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NOTA EDITORIAL

Es motivo de regocijo para la Revista Scientia presentar, por primera vez, la publicación de tres trabajos científicos basados en Ficología Aplicada elaborados por Gloria Batista de Vega y colaboradores, los cuales se convierten en un nuevo aporte y contribución al conocimiento de la comunidad científica y de la sociedad en general.

La Ficología es una disciplina de la botánica, y se encarga del estudio científico de las algas; las cuales han sido utilizadas por el hombre desde tiempos antiguos, teniendo usos industriales, alimenticios, agropecuarios, médico-farmacéuticos y cosmetológicos.

El primer trabajo de investigación se titula *"Cultivo de Algas Marinas de la División Rhodophyta cerca de la Entrada del Canal de Panamá y su Optimización en la Calidad de Carragena".* Este trabajo representa un aporte significativo para Panamá, ya que a través del primer establecimiento de granjas experimentales marinas para el cultivo de la Especie *Eucheuma cottonii*, conocida en la industria también como *Kappaphycus alvarezii*, en la provincia de Colón; se logró determinar la viabilidad de establecer cultivos de esta especie a nivel comercial, dado que esta Rhodophyta es una de las mayores productoras de carragenina a nivel mundial, utilizada industrialmente.

El segundo trabajo se titula *"Factibilidad Comercial en las Granjas de Algas Marinas de Gracilaria domingensis usando sistemas de plantación sin protección en la zona costera del Caribe Panameño". Gracilaria domingensis* ha sido utilizada tradicionalmente por las comunidades costeras del Caribe panameño de descendencia afroantillana y por los indios Kunas como medicina y alimento. Este estudio observa el comportamiento de las semillas sembradas sin ningún tipo de protección, determinándose, a través de éste, la existencia de muchos factores que afectan el crecimiento de la semilla.

El tercer estudio se titula *"Factibilidad Comercial en las Granjas de Algas Marinas de Gracilaria domingensis usando sistemas de plantación protegidos en la zona costera del Caribe Panameño".* A partir de este estudio científico se comprobó la existencia significativa de muchos depredadores herbívoros que impiden y afectan el crecimiento de la semilla, por lo que resulta fundamental buscar alternativas de sistemas de plantación protegidas que garanticen el cultivo de esta especie.

Gloria Batista de Vega

Estas investigaciones han permitido el desarrollo industrial de granjas marinas de *Eucheuma cottonni* en la provincia de Colón, que beneficia en gran medida a las comunidades más necesitadas de esta provincia.

Finalmente, se incluye un indice de autores y materias de la Revista Scientia de 1986 a 2001, elaborado por la Bibliotecóloga Paula Edilma Ortega, perteneciente al Centro de Información y Documentación Científica y Tecnológica de la Universidad de Panamá.

Gloria Batista de Vega

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1

CULTIVATION OF A COMMERCIAL RED ALGA NEAR THE CARIBBEAN ENTRANCE OF THE PANAMA CANAL AND OPTIMIZATION OF CARRAGEENAN QUALITY

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SUMMARY

In 1995 experimental seaweed farms with species utilized by the ethnic population were established on the Caribbean coast in an area around the District of Colon, at the North entrance of the Panama Canal. This area is one of the most monitored tropical coastal zones. Indeed data has been collected since the early 1900´s. In 2000, the Coastal Research Institute of GKSS, one of the fifteen national facilities that make up the Hermann von Helmholtz Society of German Research Centers (HGF), installed a high tech monitoring system to integrate environmental data at the site. The objective was to investigate sustainable utilization of renewable resources and its implications for marine and coastal zone management. Consequently, *Kappaphycus alvarezii (Eucheuma* sp*)* was established in 2002 by Gracilarias de

Panama Company for an experimental period of five years. The first phase of the experiment demonstrated that a seaweed farm could produce raw material for commercial export in addition to meeting the needs of local people and also providing a buffer zone and protection for the shoreline. We are currently monitoring carrageenan yield quality by observing the differences between seasons and between planting methods at three sites. For the year 2003, the average of DGR was 4.4%, the molecular weight of the extracted carrageenan was 1080304Da and the yield of dried weight was 43%. There was a significant influence of season and in all cases there was a high growth rate.

KEYWORDS

Seaweed farms, *Kappaphycus alvarezii,* ethnic groups, carrageenan, carrageenan yield quality, Daily Growth Rate (DGR).

INTRODUCTION

In the Republic of Panama at least two ethnic groups collect and consume seaweed: the Kuna Indians and the Afro-Antillean of West Indian decent (Batista & Connor, 1990). The first *Kappaphycus alvarezii* farm was established in the year 2000 on the coast surrounding the Caribbean region of the District of Colon, at the North entrance of the Panama Canal. The cultivation started with seedling branches brought by native people of the area. This project is part of a three phase project of an experimental seaweed farm on the Caribbean coast of Panama (Batista *et al.,* 2002).

Due to the proximity of the Panama Canal, strong development started with the constructions of new ports, shopping centers, oil tanks and container facilities which seemed to influence the Coastal Zone. The area has suffered several environmental impacts which prompted the establishment an alliance amongst the companies in the coastal zone to introduce programs of mitigation. Seaweed farms near the shoreline serve as a buffer zone showed in photo # 1 (Aerial Photography by Jim Myers, Senior, Environmental Engineer of ChevronTexaco).

The objective of the study was to investigate the optimization of the production of the seaweed as a commercial crop as well as the quality of the carrageenan obtained at the Colon seaweed site, Panama. This article presents an analysis of experimental data collected in 2003. A preliminary synthesis of some aspects of the cultivation study was presented as a Poster at the International Seaweed Symposium in Bergen, Norway (Batista *et al*., 2004).

EXPERIMENTAL PART

Description of the area

The seaweed farm project was organized in an area around the District of Colon, into 14 sea farms called “Polygons” by the Maritime Authority of Panama (AMP), (Figure 1). The experiments were conducted on three Polygons located at the North of Largo Remo Island. Polygon # 11 marked as a site 1; Polygon # 10 marked as a site 2 and Polygon # 12 as a site 3. The three sites were in a lagoon, opening to the sea and surrounded by mangroves (photo 2). All sites have basically the same bottom substratum which was sandy and covered in patches by small communities of turtle grass.

Historical data of the environmental parameters in the area by the Smithsonian Tropical Research Institute from 1982 to 1999 showed relatively stable values (Contreras & Rosenthal, 2003). The mean seawater surface temperature was 29° C. The seawater temperature remained between 25-31°C in water 30 cm deeper. Salinity averaged about 33 ‰ also with little variation (Cubit *et al.*, 1989).

Since October 18, 1999, the Coastal Research Institute, GKSS from Germany installed an oceanographic buoy at the outlet of Bahía Las Minas near the seaweed farm (Figure 1). The buoy gauges wave characteristics such as height, direction, period, and water temperature. Preliminary results of the data show that there is a relationship between lower tide levels and highest water temperature. Due to this, the hypothesis was established that low tide levels cause less water exchange into the lagoon. Therefore, temperature has a significant influence on this coastal region (Contreras & Rosenthal, 2003).

During the experiment, thirteen (13) environmental parameters were recorded directly at the sites of cultivation such as: water turbidity, pH, salinity, conductivity, speed and direction of the currents. Temperature: air, seawater surface, depth of 30 cm and other factors such as % of cloudiest, light intensity, depth of cultivation, speed and direction of the wind.

The annual pattern of the weather of this area is locally described as: a “dry season” (November to March), variable “little dry season” (March to May) and a wet season (May to July). The “little dry season” is similar to the dry season but sporadically interrupted by rain, between July and October. Turbidity of the seawater and wave action increased during the dry season.

At each of the 3 experimental sites two methods of cultivation were employed: method (a) and method (b) were designed by season through the year. This paper will show the first phase of the experiments.

Description of cultivation

Individual 100 g branches of cultivated *Kappaphycus alvarezii*, produced by Gracilarias de Panama S. A., were planted in the three selected sites described above at a depth of 1-2 m. Four (4) experiments were designed in order to evaluate the impact of season on the culture of the seaweed through the year. The experiments ran from November 14, 2002 to July 31, 2003 as follows:
Experiment I (November 14, 2002 to January 9, 2003), Experiment II (January 22 to March 17, 2003) in the dry season, Experiment III (March 18 to May 9, 2003) in little dry season and Experiment IV (May 20 to July 31, 2003) in wet season.

Two methods: method (a) and method (b) were employed to measure algal growth. In both methods a rectangular structure called a module was built by attaching 5 lines of 5 m length. A soda bottle was attached to each end of the module to provide flotation of the ropes. Each method contained a three (3) replicate modules.

In method (a) we planted 21 seed by line. The seed were spaced at 25 cm intervals and the lines were kept 40 cm apart. This gave a density of 0.84 kg/m². In method 2, 11 seed were spaced 50 cm apart and the lines kept 100 cm apart with a density of 0.44 kg/m². Harvest was carried out 50 to 70 days after planting.

Growth Measurements

Measurement was made in two ways: 1) One alga was taken at random from each site, method and replicate. This alga was marked and the fresh weight recorded. The alga was then attached again at the same point on the line. Every 10 or 15 days the same seedlings were re-weight until harvest after approximately 60 days. The environmental parameters were also registered by site and visit. 2) One seedling was collected and harvested at random every 10 or 15 days by site, method and replica. The alga was collected and fresh weigh determined. The alga was used for dry weight. Each sample was analysed in at the Cargill Laboratory in France were % yield and molecular weight of the carrageenan was determined.

Relative Daily Growth Rate (DGR)

The Relative Daily Growth Rate of *Kappaphycus alvarezii* was calculated using the formula: DGR = 100* ln (wf/wi)/time; where wi and wf are the initial and the final wet weights respectively, and time refers to the number of cultivation days. Analysis of variance was analysed separately for each experiment with site and methods as factors and DGR as the dependent variable using the statistical package Systat.

Quality of the carrageenan

A "native" carrageenan extraction (60°C, water, no alkali) was performed to evaluate the potential of the seaweed. Yield was calculated according to dry weight of seaweed material extracted. Molecular weight (Mw) was determined using Gas Phase Chromatography (GPC) (Lecacheux *et al*., 1985).

Environmental parameters

The environmental parameters were measured before the seedlings were sorted three times once every week in each replicate. The following parameters were measured: water visibility and depth were measured with a Lamotte Secchi Disc. Water pH, viscosity with a WTW pH 330/SET[1] pH meter. The salinity was measured with a WTW LF 330/SET meter. The air temperature was measured with a Springfield Thermometer (in the shade). Water surface temperature was measured with a pool thermometer attached to a float (the thermometer bulb lies just submerged). The seawater temperature at 30 cm was taken by thermometer tied below the pool thermometer. Wind speed (miles/hour) was measured using the Beaufort Wind Scale. Currents of the waves (meter/seconds) were recorded using fluorescent FLT Yellow/Green dyes tables. The light intensity (μmol S^1 m^2) in the seaweed cultivation areas were measured with a LICOR L1-1400 Data Logger and LICOR Under water sensor.

RESULTS AND DISCUSSIONS

The mean DGR for 2003 was to 5.4% per day. Growth was not consistent during all the year. If we focus on two different seasons (experiment I dry season and IV wet season), we can observe that the dry season had a lower productivity than the wet season (Figures 2). Figure 3 shows that the sites for experiment I (Nov. 14, 2002 to Jan. 9, 2003) presented for dry season growth rate effect. Example: method

(b) showed the highest growth rate in site 2. We observed a maximum DGR of 8.7% and a lower DGR for method (a).

In experiment IV during the wet season (May 23 to July 31, 2003), site 3 showed the effect of density in method (b). There was no difference in growth rates among sites, but there was difference between two methods of cultivation (Figure 4).

The figures showed that *Kappaphycus alvarezii* in Panama sustained a DGR of (4.4 to 8.7% per day). These growth values are similar also to those obtained from commercial farms on the sea farms for *K. alvarezii* and *K. striatum* in different subtropical regions (Edison *et al.,* 2002), and those from *K alvarezii* from Japan, Philippines and Indonesia (Ohno *et al.*, 1996).

An average carrageen yield of 43% of dry weight was obtained in 2003 (Figure 5) with the highest value being 47.7% of dry weight. This was obtained in experiment III, during the "little dry season" (March 18 to May 19). The lowest value (37.5% of dry weight) occurred in experiment I, during the dry season. Carrageenan molecular weight showed a large variation among experiments (Figure 6) with an average of 1080304Da for the experimental period.

The environmental parameters varied with season (Table 1). We found significant variations in growth for current, depth, irradiance, and salinity. The existence of a relationship between the environment and the growth of the seedlings was assessed by linear correlation (Table 2), between the selected environmental parameters and the daily growth rate (DGR). All the parameters were significantly correlated with the DGR (positively with depth and irradiance, negatively with the current and salinity). Primarily, this showed us that growth was linked to many environmental parameters, but each factor cannot entirely explain the recorded variations of the growth. The coefficient of determination (r^2) showed that the variations of DGR were 38.8% explained by the variations of salinity, 23.1% by current, 18.3% by irradiance and 6.5% by depth. Salinity seemed to be the most important parameter but it included many other physical components each of which had its own influence. In spite of the geographical proximity, the 3 sites were different (Table 3). Site 3 had a better production of seaweed (6.3% vs. 5.4% and 5.0% per day respectively). Environmental parameters such as pH, viscosity, air and water temperatures were excluded from the statistical analysis because they were stable in the three sites (Table 3).

CONCLUSIONS

This study demonstrated that the red alga, *Kappaphycus alvarezii,* used by the ethnic populations of Panama, can be cultivated in the Caribbean coastal waters where they are subject to relatively little disturbance. It could be cultivated all year round, with an average daily growth rate (DGR) of 4.4% per day. A seasonal pattern of DGR was evident (Figure 4). The maximum DGR of 8.7% per day occurred during the "Dry Season". This value compared favourably to those for other *Eucheuma* and *Kappaphycus* species in trial cultivation sites (Ohno *et al*., 1994, 1996; Gerund & Ohno, 1997).

In 2003 a global "identity card" of the product was given for *Kappaphycus alvarezii* of Panama. The yield of native carrageenan ranged from 37.5 - 47.7% of dry weight. These values are similar to those obtained in commercial production sites for *K. alvarezii* in the Philippines, Indonesia and Japan (Ohno *et al.,* 1996). Further analysis of long term data is required to confirm if seasonal patterns are evident in carrageenan yield and molecular weight for material cultivated in Panama.

The dry season has a strong wind effect and considerable variation in wave height which will be assessed in the following years of the experiments. The integration of the Coastal Research Institute, GKSS data from the buoy and the calibration of a numerical forecast model with high resolution at the seaweed farms areas will be conducted in the next phases.

The total Pacific and Caribbean coastal line of Panama is 2,988 km. Nevertheless, sustainable seaweed cultivation is a potential coastal activity. It is suggested that all projects involving the exploitation and or cultivation of seaweeds in Panama should be based on clear, well focused and consistent management plans. These must include an integrated coastal monitoring project for maintenance and protection of the marine ecosystem.

RESUMEN

CULTIVO DE ALGAS MARINAS DE LA DIVISIÓN RODHOPHYTA CERCA DE LA ENTRADA DEL CANAL DE PANAMA Y SU OPTIMIZACIÓN EN LA CALIDAD DE CARRAGENA

Especies de la división *Rhodophyta,* utilizadas por los grupos afro-antillanos y amerindios, fueron sembradas en cultivos experimentales de granjas marinas en 1995. El área ha sido la más monitoreada de las zonas tropicales que conocemos hasta el momento. La Autoridad del Canal de Panamá e instituciones científicas internacionales, como el Instituto Smithsonian de Investigaciones Tropicales (Smithsonian Tropical Research Institute), han venido monitoreando esta área desde principios del siglo XX. En 2000, el Instituto de Investigaciones Costeras de Alemania (GKSS), instituto que pertenece a la Sociedad Hermann Von Helmholtz de los Centros Científicos Alemanes (HGF), instaló un sistema de monitoreo ambiental de alta tecnología que integra los datos dentro de los modelos que permiten observar escenarios pasados y futuros de la zona costera. En 2002, Gracilarias de Panamá; S.A., realizó estudios experimentales con *Eucheuma cottoni* para verificar el potencial de cultivo y la utilización sostenible en las implicaciones del manejo de las zonas costeras. Los resultados, en 2004, demostraron que el cultivo produjo suficiente materia para exportación y además llenó las expectativas de los habitantes locales de bajos recursos. Con las granjas se crearon zonas amortiguadoras que protegen los ecosistemas en la línea costera del Distrito de Colón. En este momento estamos experimentando sitios seleccionados y diferentes períodos de crecimiento de la especie para determinar la calidad de carragenina. En particular, se han encontrado relaciones interesantes entre crecimiento y peso molecular de la producción de carragenina. Para el año 2003, el promedio de la rata de crecimiento (DGR) fue de 5.4 %. El peso molecular del extracto de carragenina fue 1080304Da y la producción del peso seco fue de 43%. Se vio una gran influencia en las estaciones. En todas las estaciones se presentó un alto porcentaje de crecimiento.

PALABRAS CLAVES

Cultivos experimentales de granjas marinas, *Kappaphycus alvarezii, Eucheuma cottoni*, carragenina, extracto de carragenina, rata de crecimiento (DGR).

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This report is dedicated to my advisor professor Dr. Arnold Schultz, Emeritus Professor of the University of California at Berkeley, who gave me the courage to include all the necessary elements in order to preserve the coastal ecosystem in a Seaweed Mariculture System and who continually expands my understanding of Ecosystem studies in order provide a micro and macro vision to conservation of the Coastal Zone for the benefits of all living creatures. Also Dr. John West, Professor of Botany, Emeritus, University of California, Berkeley, 1994 to present. Dr. West is also Professorial Fellow, School of Botany, University of Melbourne, 1994 to present. Dr. West has enriched my experience in the difficult process to go into a great diversity of elements of applied phycology by his perceptive scientific eyes for which I am deeply grateful. Knowing him has been a gift.

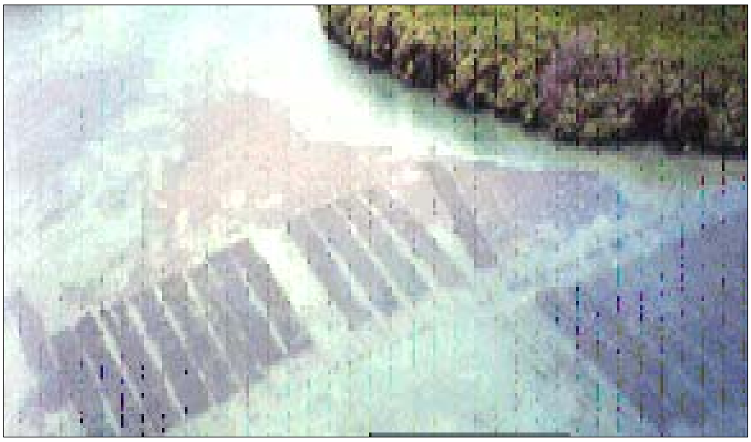
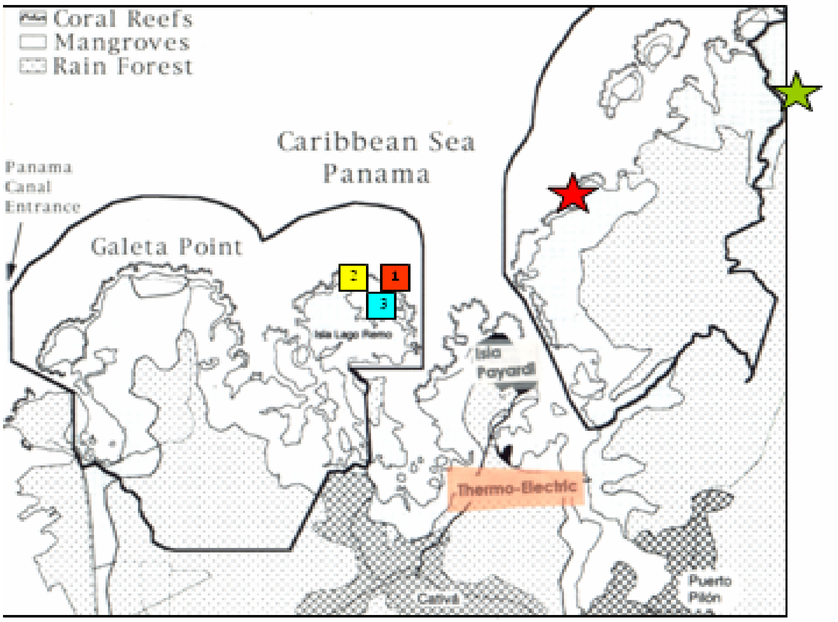


Photo 1:
Seaweed farms near the shoreline serve as a buffer zone (Aerial Photography by Jim Myers, Senior Environmental Engineer Chevron-Texaco)

Photo 2:

Site 3-Farm 12 on Largo Remo Shoreline behind site 1 and site 2

Figure 1:



Gracilarias de Panama S.A., an experimental seaweed farms areas Province of Colón, Republic of Panama.

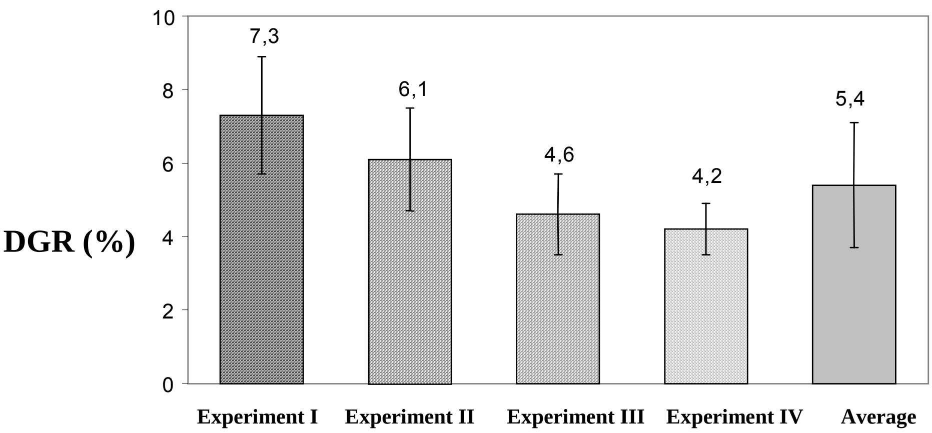
Oceanographic Buoy

Site 1 2 **Site 2** 3 **Site 3**

1 **Seaweed farms ecosystems**

Border S

Figure 2:



Representation of the growth during one year

Figure 3:

Experiment I –
Effect of density between methods (a, b), duration of cultivation and site on DGR.

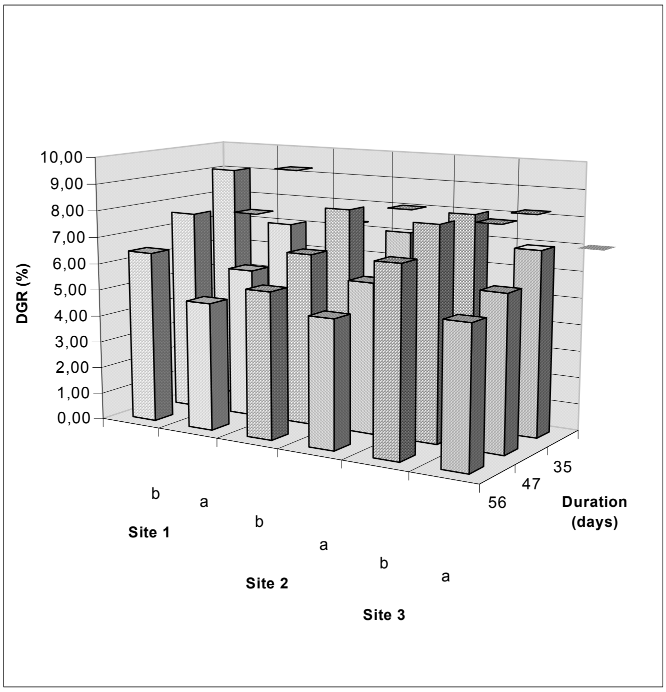
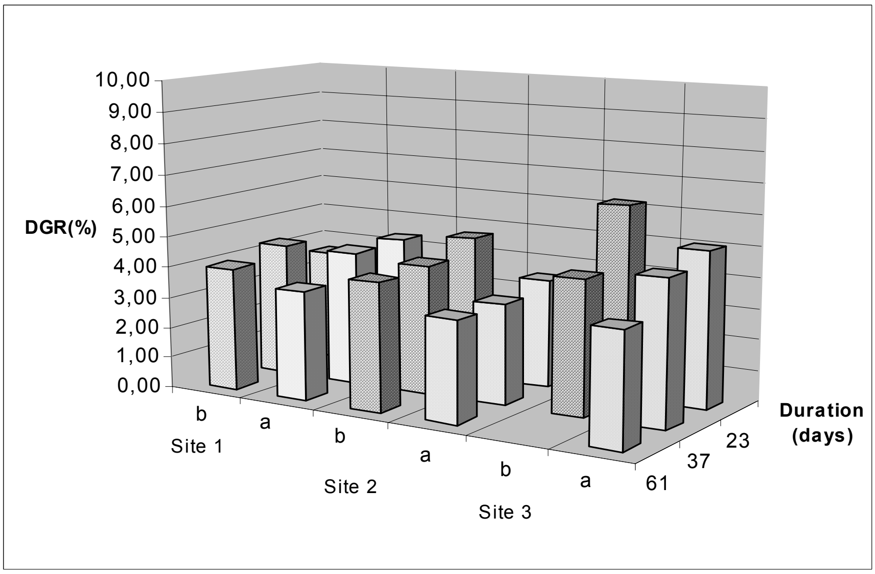


Figure 4:



Experiment IV, Site 3. Effect of density in methods (a, b), duration of cultivation and site on DGR. No difference in growth rate amongst sites, but there were difference between the two methods.

Figure 5:

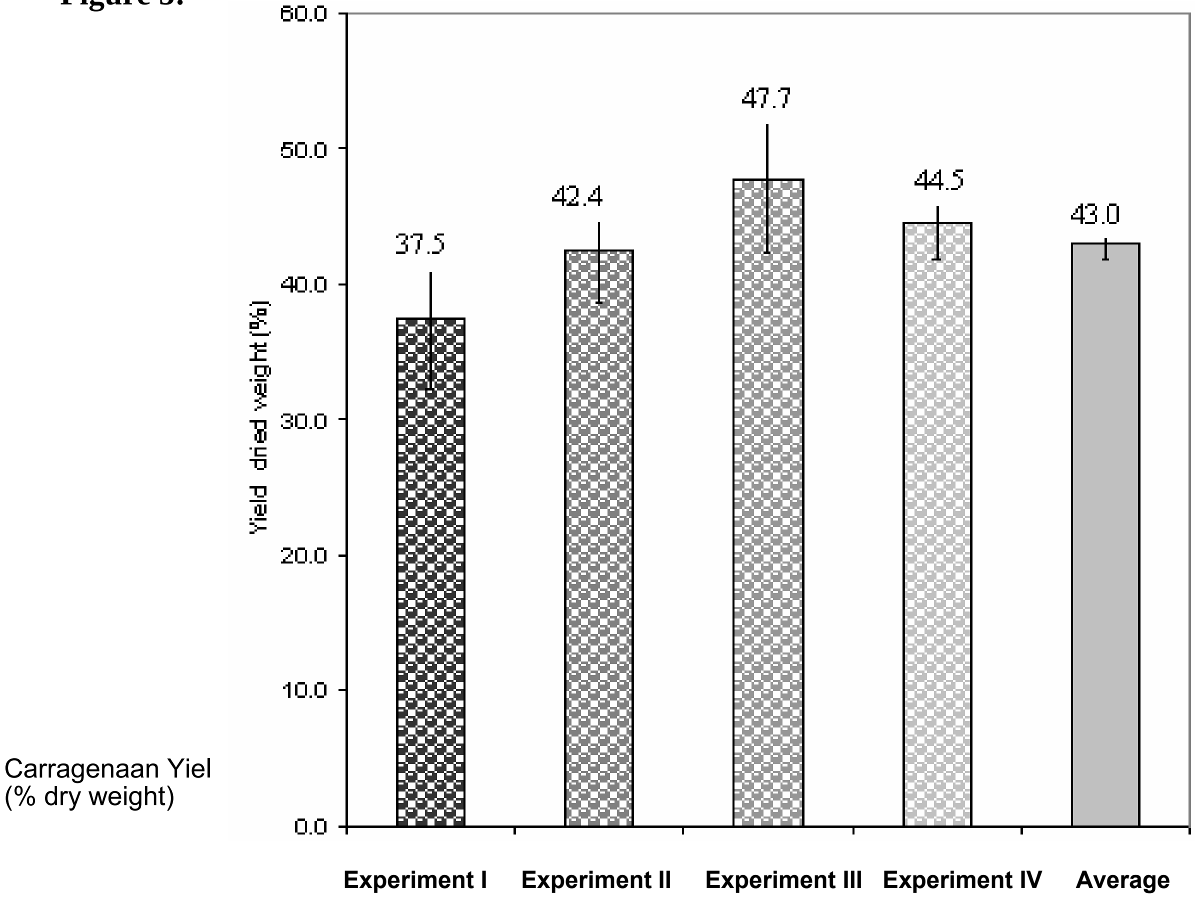
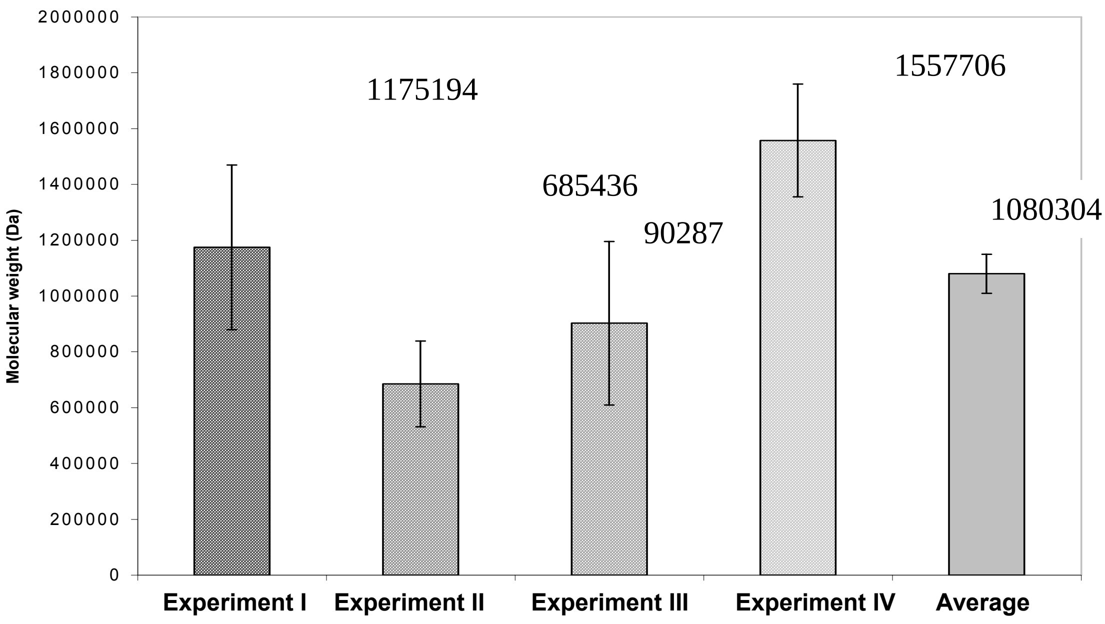


Figure 6:



Representation of the molecular weight of the extracted carrageenan during one year

Table 1:
Average

Season	Experiment	Current (cm/s)	Irradiance (µmol/s/m²)	Depth (cm)	Salinity (‰)
Dry	1	8,7 [a]	701 [a]	133 [a]	32,4 [a]
	2	13,2 [b]	798 [a]	107 [b]	32,9 [a]
Moist	3	17,8 [c]	479 [b]	110 [b]	34,9 [b]
	4	13,6 [b]	542 [b]	96 [c]	35,6 [b]

Average during the 4 periods (risk α=1%)
The same letter (a, b or c) in two cells of one column indicated that values are not significantly.

Table 2:
Average

Sites	Current (cm/s)	Irradiance (µmol/s/m²)	Depth (cm)	Salinity ‰	DGR
1	14,8	568	126	33,9	5,4
2	16,2	642	114	34,2	5,0
3	8,9 *	680	95 *	33,7	6,3*

Parameters and growth from the cultivation sites
*values which are significantly different of the others in a same column (α=1%)

Table 3:
Average

SITES	Temperature ºC air	Temperature Sea-surf	Temperature 30 cm	pH	Salinity %
1	29.9	ºC air	ºC air	8.1	33.9
2	29.9	30.1	29	8.1	34.1
3	29.8	29.8	28.8	8.1	33.7

Environmental parameters that were significantly stable in the sites

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A COMMERCIAL FEASIBILITY OF *Gracilaria domngensis* FARMING USING UNPROTECTED PLANTING SYSTEMS ON THE CARIBBEAN COASTAL ZONE, PANAMA

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SUMMARY

Since 1979, due to the Carter-Torrijos Treaty, serious conservations programs to protect a unique mangrove forest and coral reef ecosystems located at the Caribbean entrance of the Panama Canal have been established by Gracilarias de Panamá, S.A., an Acelerador Tecnológico, Part of the City of Knowledge. A diverse seaweed farms technique has been installed on the surrounding coastal zone of the Caribbean area of the District Colon. This seaweed farms serve as a buffer zone between the coastline and the land. This paper shows a commercial feasibility of an unprotected seaweeds farms of *Gracilaria domingensis* used as a food and cultural reason by Kuna Indians and Afroantillans communities on the Caribbean coast of the Republic of Panama. The unprotected seaweed farms systems were established in collaboration of the University of California, Berkeley with the main objective to mitigate the impact into a pristine coastal area that has a great demand to develop and at the same time to solve the primary needs of local fishermen of this area using unprotected seaweeds farms systems that reduce the cost of the installation of

the farms. The results of the experiment showed that *Gracilaria spp.* can be cultivated mainly in sand plain habitats on the Caribbean coast of the district of Colon; Panama. But many factors affected growth of *Gracilaria spp.* besides unprotected planting system. For example, habitats may have a relatively unique level of production.

KEYWORDS: *Gracilaria* crops, *Gracilaria* farms techniques, unprotected seaweed farms techniques, agar-agar.

INTRODUCTION

In the Caribbean side of Panama species of commercial red macro algae of the gender *Gracilaria* are currently recognized (Hay and Morris 1984), (Batista & Connor, 1986), (Batista, 1992). In this coastal zone there are a great demand for urban and commercial development due to the proximity of the Panama Canal and high rates of unemployment. Unmanaged commercial development will destroy the natural barrier that mangroves and coral reefs naturally work to protect the shoreline.

A mariculture project on the Caribbean side of the Republic of Panama can be implemented in the area with species of *Gracilaria* that the local people use for food. The main reason of this project is to improve the economic opportunities for local communities through controlloded multiple use of this coastal zone and consequently will prevent the over-exploitation of the existing habitats along the shoreline.

Species of *Gracilaria* Grenville are an important agaraphyte resource in the world. Chile is the largest supplier of *Gracilaria*, although the harvest of wild seaweed has fluctuated over the last 5 years, from 121,000 wet tonnes in 1996 down to 73,000 tonnes in 1998, and back up to 137,000 wet tonnes in 2000. Cultivation has yielded about 33,000 wet tonnes for the last two years for which figures are available (1999 and 2000). China, Indonesia, Namibia and Viet Nam all supply between 12,000 and 18,000 wet tonnes each, in most cases from a mixture of wild and cultivated material. In Argentina, between 1985 and 1995, the harvest of dried *Gracilaria* varied from 1,700 to 3,100 tonnes. In India, harvests of wild *Gracilaria* and *Gelidiella* on the Tamil Nadu coast have varied between 750 and 1,300 dry tonnes from 1996 to 1999 (McHugh, 2003).

Gracilaria is sold to agar producers and some is used as food. For food consumption, the seaweed is usually gathered and sold fresh, locally in Panama (Batista & Connor, 1990). It is most common in South-East Asian countries such as Indonesia, Malaysia, the Philippines and southern Thailand, mainly in coastal communities. It is also popular with most ethnic groups on the Caribbean (Smith, 1997). In Hawaii is sold fresh in Honolulu markets as *limu manauea* or *limu ogo* (McHugh, 2003).

The objectives of this study were to establish a commercial seaweed farms of *Gracilaria domingensis* using unprotected planting methods in order to mitigate the impact of the activity on the coastal zone and to determine the feasibility of *Gracilaria* farming. The Mariculture Project will be integrated with the management and conservation program of a Caribbean Regional management plan.

EXPERIMENTAL PART

To describe the methods, I will first explain the procedures I used to select the best local species of *Gracilaria* for mariculture, as well as habitat characteristics relevant to *Gracilaria* farming. Then, I will discuss sample size for minimum differences to biological significance to set the experimental design. Finally, I will explain some management and farming unprotected practices to cultivate algae.

Culture and Taxonomic studies

We collected *Gracilaria* species currently harvested by local people as well as other species of *Gracilaria* with a bushy growth form since these have the greatest potential growth and economic value in mariculture.

Six species of *Gracilaria* Greville (*Gracilariaceae, Rhodophyta*) of the province of Colon, Panama, have been studied by Hay and Norris (1984). These species are: *G. cuneata* Aresh*., G. cilyndrica* Borg*., G. domingensis, G. sp* # 1, *G sp* #2 and *G. sp* #3. Since a number of the species have not been formally identified and the taxonomic interpretation of the genus is currently under revision.

The *Gracilaria* species were classified by habitats using previously published information and data from the Rapid Rural Appraisal and maps made from the aerial photographs, 134 aerial photographs (scale 1:12,000) provied by Norman Duke, scientist of the Smithsonian Tropical Research Institute in Panama. Also we used available image data taken by Landsat 4 satellite (Batista, 1992).

Farming and Wild Crop Management

After determining feasible sites for farms with the fishing families, I adopted with the help of Dr. Wayne Sousa (Associated Prof. of the Dept. Integrative Bio., U.C. Berkeley) and Ms. Carol Langhauser (Lecture Emeritus, Public Health Service U.C. Berkeley) an experimental design to determine the best conditions for *Gracilaria* mariculture. I measured growth, survival, and biomass production under a variety of environmental conditions. Manipulated factors included: 1) unprotected planting systems, 2) frequency of harvesting, 3) water depth, 4) temperature and salinity.

1) Unprotected Planting Systems

Planting methods on algal growth were examined in various combinations without protecting the seeds as described below. The selected *Gracilaria* species were experimentally planted in three ways, which I will refer to as stake planting, rock planting, and fork planting. The three methods were arranged in lines in an area of 28 sq m (4 m wide x 7 m long) as shown in figure 1, map 1.

Stake planting was conducted using two 50 cm long polyvinyl chloride (PVC) ½" tubes. One strand of monofilament fishing line was strung between PVC tubes. On each strand five plants were attached 25 cm apart. Each plant was 10 cm long at the time of planting. There were a total of 15 plants per 5 lbs. fishing line. Three sets of tubes with attached lines were placed in parallel rows with a distance of 50 cm between PVC tubes of adjacent lines (Figure 2). Lines were positioned so that the strands ran parallel to the current.

Rock planting consisted of an array of algal thalli tied to pieces of coral (approximately 10 cm size and 12 grams) and placed on the bottom. The coral was arranged so that the algae were spaced in the same manner as on the stakes (Figure 3). In fork planting the algae were arranged in arrays of the same dimension as in the rock planting, however the algae were planted in mud flat and sand-plain habitats in a 0.5 m. and 1.0 m. depth using a fork of 35 cm large (Figure 4).

In order to determine the initial biomass of the planted *Gracilaria* seed, I selected 30 seeds at random from the pool of plant to be used in the experiment. The average length of each seed was 10 cm. I then took each seed dry with paper towels and determined its wet (damp) weight. The seed were dried in a drying oven at a temperature of 50-60º C for 24-48 hours until a constant dry weight was obtained.

- **Unprotected Planting Experiment Affected by Algae Growth**

To determine how methods of planting affected algal growth, I installed the three unprotected planting methods described before at depths of 0.5 m and 1.0m (Map 1). As described above, in method 1, the algae were tied to fishing line strung between two stakes. In method 2, the algae were tied to coral rocks which were positioned in a rectangular array on the bottom. Finally, in method 3, we planted the algae in the substratum with the help of a 35 cm fork. Each replicate consisted of three lines, each with 5 algae attached. Fishing lines with attached algae and stakes were arranged in rows with a distance of 50 cm between rows. The total area covered by each replicated was 1 square meter. Each treatment was replicate five times at each of nine sites. The replicate treatments were planted in uniform areas of 4 m wide by 7 m long by site and habitat (maps B, C, D, E) as shown in figure 1.

The experimental treatments were set up within areas where the seagrass cover or mud flat conditions were relatively uniform. The treatments and replicates were assigned randomly to available spatial positions and separated by at least 5 m of unmanipulated habitat. The experiment was conducted with the help of the fishing families of La Playita, city of Colon; Republic of Panama.

2) Frequency of Harvesting

To determine the effect of the interval between successive harvests on yield, I decided randomly (by coins toss) for each alga in every planting method whether the plant should be harvested once (after twelve weeks), or twice (after six weeks and twelve weeks). Fronds harvested at six weeks were removed with a knife so as to leave approximately 1-2 cm of plants for regrowth. All algae were harvested at 12 weeks.

3) Water Depth

Finally, to determine how depth influenced algal growth, unprotected plantings were installed at a depth of 0.5 m. and 1.0 m. As described above, the algae were planted in three methods: stake, rock and fork. Each treatment was replicated five times in each habitat and site.

4) Temperature and Salinity

Seawater temperatures were recorded with a Hydrolab manual thermometer. The thermometer was submerged about 15 cm below the water surface. Temperature readings were taken once a week in each site. Seawaters samples for salinity measurements were taken 15 cm below the water surface once a week for each location. Salinity was measured with a temperature-compensated, hand-held refractometer (model number 10419, American Optical Co.; Buffalo, New York).

RESULTS

Gracilaria domingensis was the specie of seamoss we identified as a having the greatest mariculture potential abundant along the Caribbean coast of Panama. The average temperature range at the sites where the planted algae survived was between 30.0 – 32.6 ºC and the salinity range was 22.9 – 27.6 parts per thousand (Fig. 5, 6, 7, 8, 9).

Algae planted in four sandplain habitats and one mudflat survived. Location 3 at the Refinery (Chaboal, behind Villa Londra) was the only mudflat site in which the algae survived. Hay (1981) observed that *Gracilaria* species were found in sandplains and attached to hard substratum in the Galeta Point area. Galeta point is located in the area of study. However, we also found some species of *Gracilaria* growing on cloth and sacking in the area. Mudflat habitats occur in locations protected from waves and in areas below the sea levels. It is also protected by slow currents (Santelices and Doty, 1989).

The unprotected planting method experiments were observed for 12 weeks. It was possible to do three types of statistical analyses bases on the number of replicates that survived. The first analyzed was a 3-way ANOVA for locations 4 and 8 (Map D). The three variables analyzed were location, depth and planting method. Locations included location 4 at Samba Bonita and location 8 at the

Texaco Refinery at the entrance La Playita in Bahía Las Minas. Depths included 0.5 m. and 1.0 m. plantings. Methods consisted of the stake, rock and fork plantings discussed earlier.

The second analysis was a two-way ANOVA for method 1, the stake planting method. The two factors analyzed were location and depth. Locations included location 2 (Map B) at Margarita Island, location 4 at Samba Bonita and location 8 at Texaco Refinery at the entrance to La Playita. Depths included 0.5 m. and 1.0 m. plantings.

The last statistical analysis was a one-way ANOVA (t-test) for location 3 at Chabola (Villa Londra) in front of Pier South at the Texaco Refinery (Map E).

The effect of depth for method 1 (stake planting) was analyzed. Depth included 0.5 m. and 1.0 m. plantings. Homogeneity of variances was evaluated with Cochran´s test. For the first and second statistical analyzed (the three-way ANOVA´s), variances of log of untransformed data were homogeneous. For the third analysis the (the one-way ANOVA) variances of untransformed and log transformed data were homogeneous.

The statistical data analyzed showed that in location 4 at Samba Bonita and location 8 at the Texaco Refinery there were statistically significant Two-Way interactions between location and depth ($P>.001$) and location and method ($P<.01$, Table 1). There was interaction between location and depth (Fig. 10). The production of the algae did not vary with depth at Location 8 $P=0.133$ but declined with depth at Location 4 $P= 0.943$.

We also observe interactions between method and location (Fig. 11). The production of *Gracilaria* showed a minimum production in location 4, method 1 (stake planting), $P= 0.000$ while method 2 (rock planting) and method 3 (for planting) showed much higher productivities. Location 8 showed very little difference in productivity for the different methods.

Interaction may have occurred because of habitat differences in the two locations although both had sand plain substratum. The flora and fauna present in the two localities were very different. In location 4 at Samba Bonita, the plantings were made about 2 m. from shore. The flora in the approximately 55 sq meters of plantings consists largely of *Laurencia papillosa, Hypnea musciformis* and *Acanthophora specifera*. There were also small numbers of

Gracilaria spp. in the area around the experimental farms. A large *Gracilaria* population was also present about 100 m. from the experimental farms. Near the plantings there was a drainage outlet carrying the effluent of a municipal slaughtershouse. Perhaps the nutrient levels near the shore were much higher than they were in deeper waters farther from shore. The fauna at 0.5 m. depth consisted of many different species of crabs and small mollusks, but no large fish were evident. The PVC tubes in the method 1 plantings were invaded by barnacles. These barnacles also attached to algae that were tied to the fishing line, impeding their growth and even killing some completely. No algal epiphytes were on the experimental algae at either location 4 or location 8.

In location 8, we planted *Gracilaria* around a seagrass bed of *Syringodium sp*. About 50 m. from shore. I select this site because the soil near the shore was completely devoid of flora and it was difficult to see any sign of life in the area. Perhaps the production of *Gracilaria* was constant at location 8 because not many herbivores lived there. However, although there was not much fauna in location 8, at 25 m. beyond the plantings there was a coralline zone from which some herbivorous fish could easily reach the alga plantings. All the algae that survived in location 8 were healthy, but some showed evidence of grazing.

Because there is no interaction between location, depth, and method also there is no interaction between depth and method, the Turkey HSD multiple comparison test was used to determine the best planting method were used (Table 2a and 2b).

The Turkey test showed that in location 4 Samba Bonita, stake planting (method 1) was more productive than rock planting (method 2) or fork planting (method 3). There was no significant difference in productivity between methods 2 and 3 in location 4. In location 8, there was no significant difference in productivity for any of the planting methods.

For Method 1 the effect of location (2 and 8) and depth of planting (Table 3) interacted with the effect or depth of planting (Figure 12). Interaction may have occurred because although the three localities had the same type of sandplain substratum, the habitats and the environmental conditions (such as industries near the habitats) and other factors were different during the course of the experiment. For example, location 2 at Margarita Island is well protected natural reserve conservation area as part of the Panama Canal. However, since 1990, some industries and ports have begun to add sedimentation of this coast line. Heavy sediments into the seawater from these activities will affect future seamoss farms.

In addition the algae in the 1.0 m. were planted far from the breakwater and far from the breakwater and far from the coral reef. The interaction of sandplain algae with reef-associated grazers is fundamentally different because assemblage of plants is excluded by herbivores from the habitats to which it is best suited physiologically and is confined to a physically marginal refuge where grazing is much reduced (Hay 1981).

At location 2, planting were done 2 m. from the coast. Location 2 was partially protected by a breakwater 5 m to the east of the algal plantings. Attached to the walls of the breakwater were different types of algae, among which the fishermen collect *Gracilaria crassisima* at a depth of more than 2 m. However, for planting method 1 (stake planting) there were big differences between locations 4 and 8.

The analysis showed differences in productivity of *Gracilaria spp.* with respect to depth. The alga had greater productivity at 0.5 m. than at 1.0 m. Predation was less in location 8, and perhaps because of this location 8 was more productive than location 4. Because depth interaction occurred (Figure 5), Turkey HSD test was used to compare depths separately. For example depth (1) 0.5 m. was compared with location 2 at Isla Margarita, location 4 at Samba Bonita and location 8 at La Playita in Texaco Refinery and Depth (2) 1.0 m. was compared with the same locations (Table 4).

At a depth of 0.5 m. the Turkey HSD test showed no difference between location 2 and location 8, but location 4 was different from location 2 and location 8 was different from location 8. In depth 2 locations were different from each other (Table 4).

Mudflat plantings were not very successful. Plantings at location 3 at Chabola in front of the southern pier at the Texaco refinery were the only ones which survived. Location 2 at Margarita Lagoon was near the road where sport and professional fishermen damaged the plantings. Location 5 at the Flame at the Texaco refinery was destroyed by a small accidental oil spill 3 weeks during the experiment. Method 1 at location 3 was the only successful planting method. In my observations in these three locations, some of the *Gracilaria* became buried deep in the substratum. I never saw many of these plants again. Mudflat habitats were very sticky in all of the three locations. The few algae I could count in method 2 and method 3 were small. I could see that the number of tips had doubled, but there was little new growth at four weeks in location 5. Algae did not show evidence of damage by fish or urchin grazing. The data in location 3 for the stake plantings (method 1) were analyzed using a one-way analysis of variance for depths of 0.5 m. and 1.0 m. (Table 5). The results showed that there were differences of production for the two depths in method 1 (P=0.04). The algae were more productive at a depth of 0.5 m. than at a depth of 1.0 m. This difference was significant (t=2.522 P<0.045). Even though *Gracilaria* species have been characterized by Taylor (1960) as deep water forms, Mark Hay (1981) showed with an experimental plantation of *Gracilaria spp* and another 76 sandplain algae such as *Soliera tenera, Spyridia aculeate, Chondria baileyana* that there was rapid growth and no indication of photo inhibition at more shallover depths.

The percent of survival of *Gracilaria* plants was also examined. Method 1 showed a higher percent survival in general but there was a four-way interaction between location, method, depth and survival as shown in the multiway contingency table test (Table 6). The G test was statistically significant 91.04 with 4 degrees of freedom P<0.001.

CONCLUSION

In many developing countries there is a strong need for careful economic development through primary industries (eg. agriculture and fisheries) without degrading the natural resources. There are increased worldwide interests in mariculture of seaweed, which is not only a commercial vision but it is also a way to contribute to solve the eutrophication problem (Cuono *et al.*, 1997). A sustainable polyculture system was designed for producing *Gracilaria* and marine fish on the Island of Molokai (Nelson, 2003).

Gracilaria spp. can be cultivated for many purposes in addition to meeting the needs of local fishermen and conserving the mangroves on the Caribbean sides of the Panama coast line. For example, *Gracilaria* can be cultivated for its ability to remove nutrients from waste water and then harvested for its agar content (Ryther *et al.,* 1979). It may also be harvested for both the production of agar and methane (Hanisak, 1987). Agar is mainly used in the food industry as a solidifying, gelatinizing and emulsifying agent; through it also has important applications in many other industries.

Many factors, besides the different treatments experimentally applied, affected the growth on the *Gracilaria* unprotected planting systems. Three-way interaction was found between location, method and depth. Four-way interaction was also found between location, depth method and survival of algae. Because of this, the production of *Gracilaria* will be very difficult to predict. Each location may have a relatively unique level of production.

There are also many factors in unprotected systems of cultivation intrinsic to gender of *Gracilaria* which affects its growth and productivity. Different *Gracilaria* species growth wild in a wide variety of habitats and it is not always possible to culture them in the areas where they are usually found (FAO 1988). *Gracilaria* often forms monogeneric stands where few, if any, other large algal genera will survive (Sanctelices and Doty, 1989).

The areas around the Texaco refinery showed lower grazing and more stable production. These areas could be repopulated with invertebrates such as those that grow on the *Gracilaria* plants. In addition, with the introduction of other commercially-important invertebrates, such as oysters and clams, polycultures could be established in the *Gracilaria* farms.

Runoff from land after periods of heavy rainfall may have some effect on sea farms planted near the shoreline. Runoff from land carries plants nutrients such as nitrates, which may improve the growth of the *Gracilaria*. However, runoff also carries large amounts of mud and silt, which could have a negative effect on the production of algae. Conservation of mangroves in the province of Colon could prevent large amounts of mud and silt from being washed into sea.

Physical factors such as temperature, salinity and light may not be economically feasible to control. However, research to determine the growth response of algae under different physical conditions is important in understanding seasonal patterns of yield and in selecting potential cultivation sites. In Brazil one year of study with 60 species of macroalga showed that *Gracilaria* spp. produced the highest biomass. The study also found a positive correlation with a decrease in salinity and water (Silva *et al.,* 1987).

The people of the district of Colon; Panama preferred to work near the coast and work close to their families. They preferred not to dry the algae in places far from the area of collection (Batista, 1992). Industries which wash and dry algae should be established near the collection sites. Colon has an economic free zone where both the processing and exportation of algae could occur.

It is important to prevent overexploitation of the specie with culture systems of lower impact such as the unprotected systems I used for these experiments. There are large beds of wild Gracilaria in Chile, and it was the fear of depletion of these beds by over harvesting that led to the development of cultivation. Wild *Gracilaria* is also harvested in Argentina and Brazil, although the quantity is decreasing in Brazil because the quality does not compare well with the Chilean product (McHugh, 2003).

The Panamanian government should set strong legal policies to protect the seamoss farms and the harvest from these farms. The government and local financial institutions should provide continuing and ongoing moral and financial support to the seamoss farmers.

An official program to establish seamoss farms should be contained in the management plan the identification of a reserve area that bring economy alternatives to the local communities. This could guarantee the future of the algae farms and will also give credibility to the fishermen in the region. The fishermen of the district of Colon working within the management plan will become an example for all the Caribbean region on: how to use creatively local resources for the good of the local people, the country and the entire geographic region.

RESUMEN

FACTIBILIDAD COMERCIAL EN LAS GRANJAS DE ALGAS MARINAS DE *Gracilaria domingensis* USANDO SISTEMAS DE PLANTACIÓN SIN PROTECCIÓN EN LA ZONA COSTERA DEL CARIBE PANAMEÑO

Desde 1979, debido a los Tratados Torrijos-Carter, serios programas de conservación se han ido estableciendo para proteger un ecosistema único compuesto de bosques de manglares y arrecifes de coral, localizados en el centro del Caribe panameño, cerca de la entrada del Canal de Panamá. Gracilarias de Panamá, S.A., Acelerador Tecnológico, que forma parte de la Ciudad del Saber, ha instalado diversos sistemas de granjas de algas marinas en los alrededores de la zona costera del distrito de Colón. Las granjas marinas sirven como zona amortiguadora entre la línea costera y la tierra. Esta publicación presenta los resultados

de un diseño experimental de granjas marinas donde utilizamos sistemas sin protección de las semillas plantadas. La especie que elegimos fue *Gracilaria domingensis* tradicionalmente usada como alimento y como afrodisíaco por los habitantes de origen afroantillano y como medicina por los amerindios Kunas. Las granjas experimentales fueron diseñadas en colaboración con la Universidad de California en Berkeley con el objetivo de mitigar los impactos en una zona costera que es natural y que tiene una gran demanda para ser desarrollada y al mismo tiempo ayudar a resolver las necesidades de la comunidad desempleada del área del distrito de Colón usando sistemas de cultivo de bajo costo. El resultado del experimento mostró que *Gracilaria* puede ser cultivada en estos sistemas, principalmente en hábitats de arena. Los resultados mostraron que muchos factores pueden afectar el crecimiento del alga en adición a los sistemas diseñados para la siembra, como por ejemplo: en el estudio observamos que cada hábitat tiene un nivel único de producción.

PALABRAS CLAVES: Semillas de *Gracilaria*, técnicas de granjas marinas de algas, técnicas sin protección de granjas de algas marinas. Agar-agar.

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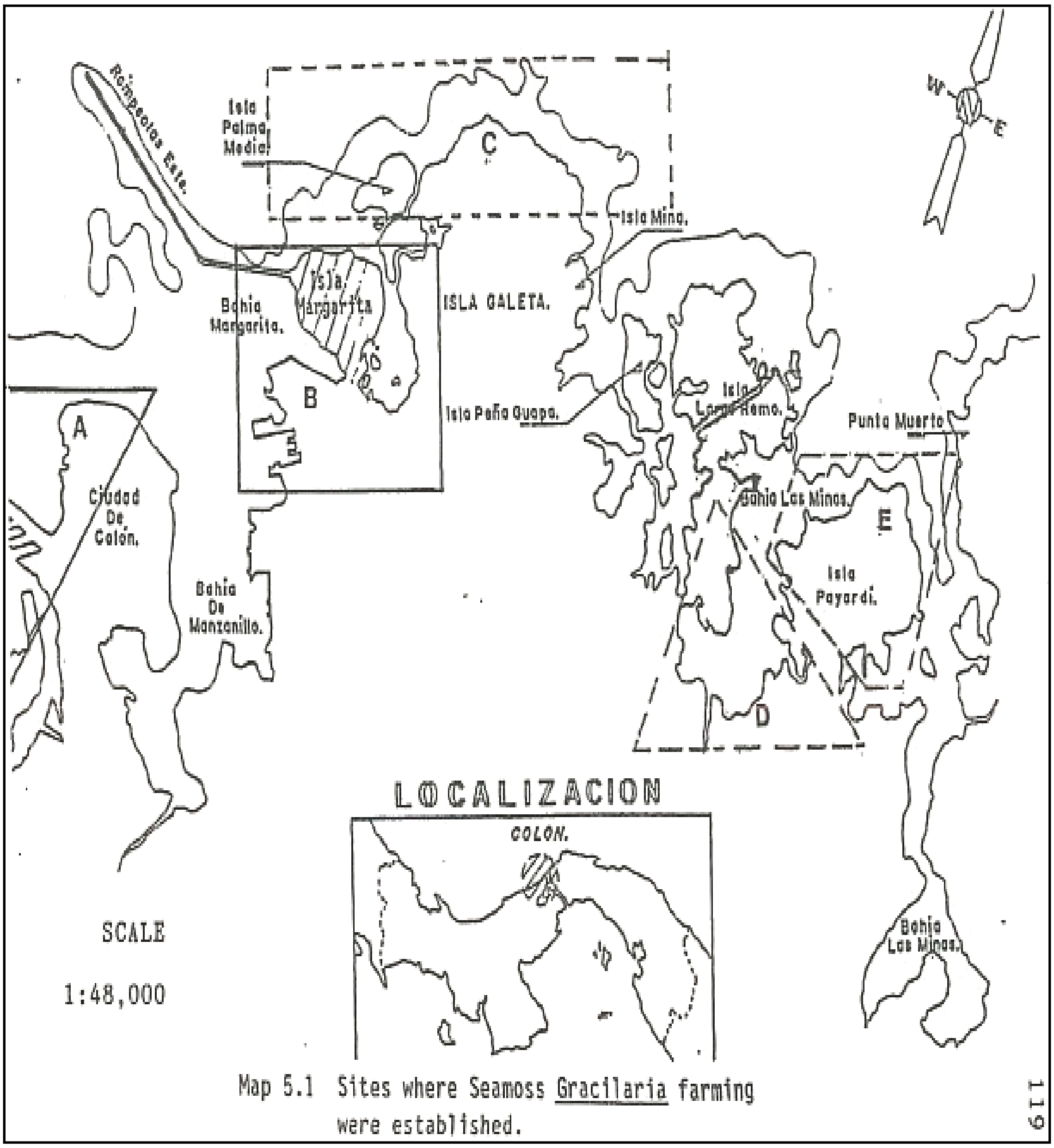
I am also greatly indebted to Dr. Ira Rubinoff , Director of the Smithsonian Tropical Research Institute (STRI) for give me the opportunity to develop my field work in Galeta Marine Laboratory at the Caribbean site of Panama and Dr. Wayne Sousa, Professor at the University of California, Berkeley to help me to design the sea-farms structures and experiments.

Map 1. Sites where Seamos *Gracilaria* farming were established

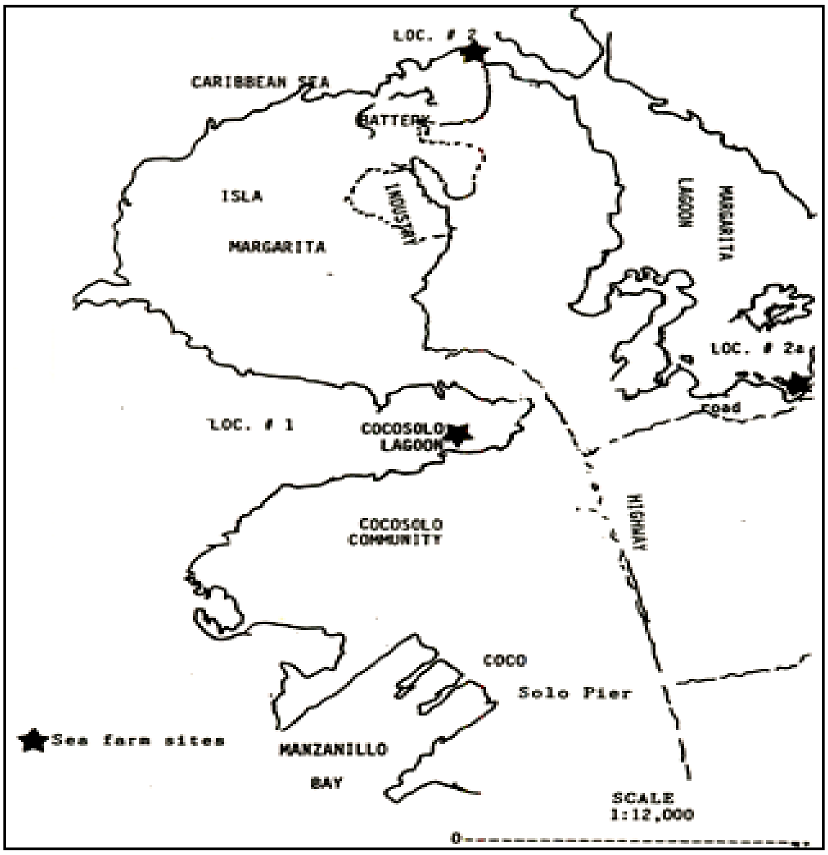


SCALE

1:48,000

Map 5.1 Sites where Seamoss Gracilaria farming were established.

MAP B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BATTERY
ISLA
MARGARITA
INDUSTRY
LAGOON
MARGARITA
LOC. # 2a
road
LOC. # 1
COCOSOLO
LAGOON
HIGHWAY
COCOSOLO
COMMUNITY
COCO
Solo Pier
Sea farm sites
MANZANILLO
BAY
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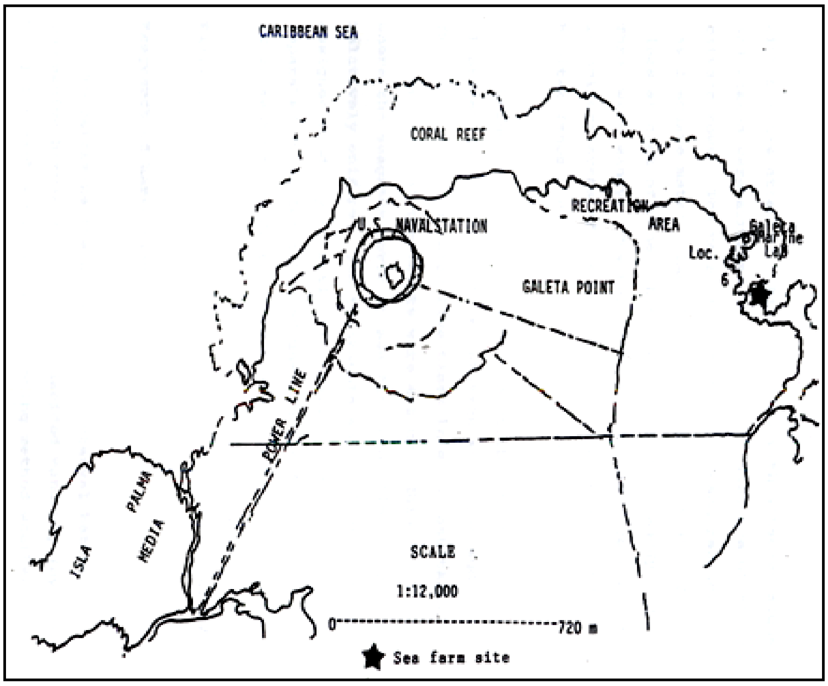
MAP C


CARIBBEAN SEA
CORAL REEF
U.S. NAVALSTATION
RECREATION
AREA
GALETA POINT
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6
POWER LINE
PALMA
MEDIA
ISLA
SCALE
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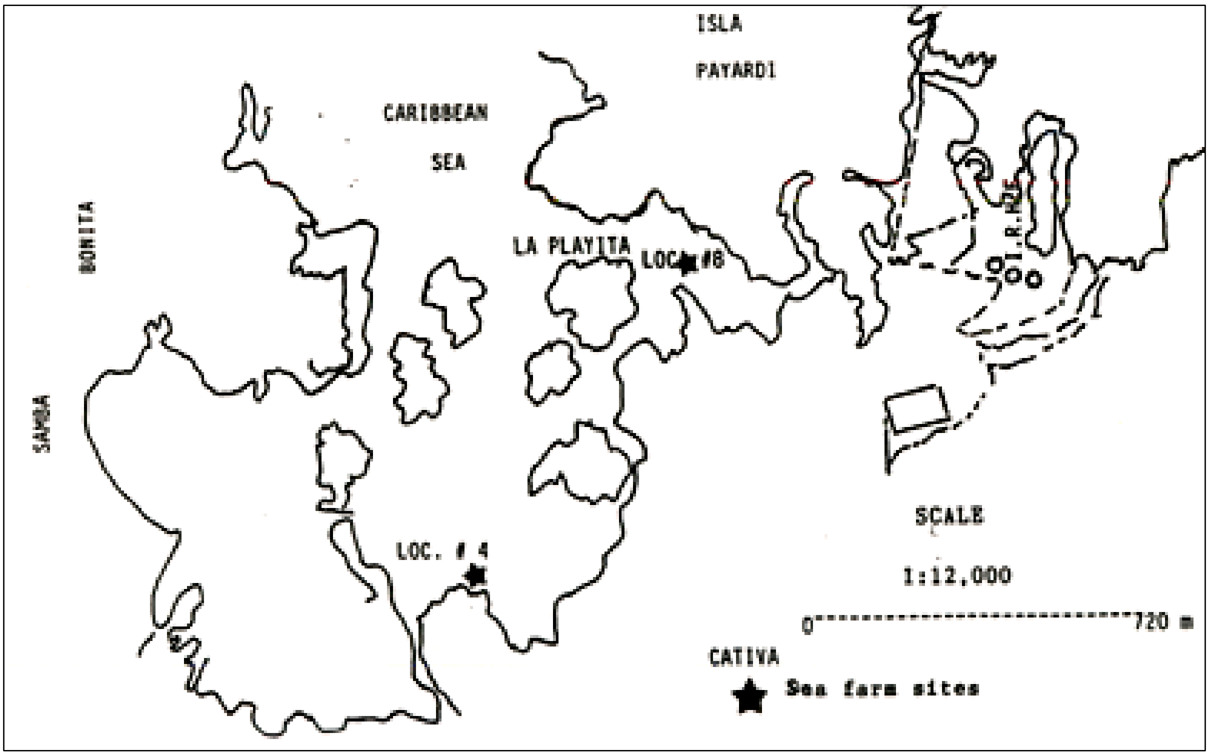
Sea farm site

MAP D


ISLA
PAYARDI
CARIBBEAN
SEA
BONITA
SAMBA
LA PLAYITA
LOC. # 4
SCALE
1:12,000
0
720 m
CATIVA
Sea farm sites

MAP E

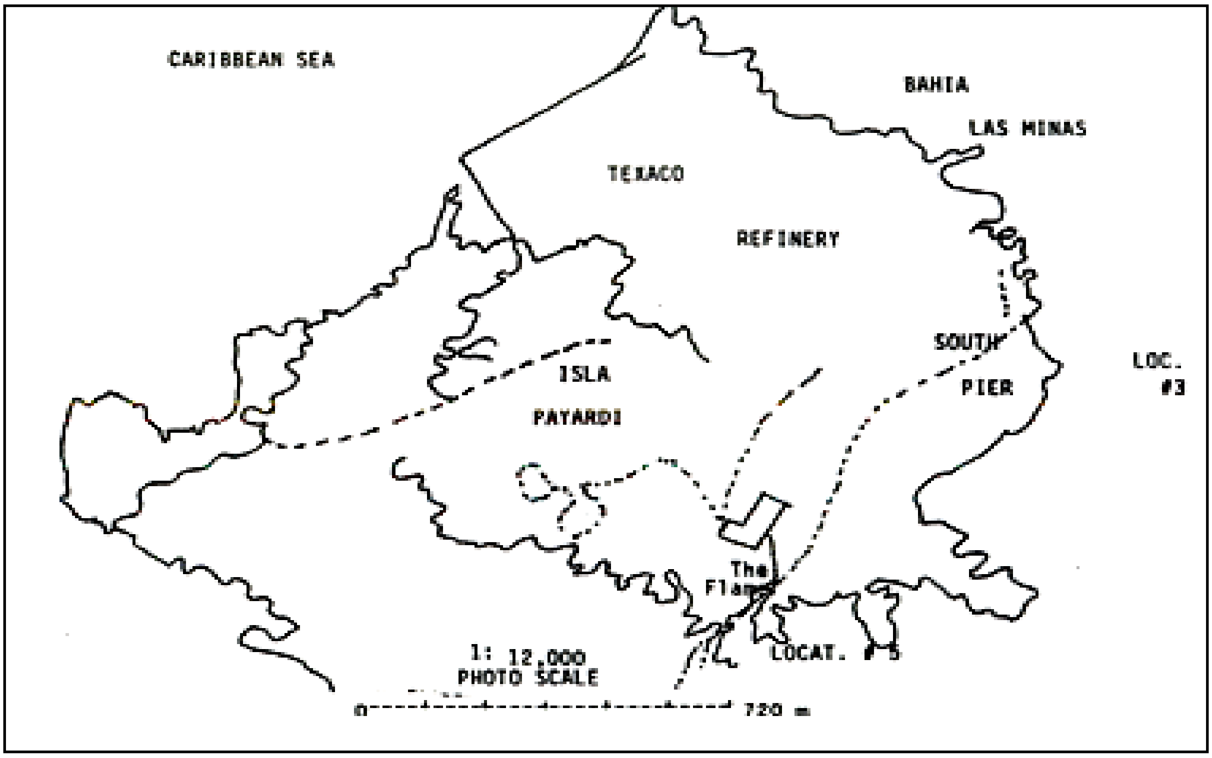
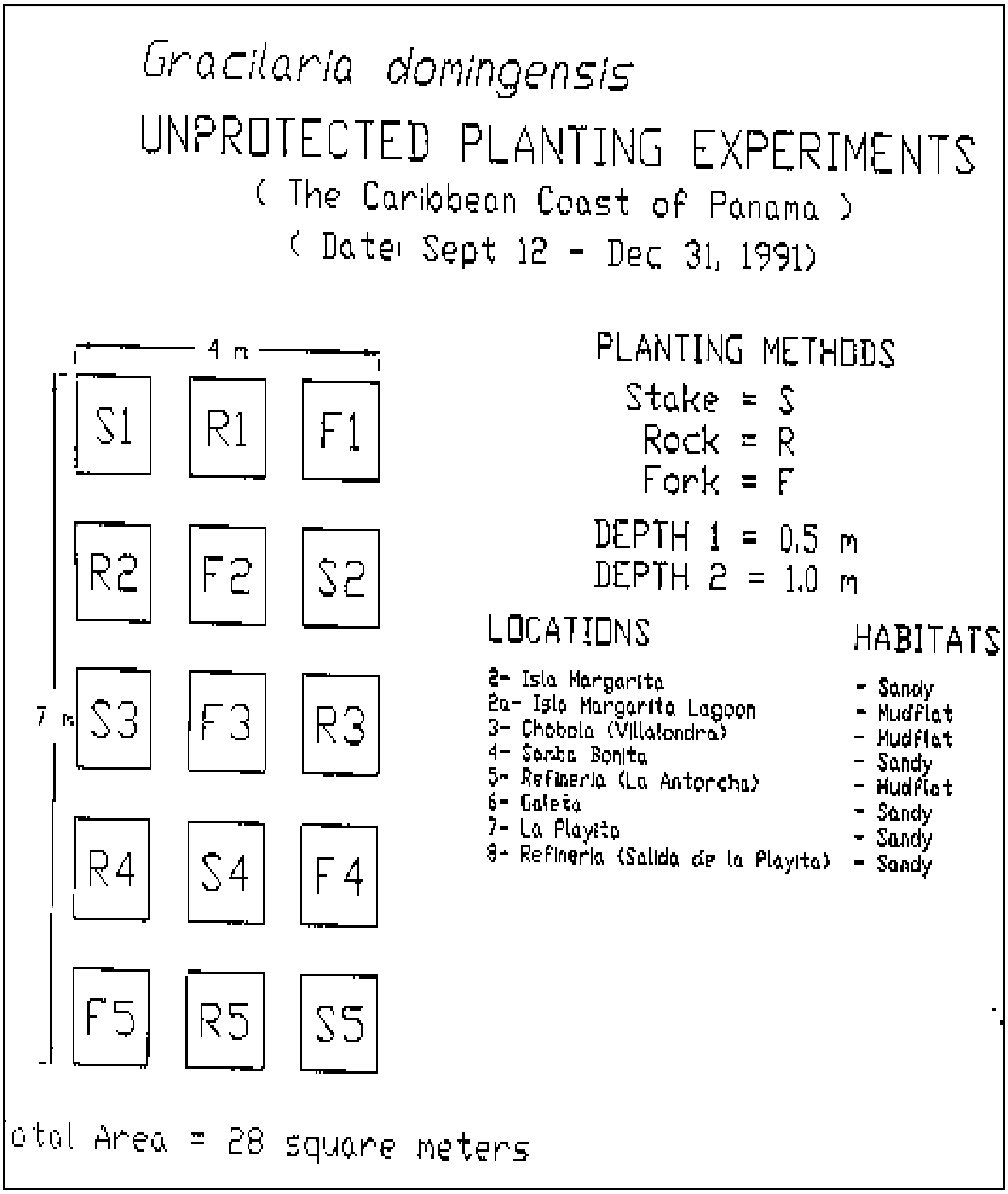

CARIBBEAN SEA
BAHIA
LAS MINAS
TEXACO
REFINERY
SOUTH
PIER
LOC.
#3
ISLA
PAYARDI
The
Flame
LOCAT. # 5
1: 12,000
PHOTO SCALE
0
720 m

Figure 1



Gloria Batista de Vega

Figure 2

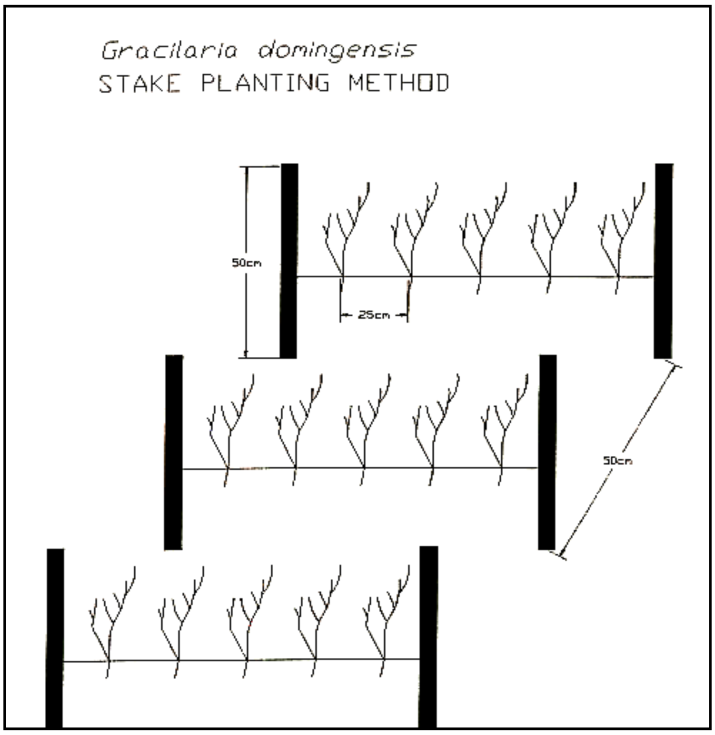


Figure 3

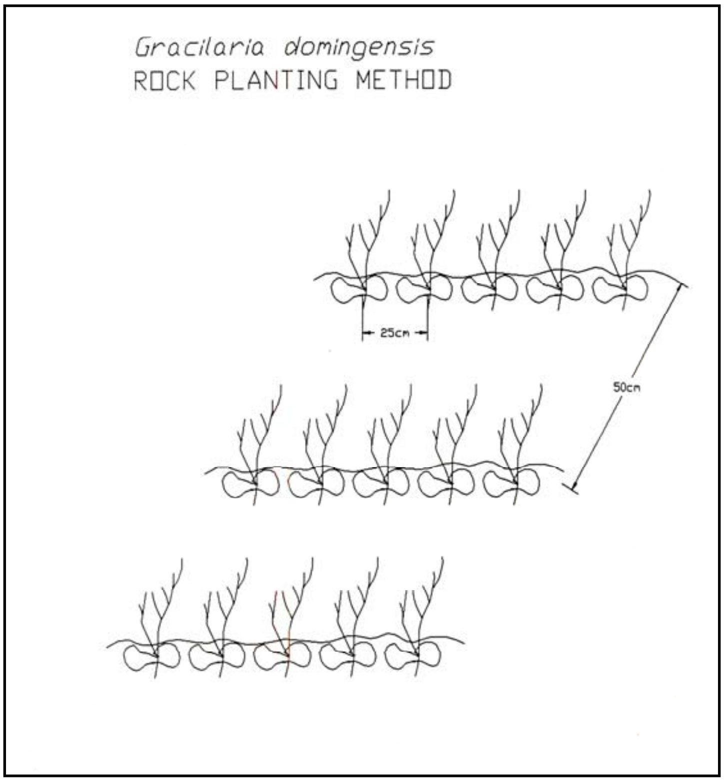


Figure 4

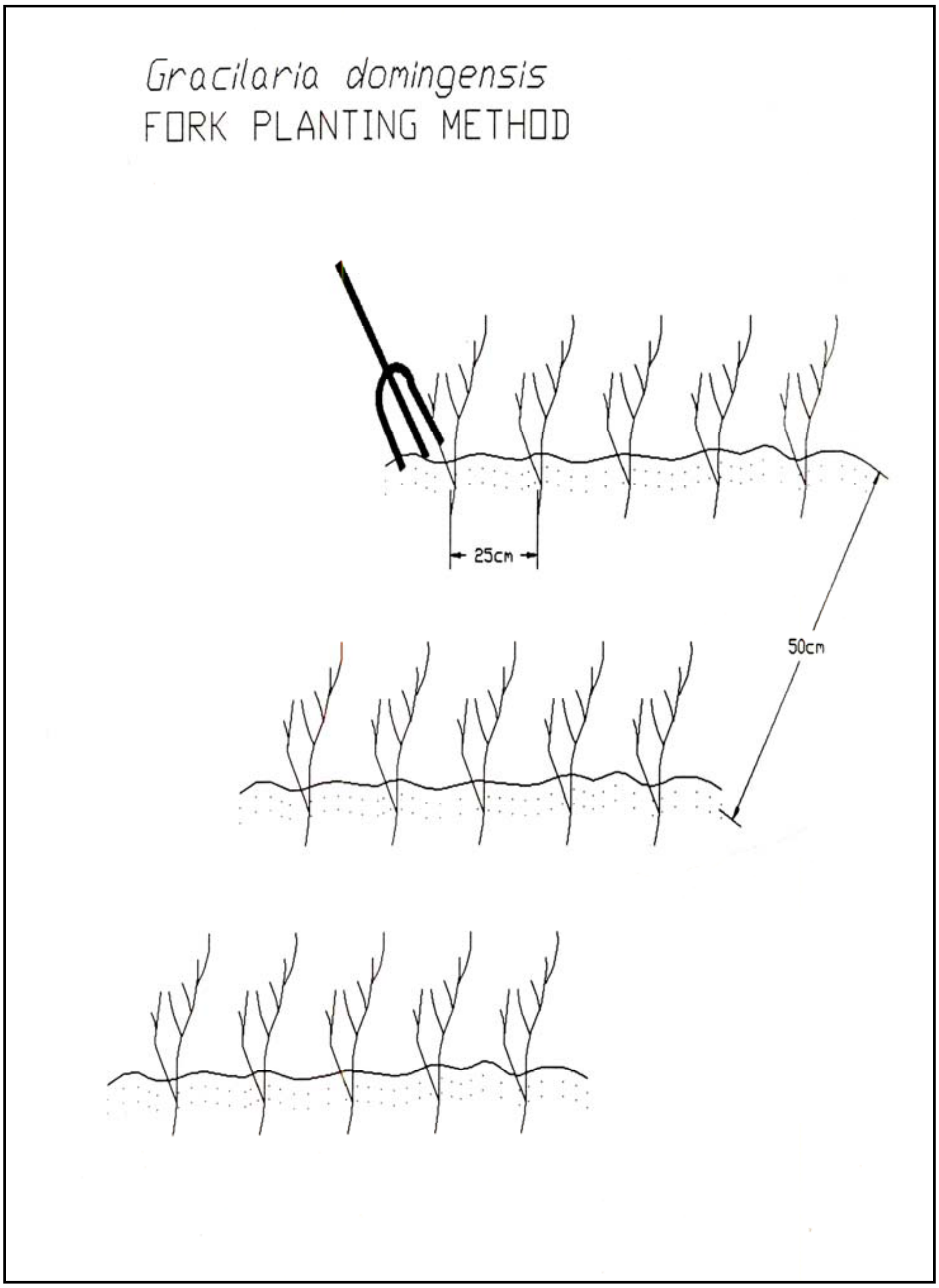


Figure 5

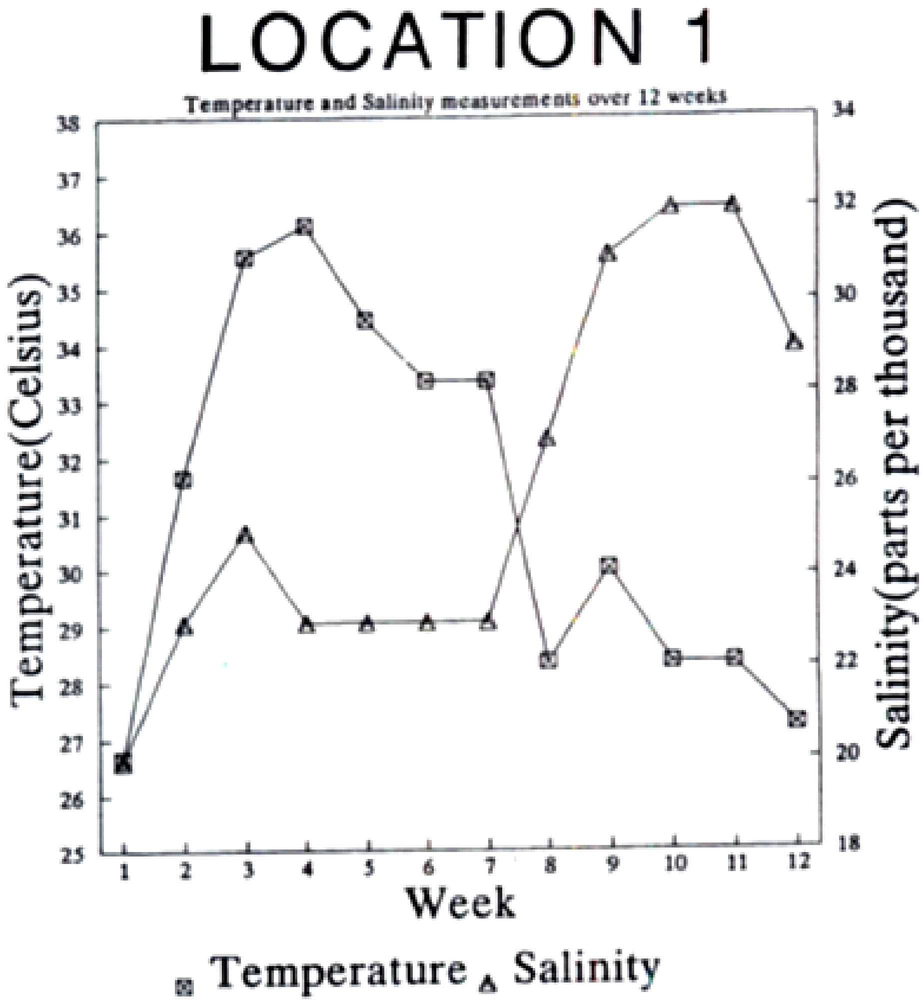


Figure 5

Week 1 – Sept 12, 1991

Week 12 – Dec 31, 1991

Figu

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (Celsius)	27	32	36	36	34	33	33	28	30	28	28	27
Salinity (parts/thousand)	20	23	25	23	23	23	23	27	31	32	32	29

Avg Temperature = 31.1
Avg Salinity = 25.9

SD Temperature = 3.2
SD Salinity = 4.0

Figure 6

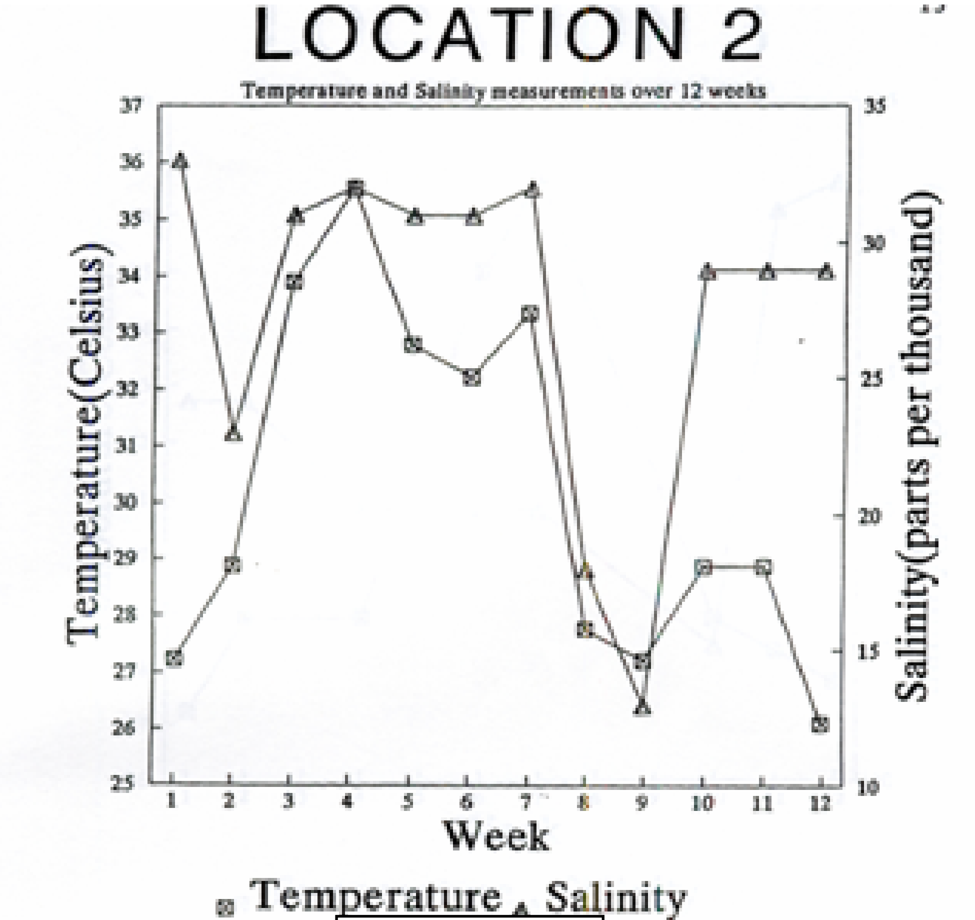


Figure 6

Week 1 – Sept 12, 1991

Week 12 – Dec 31, 1991

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (Celsius)	27	29	34	36	33	32	33	26	27	29	29	26
Salinity (parts/thousand)	33	23	31	32	31	31	32	18	13	29	29	29

Avg Temperature = 30.2
Avg Salinity = 27.6

SD Temperature = 3.0
SD Salinity = 6.0

Figure 7

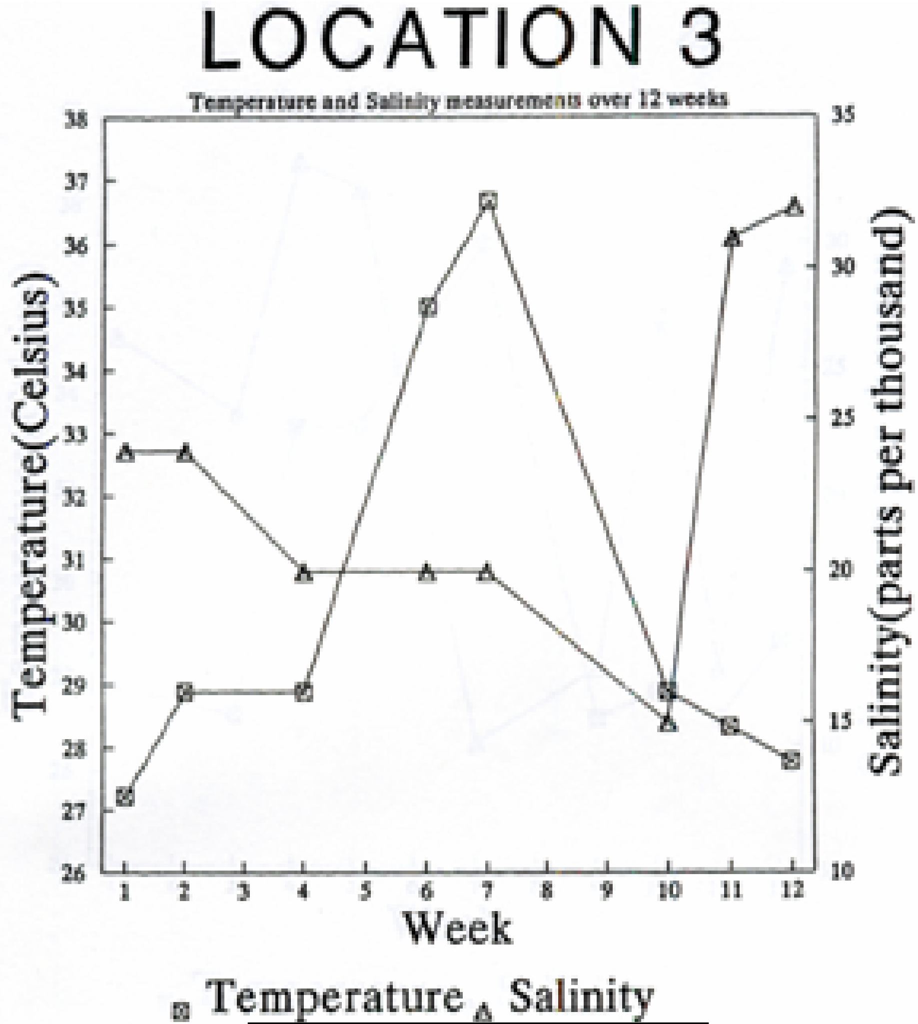


Figure 7

Week 1 – Sept 12, 1991

Week 12 – Dec 31, 1991

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (Celsius)	27	29		29		35	37			29	28	28
Salinity (parts/thousand)	24	24		20		20	20			15	31	32

Avg Temperature = 30.2
Avg Salinity = 23.3

SD Temperature = 3.3
SD Salinity = 5.4

Figure 8

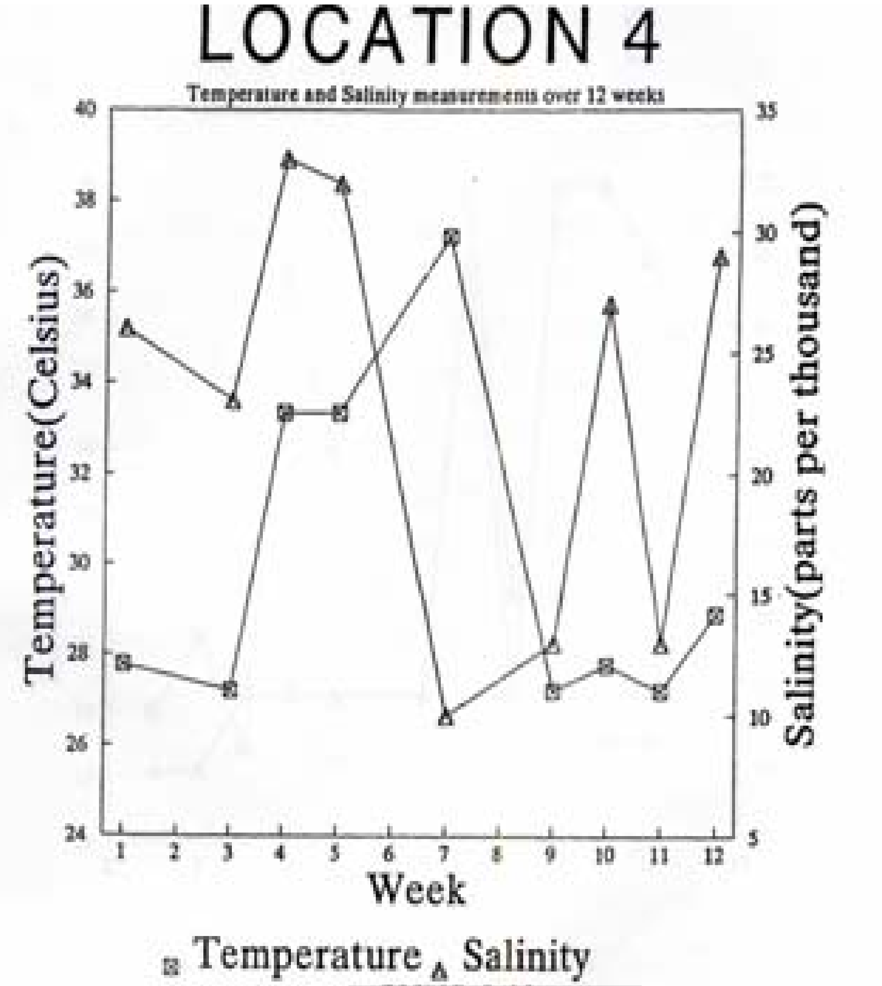


Figure 8

Week 1 – Sept 12, 1991

Week 12 – Dec 31, 1991

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (Celsius)	28		27	33	33		37		27	28	27	29
Salinity (parts/thousand)	26		23	33	32		10		13	27	13	29

Avg Temperature = 30.0
Avg Salinity = 22.9

SD Temperature = 3.5
SD Salinity = 8.2

Figure 9

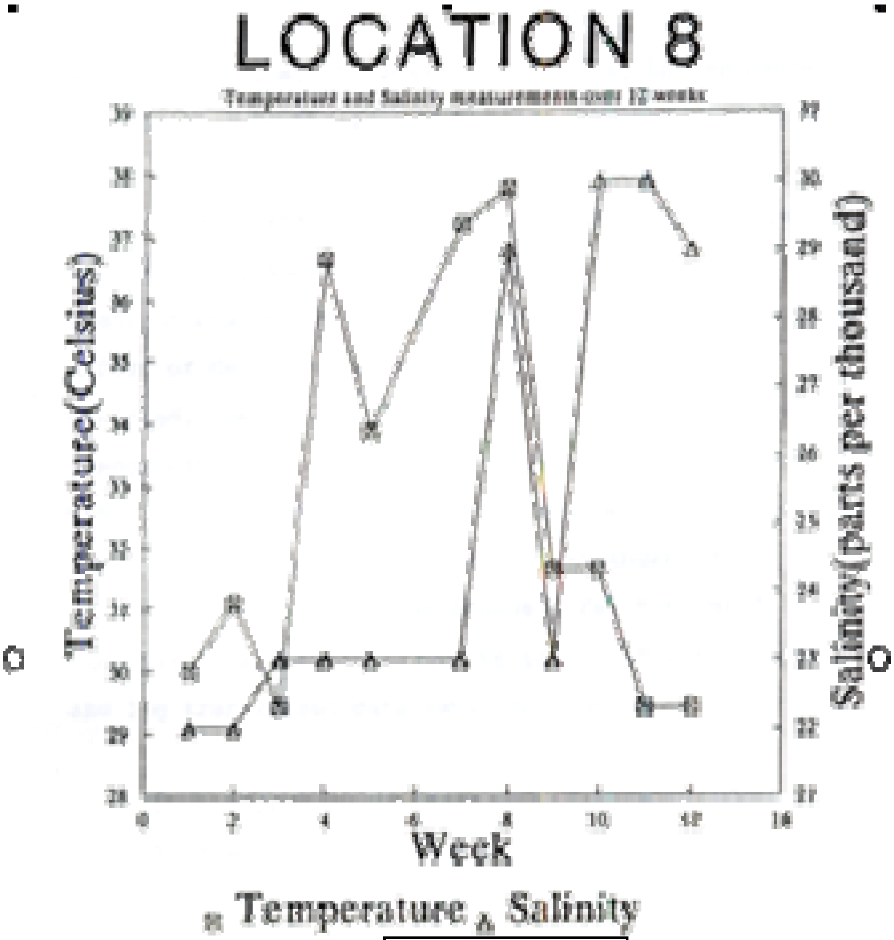


Figure 9

Week 1 – Sept 12, 1991 Week 12 – Dec 31, 1991

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (Celsius)	30	31	29	37	34		37	38	32	32	29	29
Salinity (parts/thousand)	22	22	23	23	23		23	29	23	30	30	29

Avg Temperature = 32.6 SD Temperature = 3.1
Avg Salinity = 25.2 SD Salinity = 3.3

Figure 10

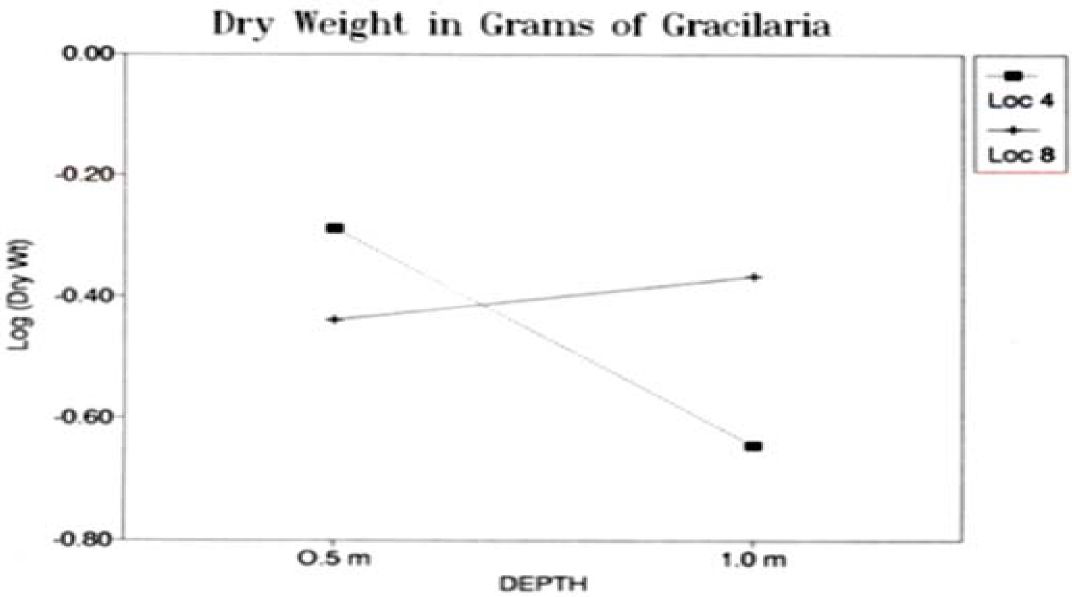


Figure 11

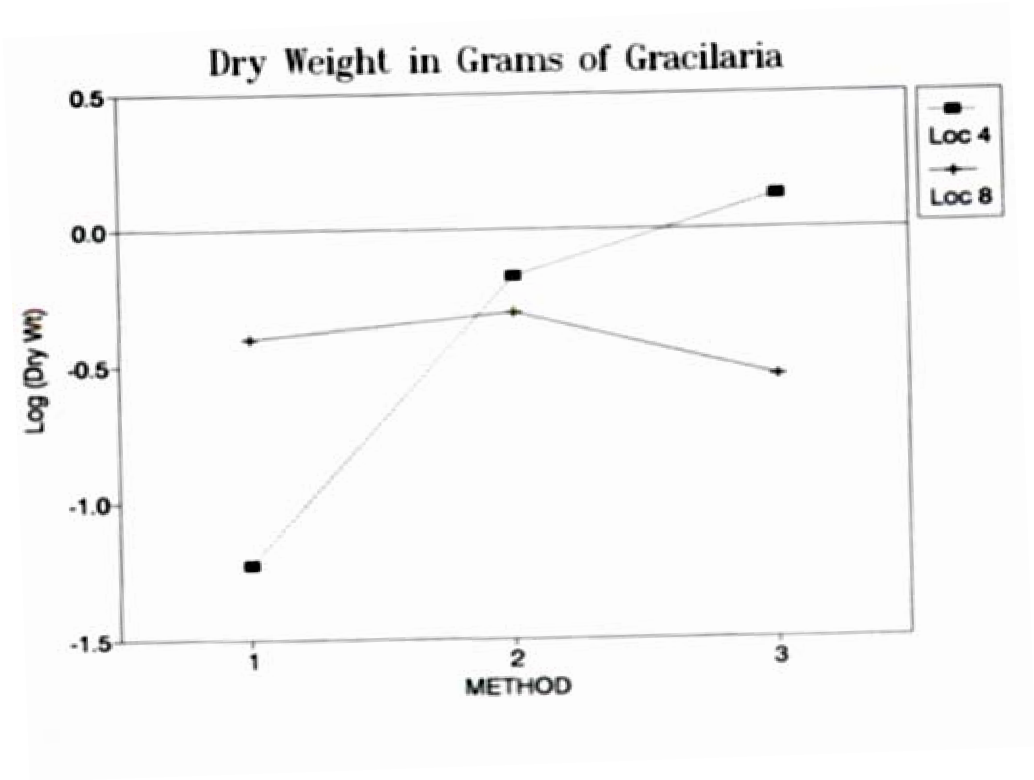


Figure 12

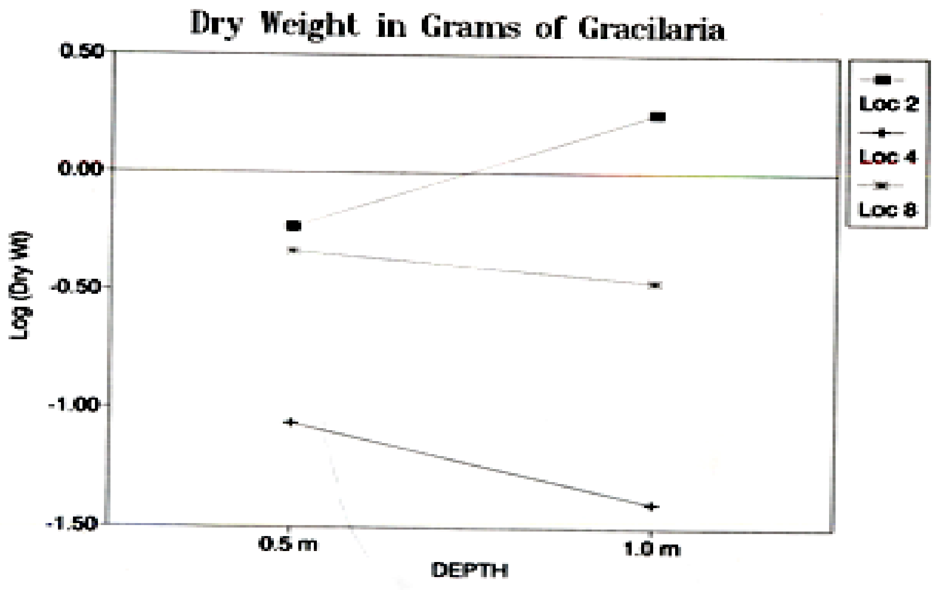


Table 1

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MEAN-SQ	F-RATIO	P
Location	0	1	0	0.005	0.943
Depth	0.236	1	0.236	2.347	0.133
Method	4.339	2	2.17	21.568	0
Loc*Depth	0.709	1	0.709	7.051	0.011
Loc* Method	5.202	2	2.601	25.856	0
Depth					
*Method	0.076	2	0.038	0.377	0.688
Loc*Method					
*Method	0.125	2	0.062	0.619	0.543
ERROR	4.325	43	0.101		
N=55					

Locations: Samba Bonita (4) and La Playita at Texaco(8) Depth: 0.5m and 1.0m
Method: Stake, Rock, Fork.

Table 2 a
Multiple Comparisons. Locations and Methods
Turkey HSD

LOCATION	COMPARED DEPHTS	VARIANCE HOMOG	COMPARISON OF MEANS		RESULTS TURKEY HSD
			F	P	
Samba Bonita	Stake M1	0.594	34.839	0	M1 M2 M3
	Rock M2 and Fork M3				
Salida	M1	0.843	1.325	0.285	M1 M2 M3
La Playita	M2				
Texaco-Refinery	M3				

METHOD LOCATION	COMPARED DEPHTS	VARIANCE HOMOG	COMPARISON OF MEANS	RESULTS TURKEY HSD P
			t	
M1	Loc 4 and Loc 8	0.235	-6.554	0
M2	Loc 4 and Loc 8	0.851	-0.783	0.444
M3	Loc 4 and Loc 8	0.175	-3.903	0.002

Table 2b
Multiple Comparisons. Locations and Depths
Turkey HSD

LOCATION	**COMPARED DEPHTS**	**VARIANCE HOMOG**	**COMPARISON OF MEANS**		**RESULTS TURKEY HSD**
			F	**P**	
Loc 4	Depth 1 (0.5 m.) and Depth 2 (1.0 m.)	0.996	-1.39	0.002	
Loc 8	Depth 1 and Depth 2	0.9	-0.621	0.54	

DEPHT	**COMPARED DEPHTS**	**VARIANCE HOMOG**	**COMPARISON OF MEANS**	**RESULTS TURKEY HSD**
			t	**P**
1	Loc 4 and Loc 8	0.039	-0.771	0.448
2	Loc 4 and Loc 8	0.000	-1.453	0.158

Table 3

Locations: 2, 4 and 8
Depth: 0.5 m. and 1.0 m.
Method: Stake
(MAPS B AND D)

ANALYSIS OF VARIANCE

SOURCE	**SS**	**DF**	**MEAN-SQ**	**F-RATIO**	**P**
Location	6.939	2	3.47	47.02	0
Depth	0	1	0	0.006	0.939
Loc*Depth	0.7	2	0.35	4.746	0.02
ERROR	1.55	21	0.074		
N=27					

Table 4

Comparisons of means with a Turkey test between depth 0.5 m. and locations 2,4 and 8 And depth 1.0 m. with locations 2, 4 and 8

DEPTH	COMPARE LOCATION	VARIANCES HOMOG	COMPRAR. OF MEANS		TURKEY HSD
			F	P	
0.5 M.	Isla Margarita (2)				
	Samba Bonita (4)				
	La Playita at Texaco-Refinery (8)	0.717	10.85	0.003	L2 = L8
					L2 L4
					L4 L8
1.0 m.	L2, L4 and L8	0.75	408.45	0.001	

Table 5

Location (3): Chabola (in front of south Pier)
Texaco-Refinery
Method 1: Stake Depths: 0.5 m. and 1.0 m.

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MEAN-SQ	F-RATIO	P
Depth	0.171	1	0.171	6.358	0.939
ERROR	0.161	6	0.027		
N=8					

Table 6

Mean rate of survival of planted *Gracilaria* as a function of location, depth of planting, and method of planting at the Caribbean coast of Panama

LOCATION	DEPTH	METHOD	% SURVIVAL
2	1	1	26.67
2	2	1	42.67
2	1	2	24.00
2	2	2	00.00
2	1	3	20.00
2	2	3	00.00
3	1	1	92.00
3	2	1	86.67
3	1	2	00.00
3	2	2	2.67
3	1	3	00.00
3	2	3	00.00
4	1	1	70.00
4	2	1	76.00
4	1	2	41.33
4	2	2	40.00
4	1	3	26.67
4	2	3	26.67
8	1	1	65.33
8	2	1	44.00
8	1	2	41.33
8	2	2	90.67
8	1	3	18.67
8	2	3	26.67

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3

A COMMERCIAL FEASIBILITY OF *Gracilaria domingensis* FARMING USING PROTECTED SYSTEMS OF PLANTING ON THE CARIBBEAN COASTAL ZONE, PANAMA

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SUMMARY

A variety of ecology studies are important to add in the construction of *Gracilaria* seaweed farms on the Caribbean coast of Panama. In the coast line of the district of Colon; Panama, five species of *Gracilaria* are currently recognized by Mark Hay and James Norris. This study presents the commercial feasibility of seaweed farms planted into a lagoon using protected semi-protected and unprotected systems of culture. The results of the experiment showed that heat grazing has a significant impact on *Gracilaria* production. But fishermen must consider the cost of establishing and maintaining the protected structure in the culture

KEYWORDS: culture, seaweed farming, protected systems.

INTRODUCTION

The marine red alga *Gracilaria* is among the most important seaweeds that local people on the Caribbean site of Panama used for food and culture reasons (Batista & Connor, 1990).

A variety of systems to protect the cultivation of the *Gracilaria* species has been studied by several groups in order to improve the production and quality of the final raw material. For example, a tank cultivation system were planted unattached plants to reduce the high labor costs. But the costs still higher on a commercial scale (McHugh, 2003).

Gracilaria is a group of warm water seaweeds. There are more than one hundred species in the world, some of which have very important economic value. *Gracilaria* is used in the preparation of food products and also an important raw material in agar-agar production. In 2001, the world's annual output of *Gracilaria* was about 37,000 tons, dry weight, and most of which comes from natural production (Porce, 2002). For example, the natural production in Chile, Argentina, and Brazil accounts for one third of this total output (Ministry of Agriculture China, 1990).

A variety of ecology studies are important to add in the construction of *Gracilaria* sea farming on the Caribbean coast of Panama. In the coast line of the district of Colon, Panama, five species of *Gracilaria* are currently recognized (Hay and Norris, 1984). The objectives of this study were to determine sites where *Gracilaria* farms could be established and to know a commercial feasibility to establish *Gracilaria* farms using protected structure in order to avoid grazer of the cultivated species.

EXPERIMENTAL PART

Culture and Taxonomic studies

Collected samples of species of the gender *Gracilaria* were dried in an oven at a temperature between 70-80º C to determine dry weight to wet weight ratios. Both dried and living specimens were brought back to University of California Berkeley for culture and taxonomic studies.

The collected live *Gracilaria* were used to establish unialgal cultures in the laboratory. Life history and taxonomic aspects of the algae were examined by Professor John West at the Department of Plant Biology at the University of California, Berkeley.

Live specimens of two *Gracilaria* species were brought to the laboratory at University of California at Berkeley from the areas we want to establish the sea farms. Sample size was chosen on the basis of how these algae grew and the preliminary design optimization analysis.

1. Grazing Experiment

Area

A lagoon in Coco Solo, located at Northeast of the city of Colon, was selected to plant series of protected sea farms systems (Map 1). To determine the effects of large grazers, grazer exclusion cages (120 cm wide x 70 cm long x 60 cm high) were installed around rock plantings positioned at a depth approximately 1 m bellow mean low water. All fish and invertebrates were removed within the enclosed area.

The enclosures were made of VEXAR plastic mesh (1/2" mesh). The cages were supported by iron bars of 2 cm diameter, rocks very light were used to hold down the bottom of the cage walls. The tops of the cages were closed to avoid entry by herbivores. Each pen had an access door to allow harvesting and periodic maintenance. I will refer to these treatments as full mesh cages (F) (Figure 1). Mesh walls were cleaned every week to minimize interference with water flow for nutrients and light penetration.

Such cages may have various artifactual effects on algal growth by changing water flow, sedimentation, or light. To test for this, partial cages (p) (Figure 2) were installed around additional rock plantings at the same depth. The sections of the cage wall were positioned to face the prevailing water current as determined by dye releases. This maximized the potential interference with water motion. One permanent opening was provided to allow grazer access. Once a week I counted the number of fish, invertebrates and algae in these partial cages (P) at high tide by snorkeling.

A second control consisted of a structure (S), which was a cage frame only, placed around the rock the rock planting (Figure 3). A third consisted of open, un-manipulated rock plantings without any exclusion cages or partial cages, also at a depth of approximately 1m. These four treatments were replicated five times in sandy beach habitats between mangroves and coral reefs. A comparison of algal production in the complete versus partial cages measured the effects of grazers, while the comparison of partial cages, frame structures only and open plantings identified any artifactual effects of the cages themselves.

The grazing treatments and replication (Figure 4) were assigned randomly to locations in a uniform sandy habitat with sea grass beds at Coco Solo Lagoon in a 900 square meter area (30 m wide by 30 m long).

2. Frequency of Harvesting

To determine the effect of the interval between successive harvests on yield, I decided randomly (by coins toss) for each alga in every planting method whether the plant should be harvested once (after twelve weeks), or twice (after six weeks and twelve weeks). Fronds harvested at six weeks were removed with a knife so as to leave approximately 1-2 cm of plants for re-growth. All algae were harvested at 12 weeks.

3. Temperature and Salinity

Seawater temperatures were recorded with a Hydro lab manual thermometer. The thermometer was submerged about 15 cm below the water surface. Temperature readings were taken once a week in each site. Seawaters samples for salinity measurements were taken 15 cm below the water surface once a week for each location. Salinity was measured with a temperature-compensated, hand-held refractometer (model number 10419, American Optical Co.; Buffalo, New York).

RESULTS

Gracilaria domingensis was the species of seamoss we identified as a having the greatest mariculture potential abundant along the Caribbean coast of Panama.

Dr. John West performed experiments on two isolates of *Gracilaria* in culture at his lab at U.C. Berkeley. These two species grew well at 25ºC, 50-100 *u*mol m-2 s-1 16:8 LD, 30 ppt PES/2 (10ml Provasoli's Enrichment Medium/liter sterile seawater) (Starr and Zeikus, 1987), enrichment seawater with 4% day growth rate. They remained vegetative (no reproduction) so it was not possible to identify them to species.

The average temperature range at the sites where the planted algae survived was between 30.0 – 32.6 ºC and the salinity range was 22.9 – 27.6 parts per thousand.

In the grazing experiments, Cochran's test showed that dry g/alga and total dry g algae had homogeneous variances. Cage experiments showed that there were grazer that were excluded as compared to controls. The cage experiments showed that production of dry g/alga was greater in the full cage treatments than in the order treatments. However, algae did not look as healthy and their color was opaque in the full cages compared to algae in the open-cage (P) also showed some degree of withering and high grazing. This suggests that the full cages inhibited herbivore damage. But contrary to Hay's (1981) grazing in partial cage treatments was not significantly different from the degree of grazing in the order treatments (Table 1).

Cage experiments were performed in a bed of *Thalassia testudinum* growing in a sandplain substratum. A large community of oysters and clams were growing attached to rocks in the sandplain. This area was visited by a great variety of fish of all sizes. Full cages were damaged by fish. Cage (F2) was broken during the course of the experiment, and we found a great barracuda (*Sphyraena barracuda*) inside. Cages (F1) was also broken and contained a porcupine fish *Diodon hystrix* about 1 m.

The Turkey test HSD multiple comparisons test showed that the dry grams of *Gracilaria* produced in partial cages, structural control cages and in the absence of cages were not significantly different. However, production in these treatments was very low compared with production in the full cage treatment (Table 2).

CONCLUSION

The grazing experiments showed that grazing has a significant impact on *Gracilaria* production. Even though Hay (1981) said that grazing fish such as Scaridae and Acanthuridae are rare in the sandplain habitats, we saw a great diversity in fish of all sizes in location 1 at Coco Solo Lagoon. There were many parrotfish such as *Cryptotumus roseus* and queen *Scarus vetula*. There were also bluespotted cornet fish such as *Fistularia tabacaria.* There were also large mollusks like the queen conch *Strombus gigas* which could easily damage the rock and fork plantings.

Site selection of seaweed farms must be done with care and may involve preliminary trials and monitoring of the growth rate.

Sandplain habitats worked better in the experiments we planted, but in some Caribbean areas *Gracilaria* spp. grows well even along muddy mangrove shorelines (FAO 1988).

Pond cultivation of *Gracilaria* is less labor intensive than rope farming (no need to fix many pieces to a rope or net) and has been quite successful, originally in China in Guandong, Hainan and Taiwan Province of China, now also in Indonesia, Viet Nam and in experimental trials in Malaysia. One disadvantage of *Gracilaria* from ponds is that the agar extracted from it is often of low gel strength and so only attracts the lower price of a food grade agar (McHugh, 2003).

Fishermen must also consider the cost of establishing and maintaining the *Gracilaria* farms. We had to spend $35 by cage with dimension of 120 cm x 60 cm. the cost of using the stake planting method to plant sq m was $7. With the rock and fork planting methods, we used materials commonly found near the planting sites, and the fishermen provided us with the tools necessary for planting. The above costs do not include the cost of boats or gasoline, or the time needed to find the algae used in the initial plantings. It may also be necessary to weed out epiphytes. The total cost for each method will also depended on how far away naturally occurring populations of the specie from the farming sites.

Physical factors such as temperature, salinity and light may not be economically feasible to control. However, research to determine the growth response of algae under different physical conditions is important in understanding seasonal patterns of yield and in selecting potential cultivation sites. In Brazil one year of study with 60 species of macroalga showed that *Gracilaria* spp. produced the highest biomass. The study also found a positive correlation with a decrease in salinity and water (Silva *et al.,* 1987).

Studies of LaPoint *et al*., 1976, encourage the development of mariculture practices with *Gracilaria* spp and *Hypnea musciformis. Hypnea* also has a commercial value in carragena industry. Each culture locality and each “clone” must be tested for total production, percent yield and agar quality (gel strength, sulfate, pyruvate and methoxyl content). Harvesting time and planting methods must focus on the factors affecting optimal growth; optimal percent yield of agar, optimal agar quality an optimal retention of seed stock.

Culture of *Gracilaria* in tanks would allow manipulation of several parameters which affect the growth of algae. However seamoss farms tanks are very expensive and are not economically feasible for the artisanal fishermen of Panama. In addition, these tanks probably would not be feasible because of the attitudes of the local people. Caribbean fishermen may be receptive to some changes in their daily lives, tanks and machines near the coast look very complicated to them (Batista, 1992). Fishermen along the Caribbean coast of Panama work with rudimentary tools. The most complicated tool same of the local fishermen have is a small motor boat. However, most of the fishermen do not even have motors to work with. Instead, they use canoes with oars.

China produces significant quantities of *Gracilaria*, mainly in the southern provinces of Guangxi and Hainan, where it is cultivated in ponds and estuaries; it is also cultivated in Taiwan Province of China. In Indonesia, wild seaweed is collected and some is cultivated in ponds (McHugh, 2003).

There are various reviews of cultivation of *Gracilaria* Santelices and Doty (1989), Oliveira *et al*, (2003) and Bellorin *et al.,* (2004) that can help new experiences and seaweed farm designed.

The Panamanian government should set strong legal policies to protect the seaweed farms and the harvest from these farms. The government and local financial institutions should provide continuing and ongoing moral and financial support to the seaweed farmers.

RESUMEN

FACTIBILIDAD COMERCIAL EN LAS GRANJAS DE ALGAS MARINAS DE *Gracilaria domingensis* USANDO SISTEMAS DE PLANTACIÓN PROTEGIDOS EN LA ZONA COSTERA DEL CARIBE PANAMEÑO

En la construcción de las granjas de algas marinas realizadas en las costas del Caribe panameño es necesario añadir estudios ecológicos en los sitios elegidos para la actividad. En la línea costera del distrito de Colón; Panamá, cinco especies de *Gracilaria* han sido reconocidas por Mark Hay y James Norris. Este estudio presenta la posibilidad comercial de establecer granjas de algas marinas usando estructuras protegidas, semiprotegidas y no protegidas para el cultivo de la *Gracilaria*. Los resultados mostraron que la depredación por herbívoros es alta y tiene un impacto significativo en la producción de *Gracilaria.* Los pescadores deben

considerar el costo del mantenimiento y el uso de las estructuras protegidas en el cultivo.

PALABRAS CLAVES: cultivo, granjas marinas, sistemas protegidos.

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MAP 1

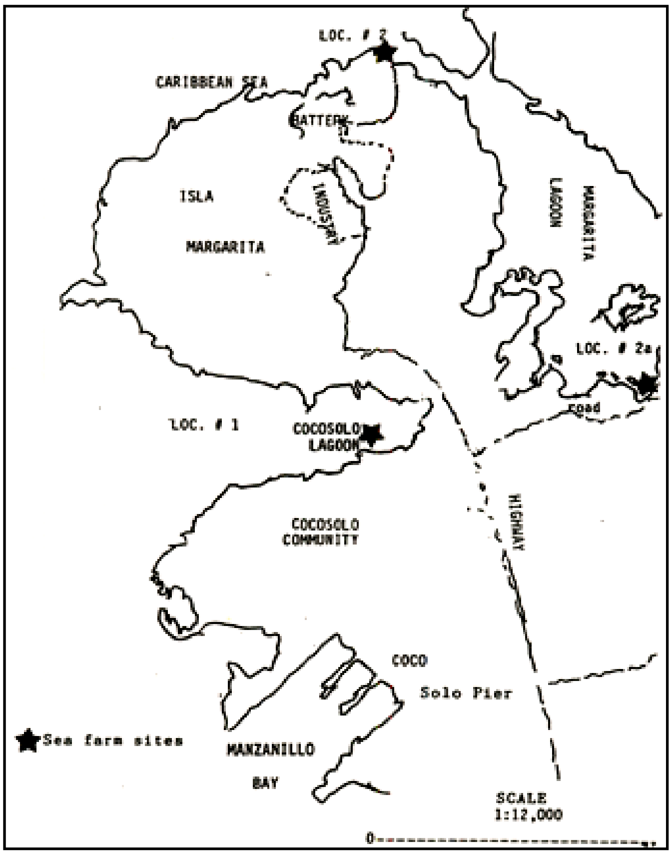

Figure 1

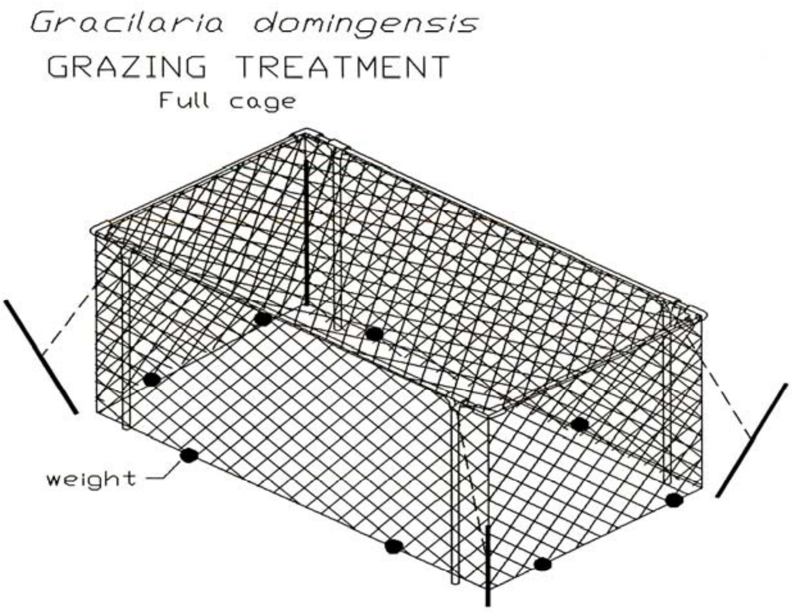

Figure 2

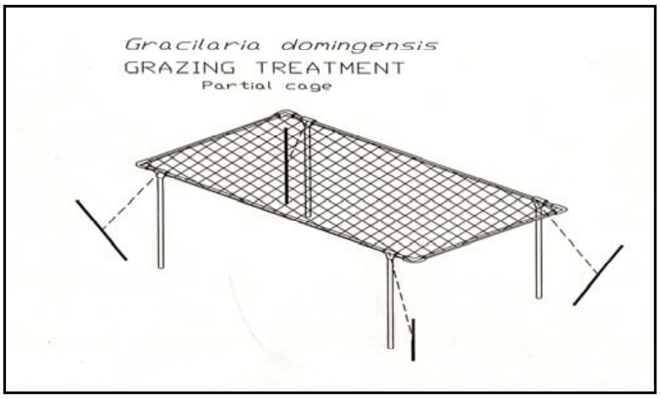

Figure 3

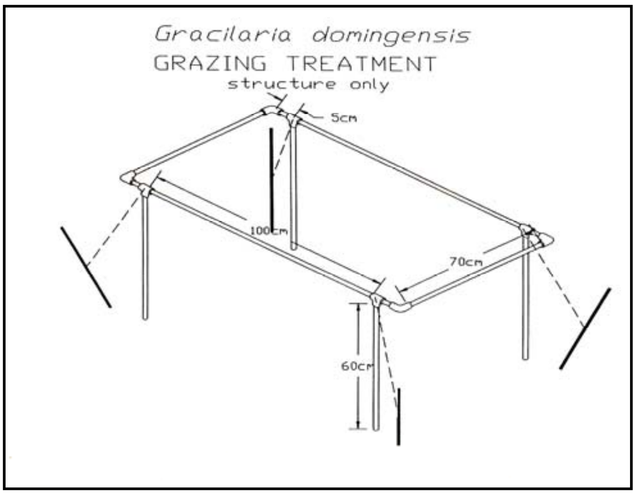

Figura 4

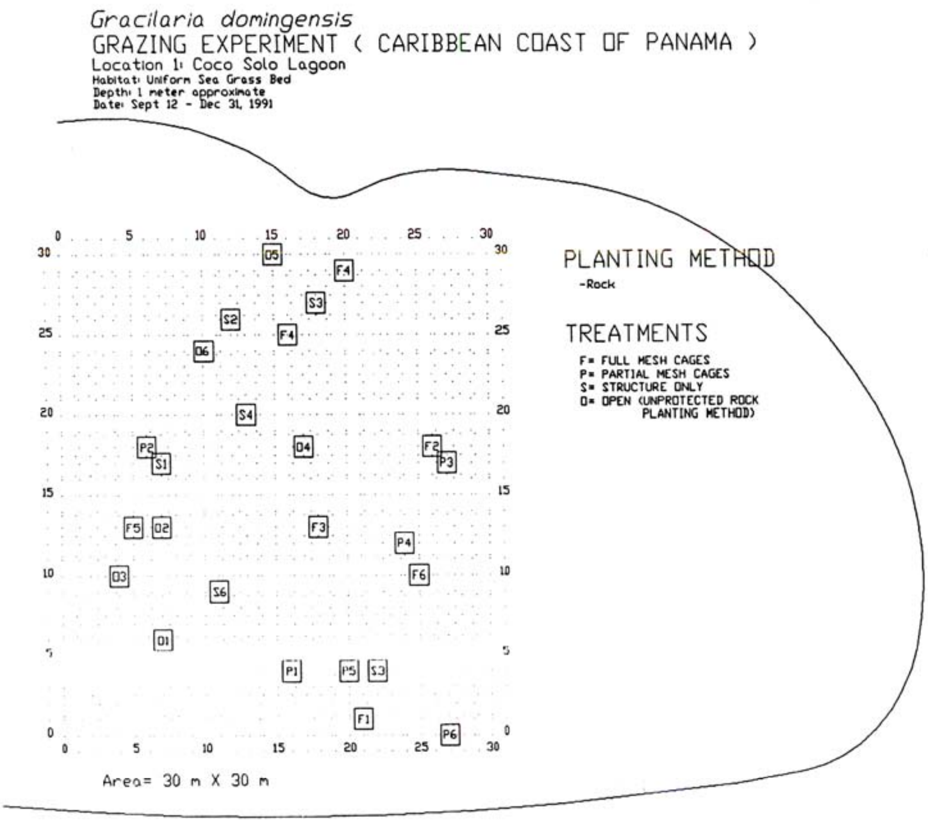

Table 1
Mean (SD) of dry weight per surviving plant and Total dry weight per replicate at six weeks in grazing experiment
Location: Coco Solo Lagoon

TREATMENT	# of Rep. 75 algae	DRY G Alga	TOTAL Dry g	MEAN # surviving algae
Full Cages	3	0.56	4097 (0.266)	15.00 (00)
Partial Cages	2	0.4	0.610 (0.325)	1.66 (40)
Structure Cages				
Only	3	0.215	0.273 (0.108)	3.00 (36)
No Structure	3	0.227	0.227 ( )	2.33 (38)
F ratio	23.663	263.55		
df	3.7	3.7		
P -value	<.001	<.001		

Table 2
Grazing Experiment
Location: Coco Solo Lagoon
Turkey HSD Multiple Comparison
Matrix of pair wise Comparison Probabilities

	FULL CAGES	NO CAGES	PARTIAL	STRUC-CAGES
Full Cages	1			
No Cages	0	1		
Partial Cages	0	0.235	1	
Structure Cages	0	0.991	0.323	1