UTILIZATION AND CONSERVATION OF *PLEXAURA HOMOMALLA*

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This account about the unexpected importance of a gorgonian coral as a major commercial source of a family of medically important substances, is a rarity: A story with a happy ending. During the 1930's, substances with unusual properties such as vasodepression and muscle stimulation, were isolated from human semen and from the semen and seminal vesicular glands of sheep. Von Euler, one of the pioneer investigators who extracted the pharmacologically active substance from sheep glands, named it "prostaglandin" in the belief that it was synthesized by the prostate gland. It has since been found that prostaglandins are produced in many kinds of tissues and cells, but early usage established the name firmly. The chemical structure of prostaglandins was determined by Bergstrom and co-workers in 1962 after years of investigation of sheep-gland extracts (951).

Prostaglandins are a family of closely related unsaturated hydroxy acids, arranged in three series depending upon the position of double bonds in a 5-membered ring, and further designated by letters indicating still other chemical peculiarities. Not being a biochemist, I will not go into this matter further but will refer you to the summary given by Pike in 1974, and the literature cited by him (951).

It was found that prostaglandins are formed enzymatically in a wide variety of tissues, but storage in these tissues is considered very unlikely. The quantity found in any particular tissue is thought to represent that which is synthesized in the time between removal of the tissue and its preparation for extraction. The amounts of prostaglandin obtainable from large numbers of sheep glands were measured only in milligrams. Not until 1965 did larger-scale laboratory duplication of the natural biosynthesis using substrate-polyunsaturated fatty acids and enzymes from sheep seminal vesicles produce prostaglandins in gram quantities.

The extremely diverse biological effects of the prostaglandins attracted much interest, and it was found that different prostaglandins may have unique and very specific actions. For example, one prostaglandin, PGE_2, lowers blood pressure whereas another related one, $PGF_{2\alpha}$, raises blood pressure. In general, these properties are the result of the broad powers that prostaglandins have in regulation of smooth-muscle activity, in the regulation of secretion including endocrines, and in the regulation of blood flow. They give to the prostaglandins several potential applications in clinical medicine. For example, they have striking effects upon the female reproductive system. Very small quantities administered intravenously stimulate uterine contraction and can be used to assist in child-birth. Oral administration has also been found effective for the induction of labor. The effectiveness of prostaglandins in inducing menstruation and therapeutic abortion has been intensively investigated, and it also seems possible that they may be developed as medication for birth-control.

Such potential applications created a vastly increased demand for prostaglandins for research. Large-scale laboratory biosynthesis did not seem to offer the potential necessary to produce the large quantities needed, because the known natural sources – i.e., sheep-glands – were insufficient, and the method also lacked the capability of producing a wide range of prostaglandin varieties. Therefore, several research groups, notably E.F. Corey and colleagues at Harvard and a team of researchers at the Upjohn Company, directed their attention to the development of techniques for total chemical synthesis. This is a difficult procedure because synthesis of the extremely complex prostaglandin molecule requires about 16 distinct chemical operations.

In 1969, A.J. Weinheimer and R.L. Spraggins reported the discovery of prostaglandins in *Plexaura homomalla,* a species of gorgonian coral living on the reefs of southern Florida (1412). The dried coenenchyme of the coral yielded between 1 and 2 per cent of certain prostaglandin isomers. Although these prostaglandins were not identical with the mammalian varieties, they could be converted by relatively easy chemical procedures to the desired forms, and the amounts obtainable from the gorgonian were much greater than from the richest mammalian source known, human seminal plasma.

Then, Upjohn chemists working with a population of *Plexaura homomalla* in the Cayman Islands, discovered prostaglandins identical with the mammalian form, as well as a completely new natural prostaglandin isomer. These discoveries stimulated even more interest in *Plexaura homomalla* as a source of the raw material for manufacturing prostaglandins for practical purposes.

The possible use of natural stocks of *Plexaura homomalla* to produce commercial quantities of prostaglandins raised several practical questions about the biology, ecology, and standing crop of that gorgonian in the Caribbean area. Several pharmaceutical and biochemical interests, among them The Upjohn Company and the chemistry department at the University of Oklahoma, became involved with these questions and initiated a series of investigations which culminated in a symposium on the subject held at the University of Miami in 1972.

One problem was the matter of taxonomic recognition of *Plexaura homomalla,* which is the reason I became involved in the subject.

A second problem was the abundance and distribution of the species in Caribbean waters.

A third was the environmental effect of harvesting large quantities of *Plexaura* from the natural reef community.

A fourth was the feasibility of mariculture – actually farming *Plexaura homomalla.*

From the taxonomic standpoint, *Plexaura homomalla* is a perplexing species because of its phenotypic variability. I was not able to distinguish any definite morphological differences among the corals yielding different kinds of prostaglandins. I could not then, nor can I now, demonstrate any clear-cut and consistent differences even between the two named phenotypes of *Plexaura homomalla,* homomalla and kükenthali. *Plexaura nina* from the Caribbean also contains prostaglandins, but may be nothing more than a deep-reef phenotype of *Plexaura homomalla. Plexaura flexuosa,* the only other Caribbean species of the genus, does not contain prostaglandins, and there is good morphological justification for removing it from the genus *Plexaura.* Accordingly, *Plexaura* appears to be the only genus of octocorals that produces prostaglandins, and perhaps only a single species, *P. homomalla.*

Fortunately, *Plexaura homomalla* is a widespread species, occurring from Bermuda and southern Florida throughout the West Indies and Caribbean. It also is one of the commonest gorgonian species wherever it occurs. On the lagoonal reefs to the east of Elliott Key, Florida, it is the second most abundant octocoral. It amounts to 14 per cent of the total population and about 24 per cent of the gorgonian biomass (899). Populations found in the Cayman Islands by scientists of the Upjohn Company consisted of almost pure stands of *Plexaura homomalla*, but this situation probably is unusual. Estimates were made by several parties, probably more than I am aware of, of the extent of the natural population throughout the West Indies, and of the standing crop. Such estimates were closely guarded commercial secrets.

If *Plexaura homomalla* were to be used as a raw material for the commercial production of prostaglandins, a question of paramount importance would be the ecological impact of harvesting the natural populations. And, in view of the fact that most of the dense stands of gorgonians occur around Caribbean islands deriving much income from tourism, the visible effect of harvesting must also be considered. In a situation where the population consists mostly or solely of *Plexaura homomalla,* as at some locations in the Cayman Islands, complete harvesting obviously would have a profound effect, not only upon the gorgonian community but upon all of the other organisms that depend upon it for support, concealment and nutrition, and could conceivably alter the physical environment as well.

Consequently, experiments were conducted to determine the yield that could be obtained if the *Plexaura* colonies were only cropped, not harvested in toto, and to determine the rate of regeneration and the quality and quantity of the prostaglandins produced by the new growth. The results showed that the regrowth of colonies after harvesting was greater than the normal growth of undisturbed young colonies, and suggested that the population could be harvested without detectable damage to the ecosystem (510).

In population having smaller proportions of *Plexaura homomalla* to other gorgonians, problems of recognition would arise in connection with selective harvesting, and the impact of selective harvesting would be different than upon a nearly pure population of *Plexaura*. It was suggested that the environmental effects of harvesting would be lessened if each of several natural stands of *Plexaura* were harvested in succession, allowing each a recovery period for four or five years between harvests (509).

Experiments were initiated to determine the feasibility of culturing *Plexaura homomalla* as a commercial crop. These consisted of transplanting cuttings of various sizes, from both large and small donor colonies, to artificial attachments located adjacent to dense natural populations of *Plexaura*. The preliminary results showed that large cuttings from large donor colonies will survive, anchor themselves to the artificial substrate provided, and begin apical growth (1052). It was concluded that vegetative farming of *Plexaura homomalla* could be expected to succeed when techniques are developed that permit optimal attachment and growth of cuttings. In view of this, Dr. John Wickstead (509) suggested that techniques for 3-dimensional raft culture be devised in order to increase the utilization of available sea-bottom, but he warned that such a program would require a long time and probably could not be developed in less than a 10-year period.

Little is known about reproduction and population recruitment of *Plexaura homomalla*. Studies carried out in the Florida Keys by repeatedly removing the gorgonian population from a marked area of reef showed that the maximal recruitment of *Plexaura homomalla* after clearing the substrate was 0.56 colonies per square meter annually, compared to 0.16 to 0.23 colonies per square meter annually in a stable population (899).

Monthly sampling of tagged *Plexaura homomalla* colonies in Florida showed that male colonies have recognizable spermaries only in June, July and August (322). Maximal sperm production, judged by the presence of tailed sperm in the spermaries, occurs about the middle of July, and by early August most colonies have completely resorbed their spermaries (68). Although female colonies have ovaries with recognizable eggs every month in the year, it is evident that fertilization can take place only for the short period in mid-summer when males are producing sperms. The fact that ripe eggs but no cleavage stages or developing embryos were found in female colonies during and after the time of sperm production by the males suggest that *Plexaura homomalla* does not brood its eggs to the planula stage before releasing them, as is common among gorgonians, but releases the eggs into the water for external fertilization. It can be predicted then, that in Florida waters recruitment of new *Plexaura* colonies occurs during only a

short period in summer, unless colonies elsewhere are actively breeding when those in Florida are inactive and so provide a source of planulae from the plankton. As no comparable studies have been done in warmer parts of the Caribbean, the length of the breeding season of *Plexaura* in regions with less seasonal changes is not known.

As it is now becoming clear from experience in the Florida Keys and several West Indian localities that disturbance of the reef environment can have very deleterious effects, it is of the utmost importance that large-scale activities, such as commercial harvesting of a gorgonian species, be preceded by intensive studies to identify clearly all the conservational precautions that must be taken. It is to the credit of commercial interests involved with the exploitation of *Plexaura homomalla* that the need for such studies was recognized and that programs for conducting them were organized even though the commitment to developing practical means of total synthesis made the exploitation of *Plexaura* a stop-gap measure only. As I said at the beginning of this lecture, the story has a happy ending. Although the need for *Plexaura* as an interim source was anticipated in terms of years – perhaps five or ten – methods of total synthesis were developed much more quickly than expected, so quickly in fact, that commercial harvesting – at least by major manufacturers such as Upjohn – never began. *Plexaura homomalla* has won a reprieve from exploitation. Though it may remain as a source for smaller amounts of prostaglandins in cases where total synthesis is unfeasible, its utilization on a large commercial scale is now unnecessary, and we have obtained as a by-product some valuable information about gorgonian biology that we otherwise would not have.