Aquaculture in Puerto Rico

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ABSTRACT

Puerto Rico fisheries yield about 1046 mt/year, representing less than 95% of the seafood consumed each year. The permitting process involves many agencies and documentation. Species cultured in Puerto Rico are *Amphiprion sp., Crassostrea crassostrea, Crassostrea virginica, Ictalurus punctatus, Macrobrachium rosenbergii, Penaeus monodon, Penaeus vannamei,* red Tilapia, and *Tilapia nilotica.* The total hectares for *Macrobrachium,* marine shrimp, and Tilapia are 86.9, 54.6, and 73.4, respectively. The total production (mt) for *Macrobrachium,* marine shrimp, and Tilapia are 69, 54, and 127, respectively. The mean wholesale price for *Macrobrachium,* marine shrimp, and Tilapia are $16.09, $12.64, and $5.73, respectively.

KEY WORDS: *Macrobrachium,* Puerto Rico, tilapia.

INTRODUCTION

Infrastructure

Puerto Rico is the easternmost island of the Greater Antilles. It lies 1,670 km southeast of Miami between the Dominican Republic to the west and St. Thomas to the east. It is 56 by 160 km in area. Puerto Rico became a Commonwealth of the United States in July, 1952, with a constitution giving it full autonomy. A Resident Commissioner in Washington has a voice, but no vote in Congress. The Governor of the island has been a elected official since 1948. United States money and postage are used, and there are no immigration formalities for U.S. citizens.

The population of Puerto Rico gathered during the 1990 census count was 3,522,037. The major cities and the population of each are: San Juan 437,745; Bayamón 220,262; Ponce 187,749; Carolina 177,806; Mayagüez 100,371; and

Arecibo 93,385. The tourist trade is strong; hotel registrations totaled 212,000 for the fiscal year 1992 (P.R. Tourism Company, 1992).

Puerto Rico's location within the U.S. market offers easy access to international markets (Puerto Rico's Caribbean Development Program, 1992). Average flight times are 2.25 hr to Miami, 3.75 hr to New York, 5.5 hr to Los Angeles, and 1.5 hr to Caracas from Puerto Rico's Luis Muñoz Marín International Airport. This airport is thirteenth out of 186 U.S. airports in terms of cargo shipped and is served by 32 airlines.

San Juan Harbor is a transhipping point for countries throughout the Caribbean (Puerto Rico's Caribbean Development Program, 1992). Among the world's ten busiest container ports, it is served by Navieras de Puerto Rico's modern fleet of twelve vessels and 39 shipping lines. Average sailing times are 2.5 days to New York, 3-4 days for Gulf and Northeast ports, 10 days for West Coast ports, and 7 days for Europe.

The communications system is an integral part of the U.S. domestic system and telephone users benefit from easy access and low rates to the U.S. Mainland (Puerto Rico's Caribbean Development Program, 1992). The Puerto Rico Electric Power Authority provides dependable single and three-phase 60 cycle alternating current at standard voltages as well as secondary transmission voltage service for big demand industrial users. Water and Sewage services are provided by the Puerto Rico Aqueduct and Sewer Authority which uses the same water quality standards as the EPA on the U.S. Mainland.

Source of Fishery Products

The Agricultural Statistics Office of the Department of Agriculture reported that the fishery products consumed per capita per year were 5.81 and 7.77 kg fish/person for 1988-89 and 1989-90, respectively. Even though the consumption is relatively high, the clear inshore waters are relatively unproductive fishing grounds. As a result, over 95% of the seafood consumed in Puerto Rico, about 27,000 mt, must be imported (Nieto, 1990). The preferred local marine species of fish are tuna, grouper, lane snapper, and red snapper. The peak consumption of fishery products is during April (Lent Season) and September.

The 891 full time commercial fisherman (51.5% of the total number of fishermen) interviewed in a 1989 census spent more than 40 hours per week in fishing related activities (Mattos-Caraballo and Torres-Rosado, 1989). These hours include the effort in transporting and maintaining the fishing craft in a secure place, securing the fishing gears, as well as the actual fishing time. However, not included is the time that commercial fishermen spend selling the catch, the time they spend preparing their fishing gear, and the time necessary to make new fishing gear.

The number of commercial fishermen and fishing vessels in Puerto Rico apparently has not changed markedly over in the the last five years (Mattos-Caraballo and Torres-Rosado, 1989). In 1989, there were an estimated 1731 and 882 fishermen, respectively. However, over the five-year period there was a decrease in the use of fish pots (the most used fishing gear) and an increase in the use of other gear types (nets and lines). The census results showed that most fishermen are conscious of the decreasing production of fish and shellfish and want to cooperate to resolve this problem.

Even though the total fish production increased from 941 to 1046 mt from 1988 to 1989, respectively, the catch per unit of effort dropped by 2.66% (Mattos-Caraballo and Sadovy, 1990) (Table 1). The average wholesale price rose by 11.17% during the same period from $3.18 to $3.58/kg. With the increased fishing effort to sustain yields and with the rise in seafood prices, the economic climate is more favorable for aquaculture development in Puerto Rico.

Permits

All commercial aquaculture operations must apply for and have approved all of the required permits (Table 2). A commercial project is considered to consist of four or more hectares of surface water. However, this definition does not necessarily mean that a smaller operation is subject to less regulations. The agencies have the right to change their regulations at any time. The application of a permit does not authorize the development of a project.

The Department of Natural Resources regulates and protects the environment by means of preservation and managed public use, including regulation of surface and subsurface waters of Puerto Rico. The U. S. Corps of Engineers authorize permits for submerged lands, mangroves, floodable lands, etc. The Planning Board approves the planned use of lands in Puerto Rico. The Regulation and Permits Administration (ARPE) ensures that the laws and regulations of the Planning Board are followed, especially in cases of flood zones. The Environmental Quality Board identifies, controls, and prevents air, land, water, and noise pollution. The State Historic Preservation Office ensures the preservation and conservation of heritages of cultural or historical significance, including archeological sites. Also the Electric Energy Authority, the USDA Soil Conservation Service, the Department of Interior Fish and Wildlife, and Health Department are involved in varying degrees of the permitting process.

The general climate for obtaining the permits basically depend on the type of project the entrepreneur will develop. The culture of exotic species are not encouraged. Generally, endorsement by the Department of Natural Resources, which has several offices which evaluate a project proposal, takes the longest time to obtain. Authorized permits from the Environmental Quality Board also take a significant length of time.

Table 1. Total Landings by Species for 1988 and 1989.

Species (English)	1988 mt	1988 US Price/kg	1989 mt	1989 US Price/kg
Tuna	66.2	1.98	59	2.67
Ballyhoo	15.1	2.12	8	2.12
Grunt	42.3	2.23	36	3.99
Hogfish	14.8	3.62	12	3.92
Croaker	0.1	3.18	0	2.38
Trunkfish	17.1	2.80	23	3.44
Dolphin	31.5	2.34	32	3.15
Swordfish	3.2	4.67	0	0.00
Squirrelfish	2.1	1.96	6	2.49
Mullet	12.2	2.38	9	2.27
Jack	11.9	2.21	17	2.34
Parrotfish	5.6	2.16	2	2.67
Marlin	4.8	2.27	3	3.86
Amberjack	0.8	1.83	1	1.81
Grouper	28.3	3.42	41	4.96
Red Hind	13.2	2.58	17	3.00
Nassau	0.9	2.56	1	3.20
Moharra	8.1	2.32	6	2.62
Snapper				
Lane	37.0	3.09	50	3.51
Yellowtail	35.4	3.26	42	3.51
Silk	79.9	4.45	112	4.61
Mutton	10.0	3.26	14	3.75
Other Snapper	17.4	2.54	18	3.09
Triggerfish	12.7	2.23	15	2.69
Barracuda	6.5	2.56	8	2.69
Porgy	4.2	2.29	4	2.65
Snook	13.6	2.82	11	2.89
Tarpon	1.6	1.30	2	2.03
Goatfish	3.2	2.62	4	2.89
Sardine	3.7	2.29	7	2.73
Mackerel	37.6	3.13	44	3.44
Shark	13.7	2.54	14	2.73
Margate	0.3	2.29	0	2.82
Classified	0.0	0		
First	54.0	2.95	98	3.22
Second	59.2	1.54	73	1.85
Third	23.9	2.23	28	1.92
Trash	2.5	1.50	2	1.23
Other Fish	61.2	58	2.73	
Total Fish	756.0	2.84	877	3.13

Table 1. Total Landings by Species for 1988 and 1989 (continued).

Species (English)	1988 mt	1988 US Price/kg	1989 mt	1989 US Price/kg
Queen Conch	108.3	3.99	73	4.59
Land Crab	1.2	9.00	2	13.52
Lobster	65.2	9.02	85	9.50
Oysters	0.6	5.09	0	4.34
Octopus	7.3	4.52	7	4.98
Other Shellfish	3.0	5.84	2	4.81
Total Shellfish	185.5	7.12	169	8.58
Total	941.5	1046		
Mean Price		$47.35		$3.58

The Department of Agriculture, Commonwealth of Puerto Rico, is the only government agency currently working with aquaculture legislation. Please refer to Table 2 for a list of the permits necessary to start a commercial aquaculture operation in Puerto Rico.

Aquaculture Farms

The farmers tend to be grouped in Southeast, West, and Southwest Puerto Rico. The largest farms (greater than 1 hectare of surface water) are also located in these areas with the exception of a large farm at Dorado on the north coast. Thirteen small-scale farms are located in Western Puerto Rico and six in the Eastern part. The six commercial farms are located equally in Western and Eastern Puerto Rico.

Marine Shrimp Culture

The development of *Penaeus* culture in the Caribbean has been slower than in Panama and Ecuador. Entrepreneurs from Ecuador considered Puerto Rico's ideal climate, stable government, international flights, and highly developed infrastructure to be a perfect site to start large marine shrimp operations. Several of these investors thought that they could simply transfer their technology directly to Puerto Rico. After investigation, however, they learned that the permitting process is difficult. The sites in Puerto Rico are different from the sites in Ecuador with little tidal fluctuations, oligotrophic waters which adds little natural productivity, difficulty in obtaining extensive acreages of land, and high energy costs. For instance, Ecuador's diesel fuel is subsidized and prices have been often several times less than diesel in Puerto Rico. (Recently,

Table 2. List of permits needed to start a commercial aquaculture operation.

Department of Natural Resources
P.O. Box 5887, San Juan, PR 00906
Telephone: 724-8774, 723-3090
Agua, Pozos
Solicitud de Franquicia Para el Aprovechamiento y uso de las Aguas de Puerto Rico-Uso Industrial o Agrícola (DRN-RA-(03-85))
Instrucciones Generales para Cumplimentar Solicitud de Franquicia Para el Aprovechamiento y Uso de las Aguas de Puerto Rico-Uso Industrial o Agrícola (DRN-RA-(03-85))
Instrucciones Generales para Cumplimentar Permiso de Construcción de Toma de Agua-Oficina Franquicias de Aguas (Tel:724-4418, 724-8774, ext. 254 o 288) (DRN-RA-(05-85))
Toma de Agua-Solicitud para Permiso de Construcción de Toma de Agua-Oficina Franquicias de Aguas (Tel:724-4418, 724-8774, ext. 254 o 288)(DRN-RA-(05-85))
Instrucciones Generales Para Cumplimentar Permiso de Construcción de Pozo
Solicitud para Permiso de Construcción de Pozo(DRN-RA-(04-85)
Area de Permisos-Instrucciones Generales para Cumplimentar Informe de Terminación de Obras Para Pozos
Area de Permisos-Informe de Terminacíon de Obras Para Pozos (DRN-RA-(09-86))
Importación de la Especie: Una carta solicitandolo que incluya nombre de la especie, cantidad a traer lugar de donde se va a importar certificación de tratamiento profiláctico y lugar dónde se colocaran a su llegada a Puerto Rico
Movimiento de Corteza Terrestre
Requisitos para Radicación de una Solicitud de Permiso Simple Extracción de Materiales de la Corteza Terrestre (menos de 5,000 metros cubicos)-División de Permisos, Corteza Terrestre
Department of Natural Resources
P.O. Box 5887, San Juan, PR 00906
Telephone: 724-8774, 723-3090
Agua, Pozos
Solicitud de Franquicia Para el Aprovechamiento y uso de las Aguas de Puerto Rico-Uso Industrial o Agrícola (DRN-RA-(03-85))

Table 2. Continued.

- Instrucciones Generales para Cumplimentar Solicitud de Franquicia Para el Aprovechamiento y Uso de las Aguas de Puerto Rico-Uso Industrial o Agrícola (DRN-RA-(03-85))
- Instrucciones Generales para Cumplimentar Permiso de Construcción de Toma de Agua-Oficina Franquicias de Aguas (Tel:724-4418, 724-8774, ext. 254 o 288) (DRN-RA-(05-85))
- Toma de Agua-Solicitud para Permiso de Construcción de Toma de Agua-Oficina Franquicias de Aguas (Tel:724-4418, 724-8774, ext. 254 o 288)(DRN-RA-(05-85))
- Instrucciones Generales Para Cumplimentar Permiso de Construcción de Pozo
- Solicitud para Permiso de Construcción de Pozo(DRN-RA-(04-85)
- Area de Permisos-Instrucciones Generales para Cumplimentar Informe de Terminación de Obras Para Pozos
- Area de Permisos-Informe de Terminacíon de Obras Para Pozos (DRN-RA-(09-86))
- Importación de la Especie: Una carta solicitandolo que incluya nombre de la especie, cantidad a traer lugar de donde se va a importar certificación de tratamiento profiláctico y lugar dónde se colocaran a su llegada a Puerto Rico

Movimiento de Corteza Terrestre

- Requisitos para Radicación de una Solicitud de Permiso Simple Extracción de Materiales de la Corteza Terrestre (menos de 5,000 metros cubicos)-División de Permisos, Corteza Terrestre

Regulation for the Control of Noise Pollution(005RR)

- Application for Approval for the Construction or Operation of Emissions Sources in Puerto Rico

Water

- Waste Load Allocation Guidelines(058RWG, July, 1990) (Guias para la Asignación de Cargas de Contaminantes)(050RWG, July, 1990)
- Underground Injection Control Regulation(020RUIC)
- Puerto Rico Water Quality Standards Regulation, As Amended (Reglamento de Estandares de Calidad de Agua de Puerto Rico)(017RW, Julio, 1990)
- Area de Calidad de Agua, Formulario de Pago de Cuotas-Radicación y Aprobación Plan CEST-1(CPC-F-005)
- Area de Calidad de Agua, Plan CEST (Informe de Progreso)(CPC-F-011)

Table 2. Continued.

Solid Wastes
Regulation for the Control of Hazardous and Non-Hazardous Solid Wastes(002RDS)
Planning Board
Estado Libre Asociado de Puerto Rico
Oficina de Gobernador, P.O. Box 41119, Santurce, PR 00940-9985. Telephone: 723-6200
General Documents Needed, Fees
Pasos a Seguir en la Radicación de Solicitudes de Determinación de Compatibilidad con el Programa de Manejo de la Zona Costanera ("Federal Consistency")
Application for Certification of Consistency with the Puerto Rico Coastal Management Program(Form JP-833)
Forma Evaluativa del Proyecto(Form JP-187, April 29, 1985)
Documentos e Información Necesarios para la Radicación de Casos sobre Consulta de Ubicació Privadas
Pasos a Seguir para la Radicación de Casos sobre : Anteproyectos Privados y Publicos (Estatales)
Formulario Ambiental para Proy. Industriales:(JP-822,1979) Instrucciones Generales
Formulario Ambiental para Proy. Industriales(JP-822,1979)
Consultas de Ubicación para Proyectos Residenciales, Industriales, Comeciales, Turisticos, Institucionales y Otros(Form JP-31 A, Sep, 1984)
Formulario Ambiental para Proyectos Residenciales Commeciales y/o Turisticos-Recreativos(JP-826, 1980)
Regulation and Permits Administration
(Administración de Reglamentos y Permisos (ARPE)
Consulta sobre Conformidad con el Reglamento de Zonificación(ARPE-15.13, Dic. 1975)
Unites States Army Corps of Engineers
400 Ave. Fernández Juncos, Parada 11 1/2
San Juan, PR 00901. Telephone: 729-6876
Regulatory Program-Applicant Information(1985, EP 1145-2-1)
Application for a Dep. of the Army Permit(ENG Form 4345)
Individual Permit (part of 4345)(ENG Form 1721)
Description of Authorized Work (part of 4345)(ENG Form 4336)
United States Environmental Protection Agency
PR 729-6951; NY, Laura Livingston (212)264-9880
Consolidated Permits Program(EPA Form 3510-1, Oct. 1980)
Application Form 2B-Conc. Animal Feeding(Form 3510-2B) Operations and Aquatic Animal Production Facilities

Table 2. Continued.

Consolidated Permits Program- Wastewater Discharge Information(EPA Form 3510-2C,1985)
NPDES Permit (National Pollutant Discharge Elimination System)
Federal Water Pollution Control Act, as Amended by the Clean Water Act of 1977(S-107)
Miscellaneous Agencies
State Historic Preservation Office (Tel.: 728-6971)
U.S. Coast Guard (Tel: 725-0857, 729-6800)

however, the Ecuadorian government changed the subsidy rates for the shrimp farmers and they now purchase diesel fuel at similar rates as Puerto Rico).

Many companies in Ecuador have "closed" the reproductive cycle in their shrimp operations. But maintaining a continuous healthy and reproducing broodstock of *P. vannamei* in Puerto Rico is different from the situation in Ecuador where wild brood shrimp are always available. These factors have to be carefully considered when transferring shrimp culture from Ecuador to Puerto Rico or other Caribbean locations. Many technological and management strategies will need to be adapted or changed. These are important factors which take time and money to consider and develop.

During 1991, Del Encanto Enterprises, S.E., located in Guayama on a 32 ha farm, produced 9 mt as part of their first crop of *P. vannamei* from six 0.25-ha ponds in Puerto Rico (B. Parra, personal communication) (Table 3). This family enterprise sells the shrimp locally for about US$11/kg (heads-on). They have the distinction of obtaining their permits faster than other start-up operations, having spent six months buying land and getting their permits one year later. Currently they harvest part of the stock in each pond twice each week using a semi-intensive management program.

Eureka Marine Products is a Taiwanese funded farm located in Dorado on a 58 ha tract leased from the Department of Agriculture. It has a hatchery capable of producing about 10 million *P. monodon* postlarvae per month. Postlarvae are stocked on the farm or sold to other farms. They have about 14 ha of surface area in 24 ponds and report 7,000 kg/ha for a four month growout in their best ponds. Because of delays in bringing in Taiwanese technicians to operate the farm, the 1990 harvest was only 18 mt. They purchase their starter feed from starter Zeigler Bros, Inc. at about $1.10/kg and their growout feed from Peru at US$0.95/kg, and sell their shrimp at US$11.00 to $15.20/kg (heads-on). They generated about $500,000 from sales of about 45,000 mt during 1991.

Ponce Marine Farms, also in Puerto Rico, experienced some difficulties in obtaining necessary permits. They now have 5 ponds (6 ha) in production and

Table 3. Aquaculture operations in Puerto Rico.

Owner/Company	Town	Ha (mt)	Sp.	Yield (heads on)	Price/kg
Aquaculture Ent.	Sabana Grande	76.49	M.r	68.04	$14.29
Acevedo, Edwin	San Sebastián	0.10	T.n.	n/a	n/a
			M.r	n/a	n/a
Bienvenido Sustache	Yabucoa	0.28	M.r	0.27	$17.64
Brunsan	Añasco	4.05	C.c.	n/a	n/a
			C.v	n/a	n/a
			M.r	n/a	n/a
			P.v	2.72	$11.03
			rt	9.07	$5.51
Castro, Miguel	San Sebastián	4.05	n/a	n/a	n/a
Colón, Gonzalo	Yabucoa	0.40	M.r	0.09	$15.44
			rt	0.14	$5.51
C-Quest	Santa Isabel	0.01	A.s	n/a	n/a
Del Encanto Ent.	Guayama	8.09	P.v	9.07	$10.91
DMS,UPR-MC	Lajas	4.26	M.r	n/a	$17.64
			T.n.	n/a	$4.41
			rt		
Díaz, Héctor	Cabo Rojo	0.07	T.n.	0.09	n/a
Eureka Marine	Dorado	36.42	rt	45	$7.72
			P.m	24.04	$13.23
Gerena, Ramón	Las Marías	0.02	M.r	n/a	n/a
Hidrocul. del Caribe	Juana Díaz	24.79	rt	107.16	n/a
Lagoa, Angel	Mayagüez	0.07	M.r	0.14	n/a
Lebrón, Reynaldo	Mayagüez	0.06	M.r	n/a	n/a
			T.n.	0.09	n/a
Morales, Daniel	Ceiba	0.16	M.r	n/a	n/a
Muñoz, Eduardo	San Lorenzo	0.20	T.n.	n/a	n/a
Pérez C., Victor	Utuado	0.12	M.r	n/a	n/a
Pérez, Ismael	Utuado	0.81	I.p.	n/a	n/a
			T.n.	n/a	n/a
Ponce Marine Farm	Peñuelas	6.00	P.m	18	n/a
			P.v	18.00	$15.40
Rivera, Julio	Fajardo	0.72	M.r	n/a	$15.44
			T.n.	n/a	$5.51
Robles, Rosendo	Añasco	0.06	M.r	0.01	n/a
			rt	0.09	n/a
			T.n.	n/a	n/a
Santiago, Roberto	San Sebastián	0.10	M.r	0.02	n/a
			T.n.	0.09	n/a
Sosa, Edgar	Cabo Rojo	0.22	rt	n/a	n/a

Table 3. Aquaculture operations in Puerto Rico (continued).

Owner/Company	Town	Ha	Sp.	Yield (mt)	Price/kg (heads on)
Ventura, Ramón	Rincón	0.81	T.n.	0.09	n/a
Total Macrobrachium		86.9		69	$16.09
Total Marine Shrimp		54.6		54	$12.64
Total Tilapia		73.4		127	$5.73

*Species:A.s.(*Amphiprion sp.*);C.c.(*Crassostrea crassostrea*); C.v.(*Crassostrea virginica*);I.p.(*Ictalurus punctatus*); M.r.(*Macrobrachium rosenbergii*);P.m. (*Penaeus monodon*); P.v.(*Penaeus vannamei*);r.t.(red *tilapia*);T.n.(*Tilapia nilotica*).

harvested about 18 mt of *P. vannamei* during 1990 (Z. Ceara, personal communication). Their product sells for US$11.00 to $15.40/kg depending on the size.

C-Quest has an indoor operation located in Santa Isabel with 1240 tanks. They are primarily interested in culturing 10 species of clown fish (*Amphiprion* spp.). After solving a recent disease problem, they have 125 pairs of clown fish which currently produced 15,000 juveniles. C-Quest has the distinction of employing a compete water treatment facility utilizing ozone, ultraviolet irradiation, bioballs in a trickle filter, diatomaceous earth, foam fractionation, and cartridge filters. It plans to export its fish to the United States at about US$2.00 each.

Small-scale Farms

There are several small freshwater farms in Puerto Rico, most of which would be considered hobbyist activities. A common problem encountered on small-scale farms is the overpopulation of Tilapia, especially when the farmer cannot drain the ponds. The farmers often complain of the price and quality of feed and of the availability of seed. Some use chicken feed (Pícalo Gallo), although some purchase a specially prepared aquaculture feed from Molinos de Puerto Rico. This is difficult for them since they are required to purchase large batches of feed.

Aquatic weeds such as *Chara* or other algae occasionally cause problems. Several of the farms simply use their ponds for recreation. Others do not have sufficient water to refill their ponds. Wild fish can be a problem if the incoming

water is not screened sufficiently. Some farmers choose not to work with their ponds rather than invest in feed and seed.

Miscellaneous Aquaculture Operations

Brunsan Aquaculture, a 4.05 ha farm located in Añasco, has tried to culture many aquatic organisms. They obtained permits to use their commercial sand extraction operation for aquaculture purposes. Since the ponds have an uneven bottom and depths to 4 m, water quality is often problem. They have tried with varying success the culture of *Crassostrea crassostrea, C. virginica, M. rosenbergii, Penaeus* sp, and red Tilapia. They plan to utilize 10 x 10 m cages since the uneven bottoms and the inability to drain the ponds prevents them from utilizing adequate harvest techniques.

Hidrocultivos del Caribe, S.E. a red Tilapia farm in Southeastern Puerto Rico is located on a 146 ha tract of land in Juana Díaz. They have 83 ponds for nursery, growout, broodstock, and sex reversal production. They market the Tilapia as St. Peter's fish primarily to one supermarket chain on the island. Yields are approximately 107 mt/yr.

Economic Data

Small-scale and commercial farms typically sell their products at ranges of US$14.29 to $17.64/kg, $10.91 to $13.23/kg, and $5.51 to $7.72/kg as wholesale prices for *M. rosenbergii*, marine shrimp, and Tilapia, respectively. Sabana Grande Prawn Farm sells *M. rosenbergii* under the name of Langostinos del Caribe and obtain prices of about $20.50/kg for their largest animals. Small-scale farmers typically sell their product locally, to neighbors or to local restaurants.

***Macrobrachium* Culture**

The high prices, however, do reflect some of the difficulties in raising *Macrobrachium* (Alston, 1989). Hatcheries are needed to supply postlarvae for the growout phase and thus add a significant expense for culturists. There is significant cannibalism within the ponds and heterogeneous individual growth occurs within the prawn populations, especially at higher stocking densities. Due to the effects the size differences, growout relies on labor-intensive, partial harvest techniques to obtain the largest prawns.

Egg bearing female prawns are usually collected from the growout ponds to supply eggs for hatchery operations (Alston, 1989). After the larvae hatch from the eggs, the newly hatched larvae can tolerate salinity changes to 13 ppt without acclimation. Optimum rearing temperatures are 28 to 31 °C. The larvae pass through 12 stages of development lasting 18 to 45 days before metamorphosing into postlarvae (early juveniles).

Systems used in the Caribbean to rear the larvae are generally clear-water techniques (as opposed to systems utilizing phytoplankton in the larval culture process) (Alston, 1989). The clear-water technique is dependent on frequent water exchanges or recirculated filtered water. Seawater for larval culture is usually clorinated and filtered before being diluted. Closed recirculating systems are also used, but expenses to maintain biological and mechanical filters or sterilizers increase the cost of the operation.

Some culturists utilize a two-phase larval rearing system to take advantage of the larval grouping behavior; however, most Caribbean culturists feel that heavy larval densities during the first 10 days contribute to delayed postlarval metamorphosis (Alston, 1989). The exact mechanism is not known for this occurrence, but it may be due to nutritional deficiencies. The larvae are primarily fed diets of squid, enriched fish and egg custard, Artemia, or dry commercial diets. Final larval densities generally range from 30 to 70 per liter with reports of 35 to 60% larval survival.

Larvae actively swim in the water column, while the PL either swim or cling to artificial substrates or to the walls of the culture tank (Alston, 1989). During the last 10 days of the larval period, when both PL and larvae are present, mortality increases as PL tend to attack the larvae, and new PL in the soft stage are attacked by both larvae and other PL. Early partial harvests of the PL are made by swirling the tank water rapidly. The PL tend to swim near the edge while the weaker swimming larvae congregate near the center of a circular tank.

Sabana Grande Prawn Farm, Ltd. and their subsidiary, Aquaculture Enterprises, Inc. have a commercial-scale farm. Hatchery production from 12 larval culture tanks of 8000 liters each reached about 3.6 million postlarvae per cycle (Alston, 1989). With 45 day cycles, the annual capacity would be 28.8 million and the monthly capacity would be 2.4 million postlarvae.

Current management techniques typically use 0.1 hectare nursery ponds in which 350 to 625 PL/m^2 are stocked and reared for 30 to 60 days (Alston, 1989). The nursery ponds are filled 1 to 2 days before the PL are released into the pond. During this stage the prawns are fed a high protein diet (40% protein) at about 20% body weight. Nursery ponds are beneficial since the culturist has more control over the water quality, feeding schedule, diet, and predators. Postlarvae are sensitive to high pH values, so the ponds should be stocked at pH values of 7 to 8.5 and never into waters having pH values over 9.0. For this reason, green water (water containing algae) is not a recommended source of water for filling the nursery ponds since algal photosynthesis can raise the pH values during the day. The ponds should be filled with clear or silt-laden water which is filtered to remove predators. Ponds with aquatic weeds such as filamentous algae or *Chara* sp. have higher pH values. *Chara* laden ponds have more odonatan nymphs while ponds with no weeds have more swimming predators such as notonectids

(Hemiptera) (Grana-Raffucci and Alston, 1991). Since the postlarvae are stocked at high densities, nursery ponds also utilize resources such as water, land, and labor more efficiently.

Juveniles from 0.5 to 2 g in size are harvested by seining each pond two to three times with a 6 mm mesh seine (Alston, 1989). Then the pond is drained and the remaining juveniles are trapped in a catch basin or box at the drain inlet or outlet. The nursery phase helps to provide greater accuracy when stocking juveniles into the growout ponds. The survival is better since larger juveniles are hardier.

Aquaculture Enterprises uses a continuous growout technique utilizing a two-phase system (Alston, 1989). Phase-1 ponds are stocked with about 7 prawns/m^2. Bi-weekly partial harvests are made with a 2.5 cm mesh seine to transfer the juveniles reaching lengths of about 7 cm to the phase-2 ponds. Phase-2 ponds are stocked with 2 prawns/m^2 and are partially harvested at monthly intervals with a 4.5 cm mesh seine. Smaller prawns escape while the larger ones are harvested. Ponds are drawn down about 20% before the partial harvest to increase harvesting efficiency. The growout ponds of both phases average 0.5 to 1 hectare in size and are filled to a depth of 1 to 1.5 meters. To prevent poor water quality, feeding rates are usually not over 30 kg/ha/day. The monthly production reached an all time high exceeding 12,000 kg per month in the spring of 1990. This would be an annual rate of about 2,900 kg/ha.

Processing is a critical operation of the project (Alston, 1989). Since the prawns are marketed as heads-on, extra care is taken to chill-kill them as soon as they are taken from the water. To maintain the firm texture of the meat, prawns should be cooked soon after being removed from the refrigerator or freezer. The shelf life of freshwater prawns stored on ice is about 10 days.

In 1983, Aquaculture Enterprises (Alston, 1989) used state-of-the-art technology developed by Weyerhaeuser (Alston, 1989), but implementation of this system at commercial scale in Puerto Rico disclosed several inadequacies. It was necessary for AEI to develop a "Modified Batch System" which greatly increased survival of juveniles. After two years of research and development at a cost of about one million dollars, a practical system was developed for commercial use in Puerto Rico.

The "modified batch system" incorporates a nursery phase and an advanced nursery phase operated on a "batch" system (Alston, 1989). The final grow-out phase remains on a periodic harvesting schedule which results in selective harvesting of the larger and more valuable freshwater shrimp by seining about once a month. Application of this system has increased production to record levels, well above the break-even point needed for the farm. However, production decreased during the latter part of 1990 because of excessive mortality of the postlarvae from a previously unrecorded disease. A similar mortality of larvae and postlarvae reported in 1987 at farms in Thailand was

termed "ideopathic muscle necrosis." This situation was corrected in Puerto Rico by thorough sterilization of the hatchery between cycles and maintenance of ammonia at non-toxic levels. This has permitted restocking of the ponds, and "normal" levels were expected to be restored in the spring of 1991. Because of the disease problem, production at the 50 ha Sabana Grande Prawn Farm in 1991 was 68 t. However, it was possible to shift the size distribution of the harvest to the large (45 to 57 g) and jumbo (65 to 90 g) classes because of reduced population density in the ponds. Since these size classes bring the highest prices, the effect of the shortfall in production was somewhat alleviated. In practice, production is now measured by the value of the harvested freshwater shrimp instead of the kilograms produced. Prices at the wholesale level have consistently averaged about $13 to $20.50 (US) per kilogram for heads-on prawns. Culturists take advantage of the large-sized prawns and usually sell 35 to 75 g animals. This marketing approach distinguishes freshwater prawns from species of marine shrimp sold in the area. This distinction is an important aspect of freshwater prawn farming since large-sized prawns bring the higher prices. Culturists have been able to sell their prawns either locally or as an export item. The year-round tourist trade and available international air flights contribute to the marketing success. Currently, they still operate the farm, but are under Chapter 11 bankruptcy protection.

Aquaculture Enterprises markets their shrimp by the name "Langostinos del Caribe," and sells about 20% at the farm, 20% to restaurants and supermarket chains in Puerto Rico, and about 60% to the continental United States and other Caribbean markets (J. Glude, personal communication 1990).

Training, Research, and Extension

Sixty-one percent of the work force has completed 12 or more years of education; one in three has has some college training (Puerto Rico's Caribbean Development Program 1992). There are many universities on Puerto Rico, so the there are many highly trained personnel capable of handling demanding assignments. Minimum wages on the island, as elsewhere in the United States, are established by the U.S. Congress.

Since the introduction of an aquaculture program in 1970 by the Department of Marine Sciences (DMS), University of Puerto Rico-Mayaguez Campus (UPR-MC), it has emphasized technical and academic training (Table 4). During the first six years, the program was sponsored by several agencies and included several projects.

The Government of Puerto Rico Commonwealth Law 1612 provided funding ($250,000) for the construction of the majority of the aquaculture facilities at the DMS Aquaculture Field Station in Lajas. In 1982, an additional appropriation of $200,000 was granted by the Council of Higher Education. Subsequent efforts led to the cooperative agreement between DMS and the

Agricultural Experiment Station of UPR. The aquaculture program joined the Hatch Regional Project for Freshwater Food Animals (S-83) and initiated projects at the Lajas Station. This also allowed DMS to participate in the Title XII Strengthening Program in conjunction with the College of Agricultural Sciences and as a result, further expand its aquaculture staff. Since 1980, UPR-MC has used a multi-faceted approach to develop the aquaculture program on a local and an international level.

In July 1979, UPR-MC obtained a Title XII Strengthening Grant under the United States Agency for International Development (USAID). One of the major efforts under Title XII has been centered in the DMS-Aquaculture Program, to provide a base for international applications of research and training in a diversity of tropical aquatic fields.

The formation of PESCA, Program of Caribbean Studies in Aquaculture (Programa de Estudios Caribeños de Acuicultura), was formed within DMS to help to identify the aquaculture program as becoming a center for aquaculture in the Caribbean. PESCA advises on a number of matters relating to aquaculture development in the Caribbean and Latin American regions, including:

1. Local and foreign, short-term advisory and consultant services by UPR-MC personnel in all areas of aquaculture development and resource management.

2. Long and short term training of foreign personnel at UPR-MC in aquaculture related subjects.

3. Degree programs at the MS and PhD levels.

4. The utilization of on-line bibliographic information by the DIALOG Information Retrieval Service through the General Library, UPR-MC, and the Technical Information Center, UPR-MC.

5. The development of aquaculture information networks through seminars, workshops, and short courses.

6. The home office of the Caribbean Aquaculture Association. PESCA personnel created this non-profit association to provide the broad structural framework required for optimal organization and planning for aquaculture development at the local and international levels.

The Lajas Aquaculture Field Station has 4.26 ha of water including the following experimental units: 6 fiberglass 0.91 m^3 tanks; 17 concrete 2.7 m^3 tanks, 8 fiberglass 1.8 m^3 pools; 1 earthen 0.2 ha water supply pond; 1 well capable of pumping 1100 liters/min; 4 earthen 0.02 ha ponds (with concrete reinforced banks); 10 earthen 0.02 ha ponds; 12 earthen 0.07 ha ponds; 12 earthen 0.12 ha ponds; 1 earthen 0.72 ha pond; and 2 earthen 0.39 ha ponds.

Work is being done at the University of Puerto Rico to increase the Tilapia yields while maintaining good growth and survival of the prawns. Polyculture techniques suitable for small-scale operations indicate yearly growout productions of 700 kg/ha of freshwater prawns and 2600 kg/ha of Tilapia

averaging 395 g each with 71% of the prawns weighing 40 g or more. The University of Puerto Rico, Department of Marine Sciences has an experimental freshwater shrimp hatchery that has the capacity to produced about 1 million postlarvae per year. They provide postlarvae for research projects and sell some postlarvae to local farmers. The hatchery is also used as a training facility. The UPR Institute of Neurobiology does research on the behavior of *Macrobrachium.*

Researchers are currently determining the feasibility of continuous partial harvesting followed by restocking of Tilapia and freshwater prawns into ponds. With a continual supply of fish and shrimp, these techniques would allow for gradual expansions of small-scale operations; meanwhile, they would not need freezers to maintain their product. Research is being done with placing red Tilapia hybrids in cages in semi-intensive prawn ponds. Preliminary results indicate no effects on the prawn production. Please refer to Table 4 for the titles of aquaculture theses and dissertations from the University of Puerto Rico.

The Agricultural Extension Agency in collaboration with the University of Puerto Rico, Mayagüez Campus, offer extension services. Also the Fisheries Development Program of the Department of Agriculture provides extension services of one technician for one-half of her work schedule. An Open House is held each month at the Center for Research and Development, Lajas Agricultural Research Station in Lajas. The purpose of this activity is to orient and assist potential local aquaculturists. A slide show and talk are presented to the participants. This is followed with a tour of the Department of Marine Sciences Lajas Aquaculture Field Station. The Open House is sponsored by the Fisheries Development Program of the Department of Agriculture, the Agricultural Extension Agency, the UPR Sea Grant College Program, and the Department of Marine Sciences.

Incentives

The Economic Development Administration offers incentives for tax exemption purposes. A firm can elect to defer its tax-exempt years on an annual basis. This enables a firm to save its tax exemption for the years in which profit flow is most appropriate to warrant exemption. Tax exemption is a contractual guarantee by the Commonwealth of Puerto Rico. A company's exemption grant may not be impaired or revoked without cause. The exemptions are 90% of income, 90% of the property, and 60% of municipal patents for periods up to 10 to 15 years in highly industrialized areas, and up to 25 years in needy areas.

Section 936 of the U.S. Internal Revenue Code permits U.S. manufacturers to repatriate profits from its Puerto Rico operations whenever they want to, free of federal taxes (Puerto Rico's Caribbean Development Program, 1992). Manufacturers are not required to wait until the end of their tax exemption period - 10 to 25 years - to take their money home.

Table 4. University of Puerto Rico aquaculture dissertations and theses.

Abreu-Volmar, Miguel A. 1978. Híbridos productos de cruces selectos de Sarotherodon (Trewavas): Cichlidae. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Ayarza-Real, Carlos Javier. 1988. Calidad del agua en estanques de cultivo intensivo de tilapias. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Bonilla-Soto, Luis A. 1978. Policultivo del bagre de canal Ictalurus punctatus (Rafinesque) con híbridos machos de *Sarotherodon*, obtenidos de los cruces *S. mossambicus* (Peters) hembra x *S. hornorum* (Trewavas) macho y *S. hornorum* hembra x *S. aureus* (Steindachner) macho a diferentes densidades en charcas de arcilla. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Bonilla-Soto, Luis Antonio. 1984. A study of the brine shrimp, Artemia, Crustacea: Anostroca, in Puerto Rico. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Carrillo-Bedoya, Diego. 1978. Evaluación de una dieta artificial para peces, en peceras y en charcas de arcilla, utilizando los peces *Sarotherodon hornorum* y el híbrido monosexual masculino, producto del cruce de *Sarotherodon aureus* (hembra) X *Sarotherodon hornorum* (macho). Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Cepeda, Evelyn. 1982. Macrobrachium rosenbergii (de Man 1879) and rice culture in Puerto Rico. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Cintron-Velázquez, Jaime. 1980. The development of feeds for the Cichlid fish *Sarotherodon aureus* (Steindachner) using locally available feedstuffs and industrial wastes and by-products. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Cortés-Maldonado, Ricardo C. 1976. Técnicas de piscicultura para la propagación y cultivo intensivo del bagre de cana Ictalurus punctatus (Rafinesque): Ictaluridae en Puerto Rico, enfatizando el policultivo con *Tilapia aurea* (Steindachner): Cichlidae. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Fram, Mitchell. 1977. Production of *Tilapia nilotica* (Linnaeus) and of the all-male hybrid, *T. nilotica* (female) X *T. hornorum* Trewaves (male), in earthen pond monoculture systems, with observations on their effects on water quality. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Gallegos, Sonia. 1978. Evaluation of two male hybrids of *Sarotherodon* obtained from the crosses: *Sarotherodon hornorum* (Trewavas) male x *Sarotherodon niloticus* (Linnaeus) female and *Sarotherodon hornorum* male x *Sarotherodon aureus* (Steindachner) female in polyculture with channel catfish (*Ictalurus punctatus*; Fafinesque) in earthen ponds. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Table 4. University of Puerto Rico dissertations and theses (continued).

Garcia-Pinto, Lope de J. 1978. Hibridación entre especies del pez del género *Tilapia* (Familia Cichlidae), en Puerto Rico. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Hawk-Almeyda, E. G. 1978. Growth and feed conversion efficiency of young green turtles, *Chelonia mydas* (Linnaeus), in seawater and dilute seawater. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Hummel, Charles G. 1986. Effects of high pH on the mortality of *Macrobrachium rosenbergii* (de Man) postlarvae in green and clear water. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Juste, Vico. 1987. Estudio preliminar sobre la viabilidad del cultivo de la almeja *Mercenaria mercenaria* en el suroeste de Puerto Rico. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Kohler, Christopher. Evaluations of fishculture trials with the cichlid fish *Tilapia aurea* (Steindachner) subjected to different levels of management. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Monterrosa-López, Oscar E. 1986. Postlarval recruitment of the spiny lobster, *Panulirus argus* (Latreille), in Southwestern Puerto Rico including observations of substrate selection in aquaria. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Olson, Meridith. 1976. Polyculture trials of channel catfish, *Ictalurus punctatus* (Rafinesque) and blue tilapia, *Tilapia aurea* (Steindachner) in earthen ponds. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Velazco-Dominguez, Aileen T. 1981. Feasibility and desirability of holding juvenile spiny lobsters (*Panulirus argus* Latreille) in wire or tire cages. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR 00681-5000.

Verdegem, Marc Charles Jean. 1987. Response of fecundity and growth to hybridization and crossbreeding of *Tilapia hornorum, Tilapia nilotica* and Taiwanese red tilapia in hapas. Thesis, University of Puerto Rico, Department of Marine Sciences, Mayagüez, PR.

Section 936 is a mechanism for economic development not only in Puerto Rico, but throughout the Caribbean Region. Congress and the Administration in Washington, D.C. confirmed more than a tax formula. Through the Tax Reform Act of 1986, and expanding the use of 936 funds to other Caribbean areas, they established a broad public policy that convey a very positive message about using Puerto Rico as a base for global private enterprise. Section 936 in Puerto

Rico is now more flexible and responsive to the competitive requirements of U.S. manufacturers.

Puerto Rico is situated in a unique position to assist through its complementary or twin plant program (Nieto, 1990). Developing countries in need of technical assistance and financing can work with Puerto Rico in joint ventures.

Recent amendments to Section 936 state that 936 funds held by private lending institution on the Island and the Government Development Bank for Puerto Rico (GDB) can be invested in active business assets for development projects in qualifying CBI countries which have signed bilateral Tax Information Exchange Agreements (TIEA) with the U.S. Government. Total 936 funds for liabilities and capital amounted to $5,717,300,000 for September, 1991 (Financial Institutions Commissioner, 1992).

The Economic Development Bank for Puerto Rico, The Corporation for Commercial and Agricultural Development, TROPICO, and private banks are other potential sources of financing. TROPICO offers grants or joins as a partner. Total commercial loan activities for agriculture in 1990 rose by 9% to $126,700,000 (Financial Institutions Commissioner, 1992).

The Farm Bureau has created an aquaculture sector which brings together almost all aquaculture producers doing business in Puerto Rico. The Farm Bureau also concentrated its efforts on the approval of Bill Number 1040 which was enacted and signed into Law 61 by the Governor of Puerto Rico (Nieto 1990). In broad terms, it helps to reorganize the industry by transferring the aquaculture program from the Department of Natural Resources to the Department of Agriculture which is viewed as a pro-aquaculture government dependency.

In addition, an Aquaculture Council was formed with six cabinet members representing the government agencies concerned one way or another with aquaculture development and four private sector representatives.

DISCUSSION

In addition to the potential of ponds for aquaculture, 19 man-made reservoirs exist in Puerto Rico providing about 30 km^2 of water (McGinty *et al.*, 1988). If incentives for leasing sections of these reservoirs were made possible, considerable fish production would be feasible in cages.

Farmers have expressed an interest in a more simple permit system, to establish areas in which aquaculture activities could be developed without competing with other activities, to develop better marketing strategies, and to train more aquaculture technicians.

Aquaculture in the Caribbean has lagged behind other countries such as Panama and Ecuador. There are a variety of reasons for the slow development, but the ideal climate and increased interest by investors still shows promise for

the region. To be successful, farms and farming technology will need to be adapted to the region, but the continued growth in tourism should help maintain the market values that are essential for commercial crustacean culture. With the increased fishing effort to sustain yields and with the rise in seafood prices, the economic climate is more favorable for aquaculture development in Puerto Rico.

LITERATURE CITED

Alston, D.E. 1989. *Macrobrachium* culture, a Caribbean perspective. *World Aquaculture* **20(1)**:18-23.

Department of Commerce. 1990. Bureau of Census, San Juan, Puerto Rico.

Financial Institutions Commissioner. 1992. In: *Puerto Rico monthly economic indicators*. Compiled by the Government Development Bank of Puerto Rico.

Grana-Raffucci, F.A. and D.E. Alston. 1991. Distribution of predatory insects in ponds stocked with Tilapia and *Macrobrachium rosenbergii*. *Proc. Gulf Carib. Fish. Inst.*, **4**. November, 1987.

Mattos-Caraballo, D. and Y. Sadovy. 1990. Overview of Puerto Rico's small-scale fisheries statistics 1988-1989. Corporation for the Development and Administration of Marine, Lacustrine and Fluvial Resources of Puerto Rico Fisheries Research Laboratory.

Mattos-Caraballo, D. and Z. Torres-Rosado. 1989. Technical report, comprehensive census of the fishery of Puerto Rico, 1988. *Corporation for the Development and Administration of Marine, Lacustrine and Fluvial Resources of Puerto Rico Fisheries Research Laboratory* **1(3)**.

McGinty, A.S., D.E. Alston, J.M. Kubaryk, and R. Cortés. 1988. Aquaculture in Puerto Rico. Department of Marine Sciences, University of Puerto Rico, Mayagüez Campus. Unpubl. MS.

Nieto, R.R. 1990. Aquaculture in Puerto Rico: the coming decade. *The Caribbean Aquaculturist* **6(2)**:7-9.

Puerto Rico's Caribbean Development Program. 1992.

Puerto Rico Tourism Company. 1992. In: *Puerto Rico monthly economic indicators*. Compiled by the Government Development Bank of Puerto Rico.

Weidner, D. 1990. United States Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, DC.