Third World Level Conch Mariculture in the Turks and Caicos Islands

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ABSTRACT

The Foundation for the Protection of Reefs and Islands from Degradation and Exploitation (PRIDE) has developed facilities and hatchery techniques for conch mariculture on Pine Cay in the Turks and Caicos Islands, a remote Third World site. The Foundation's efforts have focused on the participation of local people and ways to reduce the energy costs of the hatchery through the use of alternate energy devices. In the past two seasons (1981-1982) PRIDE established and monitored an enclosed breeding population of Queen Conch, *Strombus gigas*.

Egg farm data confirm that the egg laying season is from late March to early September with a distinct seasonal variation in number of egg masses present. A female conch was found to lay on the average 8 egg masses per 6-month season. From May to September 1982, the PRIDE hatchery reared siblings from 6 field collected egg masses through metamorphosis. Algae for use as larval food was reared in batch culture in 19-*l* carboys, in a temperature and light controlled algae room and on a sunlit, ventilated porch. Electrical energy for Pine Cay was supplied by a diesel generator which turned off from 11 P M to 6 A M. During this time and generator failures, a wind charged battery unit connected to a BEST Inverter system provided electrical power for the hatchery. A solar still provided distilled water. This season's efforts have produced a conch mariculture facility incorporating simple, economical and energy efficient systems appropriate in a developing country.

Queen conch, *Strombus gigas*, is one of the major marine natural resources of the Bahamian Bank, Caribbean Islands and Florida Keys. Its value is both as an export item and indigenous protein source. Today there are only three areas that still have commercially exploitable stocks of conch: the Bahamas, Turks and Caicos and Belize. The increased economic importance and severe overfishing of conch has resulted in a need to replenish conch stocks. This led to several years of conch mariculture research.

D'Asaro was the first to observe and describe *S. gigas* larval development (1965). Berg reported on the potential for conch mariculture (1976). Brownell demonstrated in Los Roques, Venezuela, that conch can be successfully raised to metamorphosis in a simple culture system (1977). In the past 3 years, several hatcheries have contributed important knowledge on state of the art culture techniques for repeatedly bringing large numbers of conch through metamorphosis (Siddall, pers. com.; Chanley, pers. com.).

The Foundation for PRIDE (a non-profit, scientific and educational organization) has operated a marine field station since 1976 on Pine Cay, a 2-mi^2 island in the Turks and Caicos Islands. This group is a low lying arid archipelago, located about 145 km (90 miles) north of Haiti and 810 km (500 miles) southeast of Miami. Geographically they are part of the Bahamian Plateau, politically they are a self-governing member of the British Commonwealth.

For a facility to succeed in a remote developing country, it must be started with the understanding that its construction, operation and maintenance must be simple, reliable, productive, resourceful and adaptable to local patterns of tradition and energy efficient. PRIDE has attempted to apply the above criteria to its conch mariculture development work. During the 1982 season, PRIDE conch mariculture consisted of three separate phases: (1) establishing and monitoring an "egg farm" for a breeding population of conch, which provided data on egg laying frequency and for collection of egg masses for the hatchery, (2) rebuilding a hatchery facility to rear conch through metamorphosis and to culture tropical algae (Fig. 1) and (3) growing post metamorphosed conch on large wet tables. The hatchery systems made use of alternate energy devices in an attempt to develop the highest productivity using the least amount of fossil fuel derived energy.

EGG FARM

In the summer of 1981, PRIDE established and monitored an experimental, enclosed, underwater egg farm for queen conch, *Strombus gigas*. The site selected for the egg farm was a natural breeding ground within the Pine Cay barrier reef, about 2.5 km (1.5 miles) northwest of the island. The area was stocked with mature male and female conch and several months of breeding data were collected. Indications were that such an enclosure, involving the close proximity of males and females, resulted in many egg masses being laid per individual female. The observations from the work in 1981 encouraged PRIDE to reestablish an egg farm on the same site in the spring of 1982, in advance of the breeding season. The farm had two purposes: (1) to provide a reliable source of eggs for the hatchery and (2) to obtain data on reproductive behavior throughout a complete breeding season. This was the first brood stock of *S. gigas* ever contained and monitored for the purpose of supporting a hatchery operation.

The area of the pen is 1,600 m^2; it is in water 6 m deep with a flat bottom of sand and coral rubble covered with stubby algae. Its perimeter is 75% enclosed by natural coral reef. Two natural openings through the reef constituted the remaining 25%; these were sealed off by net fences of polypropylene mesh with lead weights at the bottom and floats at the top. Table 1 describes the substrates and macro-algae found

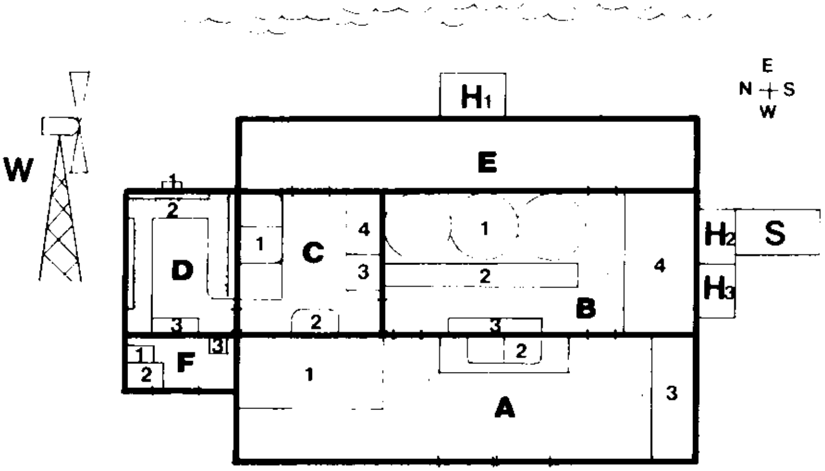


Figure 1. PRIDE Conch Hatchery Layout: A. Front room: (1) metamorphosis wet table, (2) fresh water sink and display shelves, (3) field research equipment; B. Veliger rearing room: (1) 3-500 liter conical larval tanks, (2) draining gutter, (3) egg mass aquaria, (4) 2 grow-out wet tables; C. Prep room: (1) sink and glassware shelves, (2) stove top gas burner for autoclave, (3) refrigerator, (4) microscope desk; D. Algae room: (1) 5000 BTU air conditioner, (2) shelves with 40 watt cool-white fluorescent lights, (3) bunsen burner; E. Screen porch; F. Battery room: (1) 2.5 kw Best Inverter, (2) 10 kwh battery bank, (3) battery charger; H. Head tanks: (1) veliger, (2) & (3) grow-out; S. Solar still; W. One kw Sencenbaugh Wind Generator. Dimensions of building: 9 by 6 m.

Table 1. Egg Farm substrates and macro-algae

Substrate	Macro-algae Dominant	Macro-algae Other
Large rocks, fragments of dead staghorn coral and conch shells, coral rubble, sand patches, silt covering	*Microdictyon* sp. *Digenia simplex* *Cladophoropsis membranacea*	*Sargassum* sp. *Halimedia* sp. *Rhipocephalus phoenix* *Acicularia schenskii* *Acetabularia* sp.
Small rocks, fragments of coral and conch shells, small sand patches, silt covering	*Microdictyon* sp. *Acetabularia* sp. *Acicularia schenskii* *Cladophoropsis membranacea* *Digenia simplex*	*Sargassum* sp. *Halimedia* sp. *Padina haitiensis*
Majority sand, scattered coral rubble, small rocks and fragments of conch shells	*Acetabularia* sp. *Acicularia schenskii* *Batophora oerstedi* *Digenia simplex* *Cladophoropsis membranacea*	*Sargassum* sp. *Anadyomene stellata*
Coral rubble, rocks, knocked conch shells, silt covering	*Microdictyon* sp. *Cladophoropsis membranacea*	*Halimedia* sp. *Dictyota* sp. *Sargassum* sp. *Padina haitiensis*
Large rocks, coral rubble, few sand patches, hard surface, silt covering	*Microdictyon* sp. *Digenia simplex* *Cladophoropsis membranacea*	*Sargassum* sp. *Dictyota* sp.
Rocks, coral reef	*Sargassum* sp. *Microdictyon* sp. *Cladophoropsis membranacea*	
Rocks, coral reef, coral rubble	*Microdictyon* sp. *Halimedia* sp. *Digenia simplex* *Cladophoropsis membranacea*	*Sargassum* sp. *Turbinaria turbinata*

inside the pen area. The farm is situated on the landward side of the barrier reef thus making it a highly protected area. The motion of the water often shifts the sand on the bottom, and a warm thermocline 1-2 m from the bottom is usually present. In 1982, the temperature of the water below the thermocline during the first half of the season, March to June, was an average 27°C with lows of 26°C. During the second half, July to September, the temperature climbed to an average 29°C with peaks of 30.5°C.

This breeding site was fished out in 1980; therefore, in 1981 the egg farm was restocked with fifty 4-6 year old mature conch and in 1982 with 100-120 mature conch with a ratio for both years of approximately 1:1 males to females. The density during the 1982 season was one conch/14.5 m^2, which is close to the density of one conch/10.7 m^2 found in a natural unfished breeding population in South Caicos (Hesse 1979). Conch were transferred to the farm site from several shallow areas inside the reef. They were found around "dryers," or large monoliths largely devoid of coral life. *Laurencia* was the dominant algae present. Only conch with enough spire to hold a tag were collected. These were gathered by skin diving, then moved by boat to the egg farm. Several methods of tagging were tried, the final one used was a yellow, plastic, Turks and Caicos Fisheries tag, indented with a number. This was attached to the conch with plastic pull ties. After the conch were tagged, they were returned to the water, after a total of 1-2 h in air. These transferred conch showed no sign of stress. Two days after being placed in the egg farm, the conch were observed laying egg masses and copulating with conch from different areas. In 1981, the sex of the conch was determined by placing the animals on their side and when the conch came out of the shell to right themselves, the verge of the male or egg grove of the female was seen. In 1982, the sex was determined simply by observing their breeding behavior; pairing, copulation and egg laying.

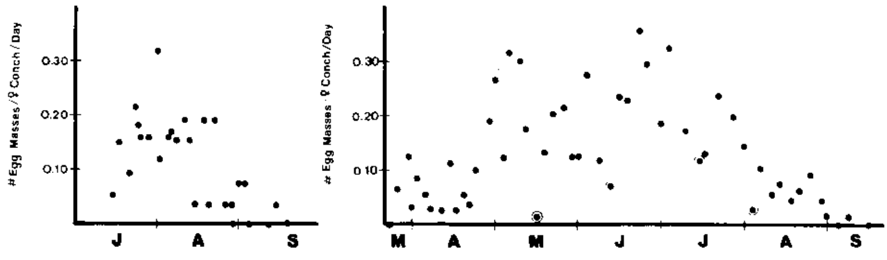
Throughout the breeding season, a marine biologist and local technician used SCUBA gear to visit the egg farm approximately twice per week. This facilitated maintenance of the nets, observations of breeding activity and collection of egg masses for the hatchery.

Figure 2 presents results from two spawning seasons (1981,82) as number of egg masses present per female conch per day. A seasonal change in production of egg masses can also be seen during each season. The aberrant points circled in Figure 2 occurred on stormy days, when storm surges decreased egg laying activity. From 1981 data, mean number of egg masses laid per female per day was calculated to be 0.062 (n=25; Sd=.053). The mean number of egg masses laid per female per day in 1982 was 0.041 (n=50; Sd=.035). Data from both years indicate that approximately 8 egg masses per female are laid on the average during a typical 6-month breeding season. The number of egg masses increased from an average of 9.6 egg masses per week with 50 conch present during the 1981 season to an average of 16.5 egg masses per week during the 1982 season with 100 conch present. This increase in production probably resulted from the increased number of brood stock conch. The majority of the egg masses were found in central and seaward areas of the egg farm.

Figure 3 shows the different levels of activity of males per day as it relates to pairing and copulation of the conch during the 1982 season. Observed activity of certain male and female individuals tended to be higher than other conch in the same area. To provide clarity of presentation visual fit lines (Fig. 4) have been drawn from the data in Figures 2 and 3. Figure 4 illustrates a possible correlation between temperature, pairing and copulation activity and egg laying. It is likely that temperature is a determining factor in the onset and termination of spawning. A definite correlation between egg laying and activity cannot be determined until other factors have been investigated. These include: (1) the lag time between copulation and the commencement of egg-laying and (2) the number of egg masses produced from one copulation.

The 1982 breeding season at the egg farm extended from late March to early September. However, egg masses were still found on the Caicos Bank at the end of September. Environmental habitat will influence breeding behavior which is a consideration to keep in mind when choosing an egg farm location.

The PRIDE egg farm was successful in providing easy and reliable access to a

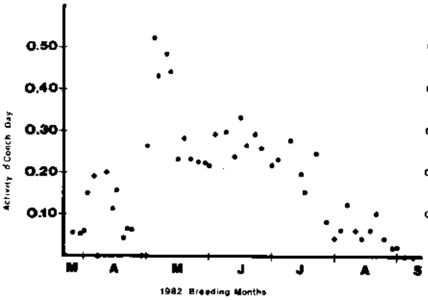


A 1981 Egg Laying Months (2nd Half

B 1982 Egg Laying Months

Figure 2. A: 1981 egg laying months, second half of the season at the egg farm; B. 1982 egg laying months, full season at the egg farm.

source of healthy, naturally developed eggs for the hatchery. From the months of May to August, there were always enough egg masses available for the PRIDE hatchery to continually operate two rearing tanks. Of the 414 egg masses produced at the egg farm during the 1982 season, 40 were used in the PRIDE hatchery and 17 were sent to the University of Miami for use in their hatchery facility. The size of this egg farm and the density of conch it contained could have assured egg masses for a large scale commercial operation to continually run 50 rearing tanks for a 6-month season.



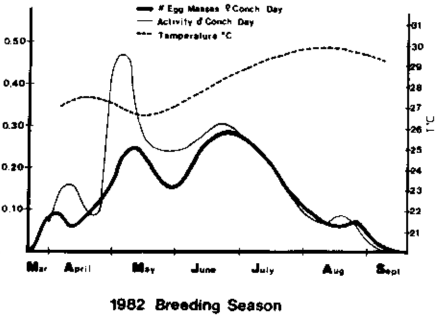


Figure 3. 1982 breeding months, full season at the egg farm.

Figure 4. 1982 breeding season, March to September, at the egg farm. Visual fit lines from data in Figures 2 and 3 illustrate a possible correlation between temperature, pairing and copulation activity and egg laying.

HATCHERY

Egg Mass

The egg masses were collected from underneath the female conch. This ensured freshness and predicted time for hatching could be determined. PRIDE always had egg masses on hand in the hatchery, even when all rearing tanks were full. If there was a failure of a batch, a new hatch could begin with little loss in culturing time.

Once in the facility, the fresh egg mass underwent the following procedure which produced a clean and healthy hatch (Siddall, 1981): The egg mass strands were gently teased apart, large sediments and seaweed were removed; it was then dipped in a mild clorox solution and rinsed several times in fresh seawater. The clorox treatment helped aid in removal of the majority of sediment and killed any worms, crustaceans or other organisms that lived in the egg masses. The treated egg mass was then placed in a mesh bag (Chanley, pers. com.) in a highly aerated aquarium filled with freshly filtered seawater. This bag kept the egg mass off the bottom, allowed for good water circulation, and made it easy to remove the egg mass for daily water changes and for transferring it to the rearing tank for hatching.

PRIDE experimented with an alternate method for incubating egg masses. A teased, but untreated egg mass was placed in a screen enclosure and hung in the raw water from the seawater line. The egg mass was brought into the lab the day before hatching, rinsed well, then placed in the rearing tank to hatch. This method also produced a healthy hatch and saved labor, equipment and handling of the egg mass.

Completeness, age and incubation temperature of the egg mass influenced when it would begin to hatch. A newly laid egg mass or one collected from underneath the female began to hatch between 85-109 h after collection, at an average temperature of 28.5°C in the PRIDE hatchery. The day before hatching, the egg mass was suspended inside a 15-cm pvc-dish, in the upper portion of the rearing tank. The weak and dead veligers, along with egg mass debris, settled inside the pvc dish. This separated the healthy, swimming veligers which floated up into the rearing tank (Siddall, pers. com.). The egg mass was left to hatch in a 500-*l* conical tank for 20-24 h, which produced an average initial density of 250-300 veligers/*l*. The quantity and quality of a hatching egg mass varied. Healthy veligers hatched from the majority of the egg masses. However, a few hatches during and towards the end of the season were less viable; and the veligers only survived a few days. Better survival rates occurred when the eggs hatched directly in the rearing tank rather than transferring the newly hatched veligers from the incubating aquarium to the tank.

Veliger Rearing

Daily 100% water changes and tank cleaning was begun 24 h after the egg mass was placed in the conical rearing tank. All the old water was removed to lessen bacterial contamination which would be lethal to the veligers after 24-48 h. Were this not done, protozoa, the secondary invaders, would contribute to a bad culture condition (Chanley, pers. com.).

Before water changes began, the proper seive size was determined by measuring the minimum shell dimension for a sample of veligers (Siddall, pers. com.). Occasionally the culture was culled, discarding the slower growing veligers which allowed uniform growth and development for the rest of the batch. To change water, aeration was first turned off. This allowed dead and weak veligers and debris to drop out of suspension to the bottom of the conical tank. Then water changes began using the midway tank draining valve. This collected all swimming veligers and reduced the pressure of water on the bottom draining valve. During water changes, veligers were collected in a tall cylindrical seive which sat inside a 20-*l* bucket. The seives were made of "Kalwal," reinforced fiberglass sheeting or 15 cm diameter pvc. Nitex or polyethylene screen mesh ranging from 157-300 μm openings was used on the sides and bottom of the seives. Water changes took place quickly, but carefully, so that the veligers were not overcrowded, did not lose growing time and were not stressed. As the veligers became larger and hardier, the water changes became faster. To speed up water changes, the hatchery had a rotation tank, enabling one tank to drain as the other was filling. Water changes were done in the morning when the temperatures were the lowest (27-29°C), compared to the high afternoon temperatures (30-31.5°C) which may have enhanced bacterial growth. Average rearing temperature for the PRIDE hatchery was 28.5°C.

The seawater line for the hatchery extends 30 m from shore into a 200-m wide channel situated between two islands. This water is in continual motion because of the swift (1-2 knot) tidal currents, making the water well aerated with little turbidity, except on very windy days. During ebb tide, the water comes from the shallow 2-4 m sandy bank; on flood tide, the water comes from the reef and open ocean. There is no runoff of rivers or fresh water from the islands; therefore, the salinity stays at a constant 35-36 ppt. Since the majority of the Caribbean waters are low in productivity, toxic debris and pathogens, it was not necessary to use UV sterilization. However, our water was filtered at 15 μm to remove any predators, small macro-algae and sediment debris. PRIDE hatchery did not monitor pH or DO of the rearing water, for these environmental tests will not indicate the condition of the batch. Daily observations of behavior and growth rate of the veligers told the development and health of the culture.

Rate of veliger development depended on handling techniques, temperature, density and most important quality, quantity and type of food. PRIDE hatchery followed feeding types and concentrations recommended from the research conducted at the University of Miami conch hatchery during the 1980-1982 seasons.

Most of our early veliger cultures failed partially due to high concentrations of food. These veligers developed faster, however, less survived to metamorphosis because of a critical stage between 9-11 days, during which a 50%-70% mortality of the culture occurred. Feeding with low food concentration slowed down development, which enabled the veligers to safely pass through the critical stage. These veligers were hardier and a larger percentage survived through metamorphosis.

Metamorphosis is a transformation which takes 12 h to occur (Siddall, pers. com.), at which time, the floating veligers change into a benthic juvenile conch which grazes upon macro-algae. There are certain morphological clues that indicate when the veligers are approaching metamorphosis (Brownell, 1977). A trigger was not needed to stimulate metamorphosis, PRIDE's hatchery conch settled between 1.2-1.9 mm. It occurred between 2-5 weeks depending on development; fast development, 14-19 days, slower development, 28-35 days. As soon as the first one or two conch metamorphosed in the tank, the entire culture was transferred to the metamorphosing, screen-enclosed basket on the wet table. Once in the basket, the veligers were introduced to unfiltered seawater, diatom and epiphtic algae growth on the screen, macro-algae (*Laurencia* and *Batophora*) and plenty of sunlight and aeration. Phytoplankton cultures were still fed until no more floating veligers were observed. One hundred percent water changes continued daily. After 3-4 weeks, post metamorphosed conch were moved to a larger screen enclosure, suspended on the wet table. Freshly collected *Laurencia* and *Batophora* were introduced every 1 to 2 weeks to the conch.

Out of the 22 cultures attempted in the PRIDE hatchery between May to August 1982, six batches successfully went through metamorphosis. Several hundred of these juvenile conch (5 to 20 mm) are presently being reared on the PRIDE wet tables for future field research experiments.

Algae Culture

Clean uni-algal cultures, Tahitian *Isocrysis, Nanocloris, Dunaliella tertiolecta* and *Thalassiosire weissflogil*, were obtained from the Marine Biological Laboratories, Woods Hole, and from the Rosenstiel School, University of Miami. These species were raised in a temperature (27.5°C) and light controlled, insulated, clean room in the PRIDE hatchery (Fig. 1,D). Stock cultures, f/2 nutrient media, and production of feeding cultures were prepared and maintained according to basic methods outlined by Guillard (1975). Media nutrients were prepared with distilled water produced by the solar still adjacent to the PRIDE hatchery (Fig. 1,S), then stored in the refrigerator.

Feeding cultures were raised in 19-*l*, aerated carboys in batch culture, ie. carboy was derived from its own starting culture. They were grown to a certain density, harvested for a limited period, then replaced by a new culture. This method, while more time consuming than continuous culture, greatly reduced the risk of contamination.

Our remote location dictated the use of a small, 15-*l* stove-top autoclave to sterilize glassware and media. Nineteen liter carboys, filled with filtered seawater, were chemically sterilized with 3 ml/*l* of clorox. After a 4-h period, each carboy was declorinated with 10 ml of sodium thiosulfate to reduce the residual clorine to zero ppm (Chanley). Twenty-four to 36 hours prior to harvest of a culture, it was treated with the bactericide, chloramphenicol, for greater confidence in the quality of food. Carboy cultures were discarded 6 days after treatment as a precaution against a buildup of bacteria contamination or the possibility of the bacteria becoming immune to the chemical.

The lab production schedule called for four to five carboys at any given time. At all times, some carboys were being harvested and some were being grown to optimum feeding density. Usually two to three cultures were harvested at one time. T. *Isocrysis* was the "stable" food source. Feeding concentrations were determined by cell counts using a heamocytometer or by visual appearance of the cultures. Carboys were harvested at a maximum of 6 days, but were terminated sooner if the culture showed evidence of being of poor quality.

In assessing the quality of our algal cultures, several characteristics were looked at: color of culture, slow growth rate, slow movement of motile cells, patches of bacteria or clumping cells. On some occasions, if the quality of food was in question, the lab would feed with only one culture to try to isolate the problem culture. A few times the animals were not fed for a day, presuming no food to be preferable to feeding poor quality food.

Algae Experiment. In terms of energy costs, the algae room can be identified as the most expensive part of the PRIDE hatchery. Constant operation of lights and an air conditioner to provide uniform "tropical conditions" is inappropriate in a Third World hatchery. During the months of August to September, PRIDE conducted an experiment to see if high quality, viable algae cultures could be grown in natural sunlight on a ventilated, screened-in porch, on the east side of the hatchery (Fig. 1,E).

Porch grown carboy cultures were compared to cultures started simultaneously in the algae room. Maintenance of stock cultures, sterilization and innoculation of carboys for the porch were conducted in the same manner as in the algae room. Carboy cultures were treated with chloramphenicol and were sampled daily to determine cell density. Daily morning and afternoon temperatures were recorded for the porch cultures. Instead of the constant algae room temperature of 27.5 °C, the porch cultures experienced regular higher morning temperatures of an average 32 °C, cooling in the afternoon or following a rain shower to an average 28 °C. Illumination for the algae room cultures was 16/8 light-dark period; and for the porch cultures, it was 14/10 light-dark period with varied light intensity. These fluctuations in temperature as a function of light density and changes in weather were regarded as the major factors influencing the growth and health of the porch grown cultures.

Porch cultures were raised with good, but not predictable, results. However, they were successfully fed to veligers which metamorphosed. Indirect light and shading may keep a more constant temperature and light intensity for uniform growth of porch algae. For stock and working cultures, PRIDE (1980) showed that test tubes and small and large flasks of algae can be raised in a temperature and light controlled kerosene refrigerator. The refrigerator was operated at a fraction of the cost of an algae room. Hatchery production of algae in natural light and in small incubating units warrants further investigation, particularly in locations where energy costs are high.

Alternate Systems

The energy associated with mariculture relates principally to the movement of water and air at rates adequate to maintain the animal and plant cultures in a healthy condition. These costs associated with electrical power in insular, developing countries might easily be 10 times as high as the USA. The Foundation for PRIDE's conch hatchery has attempted to make use of renewable energy generation devices and energy conserving equipment, both of which are thought to be new to the mariculture industry.

Wind Power and Energy Conservation. Like other remote areas, Pine Cay's electrical power is generated by operation of a costly diesel generator. Operation of this unit 24-h every day for powering pumps for air and water circulation is cost prohibitive when fuel costs exceed $2.00 per gallon in the islands. A hatchery cannot depend on small diesel generators alone, for they often cause brownouts and blackouts. These failures can be fatal to animals and plants in high density cultures.

PRIDE installed a 1 kw Scencenbaugh wind generator on an 18-m Rohn guyed tower adjacent to the hatchery (Fig. 2,W). It was used to capture approximately 250 kwh of electrical power per month in the constant 14 mph Caribbean Trade Winds. This energy was supplied to the facility as ordinary 120 volt 60 cycle AC electricity through a stand-by circuit connected to a 2.5 kw BEST M Series Inverter. Every night after the generator turned off, from 11 P M to 6 A M, and during generator failures, the unit automatically transferred the vital loads of the hatchery, air conditioned algae room, water and air pumps, to the battery bank through the BEST Inverter. When the generator returned to normal, the system retransferred the loads to the main power source and the batteries were recharged for the next evening. The wind generator was capable of producing about 50% of the research hatchery power needs, saving it $125/month in operating expenses. It has operated without maintenance for 3 years in a highly saline environment, receiving only annual coats of paint for protection.

Fresh water for washing glassware was pumped from the ground with a SPARCO wind mechanical water pump at a rate of 75-*l*/h. Using a 12 volt pump, the water was transferred from the holding tank to a gravity storage tank which supplied water to the hatchery when needed.

Solar Power. Solar energy has been employed to operate a solar still. Simple in design, the unit produced about 5 *l* of distilled water per day, more than enough to allow the facility to rinse glassware and mix chemical solutions. Additional experimental use has been made of photovoltaic panels to generate electrical power to operate a small recirculating water pump. Solar power generation worked properly only when the sun was shining. This proved ineffective for cultures requiring constant 24 h per day water motion.

These wind and solar energy systems will easily repay for themselves by guaranteeing continued power for hatchery rearing conditions.

COMMERCIALIZATION

Based on the past three seasons' research success in the various hatcheries and our facility and egg farm on Pine Cay, PRIDE views commercialization for queen conch mariculture as being practical. The Foundation for PRIDE has plans to prepare a proposal to the Turks and Caicos Islands government for scaling-up from a small research facility to a pilot plan phase and then to a large scale commercial hatchery. Before commercialization is feasible, experimental research needs to be carried out through all the stages of conch mariculture, from eggs to harvest. This will reveal the critical limiting factors for large scale application. Economic evaluation cannot be determined without a preliminary design involving qualified judgments about location, size, type of construction, specialized equipment, processes, productivity, labor requirements and assumed performance. A desirable location for a conch hatchery would be in the Bahamian or Caribbean waters. The area needs a population of adult conch for a reliable source of egg masses and available grow-out habitats for reseeding or stocking juvenile conch. A productive facility should be large enough to start a batch of conch every day while another batch is undergoing metamorphosis. The facility should be simple, utilize wind and solar energy, and fabricate much of the equipment in place. Routine techniques and specialized equipment are needed to guarantee best performance and ease of training local technicians. It must be understood that economics, engineering, management techniques, marketing and biology are highly interdependent when planning a commercial hatchery.

The majority of the biology and techniques for rearing conch to metamorphosis in small scale research hatcheries have been established. However, they need to be refined for cost/benefit purposes. A brood stock egg farm has proven that reliable source of egg masses can be provided to operate a hatchery. The nursery stage, post-metamorphosis to 6 months, has been performed under laboratory conditions. This stage could be more economical if the conch were placed in the wild at 1-2 cm, possibly in a floating structure such as a 6-m diameter blimp anchored in a swift moving current. Grow-out to harvest size, 6 months to 3 years, has briefly been researched. However, an efficient method for providing the best survival rate and least amount of labor input needs further research. The following are different methods of grow-out from extensive to intensive taking into consideration labor and maintenance: (1) Open ranching by reseeding sandy grass flats; (2) Establishing a protected park area for open ranching; (3) Stocking shallow channel-like raceways or ponds built on water front to take advantage of the tidal range to circulate water; and (4) Pening and embaying.

PRIDE conch mariculture efforts are involved with practical research which is directed toward commercialization by utilizing alternate energy, participation of local people and development of simple techniques for a Third World location. Conch mariculture is needed in order to maintain conch fisheries as a traditional way of life in the islands and to provide protein, jobs and cash for the islands' residents. With these thoughts in mind, PRIDE is prepared to scale-up our research operation to a pilot plant phase as the next step towards commercialization.

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