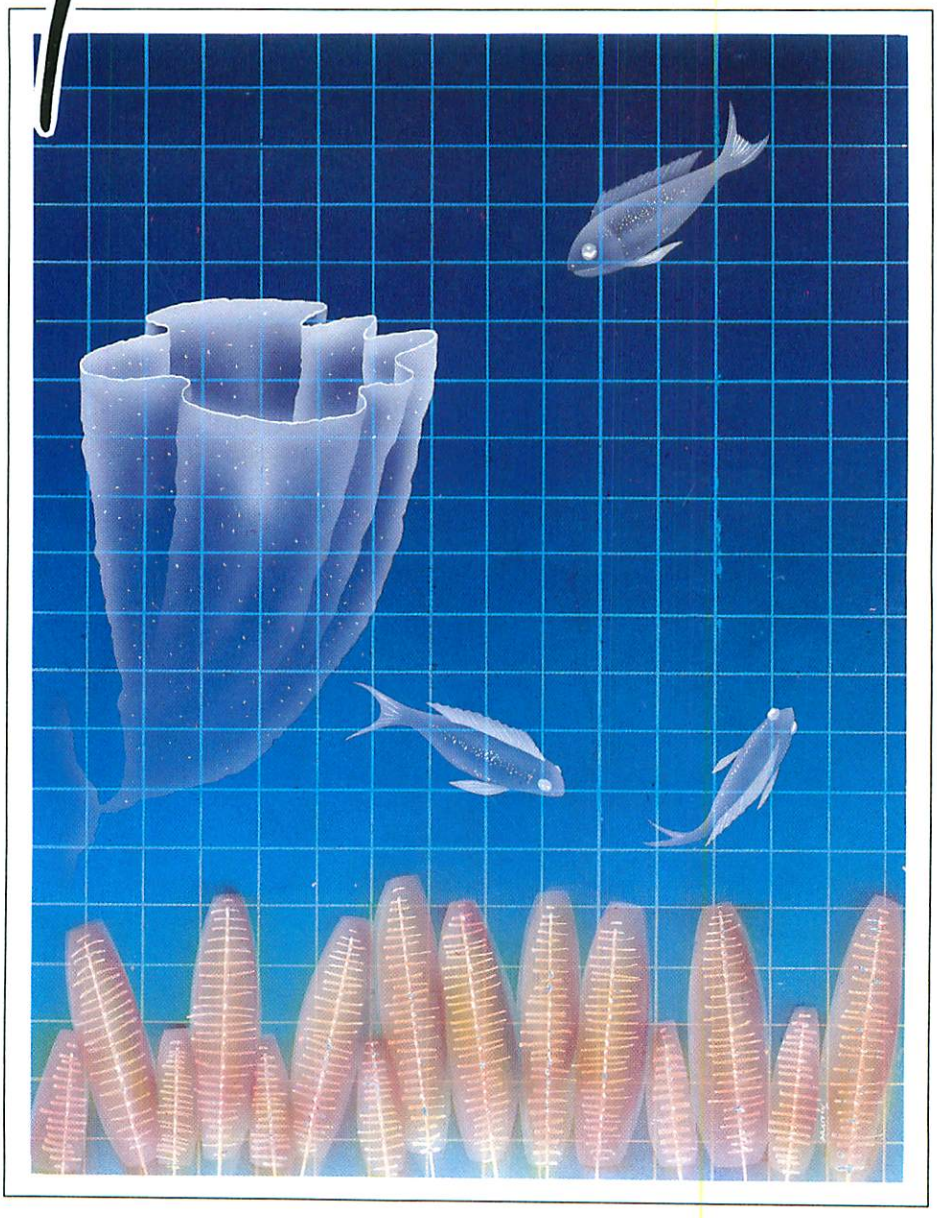
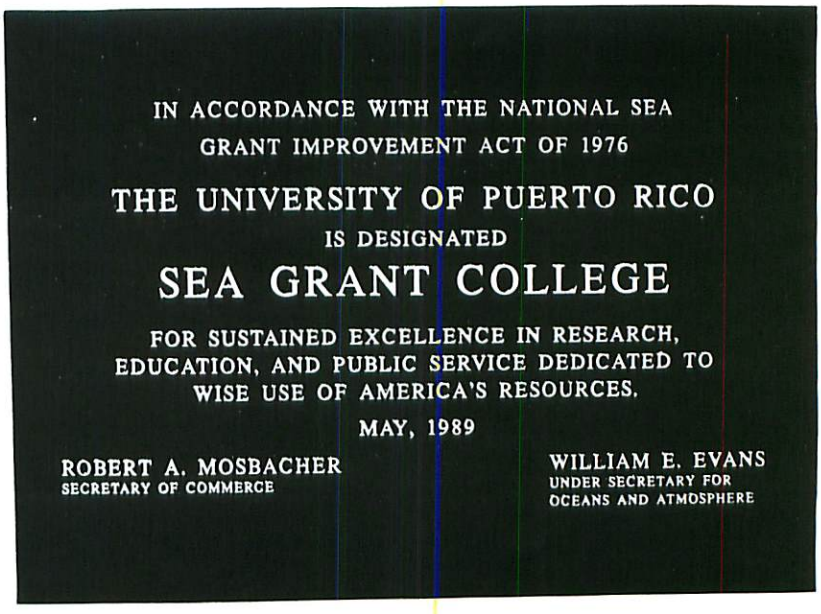
Report



1987–1989

University of Puerto Rico

Sea Grant College Program



Sea Grant College Program

University of Puerto Rico

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All text reviewed by principal investigators.

From the Director

Our proudest moment! The photograph above captures the instant in which the bronze plaque designating the University of Puerto Rico as the nation's 25th Sea Grant College Program was presented to our director by Dr. John Knauss, subsecretary of Commerce and director of the National Oceanic and Atmospheric Administration (NOAA), Dr. Ned Ostenso, former director of the National Sea Grant College Program and the incumbent director of Sea Grant, Dr. Robert Wildman. The fact that these three highly esteemed friends of our program presided over this award presentation made the ceremony especially meaningful. Mrs. Inés Arandes de Morales, widow of Dr. Arturo Morales Carrión, accompanied us. The ceremony was dedicated to Dr. Morales Carrión, former president of the University of Puerto Rico and past member of the National Sea Grant College Panel. He was the person responsible for bringing Sea Grant to our University.

The significance of, and the commitments and responsibilities represented by our designation as a Sea Grant College Program are well understood by our colleagues in the Network and especially in the National Office. However, going beyond the requirements of the NSGCPO, we would like to inform as well, our constituents, users and collaborators, including all those who benefit from our services, products, activities and research results. After all, our program is accountable to our constituents, partners and collaborators (agencies and industry) as well as to our supervisors and administrators.

Thus, for the benefit of our general readership, I am pleased to describe the significance of our

program's designation as a Sea Grant College. Being a Sea Grant College means stronger commitments and responsibilities. According to the Federal Register 75055 of December 18, 1979, in order to preserve the status of "College," our program must continue to act in accordance with the following standards and objectives:

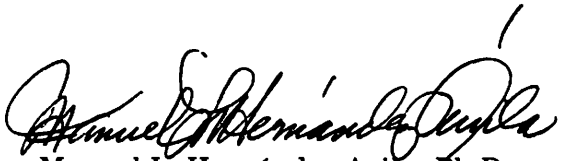
- Pursue excellence and high performance in marine research, education, training and advisory services;
- Provide leadership in marine activities, including coordinated planning and cooperative work with regional and federal agencies, other Sea Grant Programs and universities not affiliated with Sea Grant;
- Maintain an effective framework for the management and application of institutional resources toward the achievement of Sea Grant objectives;
- Develop and implement long-term plans for research, education, training and advisory services consistent with Sea Grant goals and objectives;
- Advocate and further the Sea Grant concept and the full development of its potential within the institution and the state;
- Provide adequate and stable matching financial support for the program from non-federal sources;
- Establish and operate an effective system for controlling the quality of Sea Grant programs.

As I declared to our distinguished guests and friends at the designation ceremony, the University of Puerto Rico Sea Grant College Program is fully committed to the **mission**, **concept** and **mandates** of the National Program. And we are willing and able to maintain the excellence required of a College Program with their continuing support. We are confident that our past performance and achievements exemplify our ability to confront the challenges of the future successfully.

This "Three Years Report," our third officially published, was produced with dedication and loving care by our communicators. It describes the accomplishments of the program during the 1986 to 1990 funding cycles. In hopes of preventing the "scientific isolation syndrome," we have striven to produce a publication which is not only accurate but also amenable for the general public in keeping with Sea Grant's aim to educate, promote awareness, and change attitudes. In this way, we hope to promulgate the concept and mandate of Sea Grant: "To further develop, conserve, protect and wisely utilize the marine resources of our nation."

I hope that this report will not only serve as an official document to fulfill the requirements of the National Office but, most significantly, that it be of benefit and enjoyment to our constituents, our most pressing reason for being.

My most sincere regards,



Manuel L. Hernández Avila, Ph.D.
Director

Introduction

The University of Puerto Rico Sea Grant College Program serves the Spanish and English speaking Americas through a multi-faceted program anchored in Puerto Rico and the U.S. Virgin Islands.

Our primary commitments are to scientific investigation that makes a difference in people's lives, community service based on scientific discoveries and the implementation of new technologies, and public education...both as to the value of our marine resources and the wise development of these resources.

Although one of the smallest programs throughout the national program, Puerto Rico Sea Grant's expertise and flexibility take us from international conferences on queen conch and technology transfer in Venezuela to seminars on the problems and management issues concerning the Mediterranean Sea in Italy, from agricultural fairs on the island of St. Thomas to conferences on ecotourism in Belize, from symposia on the development of environmental impact statements for the ocean and marinas in Trinidad and Tobago to planning meetings for student and curriculum exchange programs in Spain.

Our **investigative studies** range from the causes of ciguatera poisoning to the construction of artificial reefs as a means of compensating for environmental changes in tropical marine environments. Studies of our disappearing fisheries are complemented by groundbreaking work in aquaculture. We've designed life saving prognostication and evacuation plans in case of hurricanes and other natural disasters, and we've shown how coastal development has affected our reef communities.

Marine advisors in the fields of aquaculture, Caribbean fisheries and coastal recreation work actively with our universities, fishing, agricultural and business communities to inform about and make improved technologies readily accessible. We have helped to define a Caribbean fisheries economy through studies of the socioeconomic problems faced by traditional as well as new, recreational fishermen.

Our **marine education** team offers workshops to hundreds of school teachers a year. As a result, down the line, thousands of school children are taken on supervised field trips, where they learn about our marine resources first hand. On an island in which everyone lives within eighteen miles of the coast, these youths begin at an early age to consider marine and coastal resources from biological, aesthetic and economic perspectives.

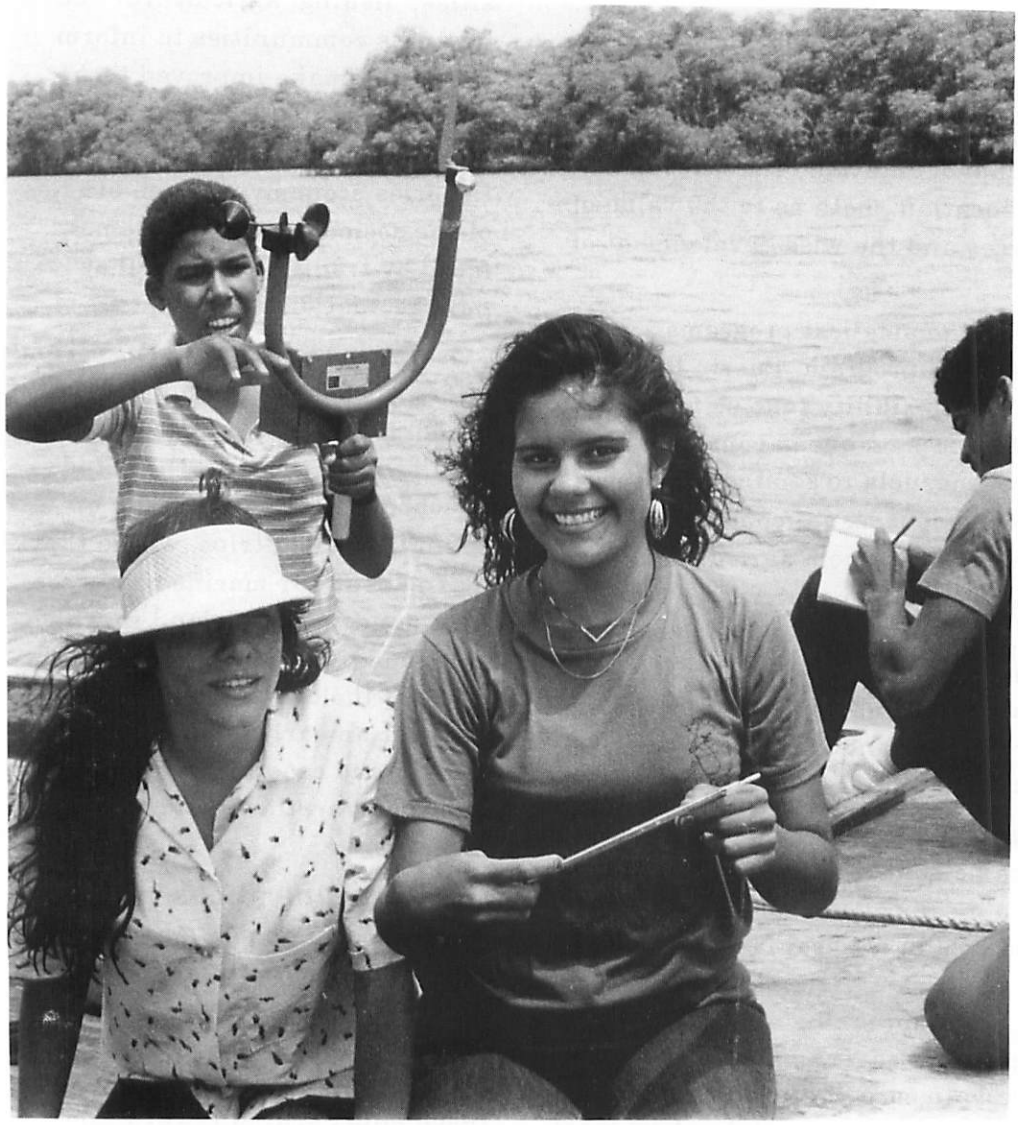
Communications is at the vanguard of Spanish language marine publications with the coastal issues magazine *Boletín Marino* and our one-to-four-page *Datos Marinos*. An active outreach effort geared toward community service is visible at places

ranging from local festivals and fairs to natural history museums; an up-to-date publications and video library meets the needs of myriad and varied users.

Are we making a difference? If the response to our newsletter, **Sea Grant in the Caribbean** is an indicator, we are creating much-needed and highly fertile links between the U.S. and all of the Caribbean and South America.

This, our third comprehensive report, demonstrates our commitment to the actualization of the goals and philosophies guiding our National Sea Grant Program. It shows how we have created a unified, highly competitive, bilingual program. All this on one of the lowest national budgets!

We sincerely hope you enjoy reading about our work in the fields of scientific investigation, management, public education and community service. For it is our work, after all, that reveals the power of our commitment.



Marine Advisory Services

In Puerto Rico and the U.S. Virgin Islands

What do fishermen, municipal planners, beach goers, seafood consumers, research scientists and school children have in common? All actively participate in our Marine Advisory Services (MAS) projects, ranging from ciguatera poisoning workshops to beach cleanups.

Our commitment? To increase the productivity of our marine resources, to help people recognize the value of these resources, and to improve the quality of life for marine resource users.

Throughout the Caribbean, the same growth which has accompanied rapid coastal development has also heightened the potential for environmental degradation and user conflict. Meanwhile, growing resident and visitor populations demand more recreation facilities, better beach access, greater harvests of marine products, and more waste disposal sites.

In Puerto Rico and the U.S. Virgin Islands, our bilingual MAS advisors link appropriate coastal development with scientific research and the wise use of marine resources. We have contributed to marine education, coastal resource management, regional anthropology and marine recreation, while encouraging the adoption and implementation of new technologies in commercial and recreational fishing, aquaculture and seafood technology.

Our outreach work takes the form of educational video productions, posters, publications, seminars, radio and TV presentations, and lots of people talking with people.

Our Fisheries:
Support and Management

About 90% of all Puerto Rican fishing vessels are under 21 feet long. Almost all of these are made of wood and utilize small (under 40 horsepower) motors. Using a variety of home-crafted nets, traps and hand lines for casting and trolling, Puerto Rican fishermen practice their trade in mangrove forests and coves, reef areas, marine grassbeds and the rocky bottoms of coastal waters. Those who challenge the open sea capture pelagic species like tuna and dolphinfish. Our traditional fishermen compete for access and space with the recreation and tourism industries, and struggle to maintain their trade within an economy that promotes rapid modernization.

Anthropological research carried out by UPR MAS investigators has revealed the socioeconomic backgrounds, problems, needs and goals of our artisanal fishermen. This work has helped us to inform and collaborate with the Caribbean Fishery Management Council, the National Marine Fisheries Service and the Department of Natural Resources in the development of **regional fisheries management, conflict mitigation** and **public education.** UPR MAS is a leader in the distribution and application of social science research findings.

For example, during 1988-89, MAS agents assisted the Caribbean Fishery Management Council in drafting the Queen Conch Management Plan. The Council utilized several findings presented in our study entitled **A Socio-economic Profile of the Divers of Puerto Rico and the U.S. Virgin Islands.**

Our marine advisors also acted as mitigators in a conflict between local fishermen and NOAA's enforcement agent in Puerto Rico. Thanks to a series of meetings held to clarify the new billfish regulations, the controversy was resolved and one of our advisors was named "member ad honorem" of the Puerto Rico Fishermen's Congress.

UPR MAS has developed and distributed information designed to improve fishing vessel safety, navigation skills and fishing gear. The results? Increased harvests of underutilized species, reduced fishing costs, and increased profits for Puerto Rican fishermen.

Fishing Gear and Technology Upgrade

Our Spanish-language booklet entitled **Advantages of Using New Materials in the Construction of Fish Traps** promotes lower production costs while contributing to the growth of reef biomass and the "saving" of small fish– representative of future fisheries– through the use of a bigger mesh size that complies with National Marine Fisheries Service and Caribbean Fishery Management Council recommendations. The booklet recommends the use of durable, vinyl-coated wire for trap walls. Biodegradable materials are recommended for trap doors as a means of preventing "ghost fishing" (the continued intake of fish in abandoned traps). Fishermen's acceptance of these technologies represents economic benefits as well as resource conservation.

Fish Handling

Puerto Ricans are avid seafood consumers, but about 95% of the fish consumed on the island is imported. To make matters worse, improper handling of fish at different processing stages has been a major problem in Puerto Rican fisheries. During 1987-89, UPR MAS –in collaboration with CODREMAR- organized eleven workshops on fish handling and preparation for fishermen's associations.

On an informal basis, MAS advisors have taught simple fish handling techniques that can be implemented with only minor investments of time and money. Our **booklets and video** on artisanal tuna fishing and handling are currently used to supplement workshop materials.

Promotion of Underutilized Species

Schools of tuna are abundant in the waters of Puerto Rico several months of the year; but despite canned tuna's popularity in Puerto Rico, in 1986 the fresh product was practically unknown to consumers. Resident and transient shark represented another underdeveloped fisheries resource. During 1987-89 MAS agents introduced consumers and food professionals to both fresh tuna and shark, increasing the demand for both fish while assisting fishermen, fish vendors and supermarkets with marketing.

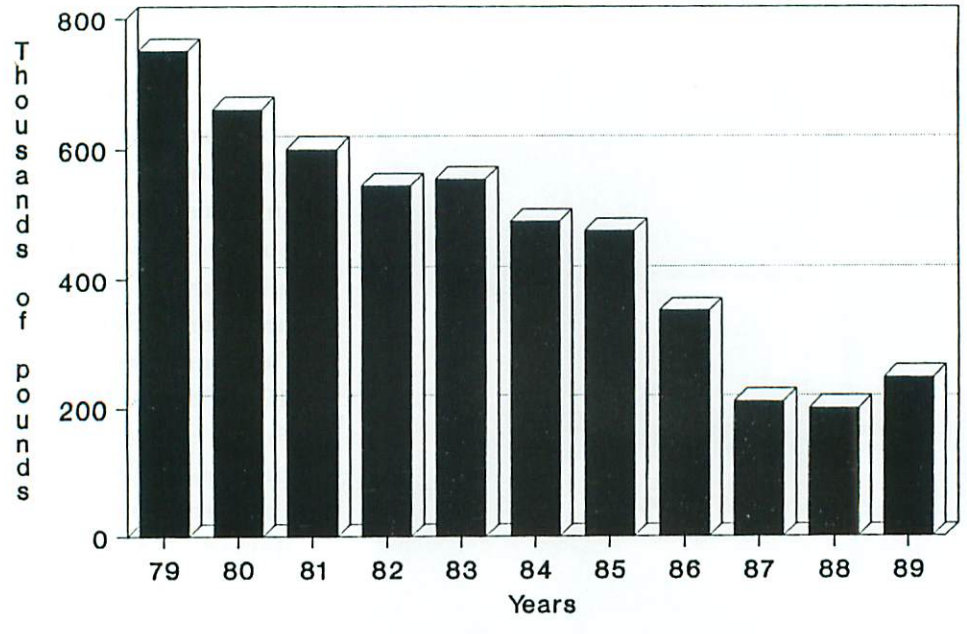
Besides island-wide radio and TV coverage that reached nearly 80,000 consumers, during 1987-89 more than 3,000 people had fresh tuna for the first time at workshops and fish tastings conducted by UPR Sea Grant marine advisors at supermarkets, malls, and community festivals. More than 6,000 copies of our Spanish language cookbook, **Fresh Tuna Recipes,** were distributed at these activities, and by mail.

As a result of our efforts, several supermarkets and fishing centers are using and disseminating our publications as part of their marketing strategies, and three local supermarket chains began marketing fresh tuna and shark for the first time. Our work has had a positive impact on market conditions, consumption levels, and profits. **Note:** Both tuna and shark are captured by fishermen using traditional methods, which in no way threaten dolphins.

Fisheries in Crisis

During our 1987 **Fisheries in Crisis** conference held in St. Thomas, USVI, scientists and fishermen exchanged information and perspectives on problems facing Caribbean fisheries. Recommendations were made to government agencies, and the proceedings were published and distributed throughout the Caribbean Basin.

Total Fish & Shellfish Landings (in pounds) in Puerto Rico from 1979-1989



Courtesy of the DNR Fisheries Research Laboratory

Coastal Community Development

During 1987-89, 33,800 people attended cultural festivals and marine sport contests sponsored or co-sponsored by UPR Sea Grant!

Throughout the year, coastal communities of Puerto Rico participate in hands-on activities, lectures and workshops on coastal planning, development, resource utilization and safety. We have involved people in projects ranging from marine access improvement to marine resource conservation.

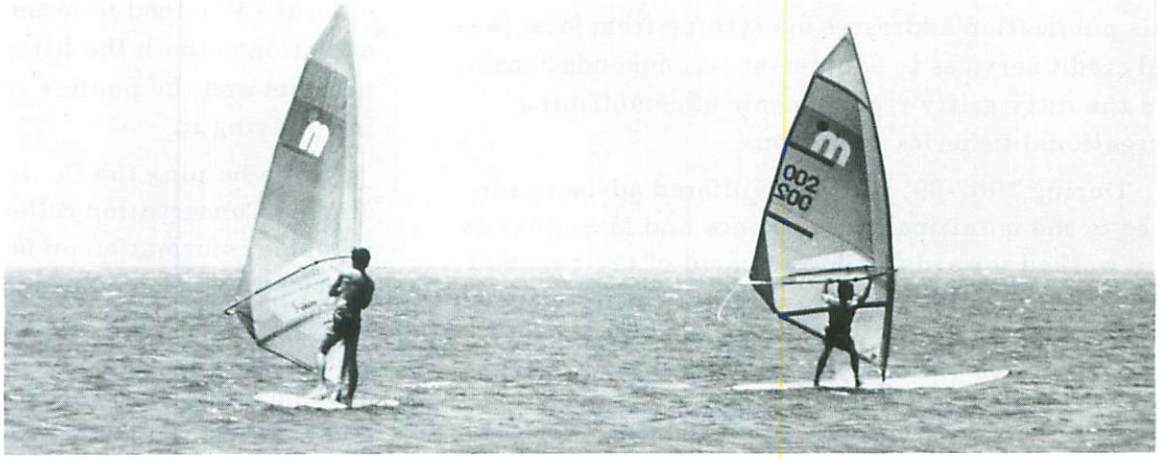
During 1987-89, our marine advisors held symposia such as **Environmental Considerations in the Development of Municipal Coastal Projects** and **Perspectives in the Use of the Coast and Marine Resources**.

MAS personnel also developed a publication on the problems of beach access, gentrification and development in the coastal zones of Puerto Rico with an eye toward renovation of these areas. This pamphlet was distributed to all coastal municipalities; as a result, representatives of five such towns contacted us to ask for advice on various coastal development projects.

Marine Recreation and Coastal Tourism

New tourism-related businesses and second homes, frequent seafood festivals, and the growing popularity of sports such as surfing, wind surfing, boating and scuba diving all attest to the importance of our coastal areas, where more and more people are competing for space and facilities. As part of marine recreation development, we have identified access and service needs as well as resource deficiencies.

In 1987, UPR MAS undertook a systematic study of our marine recreational fishing communities. This study identified patterns of entry and expansion within the marine recreational fisheries industry, the needs of tourists and native recreational fishermen,



fishing stocks, seasonal schedules of fishermen, and the industry's economic resources.

During our ensuing **Marine Resources and Applied Social Sciences** seminar, MAS advisors, marine scientists and anthropologists presented plans for resource management within a socio-cultural context.

The data base generated by our research, including a full inventory of facilities and operations, has helped to enhance the potential of Puerto Rico and the U.S. Virgin Islands as tourist destinations, while **improving sources of income and employment** among small-scale producers in the islands.

In addition, MAS personnel collaborated with the Institute for Coastal and Marine Resources from the University of East Carolina to produce a bilingual pamphlet entitled **Opportunities for Commercial Fishermen in the Marine Recreational Industry.** This publication addresses everything from local laws and credit services to equipment recommendations and the nitty-gritty requirements of establishing recreational fisheries operations.

During 1987-89, UPR MAS offered advisory services to the municipalities of Ponce and Mayagüez as they worked toward the development of their coastal areas. Two ensuing projects included the development of Ponce's port and the revitalization of Mayagüez's waterfront. We also offered advisory services to the coastal townships of Rincón, Cabo Rojo and Guayanilla on erosion control and recreational development.

Beach Protection and Conservation

Puerto Rican beaches, plagued with user pressure and use conflict, are both the magnetic force of our tourism industry and the depository of ever-present debris, which local beachgoers are accepting as a "natural" part of the beach scene.

UPR MAS' **Adopt a Beach** program offers a certificate of adoption, posters, orientation, data cards and beach cleanup support. During 1987-89, twelve beaches were adopted around the island, and up to four beach cleanups were completed at each. Over 500 participants volunteered their time for cleaner beaches and documented the quantity and types of trash collected.

The Department of Natural Resources, the Container Recycling Corporation, the town of Cabo Rojo and local musicians joined with us to celebrate and promote the program, and the participation of local TV helped to focus attention on both the litter problem and the public's role in resolving it.

While helping the Center for Marine Conservation collect valuable information on beach debris, we've also helped policy makers to solve this international problem. Puerto Ricans have begun to rid our coasts and beaches of unsightly...and deadly trash.

During 1987-89, the Department of Natural Resources, TV and radio broadcasts, municipal governments and volunteers from civic and social groups contributed to the success of this program, which has since grown to involve multinational corporations and thousands of volunteers island wide.

Community Education

Thanks to numerous lectures, booklets, videos and public demonstrations, our MAS program has helped create thousands of sophisticated consumers who know...and want to know more about **seafood's nutritional value**, cholesterol control, Omega-3 fatty acids, and ciguatoxins.

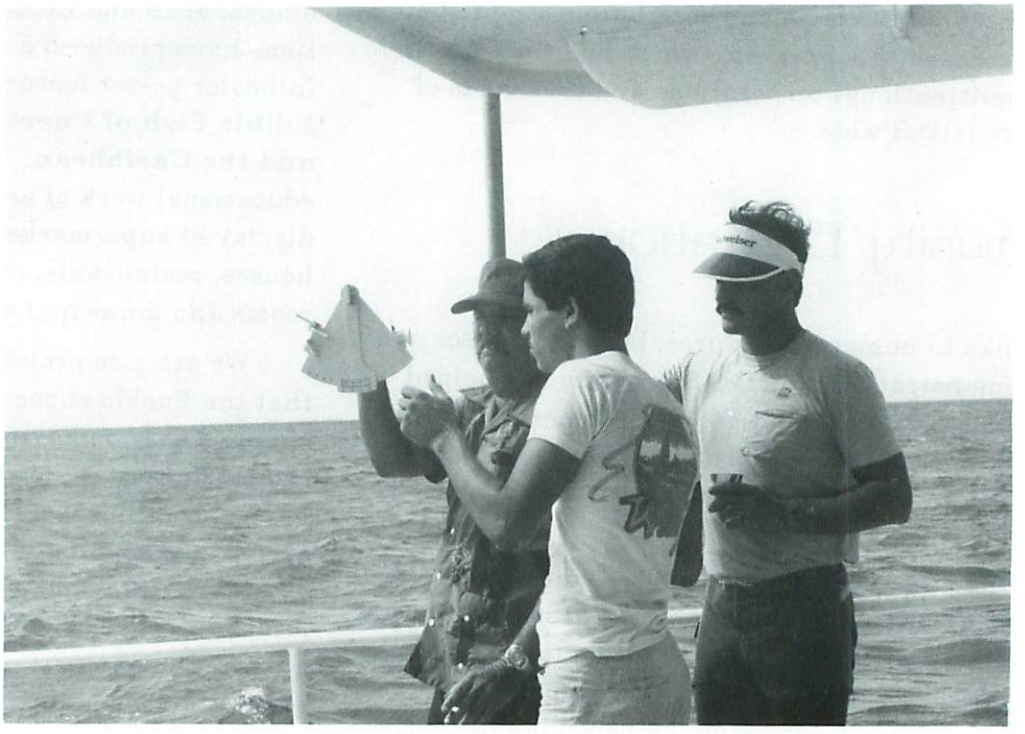
During a recent "ciguatera scare," our agents conducted a series of **workshops on ciguatera poisoning** and its impact on human health and the fishing industry. Besides informing the general public, MAS also helped provide information on poisoning incidences to the University's ciguatera research group and the Department of Health.

In 1987, UPR MAS sponsored the **Western Atlantic Marine Turtle Symposium**. Participants included 250 scientists, educators and environmentalists from the U.S., Central and South America, the Caribbean Basin, Asia, Europe and Australia.

In addition, MAS specialists have provided workshops for fish retailers on identification, handling techniques and marketing of local species. As part of our efforts, MAS and Communications have produced a popular, full-color poster featuring **Edible Fish of Puerto Rico and the Caribbean.** This educational work of art is on display at supermarkets, fish houses, restaurants, classrooms and municipal offices.

We are also proud to say that the Pueblo supermarket chain went from having no clearly-defined seafood area to having a well-developed and separate **seafood service counter** with emphasis on local species. This success story reflects important changes in attitude and policy, which benefit many levels of Puerto Rican society.

MAS educational projects have been coordinated with other agencies and programs such as CODREMAR and Cooperative Extension Services.



Safety and Navigation

In 1986, three boy scouts drowned in a small boat accident off a Virgin Islands cay. Amidst the shock, islanders identified an urgent need: swimming and boating skills for youth. Virgin Islands Marine Advisory Services joined with the St. Thomas Rotary Club II to organize the Virgin Islands **KATS** program (**Kids and the Sea**). Practice in swimming, navigation, knot tying, boat handling and other skills contribute to the youths' recreational safety and enjoyment, an understanding of the sea that surrounds them and, eventually perhaps, the pursuit of marine related careers.

A series of popular articles published in our bimonthly **Boletín Marino** presented information on topics ranging from **Safety Tips for Using Outboard Motors at High Speeds** to **Drugs and Diving**.

During 1987-89, marine advisors offered a series of workshops on diving safety at various fishermen's villages, emphasizing the use of diving tables. These workshops, which helped to develop a lively rapport with fishermen from various geographic zones of the island, dealt with both the physical ravages of poor diving habits, such as embolism and the bends, and the socioeconomic realities of the fishermen who risk their lives in order to put food on the table for their families.

Our marine advisors also joined with the Dock Workers' Union and CODREMAR to offer a course on navigation and safety to fishermen throughout the island. In collaboration with the Coast Guard Auxiliary, MAS agents use both **radio and television** spots to educate the public about diverse safety and navigation issues.

Aquaculture

Aquaculture has an excellent future in Puerto Rico, where it promises to increase local production of fish, and thus decrease our dependence on foreign imports. Since 1982, MAS and the UPR Cooperative Extension Service have offered technical assistance to hundreds of farmers, merchants and agricultural extension agents involved in developing or improving aquaculture farms in both fresh and salt water settings. MAS advisors have also collaborated with the Department of Natural Resources and a vast array of island residents in preparing and seeding fish ponds for recreational purposes.

Our Spanish-language publication **Aquaculture: Technical Facts for Development** includes information about tilapia and fresh water shrimp production, water quality, multiculture, and pond vegetation management. Our free **Tilapia Cookbook** and information on tilapia's nutritional value have been well received at public presentations ranging from supermarket "tilapia tastings" to monthly open house tours at our experimental aquaculture station.

During 1987-89, nearly 5,000 people had the opportunity of tasting tilapia, most of them for the first time. Cooking demonstrations were given along with recipes, information and exhibits on aquaculture farming techniques.

As a result of our–and Cooperative Extension Service's– efforts, Puerto Rico's largest supermarket chain has also included tilapia in their promotional and marketing strategies.

We have collaborated with Cooperative Extension Service and the Department of Natural Resources in the preparation and seeding of fish ponds for recreational purposes, and our advisors offer consultations on technology transfer as a means of helping farmers to change and improve their practices.

Marine Camp for Youth

Between 1977 and 1988, more than three hundred high school students learned to appreciate, preserve and protect our precious marine resources through participation in Cajaya marine camp.

Through participation in Cajaya, students learn about mangrove ecology, coastal processes, the marine recreation industry, resource utilization, principles of navigation, and coastal geology. In the process they also become **leaders and environmental spokespersons,** sharing what they've learned in their schools and communities.

The following was translated from an essay by high school student and Cajaya camper Roberto Colón Cruz of Ceiba, Puerto Rico:

The mangroves help to preserve marine life. They are a natural refuge, within which a myriad of birds, fish and other organisms are born, grow and develop. The mangroves form a natural wall which protects our coasts from erosion. These environmental cleansers, a gift from Nature, make our lives more pleasant and much healthier.

My hands cradle the leaves as I
sizzle in the heat, bask in the shade,
lost within the labyrinth
of interlacing roots and trunks, shoots and seeds.

Deep within, surrounded,
I see with my eyes and my feelings far beyond.

Within the mangrove forest I see with my heart.

Research

At the University of Puerto Rico, our research program is guided by one simple principle. The projects we undertake must be meaningful and beneficial to the population we serve. That is, they must have practical applications.

Focusing always on the critical issues which offer the greatest benefits in the shortest length of time, the research endeavors funded for 1987-89 as described in the following pages are directed toward:

- enhancing the productivity of living marine resources systems,
- raising awareness of activities which threaten these systems,
- supporting the economical feasibility of traditional fisheries,
- protecting consumers from phenomena ranging from contaminants in the marine environment to natural disasters.

Just as there are no real territorial barriers underwater, the benefits of our work are long-ranging and applicable to the entire tropical and subtropical region. In this way, UPR Sea Grant extends the scope of the National Sea Grant Program, and creates international links throughout the Americas, the Caribbean, and beyond.

Sedimentation:
Threat to the Coral Reefs

"A reef off Guayanilla looked pretty darned good just five years ago, and now it's dead. Why? Sedimentation's why. Thanks to everything from dredging and shipping traffic that stirs up the bottom to land erosion caused by the stripping of vegetation in order to make way for construction. The scary thing is how fast it can happen!"

Jack Morelock, Ph.D.

Coral reefs are among the Caribbean region's most important ecological and economic resources. Besides offering shelter for diverse communities of fish and other harvestable marine life, coral reefs offer adventures in marine recreation, are irreplaceable sources of biological information, and mitigate wave-caused coastal erosion and flooding.

But these unique and highly productive members of the animal kingdom are like desert flowers, specially adapted to a specific environment, and thus very sensitive to environmental conditions.

Sedimentation is a serious threat to our coral communities for the following reasons:

1) Since the process of photosyntnesis is essential to the life of a coral community, corals depend upon clear waters, admitting plenty of light. Sedimentation interferes with light, and thus reduces the depth at which corals may grow.

2) The high nutrient levels in terrigenous sediment (often "nourished" by fertilizer runoffs) feed competing life forms such as algae, which tend to grow upon the coral skeletons. This growth impedes coral colonization.

3) Colonization is also halted by sedimentation on the marine floor, since corals seek hard rock surfaces, and sediment covering this floor serves as the preferred home for competing organisms.

4) Terrigenous sediment also erodes or "scours" the coral.

5) Since corals are sessile and can not actively hunt for food, they eat algae, plancton and other substances found in their surroundings. In their struggle to nourish themselves, they ingest sediment, and must then purge themselves; this exhausting process takes the place of basic alimentary activity, and thus "starves" the coral.

During the 15 years in which the University of Puerto Rico's marine biologists have actively observed coral reefs, human activities such as dredging and sand mining have increased, and so has coastal erosion. At the same time, our valuable coral reef population has decreased notably...and rapidly. Ironically however, current water quality standards do not recognize terrigenous sediment load as a pollutant.

In order to define the effects of sediment stress and contribute toward the development of water quality limits that would protect reef areas, marine geologist Jack Morelock, Ph.D. and marine biologist Lucy Williams, Ph.D. carried out a two-year investigative study of corals in relationship to sedimentation. Specific objectives were to:

1) relate coral cover and character to the amount of terrigenous sediment influx in the environment,
2) determine the amount of sediment that the reef system can tolerate,
3) describe changes that occur in the coral reef zones in response to sediment levels,
4) determine the different effects of chronic and episodic sedimentation on coral reef systems,
5) determine variation in resistance to sediment loading by different species of coral in the field,
6) refine and use a rapid and practical technique for reef survey and data reduction.

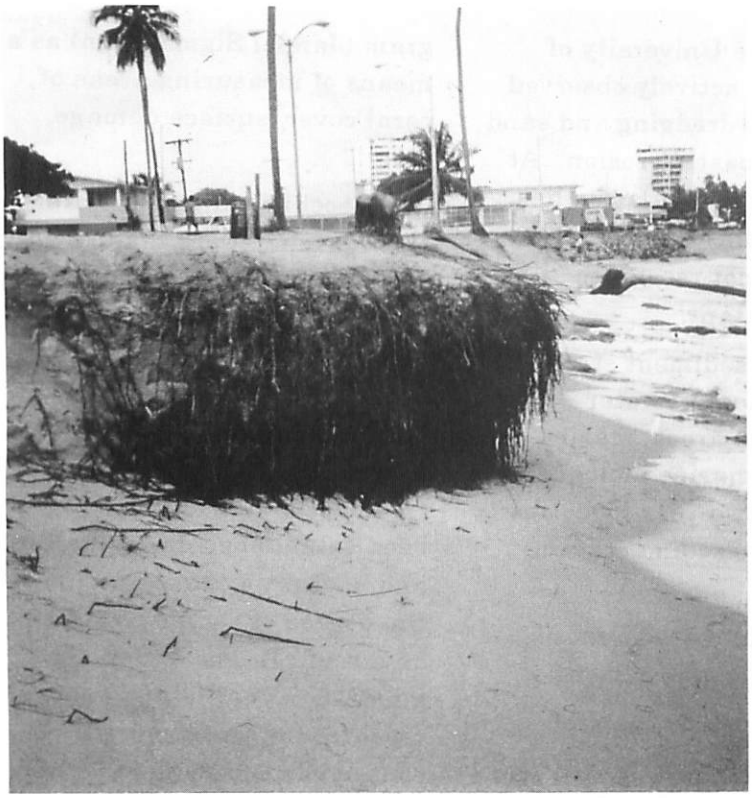
The techniques used by the research team, composed of Morelock and Williams represent a rapid and practical technique for reef survey. A total of 68 individual surveys were made on 24 reefs. Each survey involved taking 18 photos, which when placed together, show a transect of an area measuring 12.6 m^2 at a constant depth. (Reef depth ranged from 5m to 30m.) All together, 1,224 photographs were obtained for analysis of coral cover.

These photographic surveys allowed the research team to measure coral cover for 30 species, and to determine the number of species, species-percentage of total cover, number of colonies, and average colony size for each transect. In addition to the photographic transects, the researchers used – and validated the use of– a new underwater video camera/computer analysis program (Jandel Sigma-Scan) as a means of measuring areas of coral cover, surface damage, etc.

Secchi readings of water transparency were taken at all sites during the field work. On reef transects at Mayagüez, Parguera, Guayanilla, Ponce and Jobos, sediments were collected and later analyzed for grain size and percent of terrigenous sediment. This has been established as a reliable and useful way to characterize the degree of sediment stress on a reef. In Mayagüez, Parguera, Guayanilla and Jobos, researchers also analyzed percent of carbonate (denoting sea-based skeletal material as opposed to terrigenous sediment).

Through both sediment trap collection and analysis of sediments deposited on the reef front, Morelock and Williams were able to establish definite, quantitative relationships between the amount of terrigenous sediment influx and the coral cover.

For example, in Peñuelas at the site of a healthy reef, a Secchi disk monitored visibility at 8-12 meters, and the sediment trap measured 2-3 mg of (large-grain) sediment per cm^2 per day. Total cover was 21% at 15 meters of depth, and 33% at 20 meters. In Guayanilla, at the site of a nearly dead reef, the Secchi disk read visibility at only 5 meters, the trap measured 12-15 mg per cm^2 of very fine-grain sediment



daily (fine-grained sediment penetrates the reef where sand grains don't, and so is even more dangerous to the coral). Cover at 15 meters measured 3%, and only .50% at 20 meters of depth.

This study also established a pattern of zonation changes related to sediment influx. The most obvious change was a compression of the total coral reef front because of reduced light conditions. For example, the total range of living coral on the reef front at Parguera is about 80 meters, and this is reduced to 12 meters in the most severely affected areas.

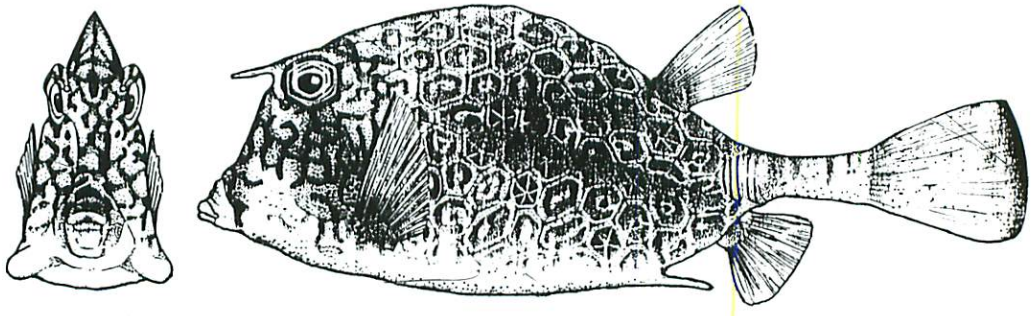
Data from Guayanilla, which experiences chronic stress, and from Mayagüez, which experiences episodic stress, show a definite difference in the amount of sediment influx and its effect on the coral reef. Even though the sediment trap measured 15-20 mg of sand per cm^2 in Mayagüez, at 5 meters there was 17% coral cover, and 7% at 10 meters. In Guayanilla, the trap measured only 12-15 mg sand per cm^2; yet at 5 meters there was only 7% coral cover, and at 10 meters, only 3%. This is just one example of the evidence showing a difference in the effects of chronic and episodic stress on the coral reef system.

Differences among species of coral in response to sediment were very marked. *Acropora palmata* and *Montastrea annularis* were especially susceptible to sediment stress, whereas *A. agaricites* and *M.cavernosa,* among others, were quite tolerant. However, a combination of greater depth and sediment stress resulted in reduced cover by all coral as depth limits of adequate light for coral growth were pushed upward. This study also showed changes in species abundance due to long periods of sediment stress.

Data analysis was eased and greatly improved (compared with previous studies) by the use of a microcomputer, which allowed rapid evaluation of a large number of photographs. A digitizer pad and the Jandel Sigma Scan program greatly reduced the time required to analyze each photograph. This allowed for much more photo coverage than previously attempted.

In summary, Morelock and Williams were able to establish strong correlations between sediment influx and reef condition. In addition, the reef survey technique they developed may serve as an efficient model for agencies such as the Department of Natural Resources, the Parks Service and the Caribbean Fishery Management Council as well as for amateurs interested in the survival of our coral reefs.

Helping to Save the Disappearing Cowfish



The bottom-dwelling cowfish (also known as trunkfish) is uniquely adapted –and armed– for survival. Instead of the supple, scaly surface that covers most fish, the cowfish is protected by a hard, box-like carapace made of a mosaic of bony scales. And when threatened, the cowfish secretes a toxic mucus from its mouth and body surface. This solitary creature is so territorial that the placement of two cowfish in an aquarium together will frequently cause enough stress to trigger the poisonous secretions that will most likely kill both.

The slow-moving cowfish is usually hard to spot. Its dull colors help it to blend in with its surroundings, which are usually shallow coral and grassy ocean areas. But during spawning season, a lucky observer may spot a male darting madly about, flashing his electric blue flanks in hopes of alluring a slightly larger, seemingly indifferent female.

Four species of cowfish are commonly found around Puerto Rico, and all are highly esteemed as food. With carapace still intact, the tail is traditionally yanked away from the body, yielding a tasty portion of the cowfish's back muscles. The yanked tail looks something like a chicken leg, and indeed, local fishermen call this delicacy *"muslo de pollo"* because of its shape and delicate flavor, very much like the dark meat of chicken.

Perhaps because of their mucus engendering fame, these fish are rarely eaten anywhere outside of Puerto Rico, where they are the fish of choice for many islanders. In fact, official surveys probably underestimate the quantities of captured cowfish because fishermen often prefer to keep this prize for family consumption rather than sell it. Cowfish or *chapín* turnovers are the pride of Puerto Rico's

beach-side kiosks, and a sure source of coastal income. Their carapaces are also used in making jewelry and other native crafts.

According to the Fisheries Research Laboratory of the Department of Natural Resources, since the late 1970s the cowfish population in Puerto Rico has gradually declined. As a result, many *"chapín"* turnovers are stuffed with the more common trigger fish. The cowfish, an economic and cultural resource, is in danger.

Very little is known about these unusual organisms, endowed by nature with so much protection. For instance, science has yet to learn about their life span, and no studies have been made of the reproductive habits of Caribbean cowfish. In hopes of discovering an explanation for the declining cowfish population, the DNR's Fishery Research Lab director Yvonne Sadovy, Ph.D. studied the reproductive biology of two species: *Acanthostracion polygonius* or honeycomb cowfish, and *A. quadricornis,* the scrawled cowfish.

Specifically, research goals were to establish:

1) the annual reproductive cycle and the length of the spawning season,

2) size at sexual maturation,

3) size at first capture by commercial fisheries,

4) the relationship between female size and fecundity.

In order to do this, ovaries and testes were collected each month throughout the year, preserved, embedded in paraffin, sectioned thinly, stained and then examined to establish stages of sexual maturation of the gonadal tissues of both males and females. Microscopical analysis of this material revealed that spawning occurs within a six month period, between December and June, with most occurring during February, March and April of each year.

Through measurements and counts of ripe eggs, or oocytes, it could also be determined that females produce multiple spawns in a single season and that females measuring about 235 mm carapace length (CL) produce about 10,000 eggs per year, eight times as many as the smallest females taken by fishermen.

In Puerto Rico these fish are captured by arrowhead fish traps up to a size of about 235 mm CL. Thanks to investigations in the field, using data from fishermen and from the DNR's own fishing centers, Dr. Sadovy and her research team found that cowfish with a carapace length of only 100 mm are being trapped and recruited into commercial fisheries. This is important data, because both species were determined to reach sexual maturity at approximately 120 mm CL. Thus, cowfish are being captured before having a chance to reproduce. This explains, at least in part, the cowfish population's gradual decline.

Data from this study will be used in preparing management recommendations for cowfish species by both the Fisheries Research Laboratory and the Caribbean Fishery Management Council. This investigation constitutes the first comprehensive histological study of the reproductive biology of the family Ostraciidae, and is one of only few that have been carried out on species of the order Tetraodontiformes.

As a bonus, during this investigation, the research team unexpectedly found that the cowfish's urinary bladder has a twin lobed structure rather than the usual single sac-like configuration. It may be found that the twin lobed bladder occurs exclusively in the Ostraciidae family. Further research plans include a survey of 16 species from 11 genera of the Tetraodontiform order.

Hurricanes...and Life Saving Missions

Compare the coastal profiles of Puerto Rico and North Carolina.

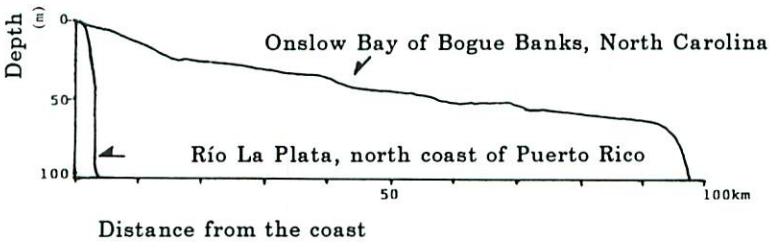


Figure 1

According to the National Oceanic and Atmospheric Administration (NOAA), if the amount of wind energy released in just one day of a hurricane's life were converted to electricity, it would be sufficient to meet the energy needs of the entire United States for more than six months! But the most destructive force generated by a hurricane is not wind, directly, but water, rising in the form of waves and still water elevation or "storm surge." Caused by winds and low pressure, the storm surge may measure up to 50 miles wide.

Along U.S. mainland coasts, a hurricane-generated storm surge may rise 18 or 20 feet. On Caribbean islands, while still water elevation is less of a concern, waves caused by high winds are extremely hazardous. That's because the island shores are not protected by gently-sloping continental shelves. As a result, waves crash in from the ocean, undiminished. (See figures 1 & 2.)

Aurelio Mercado, M.S., assistant professor at UPR's Department of Marine Sciences at Mayagüez worked toward the prognostication of wave activity during hurricanes based upon both the characteristics of the hurricane as well as bathymetric and topographic data. This information, which has already been provided to the Federal Emergency Management Agency (FEMA) and the Planning Board of Puerto Rico, may be used to create accurate and efficient evacuation models for communities. While helping to save lives, that same information will help guide engineers and architects involved in coastal construction and preservation, while aiding insurance companies to develop policies which are both fair and realistic.

Evacuation plans, as well as construction and insurance guidelines, are based on calculations made by a special computer program called SLOSH (Sea, Land and Overland Surge from Hurricanes) designed by NOAA. The SLOSH program solves equations based on data such as the hurricane's size, position and eye pressure, as well as details including the size and location of coral reefs, vegetation, raised highways, rivers, and other factors which might act as barriers to or passageways for surging waters. Scientists

use the results, plus knowledge about astronomical tides, to chart the storm surge's expected path of movement and predict to what point rising waters will penetrate at different points along the coastline.

The SLOSH model has been used for nearly 15 years to design evacuation plans for the U.S. eastern seaboard's floodable basins. However, SLOSH, originally developed for the mainland, does not take wave action –which is so important on the Caribbean islands– into account. Sea Grant has taken up the slack by funding a model program for the Caribbean designed to complement SLOSH's predictive ability.

First, Mercado took a special SLOSH model training course so that storm surge simulations could be made at the University. NOAA approved of the plan, making UPR's Mayagüez campus the only SLOSH resource center outside of NOAA's mainland laboratories. This allows the Marine Sciences Department at UPR to supply life saving statistics to government agencies throughout the Caribbean.

SLOSH-based evacuation plans have already been made for the metropolitan area. One model reaches from Río La Plata in Dorado to Río Loíza in Loíza Aldea. And even without calculating for wave action, they were used successfully during hurricane Hugo. These plans, organized by severity of the hurricane, (ranging from category 1 to category 5) are accompanied by descriptions of the expected storm surge, detailed maps of the area including descriptions of storm shelters and their suitability or vulnerability, and descriptions of all roadways, both suitable and unsuitable for evacuation purposes.

HURRICANES

category 1	winds	74-95 mph
category 2	winds	96-110 mph
category 3	winds	111-130 mph
category 4	winds	131-155 mph
category 5	winds	155+ mph

A bilingual bulletin also shows at what point –based on the position of the hurricane-- a community should begin to evacuate, and at which point evacuation should be finished, because of threatening high winds.

The current SLOSH model divides any given area into cells of 2 miles^2. Since Puerto Rico's entire San Juan Bay fits within three cells, the current model doesn't offer the degree of detail needed for accurate predictions.

UPR scientists will soon be using a new SLOSH grid with finer resolution. This will help to improve evacuation models for Puerto Rico. The creation of such plans for the entire Caribbean has been endorsed by the Caribbean Meteorological Institute.

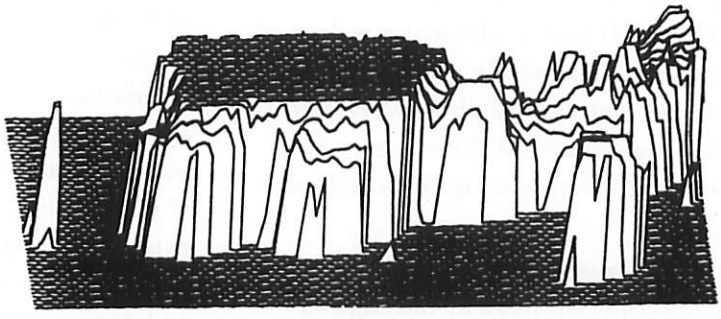
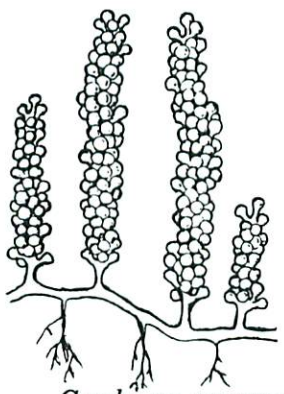


Figure 2

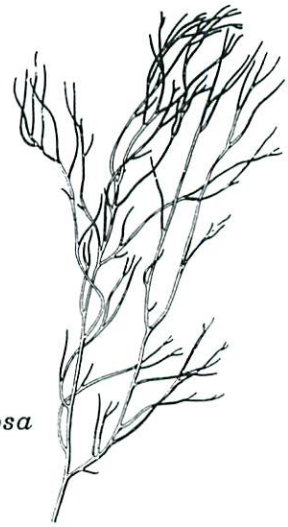
Observe the narrow platform of Puerto Rico as seen from the south. Wavy lines represent the land of Puerto Rico and the ocean floor at a depth of 280 ft.

Seaweed Mariculture
in the U.S. Virgin Islands

Chondria cnicophyla



Caulerpa racemosa



Gracilaria verrucosa

Dictyota divaricata

In the Virgin Islands, coastal development, overharvesting and incorrect harvesting methods have contributed to heavy depletion of *Gracilaria* and other varieties of edible seaweed. Valued as a mineral-rich tonic, these marine plants (popularly known as seamoss) are used in traditional cooking and in popular agar-thickened beverages.

The island of St. Thomas currently imports about seven species of seaweed from Antigua at inflated prices of up to $8.00 per lb.

During 1987-88, marine biologists Gary Owen, Ph.D. and David Ballantine, Ph.D. worked closely with aquaculture specialist John Hargreaves, Ph.D. to investigate the possibilities of developing a small-scale, seaweed mariculture industry in the U.S. Virgin Islands. Besides meeting the local market demand, it was hoped that such an industry would provide part-time occupation for people now involved in artisanal-level fishing, while cutting down on stressful harvesting of wild seaweed stocks.

The scientists' objectives were to:

1) identify local seed stocks of seaweed on the U.S. Virgin Islands,
2) identify coastal regions suitable for commercial-scale seaweed mariculture,
3) establish a pilot cultivation project,
4) evaluate criteria for selecting marine algae and commercially viable cultivation sites.

Resource surveys were made off the islands of St. Croix, St. John and St. Thomas. Several seaweed species including *Hypnea*

musciformis, Dictyota sp., Caulerpa sp., Sargassum sp., Chondria sp., Lobosphora sp. and, most abundantly, *Gracilaria sp.* were identified on each of these islands. However, only on St. Croix did populations reach levels that would support a mariculture program. (These were mostly *Gracilaria,* including the "seamoss" species of *G. cornea.)*

The largest stocks were observed on the southwest and south coast of this island, in undeveloped areas, with narrow, open bay beaches backed by low cliffs.

The pilot mariculture project was designed to:

a) practice and evaluate various methods of propagation, cultivation, harvesting and processing,

b) determine materials appropriate for the construction of cultivation rafts,

c) establish legal precedents and obtain permits for commercial mariculture projects.

One of the goals of the pilot cultivation project was to identify one or more species of seaweed capable of producing yields of 1-2.5 kg. wet weight per meter of seed line (a three-strand plastic rope within which the seaweed is planted) within a six week grow-out period. Initial results over short periods (7-10 days) were extremely positive. Growth rates reached levels comparable to values reported in the "model program" literature for both natural and cultivated *Gracilaria* populations. However, only minor positive growth was recorded after this initial period. In no case was growth over the total period high enough to reach the project's goal.

This was partially because sediment, detritus and epiphytes settling on algal bodies contributed to slower growth and deterioration of the plant. In addition, the rigid growth form of the primary species chosen *(Gracilaria cornea)* seemed to limit the self cleansing that usually occurs in seaweeds. This suggests that a different species, with a greater self-cleansing capacity, would be more productive and thus more profitable in commercial ventures.

Sedimentation, detritus and epiphytes were found on the seaweeds even at low turbidity/moderate energy habitats. Furthermore, when the scientists introduced a screened cage culture method designed to cut down on sediment and epiphyte fouling, they had excellent initial results, but seaweed populations declined, almost uniformly, after the first week to ten days.

This can be partially explained through an understanding of the reproductive behavior of *Gracilaria.* Within one given species, certain plants reproduce sexually (through spore dispersion), and others depend solely on vegetative reproduction (growth and attachment to new surfaces). Those which reproduce sexually tend to lose vigor and eventually die off after reproducing. Therefore, plants that reproduce vegetatively are preferred for propagation. The vegetative propagation method used during the seaweed pilot project involved entwining plant sections within the strands of a three-strand plastic rope suspended in the water as part of the algae cultivation raft.

The cultivation rafts were made after the design of marine biologist Alan Smith, Ph.D., who has run mariculture studies in St. Lucia since 1980. (In 1984, 30 tons of edible seaweed were exported from St. Lucia!) Since bamboo, the material used on St. Lucia is not readily available in St. Croix, rafts were constructed of inexpensive and longer-lasting PVC plastic piping.

Although growth of cultivated seaweeds within the

pilot project did not meet the investigators' expectations, the project was able to accomplish a great deal. Several seamoss species were identified on St. Thomas, St. John and St. Croix, all occurring in abundances that could serve at least as source material for an algae mariculture industry. Using seed material located in the surveys, they were also able to evaluate the commercial mariculture potential of local *Gracilaria* species, while assessing propagation, cultivation, harvesting and processing methods suitable for a low-cost, artisanal seaweed mariculture industry.

Two recommendations made regarding commercial cultivation include: 1) work with other, fast-growing species of seaweed, with a more efficient self-cleansing mechanism, and 2) development on a larger scale, especially in a more sophisticated "mixed mariculture" context, in which detritus obtained from fish cultivation could be used to nourish the algae.

A third recommendation: The process of obtaining local and federal permits for a commercial mariculture industry in the U.S. Virgin Islands takes two full years to complete! The scientists involved in this project strongly suggest the creation of a streamlined licensing procedure, which would take one year or less to complete.

Direct contacts were made with private individuals and legislators, and contributions to local newspapers, helped to make the public aware of the potential for algae mariculture within the Virgin Islands. One local businessman, who specializes in producing traditional foods, cooperated with us during the pilot study, and is interested in presenting an agar-thickened chocolate drink for sale along with his native preserves.

The Seamoss Mariculture Pilot Program initiated what is hoped will be a continuing algae cultivation program within the Aquaculture Group at the USVI Agricultural Experimental Station. This program continues to evaluate algae species and develop cultivation methods for both low technology artisanal industries and larger scale natural product and biomass applications.

Fish Population Assessment

a Step Toward Managing Our Coral Reef Fisheries

The precious coral reefs that support so many fisheries throughout the Caribbean are being overexploited. Through proper management we hope to sustain their longterm viability, promote fishery stability and improve fishermen's economic condition.

Fisheries management is based upon an accurate assessment of fish population status. That is: how many fish are present, how productive they are, how much and what kind of fishing pressure will optimize yield, and how current rates of fishing compare to this optimal level.

Coral reef fisheries are unusually difficult to assess. Artisanal fishermen operate out of individual small boats from many small landing sites. Gear used is variable and highly selective. As a result, the species and size composition of a catch simply does not reflect that of the underlying population.

In order to determine the status of fish populations in coral reefs, many fisheries biologists prefer to sample the resource themselves, rather than rely on catches from fishermen. This way, the scientists can control many aspects of sampling, such as statistical design, area coverage, and type of sampling gear. The rugged, yet fragile topography of the coral habitat prohibits the use of nonselective gears, such as trawl nets, which are dragged along the ocean floor. Selective gear must be used. The challenge is to learn exactly *how* this gear is selective so as to be able to *compensate* for estimates based on selective catches.

The overall goal of this research project was to determine the feasibility of using traps as quantitative sampling devices in reef areas.

As a starting point, Drs. Richard Appeldoorn and Conrad Recksiek chose to repeatedly sample a small number of test sites to determine the species that could be sampled using traps, and to determine how their abundance could best be estimated, and how reliable these estimates would be.

Fish traps, or *nasas*, constitute the principal gear used

in Caribbean coral reefs. Although selective, the same properties that make traps popular for fishing make them good sampling devices. Traps are left in the water to fish unattended, so many can be deployed over a large area, at one time. They are inexpensive and robust, suitable for most bottom types, can be used over the entire depth range of the reef, and the fish samples they provide are usually in good condition for further study. Finally, since traps are the dominant gear used in reef areas, survey results are more readily applicable to the fishery.

In order for fishery scientists to successfully use trap catches to determine the abundance and age composition of fisheries populations, they need to be able to "calibrate" their gear. That is, they must discover the difference between the quantity and age of the fish for each species caught in the trap in relation to the actual population density. Calibration also involves determining which species a trap will catch relative to those present.

The scientists' primary method for calibrating trap catches was to estimate species diversity and abundance using visual census. In this method, divers at each test site:

1) surveyed standard transects (lines 50 m long in areas measuring 4 m on either side of the lines),
2) identified and counted all individuals within the area of the transect, and
3) estimated their respective sizes.

A secondary method of independently estimating abundance was to tag all caught fish and monitor their recapture relative to the capture of new, unmarked individuals.

The investigators' results showed that not all species were amenable to sampling using fish traps. The only species caught in the traps were either reef-related or reef restricted fish such as damselfishes, ocean surgeon, parrotfish, groupers, grunts and squirrelfish. Pelagic and non-reef related demersal fish in the area, such as jacks and porgies were not caught.

One of the problems the investigators faced was that using visual census there were differences in the investigators' ability to estimate the density of diurnal and nocturnal species. For example, squirrelfish were commonly caught in traps, but because they are active at night, they were rarely seen during daytime transect surveys. By the same token, white grunts were frequently caught but rarely seen because their restricted daytime habitat was not covered by any of the transects; yet at night they roamed over the reef and were susceptible to trap capture.

To calibrate traps for estimating abundance it is necessary to have adequate trap catches and good estimates of abundance over a given area. These are used to calculate the calibration factor: the "effective area fished." Effective area fished (EAF) is that area around the trap from which we can assume all individuals of a given species would be caught, while none are assumed to be caught outside this area. In this way, trap catches can be related to area, to give an absolute measure of density, and thus, abundance.

In this limited study, Drs. Appeldoorn and Recksiek concentrated on three abundant species: redband parrotfish, stoplight parrotfish and ocean surgeon. They studied variations in **effective area fished** at the test sites through replicate sampling two years apart. Thanks to the efforts of two graduate students, Alejandro Acosta and Ralph Turingan,

this sampling was continued to presently contain four replicates over a period of three years. During this time the species composition has remained fairly stable, but abundance, both overall and relative between species, has varied markedly.

Estimates of EAF from these samplings have varied between test sites, between species and over time. However, some patterns have emerged. For example, the two species of parrotfish seem to have similar values of EAF. This is advantageous, for it may indicate that we can **group related species** to determine EAF, thus reducing significantly the number of calibrations needed. On the other hand, there appear to be real differences between the habitat characteristics of certain sites. Thus, any survey would need to consider stratifying the area by habitat and calibrating traps for each species-group within each habitat. This increases the number of calibrations needed.

Drs. Appeldoorn and Recksiek had enough estimates for ocean surgeon to be able to examine trends based on abundance. Here the data are sketchy, but there is evidence that the magnitude of **effective area fished** (EAF) may decrease as abundance increases; as the density of fish increases, a relatively smaller proportion are caught. Estimates of EAF seem to quickly stabilize at moderate densities; however, estimates of EAF determined from marginal catches (where fish were rare) would underestimate true fish density when applied to trap catches elsewhere.

Conversely, good estimates of EAF applied to areas of marginal catch would result in an overestimate of abundance in those areas. Overall though, the degree of variability between estimates of EAF was acceptably low, with a plus or minus factor of two. This level of precision is comparable with that achieved in large-scale (non-selective) trawl surveys of temperate fishes. Thus, for the test species studied, trap-based surveys could prove valuable for longterm monitoring of population abundance.

What about species regularly caught in traps, but not routinely sampled by visual census? Using mark and recapture data, Appeldoorn and Recksiek were able to estimate population sizes for some frequently caught, but rarely seen fishes. However, this did not help them to estimate population density. The investigators approached this problem in three ways.

First, they intensively surveyed the entire reef wherein the test sites were located, and compared reef-wide population estimates with those obtained from their mark-recapture data. This gave them a relative estimate of the proportion of the whole reef from which our trap-caught fish originated.

Secondly, they conducted a series of nighttime transect surveys for nocturnally active species. Although more difficult to conduct, comparing these numbers to the daytime results allowed them to get more EAF estimates.

Lastly, they employed the use of sonic fish tags to track individual fish and estimate the range over which they roam. This latter component is being pursued primarily by Dr. Recksiek and his graduate student, Steve Tulevech, both of the University of Rhode Island. Data from these components are still being analyzed, but Drs. Appeldoorn and Recksiek are confident that tagging-based estimates of abundance can ultimately be used to determine the population density of many species for EAF estimation.

Seed Money Project

Making the Mangrove Oyster Safer ...and More Profitable

Raw mangrove oysters *(Crassostrea rhizophorae)* are favored coastal fare in Puerto Rico, but many important shellfish harvesting areas are grossly contaminated by human sewage, and no laws exist to ensure that edible shellfish be cleaned before marketing.

In fact, little is known about the type and extent of human-passed pathogens present in edible mollusks. And since most pathogen indicator standards have been developed for temperate waters and temperate species of shellfish, it is essential that accurate indicators be established for tropical systems.

Like all bivalves, mangrove oysters cleanse themselves of pathogenic viruses and bacteria when placed in clean water. However, no information is available on the time required or the extent of such depuration for mangrove oysters.

Microbiologists Terry Hazen, Ph.D. and Gary Toranzos, Ph.D. worked to document microbial contamination of the mangrove oyster in Caño Boquerón. This site was chosen because sewage effluent was being discharged into the mangrove area close to where local fishermen were harvesting shellfish.

Hoping to contribute toward practical management policies regarding oyster collection, handling and decontamination, their primary objectives were to:

1) describe the extent and type of pathogen contamination of mangrove oysters in Puerto Rico,
2) define the optimal rate of pathogen elimination from contaminated oysters under various conditions,
3) establish models for both contamination avoidance and decontamination of mangrove oysters in Puerto Rico.

As a result of experimental work lasting one year, each objective was partially met.

Caño Boquerón is completely surrounded by a mangrove forest and opens to the bay through a single narrow outlet. Adjacent to the lagoon, 158 small vacation cabins are served by two primary sewage treatment plants, which pipe effluent directly into the lagoon.

Drs. Toranzos and Hazen collected oysters at the effluent site, where the highest concentrations of oysters were always found. Mangrove oysters, both contaminated and uncontaminated by sewage, were analyzed for enteric viruses, coliforms, coliphages and pathogenic bacteria. The water where oysters were collected was also examined.

Although high concentrations of fecal pollution indicators were recovered from oysters, no pathogenic microorganisms could be isolated. This is probably due to the fact that pathogens are usually only concentrated enough to be detected in sewage systems

serving at least 150-200 families. The fact that no pathogens were detected may mean that no or very few cabin dwellers were suffering from any enteric (intestinal) disease. However, it may also mean that the culture techniques used for detecting pathogens were simply not sensitive enough to detect low concentrations of microorganisms. It is possible that low concentrations of pathogens *were* present, but at indetectable concentrations. More sensitive techniques are needed in order to determine unequivocally if pathogens are present in oysters being sampled.

In order to establish the rate of pathogen elimination from contaminated shellfish, oysters were seeded with pathogens: *Salmonella typhimurium, Streptococcus faecalis, Escherichia coli,* poliovirus, hepatitis A virus, rotavirus SA11, and the coliphage MS2. This was done by introducing high concentrations of these microorganisms into containers of sea water, where the oysters remained overnight.

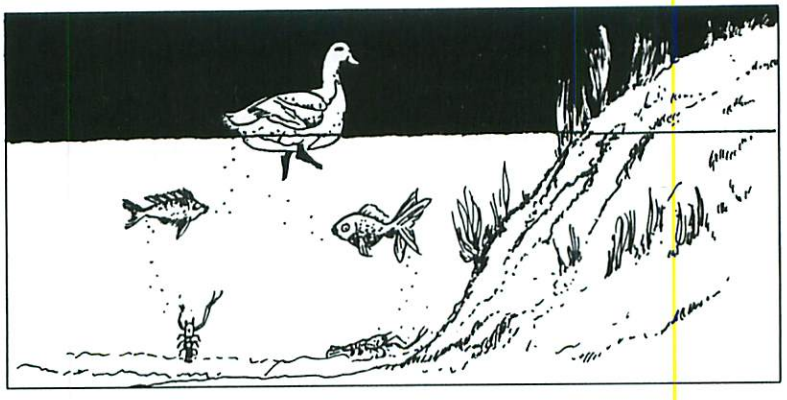
The next day, the oysters were thoroughly washed to remove excess microorganisms from the shells and placed in depuration tanks. There, they were exposed to clean water at different temperatures and salinities, and assayed over time to determine the optimal rate of pathogen clearance. It was determined that a minimum of two to three days are necessary to depurate up to 90% of the seeded pathogens.

Drs. Hazen and Toranzos were able to determine that since fecal streptococci and some coliphages (bacterial viruses) are the last to be eliminated by the oysters, these are possibly the best indicators of contamination. This knowledge is extremely important in developing health guidelines for shellfish consumption and handling in Puerto Rico and other tropical areas. It also has socioeconomic implications, as better contamination indicators will not only assure safe consumption of shellfish by the public, but also assure that fishermen do not discard their catches unnecessarily.

Further research is now being done to complete the results of their work during '87-88. One important change proposed is the use of the polymerase chain reaction (PCR) pathogen detection technique, which amplifies specific viral and bacterial pathogen genes. The use of this technique would greatly enhance the sensitivity and efficiency of pathogen detection in mangrove environment throughout the tropics.

Integrated Aquaculture

a Profitable Experiment



On the island of Puerto Rico, where the vast majority of the population lives in coastal areas, about 95% of the fish consumed is imported. Over-exploitation of certain marine species contributes to this imbalance. On the other hand, much agricultural land lies fallow, while artificial ponds and brackish lagoons are abundant.

On as little as 1/2 acre of unused land, aquaculture (the controlled cultivation of fish and other aquatic life) can provide families with socioeconomic and health-related benefits. After the initial investment of creating or cleaning an existing pond, non-intensive aquaculture requires a minimum of capital investment and very little maintenance.

Even when such projects work at an economic loss, significant benefits include:

1) having otherwise unemployed people involved in productive labor,
2) diminishment of mosquitos and aquatic snails, carriers of human diseases, and
3) nutritional enrichment at family and community levels.

Professor Ricardo Cortés Maldonado and graduate student Margarita Mulero Dávila studied an integrated aquaculture project for production and profit potential. They also hoped to determine the most desirable animal combinations for successful, small-scale aquaculture projects. Their experiment included ducks, edible tilapia and prawns, and ornamental goldfish and swordtails.

One of the advantages to this combination of animals is that only the ducks consume commercially produced feed. Both fish and prawns consume insects, worms, snails, slugs, plancton, algae and other plant life, and duck droppings which, through the process of decomposition, become a nutrient-rich food. The food

chain created is both stable and space-efficient, with prawns living at the bottom of the pond, fish utilizing the central water column, and ducks on the surface.

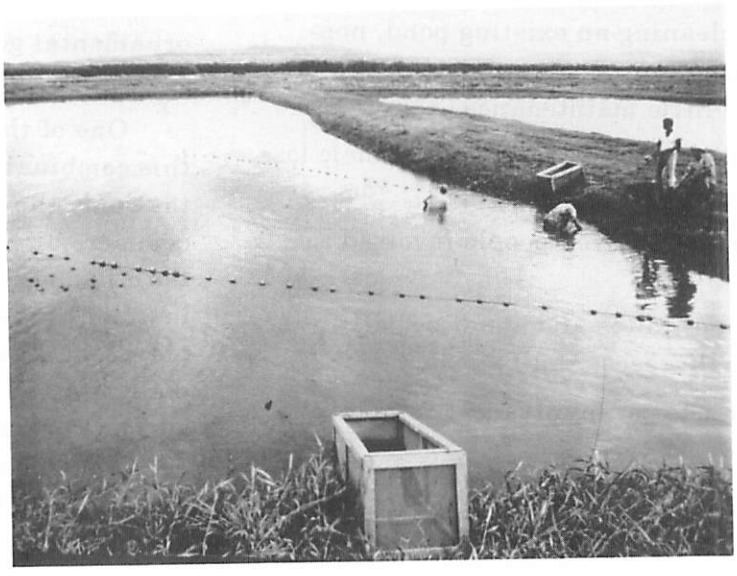
During 1987, a pond measuring less than 1/2 acre was stocked (at intervals) with 200 Peking ducklings; 894 tilapia; 3,000 post-larval, giant fresh water prawns; 302 green swordtails and 554 goldfish.

Duck cultivation proved to be the least profitable activity, with an economic loss of 27.1%. This loss was due to their initial purchase cost and transportation (there are no commercial duck producers on the island), food and labor costs, plus mortality, mostly attributable to rats and mongooses. A working farm producing grains suitable for feed could reduce the food expense. In addition, if ducks could be kept safe from predators, purchase costs for sequential generations would be cut dramatically. These modifications, and the side benefits provided by egg and feather down production, may explain the popularity of duck cultivation in aquaculture projects outside of Puerto Rico.

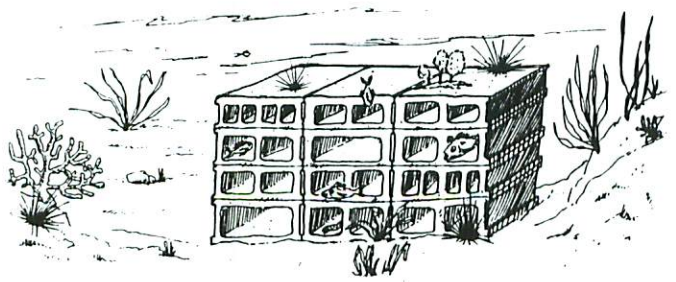
Cultivation of tropical fish (goldfish and swordtails) was the most gainful enterprise, representing a profit of 51.9% over 1.37 years. Tilapia and prawns generated a profit of 41.2% over a period of 2.82 years; they also represent a year-round source of family nourishment.

Despite major problems such as a flood in which some fish and prawns were lost, an ongoing loss of ducks to predators, and unhealthy prawn seed that lowered their survival rate to only 1.5%, productivity of the pond was increased by 700%.

As a result of this study, basic economic and production guidelines have been established for integrated, non-intensive aquaculture projects. This information is available to the Department of Agriculture as well as to agricultural and marine advisory extension personnel for the purpose of orienting local fish farmers in selecting more profitable polyculture combinations. For now, recommendations will exclude the cultivation of Peking ducks; however, experimentation with ducks under conditions of more intensive management may prove worthwhile.



Shelter is Survival for Coral Reef Fish



The eggs and larvae of coral reef fish drift in the ocean until they can settle on the reefs. Finding a reef is critical to the young fish's survival. Unfortunately, most Caribbean reefs are small, just fringing the islands. So when fishermen find spawning aggregations of, say groupers, these are easily fished into oblivion.

In general, coral-reef fisheries of the Caribbean are greatly overexploited, and in Puerto Rico, fish consumption is on the rise. The introduction of artificial reef structures has been proposed as a means of increasing reef fish populations and thus, supporting Caribbean island fisheries.

Since 1984, Dr. Mark Hixon of Oregon State University, Mr. Jim Beets of the U.S. Virgin Islands Division of Fish and Wildlife, and Dr. Teresa Turner of the University of the Virgin Islands have been involved in experiments to determine how these artifical reefs should be structured.

They were especially interested in identifying the optimum quantity and size of holes in each reef. Reef holes play an important role as prey refuges, preventing predators from over-consuming the small fish.

In 1988, Dr. Hixon and his colleagues introduced 40 one-ton artificial reefs made of concrete blocks in a large sea grass bed off St. Thomas, U.S. Virgin Islands. In the process, they learned about the relationship between shelter size and survival for coral reef fish.

In keeping with their previous studies, the 40 reefs were grouped according to five structural patterns. Eight had no holes; eight had 12 large holes; eight had 12 small holes; eight had 24 large holes; eight had 24 small holes. Tagging studies showed that the reefs were sufficiently isolated from each other to comprise statistically independent environments.

Ninety-seven species were observed on or near the reefs, representing all the major coral-inhabiting groups. Each holed reef supported hundreds of individuals.

By repeatedly censusing and comparing the reefs, Hixon and his research team found a relationship between the size and composition of reef-fish assemblages and the presence of predatory fish. Four categories of fish were studied:

1. large residents such as groupers and others too big for the small holes (most of

these fish were both predators on smaller residents and prey for larger transient piscivores)

2. small residents (most species)
3. moray eels (piscivores which could fit into the small holes) and
4. juvenile grunts (small residents which were sporadically extremely abundant, and so needed to be studied separately).

The scientists observed that fish of all categories were more abundant on holed than on solid reefs, and on 24-hole than 12-hole reefs. In addition, fish of all categories except juvenile grunts clearly preferred and survived far better at reefs with holes near their body size. Since most small fish without shelter are eaten by predators, a small number of reef holes limits the number of fish occupying a reef.

Since few studies have investigated the role played by piscivores in controlling the distribution and abundance of smaller prey, Hixon and his team also examined the effects of predation on the entire fish community. Comparing among reefs, they found that reefs with many predators such as groupers and large squirrelfish supported the residence of few small fish, while reefs with few predators supported many small fish. The rapid disappearance of larval-stage and smaller fish on large-holed reefs (favoring live-in piscivores) supported the conclusion that this was a direct, causal relationship.

But not only was the number of prey individuals reduced; the number of prey species was also observed to be reduced in direct relationship to the number of resident piscivores. Evidently, piscivores reduced and (locally) exterminated both common and rare prey species without preference. Such generalized predation affects all prey species negatively.

There was no evidence that predation enhanced the abundance of any prey species or that it allowed new prey species to colonize. In Hixon's model system, high local species diversity appears to have been maintained despite rather than because of predation.

This study shows coral reef fishes' need for appropriate shelter, if they are to survive. Most interestingly, it tells us of the importance of shelter size.

Desirable shelters, with holes of various sizes, allow for the protection of small fish by small holes; then, as larger predators get fished out of the area, smaller fish have room to grow into the larger holes. Such shelters thus support and augment a naturally diversified cycle of development.

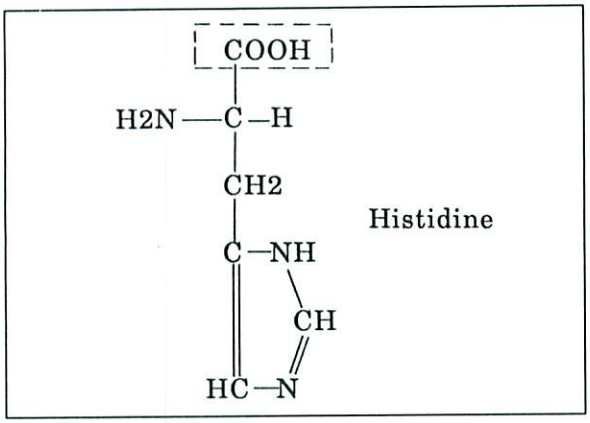
Thanks to the work of Hixon, Turner and Beets, we now know that artificial reefs with numerous holes ranging widely in size are best suited for the local development of sustainable fisheries.

Fresh Tuna:
Likely Source of Scombroid Poisoning

Thanks to the efforts of UPR Sea Grant's Marine Advisory personnel, consumption of fresh tuna is on the rise in Puerto Rico, where fishermen of the northwestern Aguada region regularly catch this popular (and previously undervalued) fish.

In Puerto Rico, artisanal fishermen leave at dawn and return about seven hours later, with little shelter from the scalding Caribbean sun. Since decomposition of scombroid fish such as tuna, mackerel and dolphinfish may lead to scombroid poisoning, Dr. Mildred Chaparro and graduate student José Díaz investigated the potential dangers posed by a lack of refrigeration and freezing facilities aboard the vessels.

The cause of scombroid poisoning is histamine, one of the most potent capillary dilators known to human beings. Histamines are created when certain microorganisms remove the carboxyl group (COOH) of molecules from the amino acid histidine, which is present in the muscle tissue of these fish.



Histidine

Scombroid poisoning, although not fatal, causes severe allergic reactions, with symptoms including flushing of the face and neck, a throbbing headache, nausea and vomiting, diarrhea, dizziness and faintness, swollen lips and a burning sensation in the mouth and throat. Just a few outbreaks of this illness could seriously affect commercial island fisheries.

The objectives of Dr. Chaparro and her assistant were to determine histamine levels in fresh tuna fish at two different temperatures, and to evaluate the risk of consuming this type of fish.

First, in order to identify the microorganisms responsible for this decarboxylation process, fish samples were collected from two fish markets on the northwestern coast of Puerto Rico. Fish samples were collected at random from total "catches of the day." Flesh was excised from the anterior section of the fish and samples were incubated at 5°C and 11°C for a period of 15 days. Samples were analyzed at 0, 4, 8 and 15 days of storage.

Fish markets were also used as sources of microorganisms. Samples were taken from several areas of the market including cutting tables, cutting machines, the freezer and refrigerated cabinet displays. Microorganism counts were done using a medium in which histamine producers grow as purple colonies. These

microorganisms were cultivated in vitro. A nutritionally-rich medium of soy broth was enriched with 2% histidine at pH 6.3. Histamine determinations were then made at 0, 3, 6, 9, 12 and 24 hours of incubation.

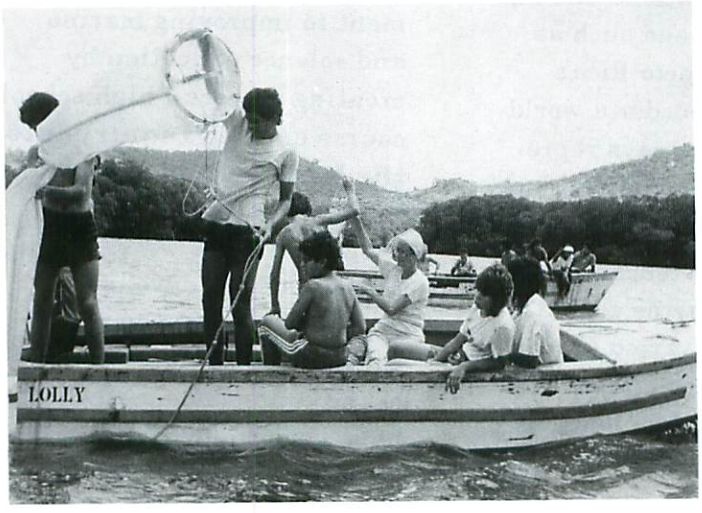
It was not surprising to find bacteria such as *Morganella morganii, Klebsiella pneumoniae* and *Klebsiella oxytoca* in microorganism cultures, as these bacteria have long been associated with histamine production. But thanks to this study, yeasts *(Candida sp.)* were also discovered to be decarboxylating agents, and thus histamine producers.

Although *Morganella morganii* was the major producer of histamine at 37°C, it lost its decarboxylating ability at 5°C. On the other hand, *Klebsiella sp.* and *Candida sp.* maintained their histamine producing capability, with the same intensity, at both warm and cold temperatures.

After 15 days of cold storage, frozen samples showed lower histamine levels than refrigerated samples. But even 15 days from capture, all histamine levels were low enough to determine that no risk is associated with eating fresh tuna which has been properly eviscerated and refrigerated upon arrival at the dock.

As a result of this study, MAS advisors have worked closely with local fishermen describing the importance of immediate cleaning and refrigeration of scombroid species. A pamphlet entitled (in translation) **Tuna Handling** was widely distributed throughout Puerto Rico's coastal region.

Education



UPR Sea Grant's **Marine Education Center** is the birthplace of an ongoing and intimate exchange between people and the marine environment. We know that when people study marine resources in their natural surroundings, the learning process is meaningful, memorable and fun. And we make it work for everyone ranging from 6 year olds to high school science teachers.

The Marine Education Center's goals include:

- promoting knowledge about our marine resources among students and teachers,
- integrating marine science themes in pre-college curricula,
- producing educational materials focused on tropical marine environments,
- establishing and lending support to marine science learning centers throughout Puerto Rico.

According to Alida Ortiz, Ph.D., coordinator of UPR Sea Grant's Marine Education Center, one of the reasons for the program's success is its **emphasis on regional marine characteristics.** On an island measuring 100 miles by 35 miles, both students and teachers are motivated by the beauty, productivity and familiarity of the ocean environment that surrounds them.

Mobility is another reason for the Center's success. During 1987-89, professor Edgardo Ortiz and Juan Gerardo González, Ph.D., associate research scientist and co-director of the Marine Education Center, traveled to junior and senior high schools throughout the island offering presentations to nearly 3,000 students on marine topics ranging from the origin of the ocean and continents to marine ecosystems and marine conservation. Each presentation was complemented by slides, video, or hands-on samples geared to motivate students to get to know their marine environment better, and to take marine sciences seriously.

Students inspired by these in-school marine science presentations often solicit **advice and guidance** from the Marine Education Center about further study. Many such students have won first prize at state and regional science fair competitions. Some have moved on to study science at the college level. Thanks to the Center, both pre-college and undergraduate students from all disciplines are now demanding closer contact with the marine environment.

For teachers, in-service marine education enhancement workshops are given at opposite ends of the island. At Fajardo, high winds and waves offer a variety of contrasting geological formations and an ideal environment for studying phenomena such as wave formation. At La Parguera on Puerto Rico's southwestern coast, mangrove forests border a world-famous bioluminescent bay, and offshore cays represent numerous low-energy marine environments characterized by turtle grass and coral growth.

Each three-day workshop prepares teachers to reach hundreds of students through marine education activities both in the classroom and in varied field environments. Through interaction with marine resources and other educators, participants learn to present marine topics in new ways as part of the science curriculum.

Since 1987, ten teacher enhancement workshops have been conducted every year, with an average of twenty teachers, school directors, science coordinators and supervisors taking part in each. Five teachers who participated in these workshops have received Presidential Awards; two of them were honored with the prestigious Christa McAuliffe Science Prize for special projects in marine related science.

Thanks to supplemental funding awarded by the Council of Higher Education (through the Dwight D. Eisenhower Science and Mathematics Enhancement Program and NOAA's Division of Estuarine Research) a growing number of teachers have been able to participate in our workshops and seminars.

Following the workshops, teachers from four schools in Río Piedras and Maunabo demonstrated their commitment to improving marine and science education by creating a special high school course entitled **Inquiry into the Marine Environment.** This is a measure of our program's achievement, since these teachers developed "Inquiry" on their own, and continue creating new facets of the course, some of which have been funded by the Department of Education.

As a **support service,** UPR Sea Grant's Marine Education Center provides these teachers with advice and instructional materials on loan whenever needed.

The popularity and effectiveness of "Inquiry into the Marine Environment" has far exceeded teachers expectations. There are always long waiting lists! The best part is that the course is designed for students at all levels of academic achievement, and it can easily be adapted for special students.

During 1987-88, biology teacher Luis Jiménez of Berwind High School geared the course content for a group of tenth grade **"high risk" students** who seemed destined to contribute to the island's drop-out statistics. Among the eye-opening results: all participating students finished the school year and

showed a marked improvement in their academic performance.

During 1987-89, several articles prepared by the Marine Education Center staff were published in *Diálogo,* the University of Puerto Rico's student newspaper. But the Center's greatest accomplishment during that period of time was probably **the inclusion of marine science courses and "mini" courses in public schools.** In each case, "Introduction to Marine Studies," a course designed by Marine Education Center staff, was used as a curriculum guide.

With funds from the John D. and Catherine T. Mac Arthur Foundation ($250,000), a three-year community education project on Biosphere Reserve Management was initiated in 1989. The project focuses on the U.S. Biosphere Reserves in Puerto Rico (Guánica and Luquillo) and U.S. Virgin Islands (St. John), and the development of a graduate program in natural resources management for the Caribbean. Through this project we have begun to promote marine education activities in other countries throughout the Caribbean.

UPR Sea Grant's Marine Education Center is known and highly respected for its innovative and far reaching work. Besides grants for hands-on workshops for teachers from Puerto Rico and North Carolina, a $34,000 Title II grant was awarded the Center by the Federal Department of Education for a 16-session course on the interaction of ocean, land and air. Finally, a $20,000 grant was received from NOAA's Marine Estuarine Division for the production of educational materials and the development of workshops at the Jobos Bay National Estuarine Research Sanctuary of Aguirre, Puerto Rico.

The Marine Education Center's work to teach about **the sea as a source of knowledge** has led to genuine respect for the marine environment and, as a result, concern and commitment toward its wise use and conservation. It's as close a guarantee as we'll ever have...for the future of the seas that surround us all.

Communications

"As part of the Sea Grant Communications team," begins graphic artist and designer José Drasich, "I'm not just making art. I'm also an educator, helping to teach skills, knowledge, and human and environmental values."

Communications assistant María Benedetti and graphic artist José Drasich discuss the layout of the "Boletín Marino", UPR Sea Grant's Spanish language newsletter.

Through well designed and illustrated publications and posters, we introduce scientific information to the general public. (This same information was once restricted to a very specialized environment.) "And," explains Drasich, "when people learn the value of their marine environment, they become eager to protect it."

According to Carlos Cardona, scuba diver, salt water aquarium designer, and Sea Grant's computer programmer, "Our Communications program is a resource center *por excelencia,* educating in Spanish and in English, throughout the Caribbean. I'm proud to be employed by an organization that truly protects and informs about our marine environment. And through the outreach program of Communications, I know we're helping fishermen, school kids, and the general public to do the same. In my own life, thanks to my work with Sea Grant, I've become a conservationist. No one who dives with me avoids a lecture on the importance of leaving the corals alone. No one leaves trash on the beach when I'm around."

The Communications program of UPR Sea Grant represents the turning point of many lives. Information specialist María Font tells of undergraduate biology students who, in using our **Marine Education and Information Resources Center** for research projects, became so interested in marine life that they went on to earn Masters Degrees in Marine Sciences.

Our **library and information center,** a place of unmatched scientific and media exchange, involves the input of many cultures. Ms. Font explains, "We receive scientific studies, popular reports and learning materials on marine resources and coastal processes from Venezuela,

Guillermo Damiani González, photolithographer

Taiwan, Ireland, Mexico, Australia, Ghana, Trinidad and Tobago, Chile and, thanks to UNESCO, even Arab countries.

"As **the only fully bilingual Sea Grant program,** words can't describe our importance in terms of Latin America. In some countries, we are the *only* source of information available on marine affairs and resources available. And hundreds of students aged 8 to 60 come each year looking for slides and videos, not to mention the teachers and even city planners who have come to borrow our slide shows." Over ten thousand titles complement videotapes and other audio-visual materials that are constantly being borrowed and/or copied by the people we serve.

Computer programmer Carlos R. Cardona Torres and communicator Laura Cotte prepare for a "public education day" at a local festvial.

Photolithographer Guillermo Damiani came on board in 1986, and throughout 1987-89 built a complete **offset printing and binding facility** as part of our Communications workshop. Our in-shop press allows us to meet the "marine information needs" of our public fast, at low cost, and with total control over the quality of our work.

The creation and design of educational products is one of our specialties. UPR Sea Grant's books, pamphlets, one-pagers and posters are an inexpensive way of reaching the public in settings ranging from cultural festivals to shopping plazas.

During 1987-89 we entered thousands of Puerto Rican kitchens through a **recipe series** featuring such delicacies as fresh tuna anti-pasto, crab stew and saucy parrotfish.

Other publications include pamphlets ranging in theme from aquaculture and tuna handling for commercial

Information specialist María Font points out the distinguishing features of certain marine mammals during a video showing at our library.

fishermen to a **Marine Recreation Service and Facilities Directory of the U.S. Virgin Islands** and the proceedings of the twenty second meeting of the Association of Marine Laboratories of the Caribbean.

With nearly 3,000 subscribers, our free, bimonthly **Boletín Marino** magazine includes an *educational section* written especially for teachers and students, an *informative section* designed to spread the word about marine-related events in the Caribbean, and a *research section* featuring the work of Sea Grant-funded scientists so that their discoveries are made known to the general public.

Our free, bilingual **newsclipping service** documents marine-related news from Puerto Rico and the U.S. Virgin Islands.

Communications secretary Maritza Más Rodríguez keeps things moving smoothly and efficiently.

Research reprints range from marine ecology featuring a *Nursery Ground for Four Tropical Penaeus Species in the Joyuda Lagoon* to a discussion of *New Derivates from the Tropical Green Alga Avrainvillea nigricans*

Our '87-89 **Marine Fact Sheets** series includes information on ciguatera and a Spanish translation of MARPOL's *Plastic Trash Leaves a Path of Death.*

Posters and maps produced during '87-89 include *Seafood: Good for Your Health, Adopt a Beach, Celebrate Coastweeks, Edible Fishes of Puerto Rico and the Caribbean,* a map of Puerto Rico and La Parguera, home of our world-famous bioluminescent bay, a hurricane tracking map for the Caribbean, and numerous announcements of festivals and seminars.

Our bilingual version of **What Is Sea Grant?** has helped to make us more familiar, and thus more accessible throughout the Caribbean.

Communications coordinator Laura Cotte is a regular on **radio programs** throughout Puerto Rico. It all started in 1987 when Communicator Vangie Hernández began to accept invitations to inform the public on radio and TV spots. Cotte comments: "Dozens of people began to call in asking questions and wanting more information. We

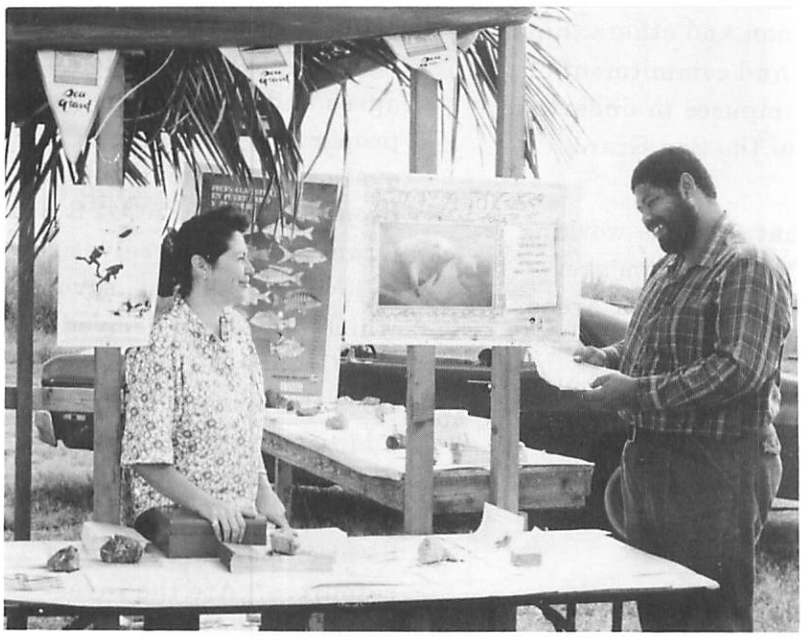
planted the seeds for a media explosion which has grown to include our own video productions, appearances in televised cooking shows, and more radio exposure than ever."

In addition, during 1987-89, our communications team contributed to the production of TV documentaries featuring sharks in the Caribbean, Mona Island and a runaground ferry.

Due to the success of our own marine magazine, **Boletín Marino**, our publishing expertise has been put to work in the form of editorial aid to Puerto Rico's Department of Natural Resources in the creation of a marine affairs newsletter.

The UPR Sea Grant communications team **works closely with both research scientists and our marine advisors.** This assures us of a tightly-knit program that truly meets the needs of our diverse communities, from the English-speaking U.S. Virgin Islands to Spanish-speaking Puerto Rico and Latin America.

At UPR, **Communications is outreach.** Moving from the laboratory into the fishermen's lodge, from the classroom to the mangroves, from our printing press to the supermarket. We go where the people who need us are, and we spread the word.



Communicator Laura Cotte converses with a visitor to our Sea Grant kiosk during the Rediscovering Puerto Rico Environmental and Cultural Festival.

Administration and Management

Program management provides the structure for developing an integrated program, and involves thorough planning, coordination, development and evaluation of research, marine advisory services and marine education. Management also means unifying the academic and marine communities, while coordinating the business and government efforts necessary for the development, conservation, enjoyment and wise utilization of the marine resources of Puerto Rico and the U.S. Finally, program management represents and ensures the scientific and fiscal accountability of our entire program.

Through efficient management practices we have stimulated greater interest and cooperation between Sea Grant and the University system, government and federal agencies, and our community as a whole. We have changed attitudes, improved skills and inspired greater aspirations in students, fishermen, housewives, industrialists, businessmen and others. Finally, we have increased the interest and commitment of university researchers on all campuses to undertake studies consonant to the goals of the Sea Grant Program.

Some of the key phrases that serve as working criteria for the management of our program are: strategic planning, relevance, programmatic areas, initiatives, justifications, flexibility and adjustment, attraction of outside funding, search for collaborators and recruitment of new research talent, pilot projects, leadership, evaluation, accountability.

Evaluation Procedures and Criteria

Five internal committees advise the director in research endeavors. These committees help the staff and the administrators choose the most appropriate projects in the fields of science and engineering, socioeconomics, marine recreation, fisheries, education and civic matters. The committees are composed of university personnel in the sciences, arts and humanities; civic leaders; commercial and sports fishermen; educators and administrators. Some also contribute to the program as specialists, each in his or her own discipline or field of expertise.

In the evaluation of research projects and core program components, we have always tried to apply the criteria recommended by the National Office because we agree and accept them as proper and rational. In evaluating the merit of each project proposed to UPR Sea Grant, we ask ourselves the following questions, several of which have been derived from Sea Grant's "Green Book": Does the proposed project address an important issue, problem or opportunity in development, use or management of marine or coastal resources? Are the investigators involved in the project fully capable of realizing their goals? Is the project likely to succeed? Will the project advance the state of

our sciences? Does the project represent innovative ways of solving problems and exploiting opportunities in resource management, development, or public outreach? Does the project offer a probably practical solution in the shortest length of time? Will the project contribute toward our regional or national Sea Grant program objectives and priorities? Will the project generate further ideas, methods or a more specific project to address the problem in an effective way? Does the project strengthen the program's relationship with our constituency, government agencies, other institutions, industrial concerns and the National Sea Grant program network? Will the project help us to attract support from other sources?

Once a project or activity has been funded, other evaluation criteria employed include surveys and questionnaires; the productivity and long-term effects of each activity; the demand for our publications and other products; public requests for information, guidance and advice; community recognition and support for our work; requests and/or demands for training and educational activities; and the expansion and/or adoption of our programs by government agencies, interest groups and other organizations.

Program Development

Quick and flexible response to research, education and community needs is one of the most important operational aspects of Sea Grant. This unique capability enhances credibility, prestige, and social utility of the program. Funds to support one-time needs, development of useful projects without waiting up to a year lead time, and immediate response to community problems provide a flexibility that increases the effectiveness of our mission.

In addition to our flexibility, we are also committed to generating innovative and specific new avenues of research, through the attraction and recruitment of highly qualified, new investigators. This enhances the capabilities of our program to deal with unforeseen problems, especially those related to the significant increase in demand from users, researchers and students for our services, training, information and resources.

SEED MONEY PROJECT STATUS 1987-1989

PROJECT NO.	SUBJECT	P.I.	INSTITUTION Start Date *Term. Date	*Status (C,T,F,D)
PD-26-R/RR-30	Assessment of Passive Deep-Water Gear	R. Appeldoorn	UPR-Mayagüez, Dept. Marine Sci. (Sept. 85) (1987	(T)
PD-27-R/LR-06	Dispersal of Reef Fish Eggs	D. Shapiro	UPR-Mayagüez, Dept. Marine Sci. (Jan. 86) (1987)	(T)
PD-28-R/MT-36	Fisheries Enhancement Using Floating FADS	L. Almodóvar	UPR-Mayagüez, Dept. Marine Sci. (May 86) (1988)	(T)
PD-29-R/MT-36	Locating Historic Ports/ Facilities North of P.R.	H. Rodríguez	UPR-Aguadilla, Dept. Humanities (May 86) (1988)	(T)
PD-30-R/ME-40	Sedimentation of Marine Macromolecules	T. Tosteson	UPR-Mayagüez, Dept. Marine Sci. (May 86) (1988)	(T)
PD-31-R/LR-06	Fishery Recruitment from the Plankton	W. McFarland	FDU-St. Croix W. Indies Lab. (May 86) (1988)	(T)
PD-32-R/RR-35	Minced Fish from Tilapia	G. Barbosa N. Díaz	UPR-Mayagüez, Dept. Chem. Eng. (May 86) (1987)	(T)
PD-33-R/LR-06	Artificial Reefs for Fishery Enhancement	M. Hixon T. Turner	UVI-St. Thomas, Dept. Sci./Math (Sept. 86) (1987)	(T)
PD-34-R/LR-07	Color Guide to Marine Algae of Puerto Rico	D. Ballantine	UPR-Mayagüez, Dept. Marine Sci. (Feb. 87) (1988)	(T)
PD-35-R/A-01	Shrimp Culture Technology Transfer	D. Alston	UPR-Mayagüez, Dept. Marine Sci. (Sept. 86) (1988)	(T)
PD-36-R/A-01 02	Multiple Stocking, Prawns and Tilapia	A. McGinty	UPR-Mayagüez, Dept. Marine Sci. (Sept. 86) (1988)	(T)
PD-37-R/A-01 02 04	Economic Assessment of Polyculture	R. Cortés	UPR-Mayagüez, Dept. Marine Sci. (Sept. 86) (1988)	(T)
PD-38-R/AO-50	Wave Data Analysis of Great Pond Bay Experiment in St. Croix	A. Lugo	LSU-Baton Rouge (March 87)	(T)
PD-40-D/PM-80	Caribbean Aquaculture and Trade Expo '87	R. Nieto	Caribbean Aquaculture & Trade Expo '87 (June 87) (Aug. 87)	(T)
PD-41-R/A-03	Stock Determination in the Queen Conch	R. Appeldoorn	UPR-Mayagüez Dept. Marine Sci. (July 87) (1988)	(T)
PD-42-R/ER-40	Artificial Reefs & Virgin Islands Fisheries	M. Hixon	UVI-St. Thomas (July 87) (1988)	(T)
PD-43-R/LR-06	Reproductive Biology of Two Commercially Important Trunkfish	Y. Sadovy G. García	CODREMAR (Sept. 87) (1988)	(T)

SEED MONEY PROJECT STATUS cont.

PROJECT NO.	SUBJECT	P.I.	INSTITUTION Start Date *Term. Date	*Status (C,T,F,D)
PD-44-R/ER-40	Comparative Study of Algae Community Dynamics and Herbivore Ecology	R.C. Carpenter	West Indies Lab., St. Croix (July 87) (1988)	(T)
PD-45-R/A-05	Seamoss Mariculture Pilot Program in USVI	G.P. Owen	Caribbean Research Institute (Aug. 87) (1988)	(T)
PD-47-E/OE-70	Support for Graduate Fellowship in Architecture	E. Crommet E. Vivoni	UPR-Río Piedras (Jan. 88) (1989)	(T)
PD-48-R/MT-35	Histidine Decarboxylating Bacteria & Histamine Levels in Fresh Tuna Fish from P.R.	M. Chaparro	UPR-Mayagüez, Dept. of Biology (July 87) (1988)	(T)
PD-49-D/PM-80	Sponsorship of Fishery Management Conference, St. Thomas	D. Moore	Dept. Conservation & Cultural Affairs USVI (Sept. 87)	(T)
PD-50-D/PM-80	Workshop on Public Access to the Shoreline in the Virgin Islands	L.E. Ragster	SGVIMAS, St. Thomas, USVI (Nov. 87) (1988)	(T)
PD-51-AS-77	Rapid Response for MAS Project	M. Valdés-Pizzini	UPR-Sea Grant (Jan. 88) (1988)	(T)
PD-52-D/PM-80	Partial Sponsorship for SEAMAP	SEAMAP-Caribbean	Caribbean Fishery Management Council (July 88) (1989)	(T)
PD-53-LR/07	Student Thesis Support: Research in Phosphorescent Bay	C.E. Seixas	UPR-Mayagüez, Dept. Marine Sci. (July 88) (Aug 88)	(T)
PD-54-D/PM-81	Shrimp Bio-engineering Workshop	SCSG Consortium	SC Sea Grant Consortium (June 88) (1988)	(T)
PD-55-D/PD-81	Support for Development of Aquatic Animal Health Lab of DMS	E.H. Williams	UPR-Mayagüez, Dept. Marine Sci. (June 88) (1989)	(T)
PD-56-R/LR-07	Student Project Support: Publication of Thesis Results	O. Monterrosa C. Cuttress	UPR-Mayagüez, Dept. Marine Sci. (July 88) (1989)	(T)
PD-57-AS-75	Conservation of the West Indian Manatee	J. Freeman H. Quintero	Interamerican Univ., San Germán, P.R. (Aug. 88) (1990)	(T)
PD-58-E/D-70	Education Project: Teachers' Workshop in Raleigh, NC	A. Ortiz	UPR-Humacao, Dept. of Biology (Sept. 88) (1988)	(T)
PD-59-SP/S-20	Mythic and Supernatural Elements in Oral Literature	A. Román	UPR-Mayagüez, Dept. of Spanish (Oct. 88) (1989)	(T)
PD-60-AS/P-76	Support for Publication of Atlas Costero de Puerto Rico	M. Cerame Vivas	M. Cerame Vivas, Inc. (Oct. 88) (1989)	(T)
PD-61-R/LR-07	Mangroves as Nursery Areas for Commercial Fishes	D.A. Hensley	UPR-Mayagüez, Dept. of Marine Sci. (Dec. 89) (1990)	(T)

SEED MONEY PROJECT STATUS cont.

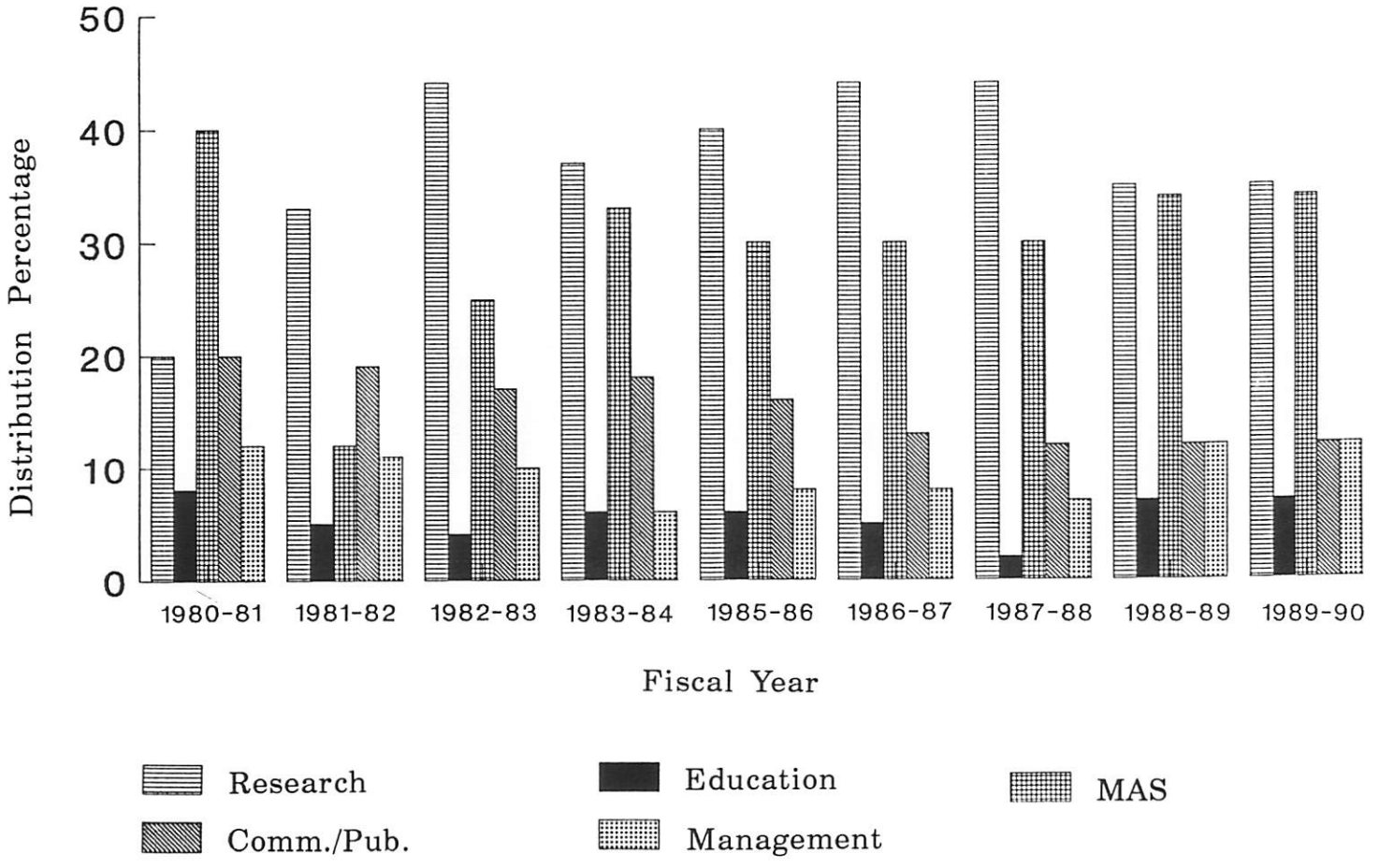
PROJECT NO.	SUBJECT	P.I.	INSTITUTION Start Date *Term. Date	*Status (C,T,F,D)
PD-62-SL/SP-20	Puerto Rican Aquaculture Industry	J. Gutiérrez	UPR-Mayagüez, Dept. of Social Studies (Oct. 88) (1990)	(T)
PD-63-P/PM-80	Workshops for Parks and Protected Areas, Dominica W.I.	Caribbean Conservation Assn.	Caribbean Conservation & Association, Barbados (March 89) (1989)	(T)
PD-64-R/RR-30	Buoyed Deep-water Passive Fishing Gear	L.H. Mendoza	UPR-Mayagüez, Dept. of Marine Sci. (March 89) (1990)	(T)
PD-65-B/C-74	Partial Support for International Conference on Ciguatera Fish Poisoning	T.R. Tosteson	UPR-Mayagüez, Dept. of Marine Sci. (April 89) (1990)	(T)
PD-66-B/C-64	Partial Support for 22nd Annual Meeting of the AMLC	M.L. Hernández	UPR-Sea Grant (May 89) (1990)	(T)
PD-67-R/LR-04	Commercial Production of Sea Urchin Roe	P. Yoshioka C. Cuttress	UPR-Mayagüez, Dept. of Marine Sci. (June 89) (1990)	(D)
PD-68-R/LR-06	Annual Reef Fish Survey of Saba Marine Park, Netherland Antilles	G. Dennis J. Kimmel	UPR-Mayagüez, Dept. of Marine Sci. (Sept. 89) (1990)	(T)
PD-69-R/MT-30	Gillnet and Trammel Net Selectivity on a Caribbean Coral Reef	A. Acosta R. Appeldoorn	UPR-Mayagüez, Dept. of Marine Sci. (Sept. 89) (1990)	(T)
PD-70-R/EM-47	Global CO_2 and the Importance of Cocolithophores in the Caribbean	A. Winter J. Briano	UPR- Mayagüez, Dept. of Marine Sci. (Sept. 89) (1990)	(T)
PD-71-R/AQ-03	Comparative Genetics of Populations of Mercenaria mercenaria	V. Juste J.G. González-Lagoa	UPR-Mayagüez, Dept. of Marine Sci. (Sept. 89) (1990)	(T)
PD-72-R/LR-08	Microbial Quality of Lucina pectinata	M. Chaparro	UPR-Mayagüez, Dept. of Biology (Oct. 89) (1990)	(T)
PD-73-R/PS-45	Fecal Contamination in Coastal Waters in Puerto Rico	G. Toranzos	UPR-Río Piedras, Dept. of Biology (Oct. 89) (1990)	(T)
PD-74-R/AQ-02	Population Genetics Aspects of Tilapia nilotica	A. McGinty C. Ayarza	UPR-Mayagüez, Dept. of Marine Sci. (Oct. 89) (1990)	(T)
PD-75-P/PM-80	Partial Support to Congress on Marine Tourism	Hawaii SG	Hawaii Sea Grant (Oct. 89) (1990)	(T)

* Status
C: Continuing
T: Terminated (Term.)
F: Failed
D: Discontinued

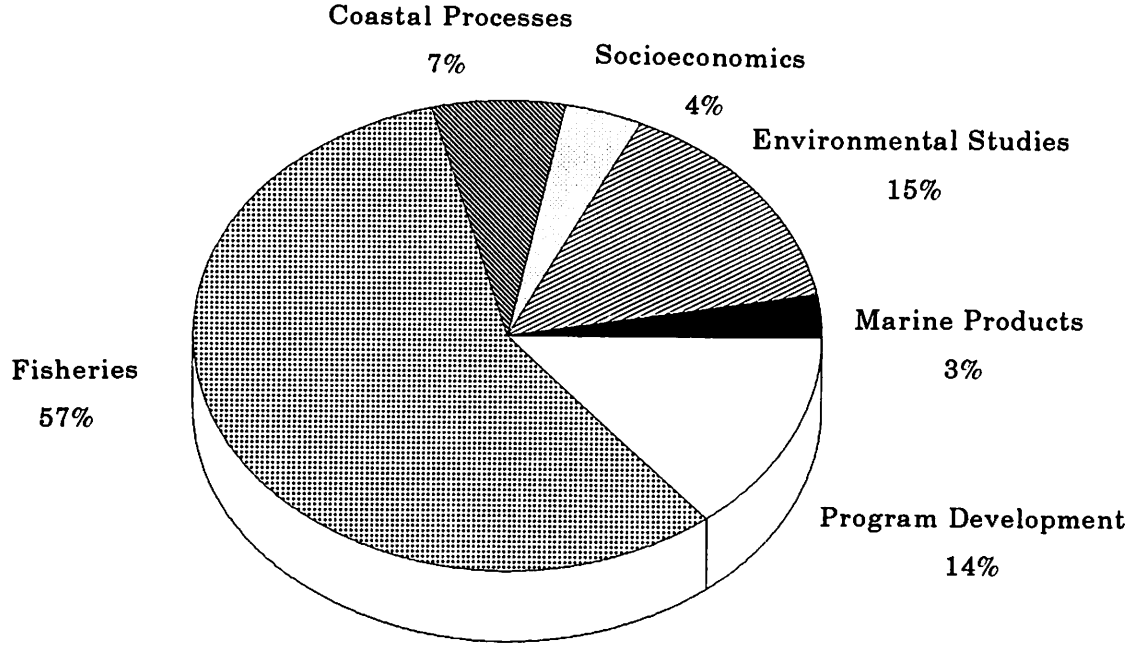
RESEARCH PROJECT STATUS 1986-87 TO 1989-90

RESEARCH	PROJECT NO.	P.I.	START DATE	*TERM. DATE	*STATUS (C,T,F,D)
Fisheries biology of four penaeid shrimp species in a tropical lagoon	R/A-01-2	A.W. Stoner R.J. Zimmerman	1986	1988	(T)
Detrimental effects of intensive fishing over spawning aggregations of a commercially important grouper	R/LR-06-1-B	D.Y. Shapiro	1986	1989	(T)
Development and testing of a new methodology for assessing lumped-species unit stocks in tropical fisheries	R/LR-06-2	R.S. Appeldoorn	1984	1988	(T)
Proposal for the design of a dock-side test for ciguateric fish	R/LR-08-1-B	T.R. Tosteson D.L. Ballantine H.D. Durst	1986	1988	(T)
Transformation of coral reef community structure and function resulting from the mass-mortality of Diadema antillarum: Implications for fishery yields	R/ES-40-2	R.C. Carpenter J.C. Ogden	1984	1987	(T)
Assessment and control of pathogens contamination in mangrove oysters, Crassostrea rhizophorae	R/LR-08-87-THA1	T.C. Hazen	1987	1988	(T)
Quantification of fish trap catches in semi-tropical and tropical fisheries	R/RR-30-10	R.S. Appeldoorn C. Recksiek	1988	1989	(T)
The evaluation of long term effects on coral reefs from terrigenous sedimentation	R/MR-09-10	J. Morelock	1988	1990	(T)
Extreme wave heights for Puerto Rico and the U.S. Virgin Islands	R/OE-25-10	A. Mercado J. Hubertz B. Taggart	1988	1990	(T)
Artificial reefs and Virgin Islands fisheries: optimizing design and predicting effects	R/ER-40-12	M. Hixon J. Beets T. Turner	1988	1990	(T)
Ecology and etiology of white band disease in elkhorn coral, Acropora palmata (Lamark)	R/LR-08-11	E. Gladfelter J. Bythell	1989	1991	(D)
Sedimentation of microbial-detrital particulates in tropical coastal marine environments	R/CM-39-10	T. Tosteson		991	(T)

Percentages of Sea Grant Funds Allocated to Each Component from 1980 to 1990.



Research Funds Distribution by Programmatic Area from 1980-90



PROGRAM BUDGET BY NSGCPO CATEGORIES
1989-1990

	NSGCPO GRANT FUNDS	UNIVERSITY MATCHING FUNDS
MARINE RESOURCES DEVELOPMENT		
Living Resources other than Aquaculture (Fisheries)	$30,000	$22,100
Mineral Resources	29,200	33,300
MARINE TECHNOLOGICAL RESEARCH & DEVELOPMENT		
Ocean Engineering	24,100	65,800
MARINE ENVIRONMENTAL RESEARCH		
Research & Studies in Direct Support of Coastal Management Decisions	30,600	28,000
Ecosystems Research	27,900	18,200
MARINE EDUCATION AND TRAINING		
Other Education: Curriculum Development & Teacher Training	30,000	47,600
MARINE ADVISORY SERVICES		
Extension Programs	147,200	97,600
Communications/Publications	50,200	65,600
PROGRAM MANAGEMENT AND DEVELOPMENT		
Program Administration	48,300	42,200
Program Development	37,500	22,000
TOTALS:	$455,000	$442,400

PROGRAM BUDGET BY NSGCPO CATEGORIES
1988-1989

	NSGCPO GRANT FUNDS	UNIVERSITY MATCHING FUNDS
MARINE RESOURCES DEVELOPMENT		
Living Resources other than Aquaculture (Fisheries)	$62,000	$75,300
Mineral Resources	31,400	33,300
MARINE TECHNOLOGICAL RESEARCH & DEVELOPMENT		
Ocean Engineering	25,900	65,800
MARINE ENVIRONMENTAL RESEARCH		
Ecosystems Research	30,000	31,000
MARINE EDUCATION AND TRAINING		
Other Education: Curriculum Development & Teacher Training	30,000	47,600
MARINE ADVISORY SERVICES		
Extension Programs	147,200	97,600
Communications/Publications	50,200	65,600
PROGRAM MANAGEMENT AND DEVELOPMENT		
Program Administration	48,300	42,200
Program Development	30,000	22,000
TOTALS:	$455,000	$480,400

PROGRAM BUDGET BY NSGCPO CATEGORIES
1987-1988

	NSGCPO GRANT FUNDS	UNIVERSITY MATCHING FUNDS
MARINE RESOURCES DEVELOPMENT		
Aquaculture-Crustaceans	$29,400	$23,470
Living Resources other than Aquaculture (Fisheries)	58,700	45,600
Pathology of Marine Organisms	77,700	73,300
MARINE EDUCATION AND TRAINING		
Teacher's Training	31,600	30,600
MARINE ADVISORY SERVICES		
Extension Programs	138,650	88,300
Communications/Publications	56,600	59,900
PROGRAM MANAGEMENT AND DEVELOPMENT		
Program Administration	32,000	37,600
Program Development	30,000	17,000
TOTALS:	$454,650	$375,770
ROUNDED TO:	$455,000	$375,800

PROGRAM BUDGET BY NSGCPO CATEGORIES
1986-1987

	NSGCPO GRANT FUNDS	UNIVERSITY MATCHING FUNDS
MARINE RESOURCES DEVELOPMENT		
Aquaculture-Crustaceans	$22,800	$24,800
Living Resources other than Aquaculture (Fisheries)	45,100	37,700
Pathology of Marine Organisms	36,000	30,400
MARINE ENVIRONMENTAL RESEARCH		
Ecosystems Research	37,300	27,000
Applied Physical Oceanography	29,000	5,700
MARINE EDUCATION AND TRAINING		
Teacher's Training	21,570	27,944
MARINE ADVISORY SERVICES		
Extension Programs	140,000	82,000
Communications/Publications	60,000	48,200
PROGRAM MANAGEMENT AND DEVELOPMENT		
Program Administration	32,900	33,850
Program Development	30,000	17,000
TOTALS:	$454,670	$334,594
ROUNDED TO:	$455,000	$334,600