zoanthidea. Also these two orders exhibit the same chemical composition of the skeleton, as far as such structure is present in Zoanthidea.

Order Antipatharia consists of two families: the Dendrobrachiidae and the Antipathidae. The zooids of those in the first family bear eight tentacles which are branched and retractile. The family is monogeneric and very little is known about it. Its relation to the Antipatharia is still questioned by many authors. The second family, the Antipathidae, is a very large and homogeneous group, all colonies having zooids which bear six non-retractile, non-

branching tentacles.

Early subfamily classification was based solely on axial skeleton characters until Brook (1889) mostly on the basis of polyp morphology, revised the entire order. To distinguish the branched from the unbranched Antipathidae, Brook created the Divisae and Indivisae. He then divided this family into two subfamilies: the Antipathinae which comprised nine genera with monomorphic zooids and the Schizopathinae comprising four genera with dimorphic zooids. Genera were separated on the basis of the number of septae, the size and position of the tentacles around the mouth and the arrangement of the polyps on the axis.

Later, Schultze (1896) proposed the division of the Antipathidae into subfamilies strictly by the number of septa present in the polyp: the Hexamerota (lacking secondary septae), the Dekamerota (two pairs of secondary septae and the Dodekamerota (three pairs of secondary septae).

Considering the number of secondary septae unimportant except probably at the species level, Van Pesch (1914) rearranged the Antipathidae into two subfamilies on the basis of the presence or absence of secondary septae. These are the Heterotaeniales and the Homotaeniales, respectively. The principal generic character used

by Van Pesch within these subfamilies was the external and internal morphology of the zooids, disregarding the arrangement of the tentacles around the mouth which Brook believed important. Specific zooid characters included branching of the corallum and size and shape of the axial skeleton spines.

Going back to the Indivisae (which is most pertinent to this study), Blainville (1834) in his Manuel d'Actinologie, considering the generic importance of their unbranched nature and Ellis' observations on the drawings of the polyps of Antipathes spiralis Pallas (which were the only available figures of any antipatharian polyp at the time), instituted the new genus Cirrhipathes for the unbranched forms A. spiralis and the new species Cirrhipathes sieboldi. Later observations of other antipathid zooids showed their external morphology to be similar to that of Cirrhipathes. Thus the simple and elongate character of the axis remained as the only feature which separated this genus from other antipathids.

Noticing that the Indivisae consists of species having very different polyp arrangement and thus that the simple filiform character of the corallum would have no generic value by itself, Brook, (1889) decided to redescribe and subdivide this genus. The resultant genera, Cirrhipathes Blainville (as emended by Brook)

and Stichopathes Brook were based primarily on the arrangement of the polyps on the colony and secondarily on the number of mesenteries in and below the oral cone and the size and shape of the tentacles.

In the latest taxonomic review of the Section Indivisae or unbranched Antipatharia (Van Pesch, 1914) the genera Cirrhipathes Blainville, emended, and Stichopathes Brook were lowered to the subgeneric level. While studying specimens collected on the Siboga expedition, Van Pesch realized that the principal generic character which divided these two genera, the polyp arrangement, was not clear cut. He noticed that in some specimens polyp distribution was uniserial over some distance in the colony and polyserial on the remaining part. While this situation occurs in older colonies, younger specimens sometimes show a uniserial arrangement along the length of the entire colony. This led Van Pesch to think that some young Cirrhipathes might have been classified as Stichopathes by Brook. As for the secondary generic characters, Van Pesch stated that the number of mesenteries in and below the oral cone are not characteristic of Cirrhipathes for other genera may have the same numbers. Also he observed that tentacle size and form vary in other genera and are not good generic character. Finally, Stichopathes and Cirrhipathes (the latter one now Eucirrhi-

pathes) were considered as subgenera of genus Cirrhipathes which name was retained since the unbranched colony became the principal characteristic. For the sake of clarity it should be mentioned that Cirrhipathes is sometimes spelled Cirripathes but these refer to the same genus and are used indiscriminately by different writers.

Other taxonomic papers mentioning unbranched species of Antipathidae are those of Pourtales (1874-1876, 1878-1879, 1879-1881), Johnson (1899), Roule (1905), Cooper (1908) and Opresko (1972).

Growth experiments with whip antipatharians were done at Curacao by Noome and Kristensen (1976). They found that whip black corals formed polyps all around the axial skeleton in deep waters but not in shallower waters.

After conducting an ecological study of the antipatharian Antipathes grandis in 1964, Grigg concluded that light is the principal factor controlling the depth distribution of this species.

In a later comprehensive study of the Hawaiian precious corals by Grigg, the bathymetric distribution of two commercially important antipatharians (Antipathes dichotoma and A. grandis) was delimited. Also the growth rate of these two species was found to be 11 and

9 cm annually, and on the basis of his later studies of the Gorgoniidae, Grigg (1970, 1972) concluded the two species lived at least 23 and 33 years, respectively.

In a study of the economics and market potential of the black coral industry of Hawaii, Poh (1971) mentioned principal exploitation areas of the world and speculated on the exhaustion time for local coral beds in case legislation for their collection continue to be ignored.

Cyclopoid copepods of the family Lichomolgidae were found to live in relationship with the antipatharian Stichopathes echinulata of Madagascar by Humes (1967). Later Davis and Cohen (1968) discovered a new species of gobiid fish and a palaemonid shrimp living on Cirrhipathes sp. The behavior of these organisms, especially the fish, were observed. In the latest taxonomic review on the order Antipatharia, by Opresko (1972), the antipatharians described by L. F. Pourtales are redescribed and reevaluated in a most precise way. Genera included in this study are Antipathes, Parantipathes, Aphanipathes. A comparative study of the structure and chemistry of gorgonian and antipatharian skeletons was done by Goldberg (1976).

METHODS AND MATERIALS

The principal site of the study is an area at the edge of the shelf approximately 10 km south of La Parguera, Puerto Rico. As the depths ranged from 70 to 120 ft (22-36 m) SCUBA was necessary. Depth was recorded in English system units since a metric depth gage was unavailable.

Specimens were collected either by snipping off portions of colonies with wire cutters or chiseling off the holdfast. Whole colonies were transported in a 1.3 m section of 7 cm PVC tube with caps on each end (Plate IA) to prevent exposure to the air and direct sunlight. In the laboratory, specimens were maintained with running sea water in large, shallow, polyethylene trays and fed Artemia nauplii every other day.

Collection of specimens for statistical analysis were made at depth between 80 to 120 ft and in a random manner. The latter was accomplished by swimming in a zigzag pattern, stopping every four kicks and collecting all colonies within a radius of 1 m.

Axial skeletons were prepared for study by allowing specimens to decompose in sea water for four days and then washing in fresh water. Sodium hypochlorite was faster but had a tendency to degrade fine structure.

A Bausch and Lomb stereozoom microscope with ocular micrometer was used to measure spine size, polyp length, tentacle length, oral cone height above peristomial surface and interpolypar distance. Interpolypar distance is that distance from the distal lateral tentacles of one polyp to the proximal lateral tentacles of the next. Spine length is measured from midpoint of base to apex. All measurements on S. lutkeni are from unanesthetized, formalin preserved specimens while those of Stichopathes n. spp. are from expanded living ones.

Specimens for sectioning were anesthetized in propylene phenoxitol and fixed with 10% neutral paraformaldehyde. Polyps were then removed from the axial skeleton, embedded in paraffin, sectioned at 10 microns and stained with Harris' hematoxylin and eosin.

Spines of the axial skeleton were photographed on 4 by 5 Polaroid PN film with an ITEC Autoscan scanning electron microscope. Colloidon peels of the growth rings were projected onto photographic paper with a Bausch and Lomb Tri-Simplex projector. Diameter of the colonies were measured with vernier calipers 5 cm from the holdfast.

Histological observations were made with the aid of an American Optical Microstar microscope.

Transects were made by attaching the end of a

Nylon line to a soft detachable substrate and paying out line from the reel while swimming parallel to the shelf edge maintaining a uniform depth with the aid of a gage. Colonies were counted and measured one meter to either side of the line. When the bottom time expired, the line was marked to obtain the length of the transect. Transects were made at 80, 90 and 100 ft depths.

Five larvae settling devices (Plate IB) were installed within the densest stands of Stichopathes. These consisted of pieces of black Formica (25 x 14 cm) the finished side of which was roughened with sand paper. Five such plates were inserted, roughened side down, in diagonal slots cut into pieces of 10 cm diameter PVC pipe 1.3 m long The pipe was weighted at one end with cement, tied to a coral head and Styrofoam float attached to the upper end. Periodically a few plates at a time were taken to the laboratory and checked for larvae. These were then cleaned and returned to the field. Several plates were left undisturbed for the duration of the study.

Growth was determined by measuring monthly ten 5 cm distal portion of colonies of each species maintained in trays. The pieces were suspended from glass rods by thread to avoid contact with the bottom. Growth of in situ colonies was measured by tagging colonies with

styrofoam bouys and remeasuring after a five month period.

Feeding experiments consisted of using carmine particles, with and without Artemia homogenate, to visualize ciliary currents and by observing polyp reactions to living Artemia nauplii.

Sexual maturity of both species was determined by checking monthly the condition of the gonads. Maturity was assumed if the ova approached the maximum diameter of 150 um or if the sperm were motile. Pieces of ripe colonies both male and female were confined together to induce spawning. In other instances male and female gametes were removed from polyps and combined.

Coenenchyme regeneration and healing capabilities were observed under both laboratory and field conditions. In the laboratory this was accomplished by removing either a specific number of polyps or area of tissue around the axis from different colony fragments and measuring the bare area every other day. In the field distal-most 15 cm of colonies were denuded with abrassive cloth and the bare area was measured weekly. To determine axial skeleton longevity in the field colonies were totally denuded of tissue and tagged.

To determine species compatibility and possibly aggressive interactions, inter and intraspecific grafts, both end to end and cross types were made. End to end grafts were made by cutting at a 45°angle 3 cm fragments from colonies and matching the two angled ends tying with

Nylon cord to a microscope slide (Plate IC). Cross type grafts were made by dissecting two polyps from the middle of each fragment, joining these two areas and tying and suspending with Nylon cord.

The effect of abrassion by surge and suspended solids was determined by transporting twenty colonies (10 of each species) to a shallow, 3 m deep zone at Turrumote Reef where wave action is high and suspended particulate material abundant.

Ten individuals of each species were used for each controlled factor. These were:

1. Trauma by cutting- The mentioned number of colonies were snipped off near their holdfast and tied with Nylon line close to their original attachment site.
2. Surge- The mentioned number of colonies were transplanted to areas of high surge where suspended particles were absent. The depth was 3 m.
3. Suspended particles- The mentioned number of colonies were transplanted to areas of low surge and presence of suspended particles. The depth was 3 m.

Methanol as well as acetone extracts of each of the two new species were measured with a Varian 309 grating spectrophotometer to determine pigment difference. KBr pellets obtained by standard techniques were made from the extractions and observed under infrared light.

OBSERVATIONS

I SYSTEMATICS

Family Antipathidae, Verrill 1865, 191-197.

Antipatharia having zooids with six non-retractile, non-branched tentacles. Marginal sphincter muscle not developed. Always three pairs of well-developed primary mesenteries of which one occupies the transverse polyp axis and bears the reproductive organs. Secondary mesenteries usually two or three pairs, rarely extending below the oral cone and never bearing filaments. Sclerenchyme horny and bearing spines in all or some sections of the skeleton. The diagnosis given here is essentially that of Brook (1889).

Stichopathes Brook, 1889

Cirrhipathes Blainville, 1834, p. 511 (in part).

Antipathes Pallas, 1776, p. 502 (in part).

Type-species.--Stichopathes pourtalesi Brook, 1889, p. 88; by original designation. Gender, masculine.

Diagnosis.--Unbranched Antipathidae with polyps arranged in a single row along one side of the axial skeleton. Colonies may be straight, sinuous or subspiraled.

Stichopathes lutkeni Brook, 1889

Plate IIIA

Stichopathes lutkeni Brook, 1889 p. 94, pl. XII. Figs. 28, 28a.

Eucirripathes spiralis Van Pesch, 1914, p. 167.

Material Examined.--St. Croix, Virgin Islands, seven colonies, depth below 15 m, collector Dr. W. Gladfelter, Nov. 1976. The following specimens were collected by the author. Point La Caleta, Dominican Republic, three colonies, depth below 24 m February 1976. Baní, Dominican Republic, nine colonies, depth below 23 m, December 1976.

Diagnosis--Colonies subspiral up to 380 cm in length. Spines papillose of two kinds: conical, blunt, on polypar side up to 0.34 mm and on abpolypar side up to 0.16 mm and abruptly dentate ones, up to 0.25 mm common on polypar side. Coenenchyme brownish.

Description.--The colonies are subspiral and up to 380 cm in length. The proximal colony is straight, but the distal takes the form of an open spiral. The diameter of the axial skeleton 5 cm from the holdfast measures up to 5.3 mm.

All spines of the colony are papillose. Polypar

spines are of two types: tapering ones, the longest from various colonies 0.19-0.34 mm in length and abruptly indented ones 0.21-0.25 mm in length (Plate IVA). Abpolypar spines, the longest from various colonies 0.21-0.25 mm, are acute and, sometimes, inclined toward the distal end of the colony.

The polyps measure 3.7 mm and 1.4 mm in their sagittal and transverse axes, respectively. The polyps are separated one from another by an incomplete mesogleal partition clothed on each side with entoderm. Interpolypar distance varies from 0 to 0.6 mm.

The following measurements are from unanesthetized polyps preserved in formalin. The tentacles are 1.3-1.6 mm long. The slit-like mouth, 5 mm long, corrugate, each depression corresponding with the insertion of a mesentery, and standing on an oral cone elevated 0.3 mm above the peristomial surface.

Three pairs of primary mesenteries divide completely the enteron. Two pairs are sagittal and one is transverse to the polyp axis. The latter bear filaments while the former are filament-free.

Living colonies are a uniform dark brown.

The ectoderm of the body wall is 110 um high. The mesoglea is variable in thickness, measuring

from 30 to 125 um and slightly convoluted on the entoderm side and smooth on the ectoderm side. The entoderm is about 30 um high

Cnidom: Microbasic b-mastigophores of tentacles, 32-45 x 5-6 um, abundant; of actinopharynx, 27-30 x 5-6 um, common; of filaments, 20 x 5 um, rare. Spirocysts of tentacles, 30-42 x 5 um, abundant; of actinopharynx, 20-38 x 4-6 um, common. Microbasic p-mastigophores of filaments, 47-53 x 10-11 um, abundant. All are uniform in size throughout the length of the colony.

Stichopathes n. sp. (species "A")

Plates IIA, C, IIIA and VIID

Material Examined.--Edge of the continental shelf 10 km south of La Parguera, Puerto Rico, thirty five colonies, depth below 22 mm, 1973-6. Point La Caleta, Dominican Republic, five colonies, depth below 20 m, February 1976. Baní, Dominican Republic, five colonies, depth below 27 m, December 1976. Palancar Reef, Cozumel, five colonies, depth below 21 m, July 1976. Cabo Norte, Mona Island, one colony, depth below 20 m, June 1975. Carabinero, Mona Island, three colonies, depth below 22m, June 1975. All collections made by author.

Diagnosis.--Colony straight or sinuous. Tentacles averaging 2.5 mm in length. Coenenchyme brownish. Spines of axial skeleton conical, usually blunt, papillose, longest polypar up to 0.32 mm. Zooids linearly arranged. Species dioecious.

Description.--The colonies, up to 150 cm in length, are straight or sinuous (Plate IIC), some over 115 cm exhibiting an abrupt 90° deflection distally, never spiral nor subspiral. The holdfast is expanded, roughly circular in outline and never more than 2 cm on its longest axis. The diameter of the axial skeleton 5 cm from the holdfast is 1.3-3.7 mm and that 5 cm proximal from the tip is 0.9-1.9 mm.

Spines are papillose and present on the axial skeleton except for the proximal 3 to 16 mm. Usually nine to eleven longitudinal rows of spines are present on the axial skeleton 5 cm from the holdfast. The rows decrease in number distal from this point. Longest polypar spines from all colonies observed are conical, blunt, ranging from 0.26 to 0.32 mm in length (Plate IIIA). The longest abpolypar spines are triangular, compressed, sometimes inserted at a 45°angle to the colony axis and measure from 0.11 to 0.18 mm in length. The spines on the polypar side are longest and diminish

in length toward the abpolypar side.

The polyps, elongate sagittally to their axis (Plate IIA), are uniform in size throughout the colony and average 1.2 mm in their transverse axis and 3.2 mm in their sagittal one. They are separated one from another by an incomplete mesogleal partition clothed on each side with entoderm. Interpolypar distance, also uniform throughout a colony, varies from 0 to 0.7 mm on different colonies. The following measurements are from living, non-disturbed polyps. The tentacles average 2.5 mm in length. The slit-like mouth, 0.3 mm long, is present on the oral cone which is elevated 0.3 mm above the peristomial surface and its margin is corrugate, each depression corresponding with the insertion of a mesentery.

There are three pairs of primary mesenteries which divide completely the enteron into six primary chambers (Plate VIA). The transverse septae bear the filaments which are bilobed, heavily pigmented and contain eosinophylic and mucous cells. Two pairs of secondary, filament free mesenteries are present on each side of the transverse primary ones. These do not reach the end of the pharynx.

The ectoderm of the body wall is ciliated, averages

75 um in height and contains large hyaline gland cells which extend from the basement membrane to the surface. Nematocyst batteries are present in the coenenchymal, tentacular and body wall ectoderm andare separated 65 um from each other. They are most heavily concentrated at the tips of the tentacles but are not present in the pharyngeal ectoderm.

The mesoglea, 15 to 100 um in height, does not contain any connective tissue cells, and its inner margin is dentate while the outer is fairly smooth. The entoderm is about 10 um in height and contains no nematocysts.

Pigmentation is primarily entodermal although some isolated pigment granules occur throughout the ectoderm, especially in the pharynx. Overall coloration of the colony, except for the tentacles, is dark brown to greenish-brown. Tentacles are dirty white at the tips and slightly darker at their bases. Not obvious are numerous scattered irregularly shaped yellow spots 0.48 mm in diameter. Pigments extracted with methanol yielded major absorption peaks at 278-280 and 399-400 um. Those extracted with acetone yielded peaks at 465-480 um.

The gonads are readily seen through the peristomial surface. Ova are numerous, non-pigmented, up to 150 um, and contained within the mesoglea of the

transverse mesenteries. The sperm heads are oval and measure 2 um on their greatest diameter.

Cnidom: Microbasic b-mastigophores of tentacles, 17-23 x 3 um, abundant; of actinopharynx 16-20 x 3 um, common; of mesenterial filaments, 10 x 2 um, common; spirocysts of tentacles, 15-36 x 2 um, abundant; of actinopharynx, 11-23 x 2 um, abundant. Microbasic p-mastigophores of filaments, 21-27 x 9 um, abundant. All are uniform in size throughout the length of the colony.

Stichopathes n. sp. (species "B")

Plates IIB,D, IIIB and VIID

Material Examined.--Edge of continental shelf 10 km south of La Parguera, Puerto Rico, thirty two colonies, depth below 22 m, 1973-6. Point La Caleta, Dominican Republic, five colonies, depth below 20 m, February 1976. Baní, Dominican Republic, five colonies, depth below 27 m, December 1976. Palancar Reef, Cozumel, seven colonies, depth below 21 m, July 1976. Carabinero, Mona Island, one colony, depth below 22 m, June 1975' All collections made by author.

Diagnosis.--Colonies straight or sinuous. Tentacles averaging 3.6 mm in length and heavily pigmented on

their distal end. Coenenchyme yellow. Spines of axial skeleton usually blunt, papillose, longest polypar up to 0.26 mm. Zooids linearly arranged. Species dioecious.

Description.--The colonies, up to 140 cm in length, are either straight or sinuous (Plate IID). The holdfast is expanded, roughly circular in outline and is never more than about 2 cm in diameter. The diameter of the axial skeleton 5 cm from the holdfast is 1.2-2.7 mm and 5 cm from the tip is 0.6-1.9 mm.

Usually nine to eleven longitudinal rows of papillose spines can be seen 5 cm distal to the holdfast. Spines are present on all the axial skeleton except 3-16 mm from the holdfast. This section of the skeleton is smooth and varnish-like. The longest polypar spines from various colonies are conical, blunt and measure from 0.18 to 0.26 mm in length (Plate IIIB). The longest abpolypar spines are compressed, triangular, with a sharp apex, inconspicuously papillose and measure from 0.08 to 0.16 mm in length. The polypar spines are only slightly longer than the abpolypar.

The polyps are uniform in diameter throughout the colony (Plate IIB). They average 1.1 mm in their transverse and 2.0 mm in their sagittal axes. Separating one zooid from another is an incomplete mesogleal

partition clothed on each side with entoderm. The interpolypar distance varies from 0 to 0.5 mm.

The following measurements are from living, non-disturbed polyps. The tentacles average 3.6 mm in length. The mouth is slit-like, measures 0.3 mm on its axis, is born on an oral cone 0.6 mm above the peristome (Plate VIB) and at its margin is corrugate, each depression corresponding with the insertion of a mesentery.

Six primary mesenteries completely divide the enteron into six primary chambers. The transverse mesenteries bear the filaments on their lower margin. The filaments are bilobed, heavily pigmented and contain eosinophylic and mucous cells. Two pairs of secondary, filament-free mesenteries are present. These are situated on each side of the transverse primary ones and do not reach the pharynx.

The ectoderm is ciliated, averages 85 um in height and contains hyaline gland cells which extend from the basement membrane to the surface of the epithelium. Nematocyst batteries are present in the coenenchymal, tentacular and body wall ectoderm but are concentrated at the tips of the tentacles. Few isolated nematocysts were seen in the pharyngeal ectoderm.

The mesoglea varies in thickness from 10 to 70 um and does not contain any type of connective tissue cell. Its inner margin is dentate while the outer is smooth.

The entoderm average 20 um in height, is heavily pigmented and contains no nematocysts.

Pigment granules occur primarily in the entoderm but are also heavily concentrated in the pharyngeal ectoderm (Plate VID).

Gross coloration of the colonies is consistently greenish-yellow. Pigmentation is very dense in the zooids and overall coenenchyme except at the base of the tentacles where it is least. The pharynx is dark brown and contrasts with the yellowish oral cone. Pigments extracted with methanol yielded major absorption peaks at 373 um and two minor peaks at 270 and 274-280 um. Those extracted with acetone yielded peaks at 470-480, 330 and 350 um.

Ova are contained within the mesoglea of the transverse mesenteries and measure about 150 um. They are very numerous (100 + per zooid) and dark orange in color. Sperm are contained within spermatic cords oval in section embedded in the mesoglea of the transverse primary mesenteries. The sperm heads are oval and

measure about 2 um accross.

Cnidom: Microbasic b-mastigophores of the tentacles, 18-26 x 3 um, abundant; of actinopharynx, 9-20 x 3 um, common; of mesenterial filaments, 10-20 x 2 um, common. Spirocysts of tentacles, 15-36 x 2 um, abundant; of actinopharynx 10-17 x 2 um, abundant. Microbasic p-mastigophores of filaments, 18-24 x 9 um, abundant. All are uniform in size throughout the colony.

Statistical Analysis

The following characters were treated statistically to determine degree of dissimilarity between the two new species: polypar spine length and the ratio of colony length to its diameter near holdfast.

Longest polypar spine size from 36 colonies of species "A" and 39 of species "B" was measured. Distribution for each species was close to normal (Fig. I) and presented means of 0.30 mm for species "A" and 0.21 mm for species "B". This means proved to be different at the .005 level of significance and had a t-value of 11.5. Overlapping was minimal, species "A" having spines ranging from 0.24 to 0.27 mm and species "B" from 0.17 to 0.26 mm. The standard deviation, variance and standard error are shown in Table I. The standard error of the difference between the means was less

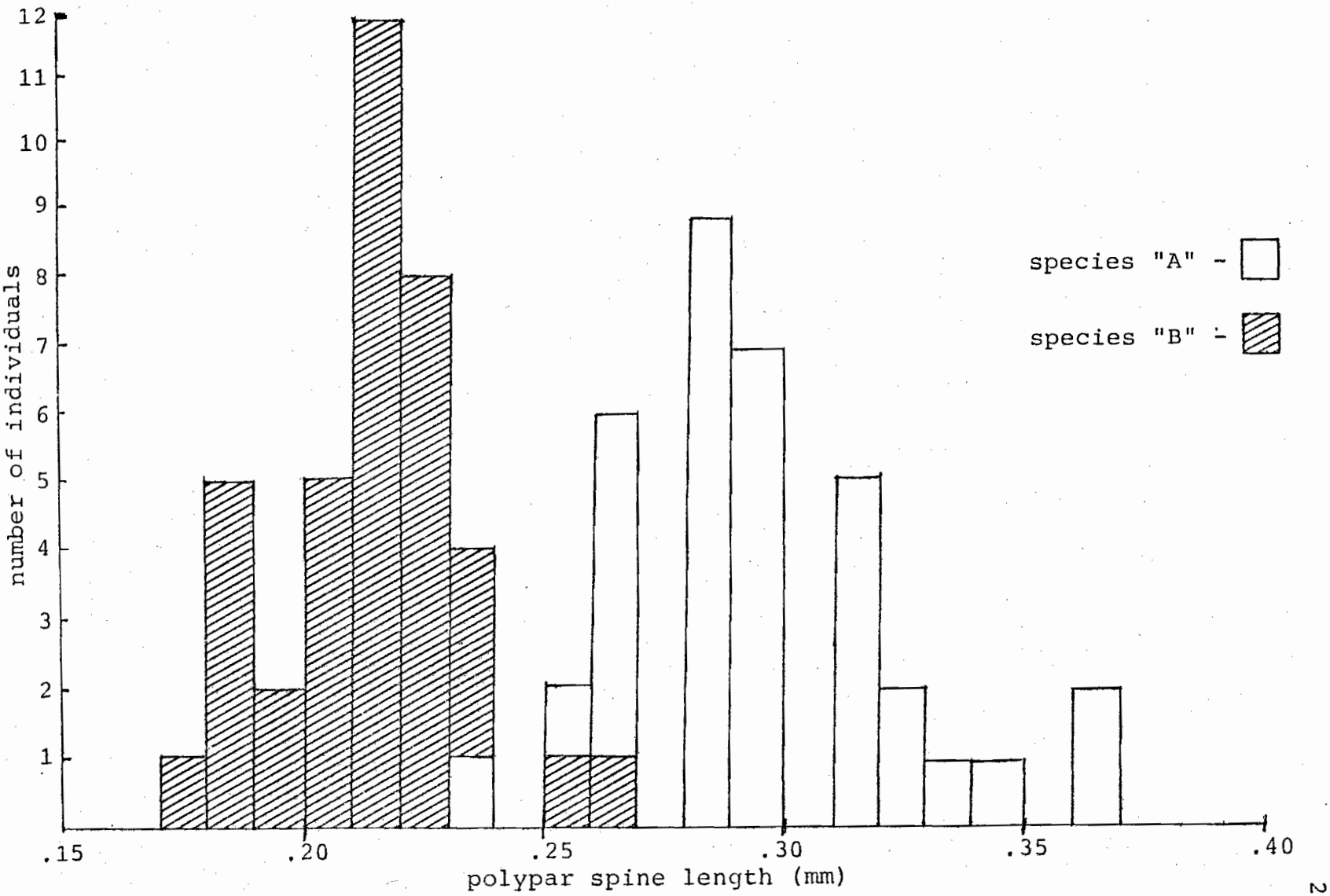

12
11
10
9
8
7
6
5
4
3
2
1
number of individuals
species "A" -
species "B" -
.15
.20
.25
.30
.35
.40
polypar spine length (mm)

Figure I. Polypar spine length frequency diagram.

Table I

Mean, standard deviation, variance, standard error and coefficient of variation of polypar spine length.

Species	Mean	Std. dev.	Variance	Std. err.	Coef. var.
"A"	.30	.032	.001	.005	10
"B"	.21	.027	.001	.004	14

Table II

Correlation and regression coefficient, degrees of freedom and t-values of the relationship between length and diameter of the colonies of species "A" and "B".

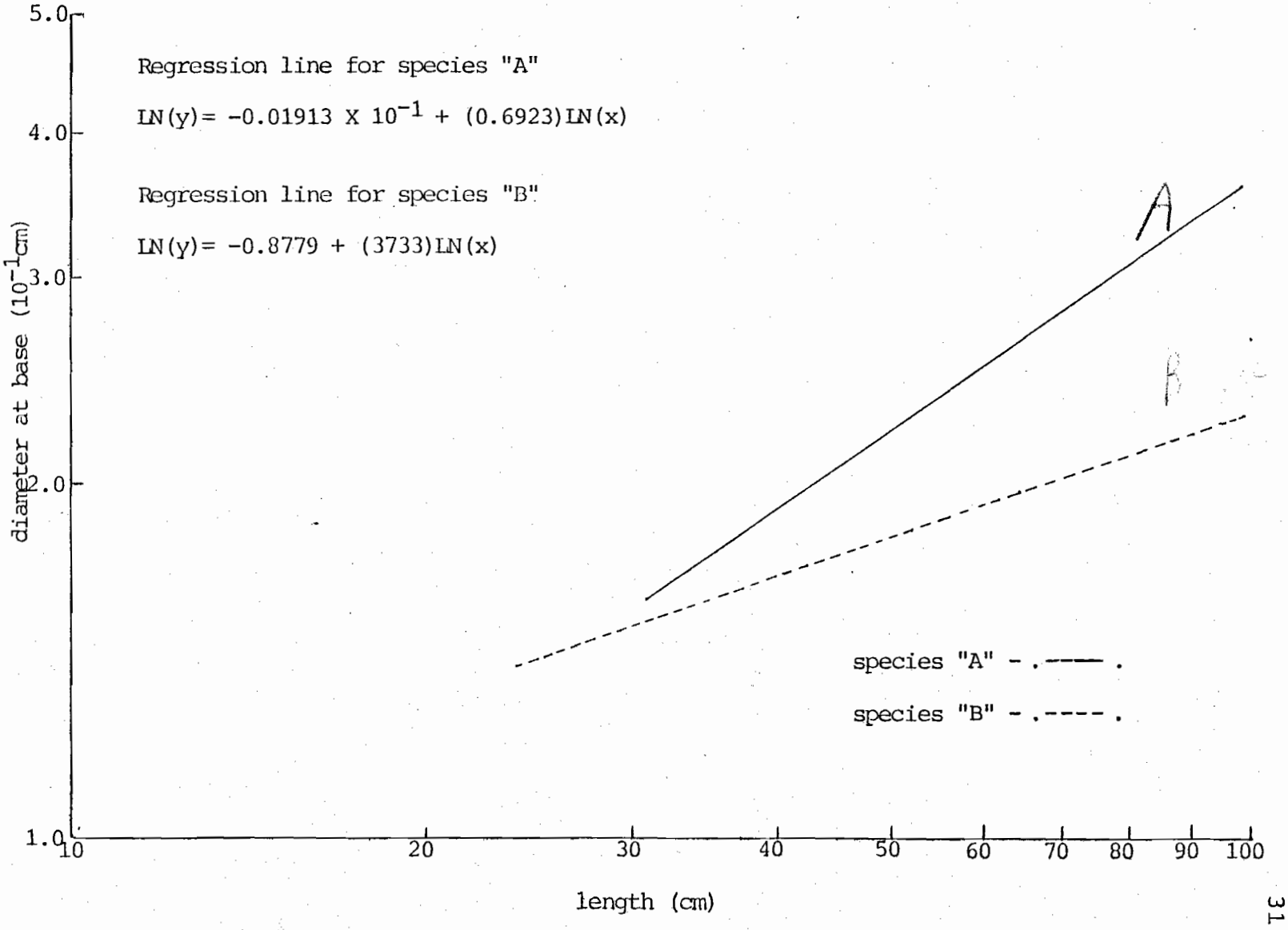
Species	Corr. coef.	Regr. coef.	Deg. fr. (n-2)	t-value
"A"	.76	.76	22	5.3
"B"	.75	.75	21	3.5

than one third the difference between the means, confirming the fact that these are unequal. Also, it can be concluded from the coefficient of difference (defined as $\frac{M_1 - M_2}{S.D._1 + S.D._2}$), 1.8, that more than 96% of the longest polypar spines of species "A" are different from more than 96% of those of species "B".

Using the Wilcoxon Rank Sum Test, it was determined that ratios between the length of the colonies and the diameter near the holdfast ($N_A = 24$ and $N_B = 23$) were different between the two new species at the 1% probability level.

The t-test showed that the length of the colonies are highly correlated ($p = .05$) to their diameter near the holdfast. Linear regressions of these characters were made for each species. The formula for the regression of both species is shown in Fig. II. These lines differed significantly from each other. Correlation coefficient, regression coefficient, degrees of freedom and t-values are shown in Table II.

Figure II. The relationship between colony diameter near the holdfast and its length.


Regression line for species "A"
LN(y)= -0.01913 X 10^-1 + (0.6923)LN(x)
Regression line for species "B"
LN(y)= -0.8779 + (3733)LN(x)
5.0
4.0
3.0
2.0
1.0
diameter at base (10^-1cm)
10
20
30
40
50
60
70
80
90
100
length (cm)
species "A" - .——— .
species "B" - .---- .

II BIOLOGICAL ASPECTS

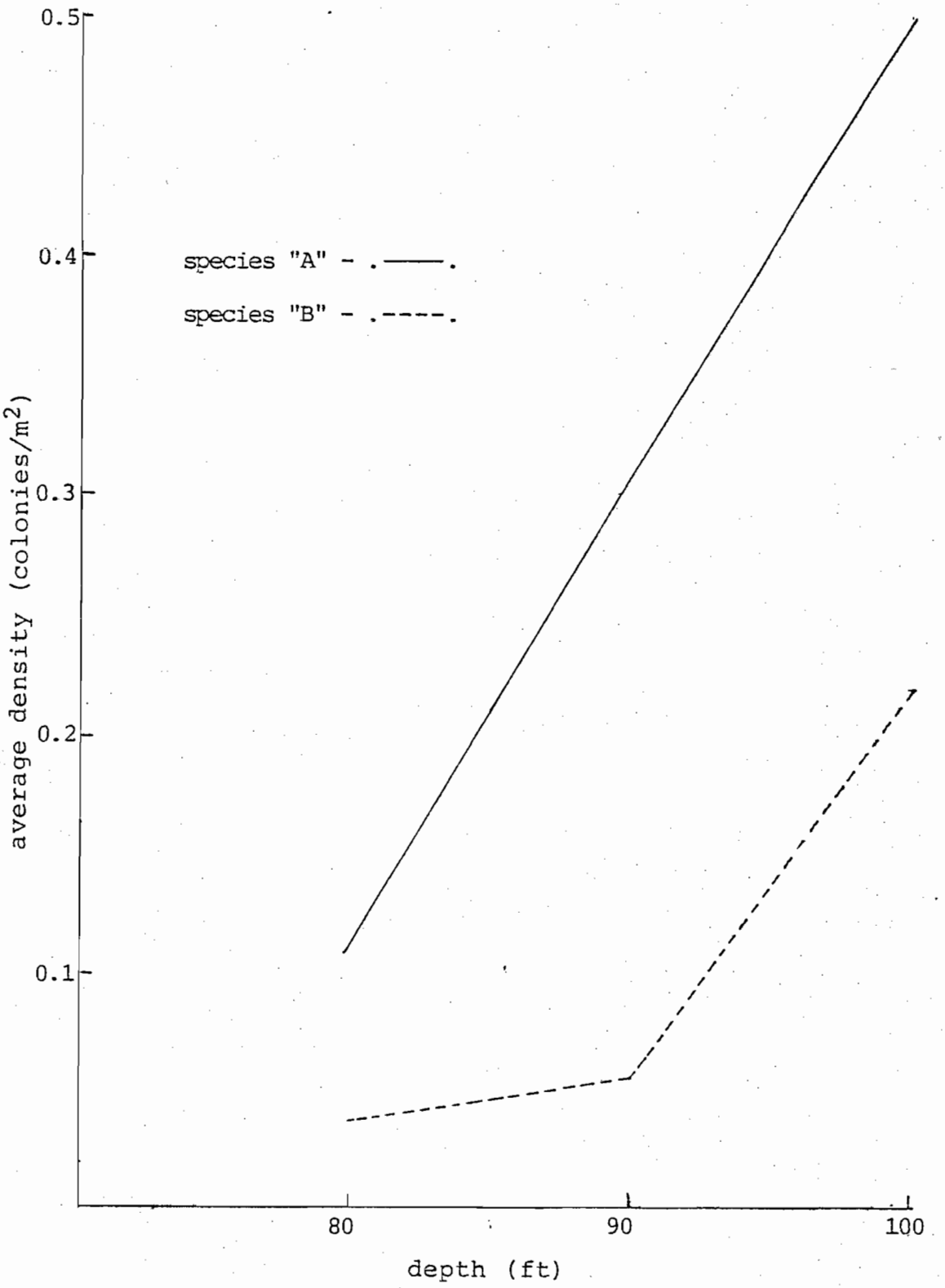
The shelf edge at the main study area, 10 km south of La Parguera, has a foreslope angle between 44°and 48°. The bottom consists of a cemented dead coral pavement. A groove and spur formation, probably resulting from exposure during the Pleistocene, is present. Colonies of the two new species of Stichopathes, species "A" (brown) and species "B" (greenish-yellow), have been observed at the site below 70 ft although they occur as shallow as 40 ft in other locations. Both species are always found on sloping, firm substrate which is generally the consolidated limestone mentioned. Occasionally ones are found attached beneath living scleractinian corals of the genus Agaricia apparently causing no damage. Attachment is almost always 5 to 25 cm within crevices or under ledges indicating larval negative phototaxis. The colonies grow from under the shelter and orient toward the surface. Depth alone is not limiting to the species for colonies were able to live and grow indefinitely in trays 12 cm deep.

Interaction with other organisms between the depths of 80 and 100 ft involves, first of all, competition for space with scleractinian corals, sponges, bryozoans,

algae, etc. Also adult colonies are frequently partially overgrown by the hydrocoral Millepora. Colonies of Stichopathes tied to those of Millepora with Nylon cord were invariably overgrown partially by the latter within a month. Never, however, have complete colonies been observed overgrown by hydrocoral as happens with the whip-like gorgonian Ellisella which grows in the same area. Other organisms which overgrow stichopathids include Briareum, sponges, bryozoans and algae. It is not known whether the latter actually kill the black coral tissue, as in the case of Millepora, or just invade the naked skeleton. Scleractinian corals such as Mycetophyllia lamarkiana appear to avoid contact with Stichopathes by growing around the latter, consequently assuming a U-shape.

Colonies of Stichopathes are abundant on the slope of the shelf south of La Parguera and other collection sites except Cabo Norte, Mona Island. At the former site colony density increases abruptly with depth beyond the shelf edge (Fig. III). Line transects parallel to the shelf edge carried out at several locations showed the average abundance of species "A" to be 0.11 at 80 ft, 0.30 at 90 ft and 0.50 per m^2 at 100 ft depth. The respective abundance for species "B" are 0.03, 0.05 and 0.21 per m^2. Colonies appear to be totally absent

Figure III. Average density of species "A" (.———.) and "B" (.------.) as a function of depth.


0.5
0.4
0.3
0.2
0.1
species "A" - .——.
species "B" - .----.
average density (colonies/m²)
80
90
100
depth (ft)

at the shelf before the edge except on the walls of the surge channels leading to the slope. Colonies are absent in the channels which do not lead to the shelf edge even though the depth can be from 60 to 80 ft. On a dive to a depth of 220 ft (bottom time 20 min) both species were observed and a possible reversal of the abundance of the two seemed apparent. While the proportion of species "A" to species "B" at 100 ft depth is approximately 2.4 to 1.0, rough estimate of that observed at 220 ft is 1.0 to 10.0. Although the area covered was small nevertheless these proportions had never been recorded at depth between 70 to 100 ft.

The species is dioecious, whole colonies being the same sex. Reproduction occurs almost all year round. Species "A" shows a slight advance in reaching sexual maturity by starting in February, having a peak from May to June and slowly starting to decline up to October. No mature gonads were observed from November to January in this species. Mature gonads in species "B" appeared first in April having a peak in June and slowly declining afterwards. No mature gonads were observed from November to March in species "B".

Neither fertilization nor larval stages were obtained. However, on June 8, 1974 while keeping male and female colonies of species "A" together in the laboratory the former

spontaneously spawned leaving a film of sperm in the bottom of the dish. Examination of the males showed that they were entirely spawned out. The following day all females spawned. Ova were checked periodically for the next 48 hours for cell division but conditions were apparently not appropriate since there was no fertilization. This seemingly coordinated behavior possibly due to the release of some chemical by the male stimulates the female to release the ova. If this occurs in nature, fertilization is external as is the case with other zoantharians.

The primary transverse septae bear the gonads. Sperm with round heads measuring approximately 2 um in diameter, and tails of variable lengths, are contained within sperm cords which in turn make up the testes. Ova are very numerous and measure up to 150 um. These are much more heavily pigmented in species "B" than in species "A".

Axial skeleton growth occurs concentrically and linearly. Concentric growth is by deposition of skeletal material around a hollow core (Plate IVB), The material is thought to be secreted by a layer of flattened cells which surrounds the sclerenchyme and was termed axis epithelium by Koch (1878). The axis epithelium is surrounded by a mesogleal sheath and the whole is

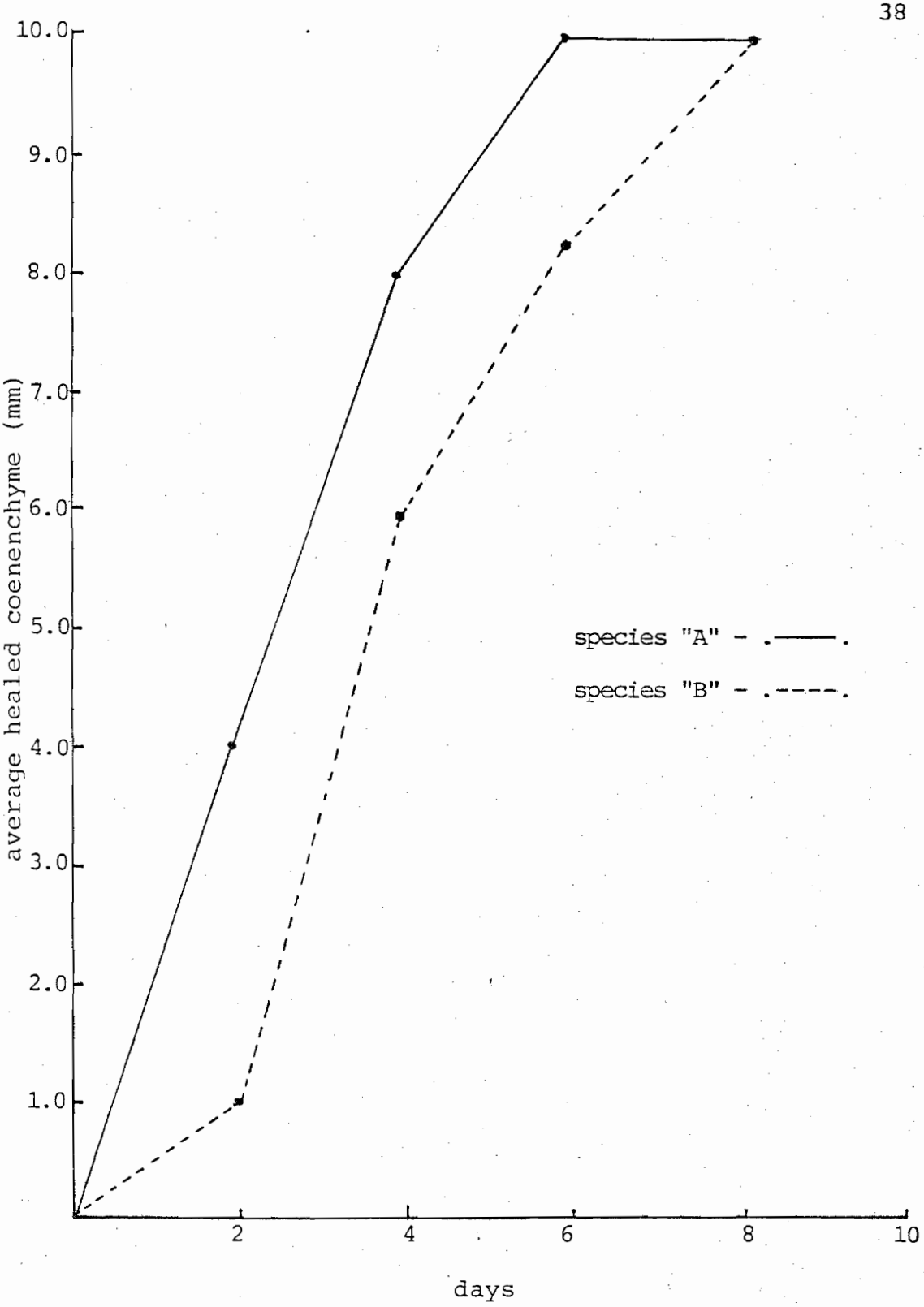
covered with the entoderm of the coenenchyme. Longitudinal growth was considerably more rapid at the tip of the colony. This was evident when growth rates of fragments from mid colony were compared with those from the tip.

The skeleton is very resistant to decomposition as shown by colonies denuded of tissue at the beginning of the investigation. These were overgrown by many organisms but did not showed any signs of decay.

Average annual growth rate for distal segments was 8 cm and 6 cm for species "A" and "B", respectively. Growth in situ for adult colonies was 7 cm/yr for species "A" and 3 cm/yr for species "B". Since the latter data includes colonies of different lenghts and thus different age classes which may have different growth rates, as shown for gorgonians by Grigg (1970, 1972), it is to be taken as a rough estimate.

Coenenchymal regeneration and healing capabilities under laboratory conditions yielded a slight but marked difference between the two new species (Fig. IV). From 40 fragments from each of both species "A" and "B" a 15 cm annulus of tissue was removed. In this experiment species "A" consistently recovered and healed faster than species "B". The latter was frequently overgrown by algae before healing. In most cases the coenenchyme extended evenly wrapping the

Figure IV. Average healed coenenchyme as a function of time.


10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
average healed coenenchyme (mm)
2
4
6
8
10
days
species "A" - .——.
species "B" - .----.

denuded area and healing at the tip unless there was algae overgrowth in which case healing did not occur. Healing took place at the same rate regardless whether the injury was toward the distal or proximal end of the fragments. Although coenenchymal regeneration was total zooids never reappeared in the area of regeneration.

Individual zooids of both species healed readily when dissected off the colony. After a 48 hour period the walls surrounding the open coelenteron fused together leaving a barely noticeable scar.

To determine the degree of compatibility between the two new species, several grafting procedures were attempted. End to end grafts were most succesful. Cross type grafts involved foreign contact with the grafting site and were not succesful. Of the intraspecific or control grafts (between fragments of the same species but belonging to different colonies) 46% of species "A" and 59% of species "B" were succesful. Here the tissue from both colonies fused with each other around the axis leaving a barely noticeable scar. No histological sections were made to determine whether fusion at the cellular level had occurred.

No interspecies grafts were obtained by any method used. Here the tissue of both fragments never touched each other leaving instead a narrow zone of bare skeleton where further growth did not occur.

A natural intraspecific graft between two colonies of species "B" was observed at one time in the main study area and collected. Here the tissue of both colonies was fused approximately 40 cm from the basal attachment. Dissection in this area revealed that the axial skeletons were also partially fused.

Stichopathes n. spp., as other non-zooxanthelae containing zoantharians exhibit carnivorous habits. Ciliary currents, tentacles and oral cone show coordinated responses to the presence of food. To determine the principal ciliary current direction in the starved zooids carmine dye was added after allowing the zooids to expand fully. The particles are slowly transported toward the tips of the tentacles, up the oral cone and out when reaching the oral aperture. Coenenchymal cilia transported the particles unidirectionally along the colony toward the distal tip.

If an Artemia homogenate is added to the carmine suspension, ciliary current velocity increases considerably up the oral cone and into the mouth. The current toward the enteron caused by the long cilia of the siphonoglyph (Plate VID) is very strong. Tentacles start to move in all directions and the mouth opens wide.

If living Artemia nauplii are placed in the vicinity of a non-excited zooid there is no response until there

is contact with a tentacle or with the surrounding epithelium. In such case the following sequence of events takes place: 1). the tentacles in contacted and nearby zooids start moving in all directions, 2). nauplii captured by tentacles are, within 20 seconds, brought in contact with the pharynx which by this time is open wide, 3). the nauplius is detached from the tentacle and engulfed completely in 20 seconds more. Under laboratory conditions as many as 40, one day old nauplii have been fed to a single zooid in 30 minutes. The mouth can enlarge up to 5 times and the enteron distends considerably. Occasionally nearby zooids have been observed assisting each other in the feeding process. These push food into the other's gullet with their tentacles.

Rapid food transport along the colony is suggested by the fact that when an individual ingests several nauplii, nearby zooids decrease the ingestion activity even though capturing may continue. Zooids which are far from the one which ingested the nauplii will still feed thereby creating a gradient in feeding activity along the colony.

Colonies kept in the laboratory expand more fully and feed more actively during the night than during the day. Even so, colonies collected in the field during

the daytime frequently contained partially digested crab zoea, echinoderm plutei and harpacticoid copepods within their enterons. Discharged cnidae were often observed penetrating Artemia nauplii after being captured with the tentacles.

While the antipatharian larvae is probably restricted to sloping, non-illuminated surfaces it is unknown whether adult colonies can endure other habitats. Surge has been observed before to limit the distribution of other antipatharians (Grigg 1974). Adult colonies transported to a zone of high surge at Turrumote Reef, south of La Parguera to determine the effect of particle abrassion remained healthy for one month after which algae began to overgrow them. Controls for effect of cutting, transportation, surge, depth and suspended particles were not affected. Measurements to determine whether growth had occurred were not done for any of the groups.

III SYMBIONTS

Four species of symbionts were found on each of the two new species of Stichopathes. A polychaete of the family Myzostomaridae and a cyclopoid copepod of the family Lichomolgidae occurred in passages between the coenenchyme and the axis epithelium. Occurring on the surface of the colonies were a caridean shrimp of the family Palaemonidae and a polychaete of the family Pilargidae.

The lichomolgid copepod, (Plate VIII) representing a new genus and a new species, is the first to be reported from an Atlantic antipatharian (Humes and Goenaga, in press). It infects 73% fo the colonies of species "A" and 6% of the colonies of species "B". Copepod densities of 1.2 per cm^2 of colony were found on species "A". The copepod is pale salmon and is 0.64 to 0.70 mm in length and 0.16 mm at its greatest width. The elongate animal has a rounded rostrum that is posterior-ventrally deflected and caudal rami with six setae. The first antennae consists of seven segments, and the second antennae have four, the terminal one with a claw-like process. The mouth parts consists of a bilobed labrum, mandibles and second maxillae with long lash-like setae and first maxillae with two setae. The females have a five segments

urosome, maxillipeds of three unarmed segments, segment of leg 5 and genital segment fused and the fifth pair of legs with a large, free segment bearing two setae. The males have a six segment urosome, maxillipeds of four segments of which the second is expanded inward and bears two setae and the fifth pair of legs lack a free segment which result in the setae arising from small prominences. In addition, the second pair of legs, in males, bear spines on the third segment of the endopods.

In living pieces of Stichopathes n. sp. "A", the copepod can be seen moving along in channels within the coenenchyme. Possibly the spines of the antipatharian's axial skeleton provide purchase for the copepod's activities. No evidence of injury to the host by the copepod was ever detected even in the heaviest infections.

The palaemonid shrimp (Plate VII A, B, C) is a new species belonging to the genus Pontonides and is the first reported from an Atlantic antipatharian (Chace, 1977, personal communication). The species had been previously collected on Virgularia at Bonaire and a sponge in the Gulf of Mexico. Dr. Richard Heard of Dauphin Island Sea Lab, Alabama, is describing the shrimp.

Pontonides n. sp. was found on about 10 per cent

on each of both new species of Stichopathes. The shrimp is about 8 mm long and is solid brown when present on Stichopathes sp. "A" (Plate VIIA,C) and has yellow transversal bands when on S. species "B" (Plate VIIB,C). Although conspicuous when isolated, it can, within a few hours, change color to match either antipatharian. It reluctantly leaves the antipatharian and shows no preference for either species. While on the surface of the black coral, most of the shrimp's appendages, telson and dorsal carapace are laden with mucus obtained from the host. The first pair of pereiopods are more agile but posses weaker chelae than the second ones. Third, fourth and fifth pair of pereiopods are used for locomotion along the colony.

It is not known what the shrimp may feed upon in nature. In the laboratory, Pontonides readily accepts Artemia nauplii. Contact with the Artemia immediately elicits a feeding reaction consisting of sweeping motions of the chelate first and second pereiopods. Occasionally, an Artemia is captured while it is swimming by, but usually Pontonides retrieves the food trapped on the surface of the black coral. The prey appears to adhere to the mucous coat on the shrimp's appendages rather than being grasped by the chelipeds. Prey may also adhere to almost any part of the shrimp (i.e. antennae,

telson, dorsal carapace) in which case the food laden structures are flexed toward the mouth and the food removed primarily by the first chelipeds. The latter frequently remove food from the actinopharynx of the polyps. The shrimp feeds almost continuously, ingesting a considerable number of nauplii.

When Artemia homogenate is added near Pontonides, a feeding response ensues, thereby indicating that chemical as well as visual stimuli are received.

The myzostomarid polychaete is dark green to brown, measures about 1.5 mm in length and 0.8 mm in width and occurs in about one out of five colonies. It is very sluggish and reacts little to tactile stimuli. Its chaeta are slightly hooked at their ends and the parapodia are much reduced. Injuries to the black coral by these organisms are not evident.

The pilargid polychaete is about 7.0 mm long and is colored various shades of yellow. It is inconspicuous in the antipatharian colony and reacts abruptly to touch by hiding within the interzooidal areas and between the tentacles and pharynx. The relation to its host is unknown. Its incidence on Stichopathes n. spp. is about 5 % on each species. According to Dr. Marian Pettibone (personal communication, 1975) this worm may represent a new species of the family Pilargidae.

DISCUSSION

I SYSTEMATICS

In his monograph on the antipatharians of the Siboga Expedition, Pesch (1914) reduced Stichopathes to a sub genus of Cirripathes. He claimed that the principal characters which Brook (1889) used to separate these two genera, polyserial and uniserial arrangement of the polyps, occasionally overlapped, and sometimes both conditions could be found on one and the same colony. He also observed young Cirripathes with a uniserial polyp distribution along the entire length of the colony. The question raised is how did he decide these were cirripathid instead of stichopathid colonies when it is essentially the arrangement of polyps that separates them. In an experiment with unbranched Antipatharia, Noome and Kristensen (1975) found that colonies below 20 m had polyps all around the stem but when these were transplanted to shallow waters they formed polyps only on the underside. This certainly would abolish the obstacle to unite both genera; however, this observation is seriously questioned by the author. In over 150 colonies of both genera observed throughout this investigation, none had a uniserial and polyserial polyp distribution at the same time. Also, colonies of

Cirripathes sp. collected at depths of 15 m have been transplanted to trays a few cm deep in the laboratory and no noticeable change occurred in the polyp distribution. The writer not having seen the material of Pesch and Noome and Kristensen chooses for the present to retain Stichopathes as a genus.

Three of the four previously described West Indian Stichopathes have smooth spines. The spines of S. desbonii Duchassaing and Michelotti are in regular horizontal rows, and the colonies always grow in clusters of a dozen or more. The spines of S. occidentalis Gray are short and slightly subconical. The spines of S. pourtalesi Brook are triangular and compressed while the colonies'growth is in the form of an spiral.

Four Stichopathes possess papillose spines; three are from the Indian Ocean and one, S. lutkeni, is West Indian. Of these only S. bourneii Cooper has a straight growth form. Its axial skeleton lacks spines on one side, and the diameter-length ratio exceeds that of both new species. The three species with spiraled growth form are S. lutkeni Brook, S. papillosa Thompson and Simpson and S. alcocki Cooper. The latter has an unusually large central canal which reduces the skeleton to a thin shell. Its spines are triangular and compressed; those on the inside of the spiral are

hooked. S. papillosa has a spiral growth form and its diameter-length ratio exceeds that of both new species. Scattered among the large spines are secondary spines which are identical to the larger ones except for size. Because of the similarity of its papillose spines and because of its occurrence in the West Indies, S. lutkeni appears to be the most closely related to both new species but differs from them in several respects. Growth form in S. lutkeni is subspiral or, as described by Brook (1889), "lower portion nearly straight, the upper flexed and twisted into three irregular open spirals." Both new species are always either straight or sinuous. Secondary spines abruptly indented at their distal end are present on S. lutkeni but absent on Stichopathes n. spp. The axial skeleton of S. lutkeni bears spines along its entire length, whereas in both new species there is a spine free area just above the holdfast. Also, there is evidence that the growth rate of S. lutkeni is very dissimilar to that of the new species. Individuals of the former species measuring up to 3.8 m have been seen by the writer on a strip of land which sank in 1949 below sea level at Baní, Dominican Republic. Assumming that these settled immediately after the land subsidence, which is highly improbable, the growth

rate must have been approximately at least 14 cm/yr, almost twice the growth rate of species "A" and almost five times that of species "B". Colonies of both new species present in this area never exceeded 1.5 m in length. This evidence plus the fact that colonies of S. lutkeni occurred together with the new species in various locations (Baní, Dominican Republic, La Caleta, Dominican Republic and St. Croix, Virgin Islands) but not in others (Mona Island, Cozumel and main study area) suggest that, although the new species appear to be closely related to S. lutkeni, they are definitely different.

The two new species cannot be distinguished one from another in the field except by their color. Gross coloration is very uniform throughout a colony but may vary between different individuals of species "A". This difference, however, appears to be qualitative since methanol and acetone extracts obtained from unequally colored colonies yielded identical absorption peaks under visible light. There is a possibility, however, that the pigment responsible for the different colorations was not extracted by the solvents used. The color of species "B" is very constant throughout all the colonies observed. Extracts of this pigment or pigment complex show absorption peaks that are distinctly

different from those of species "A". Absorption spectra under infrared light were very similar for the two species and may denote that these species have chemical components with analogous functional groups which are differently arranged within the molecules. Identification of these functional groups was beyond the scope of this work.

Nicol (1967) mentioned that "closely related species are often slightly dissimilar in colour and markings due to relative differences in the amounts of various pigments present." Color varieties are common in coelenterates, occurring in the scyphomedusae, Alcyonaria, Actiniaria and Madreporaria. Most of these varieties are of environmental origin especially in those species containing zooxanthellae. Some, on the other hand, are genetically determined as in Metridium senile which exhibits four principal color phases while living in one type of environment (Fox and Pantin, 1941). These forms do not differ morphologically otherwise as is the case with the two new species described in this work.

Morphological characters used in this thesis to differentiate between the mentioned stichopathids are: spine size and shape, ratio of length to diameter near the holdfast, tentacle length, elevation of the mouth above the peristome, polyp size, interpolypar distance, and height and differences in histology. Of

these, the first two were found most reliable, the next two, partially reliable, and the rest, non-reliable. Characters such as spine density and spine arrangement, used by previous workers, were not considered at all because of their high inconstancy between colonies and within individuals.

Cooper (1908) mentioned that size, shape and arrangement of the axial spines "may be of sufficient value to separate forms from one another in the Indivisae (unbranched antipatharians)." Although spine shape is very similar in both new species, their size is different. This character has proved to be very reliable when the species variability is taken into consideration. Since spine length may vary within a single colony the measurements should come from that area where it is most constant between individuals, in this case, the mid area of the colony. The means of the lengths of the longest polypar spines from various colonies of both species were found to be significantly different, indicating that the measurements came from two distinct populations. Supporting evidence was the standard error of the difference between the means which was less than on third the difference between the means. Also, the coefficient of difference shows that more than 96% of the longest polypar spines of species

"A" were dissimilar to more than 96% of those of species "B". This is noticeable in life when a colony of species "A" is disturbed, its longer spines frequently project out through the coenenchyme while in species "B" they do not.

The ratio, length/diameter near holdfast, was found to be significantly different between the two species, using the Wilcoxon Rank Sum Test. The t-test showed that the two variables in the ratio are highly correlated, and a linear reggression was made for each new species. The two reggression lines, which are significantly different, can be used as reliable taxonomic characters. From Figure II it is clear that for a given length a colony of species "A" will have a greater diameter than one of species "B". Mayr (1969) stated that proportions "are often more important in taxonomy than absolute size."

Tentacle length, although variable did prove to be greater in species "B" when measurements were taken from many colonies.

Polyp size and interpolypar distance were generally found to be very constant within a single colony but very variable among different ones and were deemed unsatisfatory characters. Occasionally individual polyps within a colony change their size, possibly as Opresko (1972) states by

"a nutritional mechanism whereby coelenteric fluid is pumped from polyp to polyp.

Although the mesoglea appears to be slightly higher in species "B", the height of the tissue layers is probably as variable as polyp size and is also considered of no taxonomic importance, at least at the species level. Zooxanthellae have been observed in other stichopathids (e. g., S. diversa Schultze) but were totally absent in the two new species.

The kinds of cnidae in both new species are identical. Size is very variable within each species and even within a single zooid and do not merit specific taxonomic consideration except for the p-mastigophores of the mesenterial filaments. 54% of those in species "A" are over 24 microns long, but they are never longer than this in species "B".

The two species differ otherwise in densities (number per m^2), change in density with depth, reproductive period, average annual growth rate, coenenchymal regeneration rate and percentage parasitically infected. These topics will be discussed in the next section.

II BIOLOGICAL ASPECTS

Known bathymetric ranges of West Indian Stichopathes are shown in Table III. Cutress reported (personal communication) the collection of a stichopathid colony of unknown species at a depth of 5 m at Caballo Blanco Reef south of La Parguera, Puerto Rico. The area was searched subsequently by the author, but no more specimens have been found at the mentioned depth. The only other species known to occur at such depths is S. filiformis Gray, which Brook (1889) reported as having a range of 0-18 m in Australian seas.

Hartman (1973) observed from the submersible Nekton at Jamaica on the shelf edge north of Discovery Bay, that different species of whiplike antipatharians reach the deepest point of their range at different levels. Grigg (1976) found that the lower limit of the branched antipatharian Antipathes dichotoma and A. grandis in Hawaii is about 110 meters which is close to the top of the major thermocline in those waters. This suggests that temperature plays a role in determining the lower depth limit of these species.

The fact that no colonies of Stichopathes have been observed at less than 40 foot depth and those occuring above 100 foot depths usually are in crevices

Table III

Bathymetric ranges of West Indian *Stichopathes*.

Species	Bathymetric range (m)
pourtalesi	30-3000
desboni	30-3000
lutkeni	20-?
n. sp. "A"	13-30+
n. sp. "B"	13-30++

or under ledges whereas several healthy colonies have been observed in the open at greater depth suggests that light may be an important factor in distribution. Grigg (1965) found that colonies of Antipathes grandis never grow where the light intensity is more than 25% that at the surface. However, during the present study, adult colonies of both new species survived and grew when maintained over a year period in the laboratory, and other colonies transplanted from deep to shallow water in the study area stayed alive. Thus, if light intensity is a limiting factor it must be operational only during the larval stage. Wells (1957) referred to the fact that corals which lack algal symbionts, as is the case of most Antipatharia, do not need light and tend to avoid it living in non-illuminated areas.

Densities of the new species increase very abruptly with depth beyond the shelf edge at the study area. At the same time, they are different for each species. Table IVA and B show the numbers of colonies recorded at 80, 90 and 100 ft with the object of comparing their proportions. Chi-square tests carried out to determine whether the proportion of species "A" to species "B" colonies was different at the three depths indicate that these are different between 80 and 90 ft with

Table IV

Contingency tables showing number of animals of species "A" and "B" observed at 80, 90 and 100 ft over transects of the same length.

Depth (ft)	sp. "A"	sp. "B"	Total
80	15	6	21
90	47	8	55
total	62	14	N=176

Depth (ft)	sp. "A"	sp. "B"	Total
90	47	8	55
100	86	33	119
total	133	41	N=174

a probability of 60% ($chi^2 = 1.05$) and between 90 and 100 ft with a probability of 90% ($chi^2 = 2.9$). Furthermore, ratios between number of colonies of the same species from different depths also different with the same probabilities. It can be inferred from this data that the increase in density with depth is much greater for species "B" than for species "A". By extrapolation, perhaps to too large an extent, this lends support to the single observation at a 220 foot depth of an apparent reversal of abundance. This should be taken as very tentative until more observations at this depth are done. Frequent glimpses by the author from the 100 ft level down, having vertical visibilities of over 80 ft, strongly support this argument.

Up to the present, nothing has been known about sexual reproduction and embryology in the Antipatharia. During the present study, spawning was observed in the laboratory occurring first in male colonies then, after one day, in females. This is the first report of spawning in the Antipatharia and suggests that fertilization is external and coordinated by secretion of some chemical compound by the male which stimulates the female to liberate ova. Gametes were produced in large quantities by both sexes, another indication that fertilization is external, the chance that sperm will contact the ova

thus being increased.

Attempts to induce fertilization in laboratory by various methods were not successful, indicating that pressure, salinity, pH or other unknown factors may be critical. These were not controlled.

Reproductive periods in the two species overlapped but started two months earlier in species "A" than in species "B". This difference is slight but noteworthy since no ripe gonads were observed at all in species "B" during February and March.

Although Formica settling plates, some of them roughened with coarse sand paper and cut with slits to approximate the natural substrate, were placed in areas with high densities of the two Stichopathes, larval stages were not obtained. According to Cary (1914), the distribution of gorgonians is related to the texture of the substrate, Grigg found the same to be true in A. grandis and noted that the exceptionally smooth basaltic ledges of Molokini do not support many colonies. Perhaps the plates used in the present study were not roughened enough to approximate the texture needed for antipatharian colonies to settle.

Electron micrographs of longitudinal and cross sections of the new species (Plates VA, B and IVB)

reveal a skeleton composed of tightly fitting laminae interrupted by the spines which are perpendicular to the longitudinal axis of the colony. Papillae, which are more noticeable on the polypar than on the abpolypar spines, are more common in the distal area of each spine, the proximal area being quite smooth. These two areas are sometimes separated by an outfold of the spines as shown in the micrographs. A non fibrous, non consistently cross-chambered central canal is present. The partitions are oblique and often incomplete. The structure of the axial skeleton of Stichopathes lutkeni, a species closely related to both "A" and "B" has been studied by Goldberg (1976). All features of the new species are indistinguishable from those of lutkeni. The present micrographs as well as those of lutkeni demonstrate the fibrous nature of the black coral scleroprotein. Fibers are arranged into bundles and bundles into laminae.

Deposition of the scleroproteinaceous skeleton material, which is longitudinal as well as concentric around a hollow central canal, is discontinuous. This is shown by the presence of discrete concentric rings in the skeletons of species "A" and "B". The rings are variable in thickness probably due to extraneous biological or physical factors. Overgrowth by benthic

organisms and presence of symbionts is not uncommon and may play an important role in this irregularity. Also scarid fishes have been occasionally observed nipping off the tips of stichopathid colonies. Grigg (1974) has observed that growth in Muricea sp. is variable due to intrinsic and extrinsic factors.

Growth rings have been shown by Noome and Kristensen (1976) to be deposited daily in whip antipatharians growing from car wrecks. Annual growth rings have been observed by Grigg (1974) in Antipathes dichotoma.

Linear growth, although not confined to, is about 10 times faster at the tip than in proximal portions of both new species. Noome and Kristensen (1976) found that growth rate at the tip of Stichopathes fragilis is at least 20 times faster than at its proximal portions. In situ linear growth of species "A" was found to be more than twice faster than that of species "B". This data assumes growth to be linear during the life of the animal and is to be taken as a rough estimate. Ideally, similar age class individuals should have been compared, however, the short bottom time of the dives did not permitted it. Results obtained for growth rates of distal tips of both species in the laboratory are close to in situ ones.

Species "A" proved to be less susceptible to algae

overgrowth and was capable to heal the coenenchyme upon dissection faster than species "B". These experiments, conducted primarily in the laboratory, also show that once algae overgrows a portion of the skeleton tissue rarely heals over the infected area. Algae, however, never spreads to the rest of the colony. The same experiments carried out in the field showed similar results. Since coenenchyme healing occurs in fed as well as in unfed colony fragments it is assumed that this is a result of cellular movement and not the formation of new tissue. In fact, the tissue covering the bare area became very thin and transparent as if stretched. This situation has also been reported in the hydroid Tubularia by Steinberg (1953) and in Telesto by Rees (1969). After the coenenchyme had grown over the bare axial skeleton and healed at the extremities there was no evidence of zooid regeneration for a period of one month.

Grafting experiments between fragments of different colonies were succesful. Although it is not known whether fusion had occurred at the celullar level, it is suspected by the adhesion between the two pieces and the lack of a scar at the fusion site. On interspecific grafts either a line of inhibition resulted between the coenenchyme of the two fragments or their tissues healed individually. No adhesion between the latter fragments

was recorded. Negative or aggressive interactions were never observed. Unprovoked grafts between colonies of the same species sometimes occurred also in aquaria where stock specimens were kept. These adhered firmly to each other at a single site along the axis. Non compatibility between closely related species in the Anthozoa has also been reported by Lang (1971). Here the scleractinian Scolymia lacera showed an aggressive response toward S. cubensis when these came into contact.

Feeding responses in both new species of Stichopathes seem to lead to a more efficient capture of the prey. A coordinated action of the mouth, tentacles and cilia is apparent as soon as a food particle or juices contact the epithelium. Cnidae discharged into the victim also seem to play an important role in its capture. Chemical stimuli by itself is capable of producing the series of responses described while tactile stimuli alone produces an opposite reaction (tentacle retraction, mouth closure, etc.). Colonies kept in the laboratory feed very actively during the night and hardly feed during daytime. Frequently colonies collected during daytime contained partially digested food within their enterons. This suggests that light, which is considerably less during the day in their natural habitat than in the laboratory, may play an important role in feeding being inhibitory at high intensities.

Food transport along the colony is suggested by the decreasing feeding responses in unfed zooids when distant ones ingest Artemia nauplii. Being imperfectly divided from one another, the zooids of Stichopathes n. spp. may easily transport food with the help of entodermal cilia.

Food transport in colonial coelenterates is known to occur either through the hollow stems and stolons of colonial hydroids and/or by a syncitial mesogleal cell plexus (Rees, 1969).

The first mechanism occurs in Campanularia (Strehler, 1961) and in Pennaria (Rees, Davis and Lenhoff, 1970). The second occurs in Alcyonium (Pratt, 1906), Lobophyllia (Yonge, 1931) and Campanularia (Crowell, 1957). Assimilation in areas distant to the point of feeding occurs in Campanularia (Lunger, 1963) and in Telesto (Rees, 1969). The possibility of mesogleal transport is not discarded for Stichopathes n. spp. although sections revealed no evidence of a cell plexus.

The limiting factor restricting Stichopathes n. spp. to depths below approximately 13 m appears to be a combination of surge and suspended particles. Control colonies proved by their survival that light, pressure, turbidity and surge are by themselves not limiting in the adult and that trauma by cutting did not increase their mortality. Yearly studies conducted by González (1965)

at different stations close to the experimental site of this experiment (Turrumote Reef) and the natural habitat (shelf edge south of La Parguera) vary little at the depths investigated and it is unlikely that these factors are limiting either. Growth was never measured so the possibility of surviving alone without growing is questioned. Also it is unknown whether reproduction of the species can occur in habitats other than the natural. Grigg (1964) found similar results for Antipathes grandis. He believes suspended particulate material rather than frictional drag of the water itself is the cause for tissue abrasion which is supported by the fact that A. grandis is able to withstand fast currents where the water is free of suspended material.

SYMBIONTS

The occurrence of four different symbionts representing two different phyla with the stichopathid colonies is probably indicative of the lack of available space at the edge of the shelf south of La Parguera from 70 to 120 ft where most observations were made. This type of relationship may provide the guest symbionts an alternative habitat where competition pressures are reduced and where especially the external ones, can approach the environment for feeding higher in the water column.

The new copepod found on Stichopathes n. spp. belongs to the family Lichomolgidae. Of the 57 genera that comprise the Lichomolgidae, the single species of this new monotypic genus can be distinguished by the extreme sexual dimorphism in leg 5 and in most cases by the absence of an inner setae on the first endopod segment of legs 1-4. In species of other genera where such setae are also absent (Amardopsis, Cerioxynus, Mycoxinus, Ravahina Humes and Ho, 1968 and Amarda Humes and Stock, 1972), the reduction in the number of segments in the endopods of one or more legs separates them from the new genus.

The different frequencies with which the two new Stichopathes are infected with the lichomolgid copepod supports the belief that these are, in fact, two different species. Mayr (1962) stated that sibling species often differ in the number or the kind of parasites they carry. The avoidance of the copepod to species "B" is of unknown nature but may be related to chemical or morphological factors present in the host to which it is incompatible or partially so. Axial skeleton spines which are used for locomotion of the copepod whithin the colony are significantly reduced in species "B" as compared to species "A".

Another similar association between vahiniid copepods and Stichopathes echinulata Brook from Madagascar has been reported by Humes (1967).

Members of the subfamily Pontoniinae, in addition to being symbionts of antipatharians also commonly occur on certaing genera or families of the Mollusca and the Echinodermata. Although the whip-like gorgonian Elisella which is moderately abundant in the study area was examined, Pontonides n. sp. was never observed on it. Spines of carapace and rostrum, normally present in free living shrimps, are frequently reduced or lacking in the Pontoniinae. Members have very large

chelae on the second pair of legs as is the case with the species occurring on Stichopathes n. spp. Refering to an association between pontoniniid shrimps and molluscs, Bruce (1972) has questioned the significance of these heavy chelae given that the shrimp are not too vulnerable to attack by predators. He postulates that the chelae have evolved to defend the host from further colonization by members of the same species this way reducing competition for available food supply. Too many commensals sharing food could result in starvation of the host. In the case of Stichopathes this is probably not the case since as many as six shrimps have been collected from a single 1 m long colony.

Davis and Cohen (1968) reported on the occurrence of Pontonides uncinger on the sea whip Cirripathes in the Pacific Ocean. They suggest that the antipatharian in this case, "provides a pathway that allows the shrimp... adapted to living on the bottom of fixed surfaces, to ascend into the midwater" for feeding. At the shelf edge south of La Parguera there is especially severe competition for food by sessile plankton feeders, therefore this adaptation may enable the shrimp, primarily a passive plankton feeder, to receive food from all directions.

Insufficient time and literature on the symbiont polychaetes precluded investigation of their biology.

SUMMARY AND CONCLUSIONS

1. Stichopathes n. sp. ("A") and S. n. sp. ("B") are found sufficiently distinct from one another to be considered two new species. Morphologically, these differ primarily in color, polypar spine size, colony diameter near the holdfast, ratio of colony length to diameter near holdfast and height of the oral cone of the zooids.

2. The two new species plus S. lutkeni are the only three West Indian Stichopathes reported to bear papillose spines. S. lutkeni, however, exhibits a subspiral growth form while the axial skeleton of the two new species is always either straight or sinuous.

3. In the evaluation of the species morphological characters such as polypar spine size and shape, ratio of colony length to diameter near holdfast and color are considered reliable diagnostic features due to their constancy throughout different colonies. Tentacle length and elevation of the mouth above the peristome are partially reliable due to differences at various states of polyp contraction. Polyp size, interpolypar distance, histological features and spine density and arrangements are considered non-reliable specific characters due to their high variability within and between colonies.

4. Densities at 80, 90 and 100 ft were 0.11, 0.30 and 0.50 colonies per m^2 for species "A" and 0.03, 0.05 and 0.21 colonies per m^2 for species "B". Although not conclusive, the fact that the abundance of species "B" increase faster with depth than that of species "A" plus a single observation at a depth of 220 ft showing a very high estimated abundance for species "B" suggest different bathymetrical distributions for both new species.

5. Stichopathes n. spp. are dioecious, whole colonies belonging to the same sex. Species "A" shows a slight advance in reaching sexual maturity than species "B".

6. Unsuccessful interspecific grafts between the two new species show these to be incompatible.

7. Coenenchymal regeneration experiments show that species "A" has a higher regeneration rate than species "B".

8. A combination of surge and suspended particulate matter is an important factor limiting the distribution of the two new species as shown by the injuries and algae overgrowth exhibited by colonies transplanted to a site where the former conditions predominate.

9. Stichopathes n. spp. exhibit carnivorous habits showing a coordinate action of tentacles, mouth and ciliary currents, in response to the presence of food, which lead to a more effecient capture of the prey. Food

transport takes place along the colony probably through channels formed by the incomplete septae dividing the zooids. Feeding activity is higher at night hardly occurring in the daytime under laboratory conditions. In situ feeding does occur in the daytime.

10. No colonies of Stichopathes n. spp. less than 20 cm in length nor dead ones were ever observed in the field despite the resistance of the axial skeleton to decay. This evidence along with that of the species slow growth rate indicate that the population turnover is very low. Number of ova by polyp (over 100 on each species) and length of the breeding season suggest, on the other hand, that the species should be prolific. Possibly, high mortality of the larvae, due to the limited and specific nature of its site of attachment is the reason for the low recruitment observed. Since yolk content in the ova is very high, it is suggested that the larvae does not feed in the plankton, it is short-lived and will die if an appropriate settling place is not attained promptly after its formation. Under these conditions, natural selection will probably favor a negative phototactic larvae which settles on uncrowded areas as beneath overhangs.

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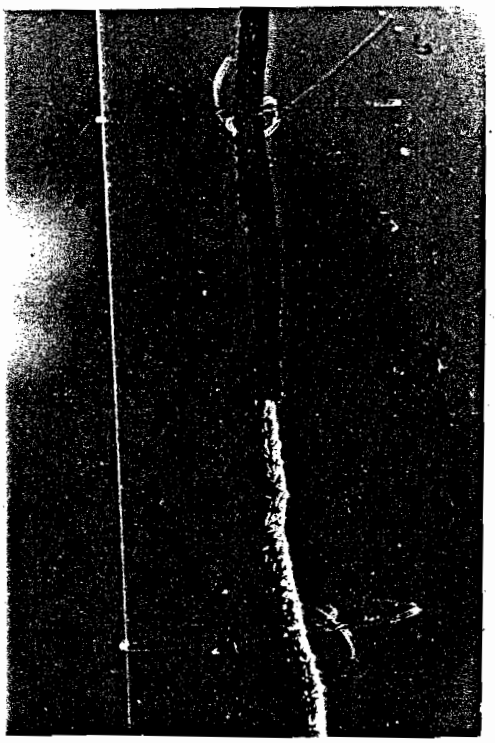
Plate I



A



B



C

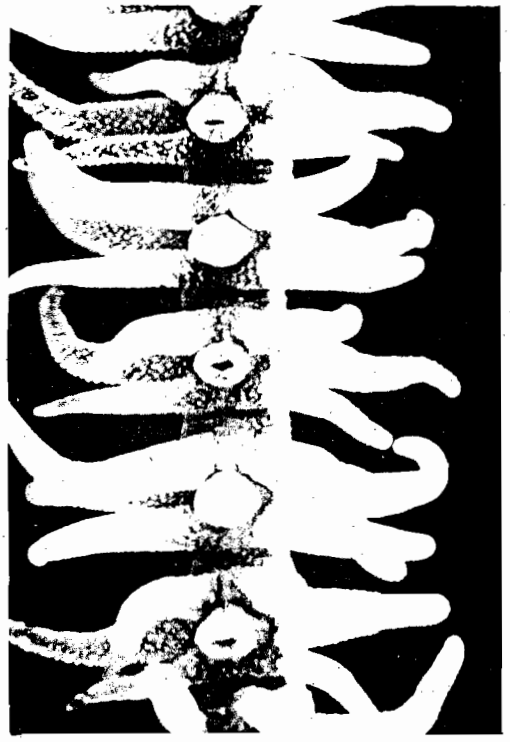


D

Plate II



A



B



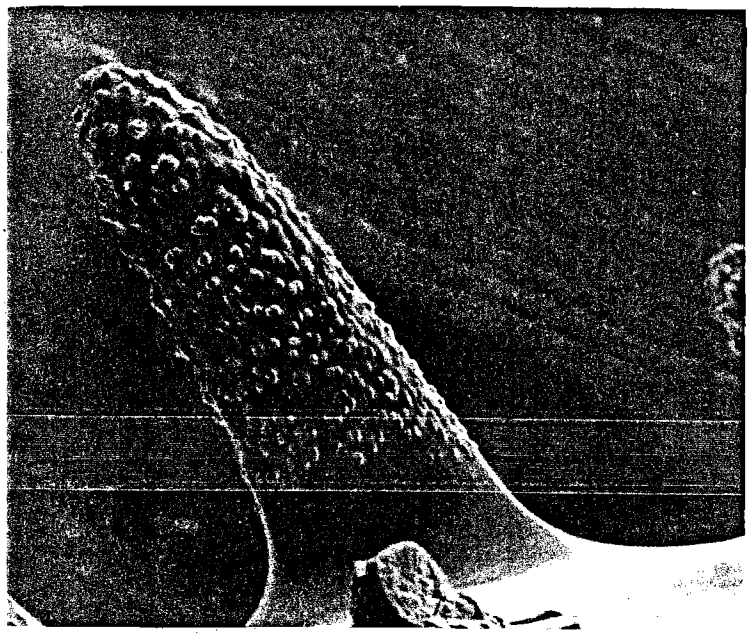
C



D

Plate III

A



B

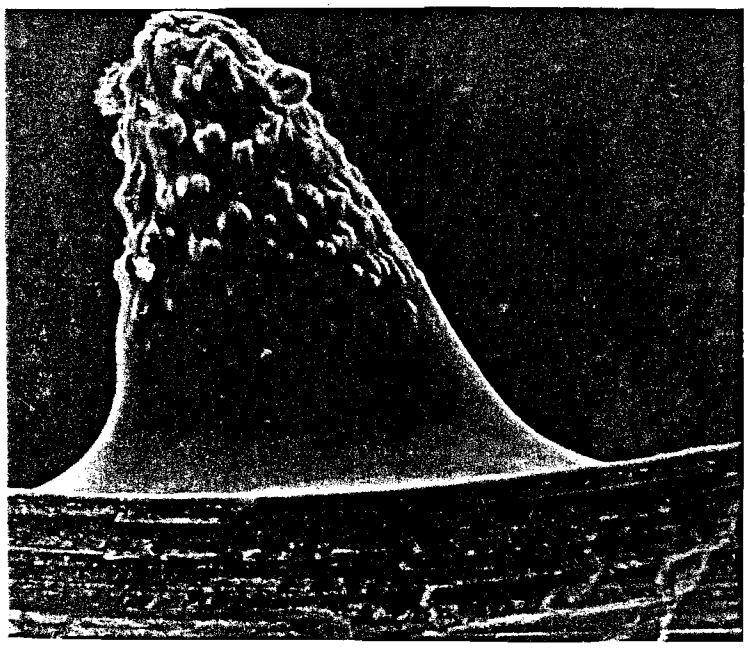
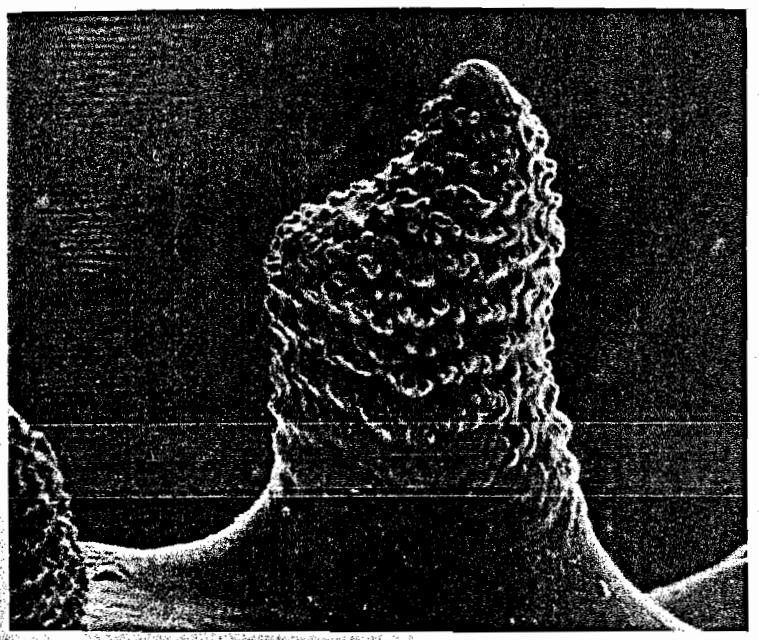


Plate IV

A

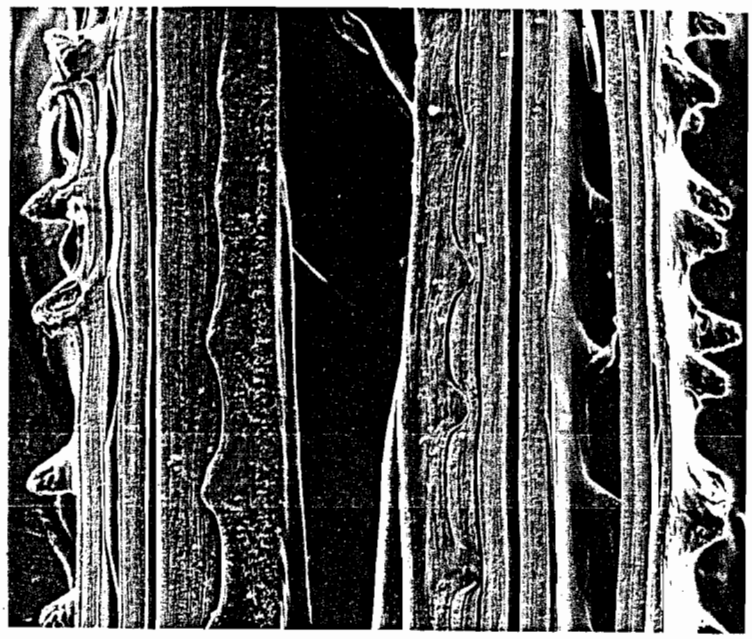


B



Plate V

A



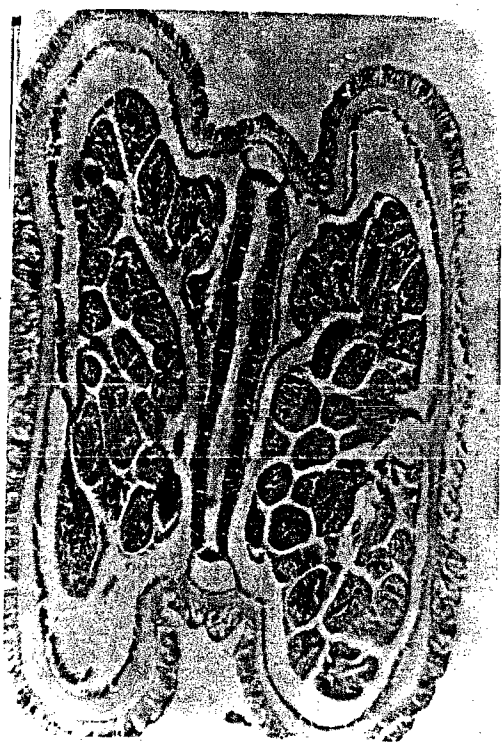
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Plate VI



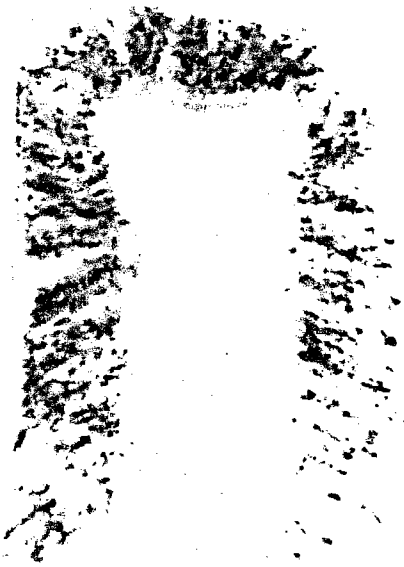
A



B



C



D

Plate VII



A



B



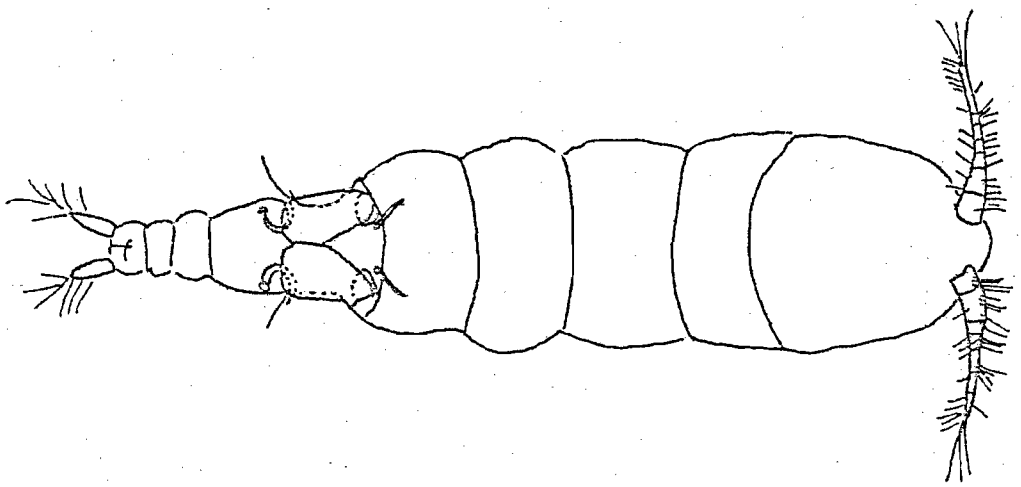
C



D

Plate VIII

A



B

