A STUDY OF THE BIOLOGY AND ECOLOGY OF THE BLACK SPONGE *CHONDROSIA* SP. COLONIZATION IN SEMPORNA ISLANDS, AND ITS IMPACT ON THE REEF ECOSYSTEM

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DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

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ABSTRACT

A STUDY OF THE BIOLOGY AND ECOLOGY OF THE *CHONDROSIA* SP. COLONIZATION IN SEMPORNA ISLANDS, AND ITS IMPACT ON THE REEF ECOSYSTEM

This study involved carrying out research into the biology and ecology of an invasive species of sponge called the black sponge from 1999 to 2004. The aim was to investigate its impact on the reef ecosystem and consider the implications of the infestation on reef management. The sponge was found to be locally common at depths between 2.0 - 20.0 m during surveys carried out in the initial phase (Phase I) of the Semporna Islands Project, in Sabah, Malaysia. It occur as a thin film growing over rock, rubble and dead corals, leaving only isolated patches and certain dead corals uncovered. It is particularly common at Bodgaya West reef, Maiga South and Maiga West reefs. This phenomenon have not previously been described for the area and it was for this reason that a study on its biology and ecology was carried out. The research included identifying the black sponge, comparing results of Line Intercept Transect (LIT) method surveys and studying the spread of the sponge over different substrata. It was found that the black sponge can move over the substratum at rates of 1.8 – 1.9 mm^2 per day. The fastest spread occurred where the sponge was growing over the dead part of live hard coral or other non-living substratum. The fastest spread rates recorded were over terracotta brick where the sponge grew at an average of 1.9 mm^2 per day, and over dead coral where the sponge grew at 1.8 mm^2 per day. However, the area, which was initially dominated by the black sponge species, has been reduced year-by-year from 61% in 1999 to 3% in 2004. The black sponge was eventually identified and confirmed as an undescribed species of *Chondrosia* by a sponge expert Dr. Michelle Kelly and Dame Professor Patricia R. Bergquist, Emeritas Professor, Department of Anatomy, School of Medical and Health Sciences, University of Auckland, New Zealand.

ABSTRAK

KAJIAN TERHADAP BIOLOGI DAN EKOLOGI CHONDROSIA SP. DI KEPULAUAN SEMPORNA DAN KESAN KEATAS EKOSISTEM TERUMBU KARANG

Kajian ini bertujuan untuk mengkaji biologi dan ekologi serta kesan jangka panjang terhadap ekosistem terumbu karang berikutan pertumbuhan meluas satu spesies span baru yang dikenali sebagai span hitam di pulau-pulau Semporna. Pertumbuhan meluas span hitam telah dikesan pada kedalaman 2.0 - 20.0 m ketika kerja-kerja penyelidikan awal terumbu karang Projek Pulau-Pulau Semporna (fasa I) di Semporna, Sabah bermula. Span hitam yang menyerupai filem hitam nipis, tumbuh di atas serpihan terumbu karang mati, walaupun bukan keseluruhannya. Span hitam ini boleh ditemui dengan banyak di bahagian Barat Pulau Bodgaya, Selatan dan Barat Pulau Maiga. Kajian terperinci terhadap pertumbuhan span hitam ini amat penting kerana tidak ada kajian mahupun laporan tentang kewujudan fenomena sebelum ini. Oleh itu kajian terperinci telah dijalankan secara tidak langsung dari tahun 1999 hinggalah 2004. Ini melibatkan kerja-kerja pengenalpastian spesies span hitam, perbandingan terhadap peratusan pertumbuhan span hitam menggunakan teknik Line Intercept Transect (LIT), kadar pertumbuhan span hitam menggunakan video digital serta mengukur kadar pertumbuhan dari masa ke semasa. Kawasan kajian ini merupakan antara kawasan yang teruk di tumbuhi oleh span hitam. Kadar pertumbuhan spesies ini juga menunjukkan bahawa spesies ini boleh bergerak dan tumbuh keatas sesuatu substrat mati pada kadar 1.8mm persegi/hari hingga 1.9mm^2 /hari. Kadar pertumbuhan tercepat direkodkan pada terumbu karang mati iaitu pada kadar 1.8 mm^2 / hari diikuti pada bata merah, 1.9 mm^2 / hari. Walau bagaimana pun, kajian berterusan dari tahun 1999 hingga 2004 menunjukkan penurunan peratusan span hitam di kawasan kajian dari 61% kepada 3%. Secara keseluruhannya kajian terperinci terhadap fenomena ini amat penting terutama sekali dalam pengurusan terhadap ekosistem terumbu karang dalam jangka masa panjang. Hasil dari kajian, span hitam tersebut akhirnya dikenalpasti sebagai satu spesies baru dalam genus Chondrosia sp. oleh pakar Span Dr. Michelle Kelly dan Professor Patricia R. Bergquist, Emeritas Professor, Jabatan Anatomi, Sekolah Sains Perubatan dan Kesihatan, Universiti Auckland, New Zealand.

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CHAPTER 1

INTRODUCTION

1.1 Background

Coral reefs are among the most biologically diverse marine ecosystems with high biological diversity on earth (English *et al.* 1997), rivalled only by the tropical rainforests on land. Coral reefs deserve protection for their intrinsic natural value, and for their importance to humans. People obtaining part of the protein in their diet from coral reefs are estimated to number in tens of millions (Salvat, 1992). Coral reefs not only contribute directly to human livelihoods but also indirectly, for example as a main food supplier for both oceanic and inshore pelagic fishes (Birkeland, 1997), which are utilized by fishers throughout the world.

Importantly, some of the economic, fishing and recreational resources of tropical areas around the world depend upon healthy coral reef systems. However, there is now widespread concern about threats facing reefs, which are affecting their sustainability and biodiversity. These threats and documented impacts are due to a variety of factors, which fall within two categories: natural disturbances and anthropogenic (man-made) disturbances. Although natural disturbances may cause severe changes in coral communities, anthropogenic disturbances have been linked to major and widespread degradation of reefs and their resources. Hodgson (1999), refers to "coral reef health" as a general concept to a balance in the ecosystem that might be shifted by human activities.

The proposed Semporna Islands Park, covering an area of 350 sq. km, is situated off the east coast of Sabah (figure 1.1). The natural resources of the proposed park are of considerable biological, social, cultural and economic value, and the reefs and islands have a natural beauty and interest that provide enormous potential for eco-tourism. The coral reefs are of particular significance because of their high biodiversity, unique species and value to local communities (Wood, 1998).

The Semporna Islands Project (SIP) began in 1998 under the leadership of Dr. Elizabeth Wood, Coral Reef Conservation Officer of the Marine Conservation Society, UK. It is a collaborative venture between the Marine Conservation Society (MCS), Sabah Parks, WWF Malaysia and Nature Link. The project was funded by the European Community under its global environment budget line. The aim of the project was to produce a plan for effective management and to ensure a healthy future for the area by safeguarding livelihoods, promoting sustainable use of natural resources and encouraging environmentally-sensitive development (Wood, 1998).

During the surveys carried out in the initial phase of the project, one of the reef sites investigated (Bodgaya West) was found to be severely affected by a black organism of uncertain identity that grew as a very thin film over rock, rubble and corals, leaving only isolated patches and certain corals uncovered (Wood, pers. Comm.). It was confirmed to be black sponge following examination of specimens at the Natural History Museum London, and by Dr. Michelle Kelly, a sponge expert from the Marine Ecology and Aquaculture Group, National Institute of Water and Atmospheric Research (NIWA), New Zealand.

This sponge infestation had not previously been reported for the area, or from elsewhere in Sabah, but was clearly having a profound effect on the reef. Research into the phenomena of ecological significance is vital, and it was for this reason that a decision was made to carry out a full investigation of the biology and ecology of the sponge. The study was also important because this area is a proposed marine park, and particular management strategies may be required for the affected reef.

1.2 Aims and Objectives

The overall aim of this project was to carry out research into the biology and ecology of the black sponge, investigate its impact on the reef ecosystem and consider the implications of the infestation on reef management. The specific objectives of this research were to:

1. Describe the sponge and determine its identity.
2. Map the main area on Bodgaya West reef covered by the black sponge and investigate its occurrence elsewhere in the proposed Park and on adjacent reefs.
3. Determine how fast the sponge grows and spreads over the reef.
4. Determine the impact of the sponge infestation by investigating which reef organisms are being smothered and which are apparently able to withstand the spread of the sponge .
5. Consider whether particular management strategies may be required for the affected reef.

Figure 1.1: Sabah Map – Research Location

CHAPTER 2

LITERATURE REVIEW

2.1 General Biology and Morphology of Sponges

Sponges are the most ancient, and primitive of all multicellular aquatic animals. They are present at water depths from the tidal zones to the deepest regions (abyss) (Sorokin, 1993; Hooper, 2000). As an element of the sessile benthos, sponges are second most important after coral and zoantharians in terms of functions and roles on the coral reef ecosystem (Sorokin, 1993). Moreover the role of sponges is similar to some of the functions of coral on the coral reef ecosystem (Sorokin, 1993). For instance, the calcareous sponges produce lime and take part in the reef-building processes cementing carbonaceous material during the formation of reef-flat rocks.

Sponges are essentially divided into two main morphological categories encrusting and free standing. Encrusting sponges are similar to moss because they tend to cover the surface or grow attached to shells, stones, rocks or any solid object on the bottom. Free standing sponges, the type most commonly known, grow into odd shapes, may be quite large (up to two meters in diameter), and have a significant amount of inner volume compared with their surface area (Hayden, 1999). The sponge phylum Porifera, is divided into three classes: Calcispongiae, Hyalospongiae and Demospongiae, based on the composition of the skeletal elements (Hooper, 2000).

The colour of sponges variy according to the species, but also varies within species. Sometimes the colour is influenced by the depth where it is growing. For instance, deep-water sponges usually show a neutral drab or brownish colour, while shallow-water sponges are generally brightly coloured, ranging from red, yellow, and orange to violet and occasionally black (Hooper, 2000). Certain sponges (e.g. the *Verongida*), contain what are known as aerophobic pigments that darken upon contact with air (Hooper, 2000). Some species of sponges such as the Family Spongilidae are often greenish because green algae live in symbiotic relationship within them, and others are violet or pinkish, because they harbour symbiotic blue green algae (Hooper, 2000).

2.2 Skeleton

Most sponges live in moving water and support themselves with a well-developed skeleton. The skeleton of the sponges are formed by units called spicules which are either scattered throughout the sponge or united to form fibres. Spicules are classified as megascleres, which function in support, and microscleres which function in protection and aid in support (Hooper, 2000). In most species of sponges, spongin and spicules occur together. As shown in figure 2.1 A, spongin welds together the tips of spicules to form a skeletal network. Figure 2.1 B, spicules are embedded into spongin fibres themselves. Some species of sponges lack spicules, but secrete organic spongin. For example, in some species of demosponges (*Scleresponges*), the siliceous spicules are secreted in the mesohyl (Figure 2.2).

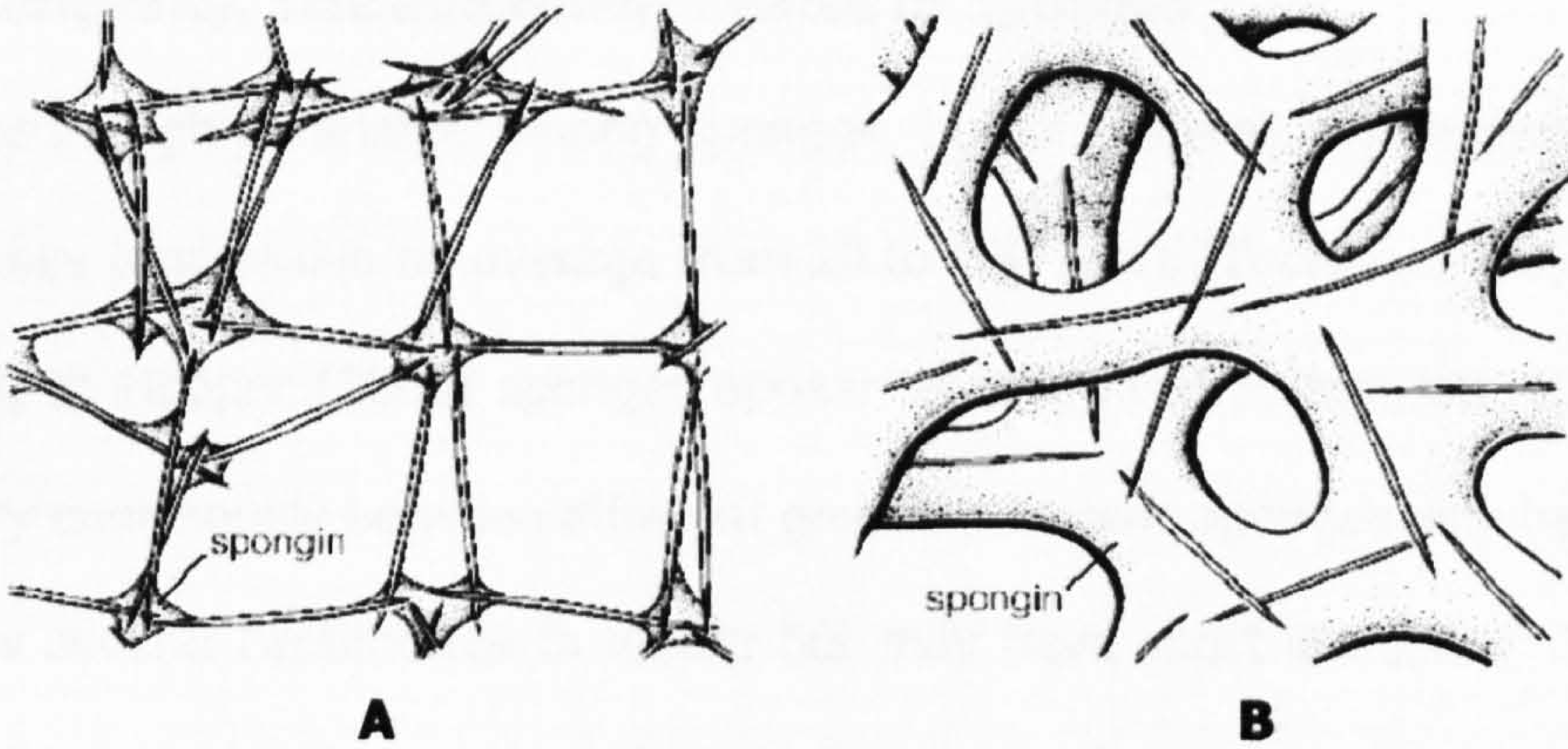

Figure 2.1: **A,** siliceous spicules (oxeas) glued together at their tips with spongin to form a network in *Haliclona rosea*. **B,** spongin fibers with embedded siliceous spicules (oxeas) form a reinforced network in endectyon. *(Adopted from: "Porifera" and Placozoa" in http://64.78.63.75/samples/04BIORuppertInvertebrateZoology7ch5.pdf)*

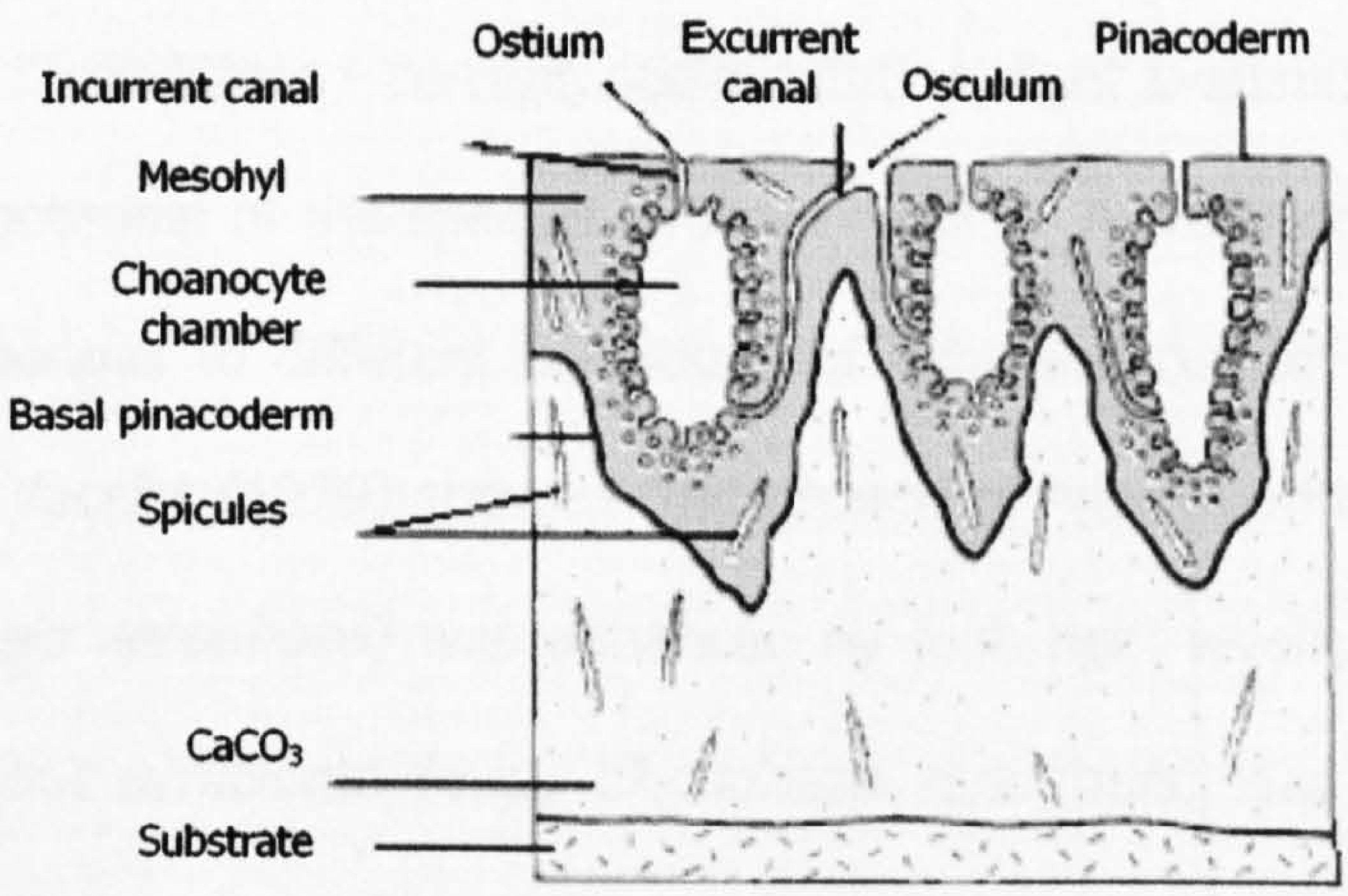

Figure 2.2: Porifera: Cross section body wall and skeleton of calcifying sclerosponge (Demospongiae: Ceratoporellidae). The calcareous exoskeleton is secreted by the basal exopinacoderm and contains embedded siliceous spicules. siliceous spicules also occur in the mesohyl of the living tissue. *(Adapted from: "Porifera" and Placozoa" in http://64.78.63.75/samples/04BIORuppertInvertebrateZoology7ch5.pdf)*

2.3 Longevity, Size and Growth Rates of Sponges

Longevity is highly variable among sponges, but in general, and especially in the tropics, they tend to live on average from 20 to 100 years (Toonen, 1996). However, according to Hooper (2000) sponges appear as long lived animal, although growth rates vary enormously between different groups but some sponges, like haplosclerids can grow several centimetres in weeks but may have short life span. The size of sponges is very variable, ranging from a few centimeters in diameter to vase, tube and barrel sponges that can grow one to two meters tall and broad rounded masses may be one to two meters in diameter (Hooper, 2000).

Encrusting sponges, which cover a very large area, can also be considered enormous individuals. Some sponges, like *Terpios* sp. from Guam, grow an average of 2.3 cm per month (Toonen, 1996). However, the growth rate and size within a species of sponge may be influenced by many factors, such as the individual's age, environmental conditions - current, sedimentation, light availability, food supply, and the genetic potential of the species (Hooper, 2000). A study on the transplantation of marine sponges to different conditions of light and current on natural reefs by Wilkinson & Vacelet (1979) showed that growth of species with obligate symbionts (e.g., *Verongia aerophoba*) was enhanced by high light levels, whereas growth of species without symbionts (e.g., *Chondrosia reniformis*) was inhibited by strong lighting. Species such as *Chondrilla nucula* and *Petrosia ficiformis*, which contained facultative symbionts, did not appear to be affected by the light regime (Wilkinson & Vacelet, 1979).

2.4 General Ecology and Habitats of Sponges

In general, little is known about sponge ecology, compared with other animal groups but most sponges are very sensitive to a wide range of ecological factors (Hooper, 2000). As immobile animals, sponges are vulnerable to being overgrown, and have to compete for space to survive (Shimek, 1997). It has been shown that some of them are able to move slowly (up to 4 mm per day) within aquaria but it is still unknown whether this movement occurs in the wild and is important for sponge ecology under natural conditions.

Sponges may compete with other reef organisms for space on the reef including species with defense mechanisms such as sweeper tentacle formation or morphological adaptations (Vicente, 1993). Studies have indicated that sponges are the superior competitors in 80% of these encounters (Vicente, 1987). In addition, Bryan (1973) has also documented the extensive takeover of a section of reef in Guam by an encrusting species of the sponge *Terpios hoshinata*. Among coral-overgrowing and coral-killing sponges, the most notorious to date is probably *Terpios hoshinata* (Bryan 1973, Plucer-Rosario, 1987), or *Terpios hoshinota* respectively (Antonius, 1993, Rützler & Muzik, 1993). *Terpios hoshinota* has infested hundreds of meters of coral reef in Micronesia (Bryan, 1973), and has also been reported from Nothern Pacific, from Samoa (Plucer-Rosario, 1987), from southern Japan (Rützler & Muzik, 1993), as well as from Mauritius and Sinai (Antonius, 1993). However, it was never observed in Atlantic waters (Antonius, 1996).

According to Hooper (2000) and Porter and Targett (1988), sponges may use chemicals made from the most poisonous materials found in nature (Shimek, 1997) to compete for space and protect themselves from predators. In addition, sponges may release chemicals to poison corals and other animals that would tend to overgrow them. Other sponges that try to grow into corals spaces do not succeed. In spite of the abundance and competitive dominance of sponges, consistently high coral cover on Caribbean reefs indicates that sponges are somehow prevented from reaching their competitive potential (Shimek, 1997). Some predators have enzymes that allow them to detoxify the sponge chemical. They may have an advantage over other predators in the exploitation of that sponge, and this may put the sponge at a disadvantage (Shimek, 1997).

Light is one of the most important factors in influencing the distribution of sponges, as it is one of the limiting factors for their survival. Some species of, littoral-dwelling sponges are not dependent on light and generally occur in caves, on shadowed walls, or under small shelters such as those provided by crevices. Others, mainly in the tropics, are covered by a meter or less of water and thus are almost completely exposed to irradiation from the sun. Symbiotic relationships between algae and sponges usually occur in these strongly illuminated zones, and the algae may act as a protective device because they deposit pigments in the superficial cell layers of the sponge. In some sponges (e.g., *Petrosia ficiformis*), colour is related to the density of symbionts within the sponge tissue. In a cave, for example, the sponge gradually change from intensely coloured specimens to light-coloured, sometimes white, once in the depth of the cave where the number of algae decreases (Sorokin, 1993).

2.4 Reproduction

Sponges reproduce both sexually and asexually. Most are hermaphrodites, meaning that male and female germ cells are in one individual. During sexual reproduction, sperm are spawned from one sponge and transported by water currents, to another individual. They are captured by specialised cells called choanocytes, and fertilization

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