



## DEVELOPING SHELLFISH INDUSTRY IN NIGERIA: TECHNOLOGY AND ECONOMICS

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### Introduction:

The exploitation of shellfish resources plays an important role in the national economies of many countries. This can range from being used as a cheap source of protein to being a source of significant export earnings when highly developed.

In addition to being used as a source of food and economic wealth, Bivalves also decrease concentrations of particulate matter in water, thereby increasing water transparency and primary productivity (Short and Burdick, 1996, Newell and Koch, 2004). Shellfish cultures enhance water quality through nitrogen uptake and removal (Hudson, 2010), and their provision of habitat and structure for juveniles of other species (Spencer et al., 1996; 1998).

The rapid expansion of marine shrimp culture on the other hand, was accompanied by environmental degradation including loss of mangrove ecosystems, eutrophication due to nutrients disposed into mangrove creeks, and soil salinization from inland culture of brackish water shrimp. Sustainable production strategies have been developed to address these issues including farming away from mangrove areas, mixed shrimp-mangrove farming (Robertson and Phillips, 1995) and improved farm management due to new water management technologies (Anh et al., 2010).

Shellfish resources are poorly utilized in West Africa, (FAO Fish Stat statistics, 2010). In 2008, total marine shellfish capture production (including crustaceans) in West Africa was only 29,815 tonnes. Aquaculture production of these species was very limited in West Africa with only Senegal producing 40 tonnes of the mangrove oyster, *Crassostrea gasar*. By comparison, the estimate of worldwide aquaculture production of shellfish in 2008 was 801,360 tonnes of which 710,395 tonnes are bivalves (excluding crustaceans).

In developing a viable shellfish mariculture industry, Nigeria has several advantages including its possession of an extensive coast line with different coastal features, the low population density along most of this coast line means long sections have been little affected by industrial pollution. The tropical climate also encourages rapid growth of cultured shellfish and it has reliable air links and relatively short distances to major foreign markets in Europe, Asia and the Middle East. The disadvantages that the country has are due mainly to its late entry into the mariculture field. These include a labour force that is relatively inexperienced in mariculture and the competition that it must face with already well-established industries in other countries. The relative lack of infrastructure can also be expected to increase the costs of production.

To realize the country's true potential in shellfish mariculture requires education, training and research in the following areas:

- Seed production technology
- Grow-out technology and

- Processing and Marketing.

These areas are reviewed in this paper with emphasis on the culture of the mangrove oyster and the tiger prawn (*Penaeus monodon*), which have been the target of previous and current mariculture research efforts in Nigeria.

### **Seed production:**

The predictable production of sufficient quantities of high quality seed is a prerequisite for the successful establishment of an aquaculture industry. At the beginning of many aquaculture industries, many operators simply collect the required seed from natural breeding grounds in the wild. However, as culture operations expand, or the inclusion rates of unwanted species increase, or in the absence of natural breeding areas, or the need to produce an exotic, non-local species, the necessity to build a hatchery arises.

Hatcheries have many advantages over natural collections of seed: They are reliable, and seed can be produced to order. They can supply seed not available in the wild, the seed are of more consistent quality and breeding for specific traits can be performed. With the development of hatchery technologies has also been the further development of specialized hatchery equipment and feeds as well as advances in water quality management and grow-out technologies which all combine to make a successful aquaculture industry.

Shellfish hatcheries may vary in design, but will consist of the following basic areas:

- Broodstock maturation area,
- Spawning and larval rearing area
- Post-larval and juvenile rearing areas
- Live food (algae and zooplankton) producing areas.

### **Site selection**

Site selection is one of the most important factors affecting hatchery production. Shellfish larvae, juveniles and adults have strict physiological requirements that must be met and maintained in hatchery and nursery settings. A supply of good quality sea water is a pre-requisite for establishment of a successful shellfish hatchery operation and although aquaculturists have to compete with other uses for coastal land, siting the hatchery close to the sea reduces costs associated with pumping large volumes of water long distances.

In the case of sensitive larvae and post-larvae, the importance of good quality water is heightened. To avoid or reduce the need for costly remedial water treatment, analysis of the water should be carried out to determine the concentrations of the total heavy metals, arsenic, cyanide and other PCB pollutants that may interfere with the survival, growth or development of the cultured seed.

Areas with blooms of toxic algae which may release toxins affecting larval and juvenile shellfish should be avoided. In addition, areas with domestic, municipal and industrial effluent discharge should be avoided. In areas of high precipitation and run off, intakes should be located deeper in the water column to avoid salinity fluctuations and reduce the drawing in of silt. The design of the hatchery should be for the maximum number of all species that are being considered for culture and the use of toxic materials (mild steel, brass, copper) in the sea water system should be avoided.

In addition to these, in-coming seawater needs to be physically filtered, and in some cases, excessive organic material which encourages proliferation of bacteria, needs to be removed. The water may further require disinfection to reduce the microbial loading

before being supplied into the hatchery. Disinfection is commonly achieved with ozone or ultraviolet light irradiation.

### **Broodstock Maturation:**

For both bivalves and crustaceans, the most important parameters for successful maturation are maintaining good water quality conditions, constant temperatures, pH and salinities, as well as good nutrition.

Bivalve broodstock may be held in shallow, circular or square tanks (Figure 1), which may be stacked or free-standing depending on the configuration adopted. The tanks are supplied with a constant flow of clean sea water and fed with cultured, mixed algae. Mature adults are spawned by thermal shock achieved by alternately raising or lowering the water temperature by about 5°C, with the addition of algae, eggs or sperms for additional stimulus. Oysters may also be sacrificed and the gametes stripped. The gametes from several adults are collected and mixed and the fertilized eggs are moved into other tanks where they develop to the prodissoconch (D) stage larvae at which time, feeding can begin.



**Figure 1: Shellfish broodstock tanks holding cockles (left) and oysters (right)**

Shrimp broodstock are kept at up to 5/m<sup>2</sup>, at a sex ratio of 1:1, in maturation tanks in a dark room with low levels of light. Mating occurs between a hard shelled male and a soft shelled female and moulting may be induced by changing the salinity of the seawater. During mating, the spermatophore is deposited in the thelycum of the female. As female penaeids rarely undergo ovarian maturation in captivity, ablation of one eyestalk of the female is generally carried out to reduce the production of gonad inhibitory hormone (GIH) and permit full maturation of the ovaries. To improve the productive performance, the broodstock are fed chopped fresh or frozen squid, fish, bivalves or polychaete worms several times a day and the tanks are siphoned daily.

Females with ripe ovaries are transferred into spawning tanks where they spawn. After spawning, the females are removed from the spawning tanks and the eggs are left to hatch into nauplii. The nauplii are phototrophic and light is used to attract them to the surface of the tanks where they are collected.

Proper nutrition is important in broodstock maturation as the energy requirements of most animals must be met before additional energy can be committed to growth or reproduction. However, eyestalk ablation of penaeids also affects a variety of other neurohormones/neuromodulators systems in addition to the GIH. As a result, eyestalk ablated prawns will exhibit a hormonal insensitivity to physiological or environmental limitations such as food supply, nutrient limitation, improper oocyte differentiation and will undergo rapid gonadal development even without the prerequisite accumulation of

nutrients to support reproduction making the maternal nutrient intake particularly important during maturation of the prawns (Harrison, 1997).

Although dietary requirements for maturation vary between species, incorporating the polyunsaturated unsaturated fatty acids arachidonic acid, (20:4n-6), eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3) into the maturation diets has been shown to be necessary for bivalves (Besnard et. al., 1989; Marty et. al., 1992; Soudant et al, 1996a,b,c; Utting and Millican,1998; Ehteshami et al. 2010), and shrimp (Lytle et al., 1990; Xu et al., 1992; Alava et al., 1993; Wouters et. al., 1999).

### **Larval Rearing:**

Larval rearing is generally carried out in cylindrical tanks which may range in size from 500L to 40,000L (Figure 2). More recently, smaller (about 250L) cylindroconical tanks are used for high density, flow through larval rearing. The size of tank used depends upon preferred rearing methods. Larvae are stocked at densities between 1000 to 20,000/L with the lower densities in the larger volume tanks. These are generally run as batch cultures whereby the water is exchanged periodically (every 2-3 days), or as a flow-through system with a constant flow of fresh sea water. The larvae are fed on monocultures or mixed algae species. Routine size selective grading to separate and discard slow-growing and compromised animals from the populations, is performed during water changes.

Shrimp nauplii are stocked at 50 - 200 per liter in tanks filled with filtered and disinfected water and at the protozoal stage, are fed with cultured algae, *Skeletonema costatum* and *Tetraselmis chuii* at 45 and 25cells/ $\mu$ l respectively.

In addition to mixed phytoplankton, later mysid stages in the prawns are fed on decapsulated *Artemia* at 2 nauplii/ml from the mysis 1 stage when they may also be supplemented with microencapsulated diets. Shrimp larval cultures may similarly be run as batch or continuous flow systems.



**Figure 2: Different types of larval rearing tanks**

### **Live food production**

An algae culture facility is an essential part of a marine fish or shellfish hatchery. Algae are required by all stages of bivalves as well as larval fish and crustaceans as rich sources of both macro and micronutrients. Algae culture can be carried out in closed or mostly closed systems (photobioreactors) or in open ponds or raceways. Successfully cultivating algae requires that they be provided with specific environmental conditions, which vary between species. These include requirements for light (intensities,

wavelengths), specific temperature and salinities ranges, CO<sub>2</sub> concentration, nutrient composition and mixing conditions. Production of algae in photobioreactors is characterized by a high degree of control over many of these environmental parameters. The requirement to produce high quality algae free of unwanted contaminants as feed for the sensitive early life stages of the shrimp and shellfish, make algae production expensive. As a result, the feed requirements for the larger juveniles in nursery sections are usually satisfied from large scale, open pond systems. The open nature of these systems as well as the lack of environmental control makes it difficult to avoid contamination in open ponds. Culture crashes are frequent in these systems, and they are only suitable for cultivating a small number of algal species that can tolerate extreme environmental conditions to the exclusion of most other species in aquaculture situations.

Only a few species of microalgae are widely used in fish and shellfish hatcheries world wide. These have been selected based on their biochemical compositions, nutritional values for the various animals, dimensions, digestibilities and ease of culture in mass rearing systems. There can be great variation in the food values of the same alga to different animals and when this is not known, mixtures of different species of algae are fed to larvae and juveniles, thereby ensuring that all their nutritional requirements are met. Although live feeds are an excellent source of nutrition, there are several drawbacks associated with their use. Algal cultures are expensive, and require considerable expertise to maintain them in peak nutritional condition. *Artemia*, fed to crustacean mysids and post larvae (PLs), are purchased as cysts, which are collected from the wild and hence, suffer from inconsistent supply and quality. In addition, high bacterial loads usually associated with *Artemia* cultures have been implicated in the transfer of disease to larval cultures and a disinfection step is frequently warranted before use. Such problems with live feeds have led to research into the development of diets as total replacements for live feeds. Although the use of formulated larval feeds is now widespread in commercial crustacean culture, total replacement of algae and *Artemia* has proved to be more difficult (Jones 1998), and these diets are added at best, as a partial replacement item in the diet of larval shrimps.

#### **Juvenile rearing:**

Late stage, pre-metamorphic bivalves are identified by the development of pigmented eyespots, and/or a prominent foot. Different strategies are employed to “set” the different species depending on their biology. Species which attach to substrates by byssal threads (such as mussels, scallops), or cement (oysters), are provided with substrates presenting high surface areas. These may be hung directly inside the larval rearing tanks, or dedicated nursery tanks. Suitable substrates that have been used include artificial seaweed and coconut rope for mussels and scallops. Oyster larvae may also be set on these but are more commonly set on hard cultch such as old oyster shells. Oyster larvae may also be induced to settle without substrates (single oysters), by the addition of epinephrine which stimulates the oyster larvae to undergo metamorphosis settle without a substrate. Single oysters may also be produced by putting competent larva into a tank with a thin layer of ground oyster shells. The shells are ground fine enough that only one or two oysters can settle per shell fragment. Clams and cockles may be put directly into settlement tanks.

Juveniles may be reared in down-welling tanks, which consists of one or more cylindrical tubes, which are screened at one end. These tanks are half suspended in one chamber of a 2-chambered, larger tank. Water and food supply to each cylinder are from the top



and pass through the mass of animals which are retained on the mesh screen (Figure 3).



**Figure 3: Down-welling tanks (left), and “coke bottle” nursery tubes**

Single oysters, clams, and settled mussels (removed from the substrates), can be reared in these tanks and feeding and care continues similarly to that of the larval rearing stages. As the animals grow, the water input into the tanks can be changed from down-welling to an up-welling configuration in which case, the supply of fresh water to the tanks comes from underneath the screens and the waste water is discharged from the top.

Inverted “coke” bottles of the type shown in Figure 3 is also used to rear juvenile oysters and clams. The animals are placed in a cylindroconical bottle with the water flowing in from the opening at the bottom. A marble is placed inside and sits at the neck to act as a check valve and the seed are poured in. Food is mixed with the incoming water, which is adjusted to a flow rate that is sufficient to lift the marble and fluidize the mass of oysters. The waste water flows out from a screened pipe at the top of the vessels.

Nursery of bigger juveniles can also be carried out in floating upwellers which use tide or mechanical paddles to force oceanic water containing naturally occurring phytoplankton upwards through seed within stacked or individual trays attached to the upwelling unit. These floating upwellers generally consist of a floating structure which supports a series of individual containers which are connected to a central channel in which water is continually being pushed out. The water movement is accomplished by a paddle wheel or propeller and the lost volume is replaced by the upwelling flow of water through the attached contained containing seed. Seed nurseries may also be established intertidally on the beach under protective netting. It is important, when considering beach nurseries to avoid areas that are subject to siltation, freshwater intrusion, or severe wave action.

Post larval shrimp are usually moved from larval rearing tanks into nursery systems at the PL-5 –PL-10 stage. These are shallow raceway tanks or ponds (Figure 4) with large bottom areas which may be provided with a natural muddy sand substrate to prevent cannibalism and enable the production of some natural food. In these systems, the prawns are weaned onto a mixture of natural and formulated diets. The formulated diets must contain at least 40% protein and 0.8% PUFAs (Table 2), and fed at high rates of up to 40 x the body weight in order to sustain the high growth rates of the prawns. The nursery stages require particular attention to avoid mortalities due to the leaching of nutrients and breakdown of uneaten feed supplied at this stage. The prawns are raised

for up to 30 days in the nursery systems and moved out into grow-out ponds at between 1 – 2gm.



Figure 4: Nursery raceway (left) and ponds for penaeid shrimp culture.

### Grow Out

Bivalve grow-out is ocean based, taking advantage of natural primary productivity and water movement. The grow-out can be intertidal or subtidal (Table 1), depending on the biology of the species being cultured. When choosing a culture site, the required site selection criteria include the ranges of temperature and salinity experienced, dissolved oxygen, food availability, wave action, tidal flow, suspended sediments, presence of predators, surveillance, pollution, availability of services and infrastructure.

Table 1: Summary the main methods for grow-out of several bivalve species.

<b>Products for market</b>	<b>Intertidal Systems</b>	<b>Deepwater systems</b>	<b>Combination</b>
Shucking Oysters	Bottom or off bottom on racks, stakes, sticks or long lines	Strings	Grown on strings and later placed on the beach to remove fouling and beach harden
Single oysters	Bottom or off bottom on racks and pouches	Trays	Product grown in trays then, water hardened
Manila clams	Planted onto intertidal plots		
Geoducks	Planting into intertidal or subtidal substrates		
Mussels	Pole (Bouchot) or Subtidal on bottom	Long lines or trays	
Scallops		Bottom seeding, Lantern nets, trays , or ear-hanging	

Provided that silting is not excessive, oysters (singles and on cultch) and clams may be planted onto the intertidal zones under predator netting at densities of about 200/ m<sup>2</sup> and 700-800/m<sup>2</sup> for oyster singles and clams juveniles respectively. Required management



activities include periodically reducing the densities as they grow and removing predators and fouling on the mesh. Less than ideal beaches can utilize off bottom intertidal systems which also increases the growth rates of the oysters. The oysters are put into pouches or shucking oysters on cultch of pipes or sticks are put into trays in raised racks (Figure 5). The racks can be made of any material that can hold up in sea water.



**Figure 5: Off-bottom rack culture of oysters**

Three dimensional, deep water oyster culture systems have some advantages over the intertidal systems including more efficient feeding and a shorter growth period since the crop is always submerged. However, the adductor muscles are weak and their shelf life is shorter than those of the intertidal cultures. In these systems, strings, trays, or baskets containing the products are suspended from floatation rafts or long lines (Figure 6). This method of culture requires more initial investment of capital as well as more handling to size grade, tumbling, to harden the shells and control fouling.



**Figure 6: Raft culture (left) and long line culture (right) of oysters**



Although some overlap may occur among systems, grow out systems for penaeid shrimp may be divided into extensive, semi intensive, intensive or super intensive systems.

Extensive systems involve trapping the wild penaeid postlarvae as they migrate inshore and placing mesh gates across the pond channel to the sea. No aeration is provided and water exchange is by tidal flushing. Post larvae are stocked at low densities of about 0.2 - 5/m<sup>2</sup>, and the shrimp feed on the natural diets within the ponds. Low yields of 50-500kg/ha/crop have been reported for these systems (Jones 1988; Weidner and Rosenberry, 1992). These systems are viable as costs are minimal (until the coastal land prices rise).

Semi intensive systems range in size from 0.4 to 40ha ponds (Hirono, 1992; Wiedner and Rosenberry, 1992), eliminate competitors and predators, and stock at higher densities of 5-40PL/m<sup>2</sup>, water is exchanged regularly with pumps, and these farms have some energy input in the form of aeration and water circulation devices which are used as needed. (Hirono, 1992). The natural food in the ponds is boosted by fertilizers and supplemented with formulated diets. Crop yields of 500kg – 9,000kg/ha/crop have been reported from these systems.

Intensive systems generally use smaller ponds, tanks and raceways of 0.01ha to 5ha (Hirono, 1992; Wiedner and Rosenberry, 1992; Son, 2010). These have reduced or zero water exchange regimes and rely heavily on water treatment and reuse. Post larvae are stocked at 15-50/m<sup>2</sup>, and formulated diets are the main source of nutrition. Significant energy input is regularly applied to the ponds for water circulation and aeration. Production yields of 5,000kg – 12,000/ha/crop have been reported for these systems.

Super intensive systems generally use ponds and raceways of 0.03-0.1 ha which are stocked at densities of 50 – 250/m<sup>2</sup>. They have continuous, high rates of water exchange with new or treated water. Formulated diets are the only source of nutrition and continuous aeration devices used are sometimes supplemented with oxygen. While high yields of 10,000 to 50,000kg/ha/crop have been reported for these systems, only sporadic successes have been achieved in these systems.

#### *Cage culture*

As alternative to pond and raceway culture, pen and cage culture of penaeid shrimp have the advantages of reduced financial investment, lower dependence on energy, higher water exchange rate and enhanced use of natural productivity. Pen and cage cultures are in use by some small-scale operators in several countries.

Pens are normally constructed of plastic mesh nets supported by rectangular bamboo or wood frames with the bases of the nets in contact with the mud. In contrast, cage culture enclosures are floating. The systems require areas that are sheltered from strong waves and currents. In addition to facilitating water exchange, the mesh also provides a surface for the attachment of microalgae and detritus on which the shrimp can graze in addition to supplementary diets. The shrimp are stocked at densities of 40–200/m<sup>2</sup> and survival rates of 70 - 94% and production equivalent to 8,200 - 27,000kg/ha have been reported from pen and cage cultures (Tookwinas 1990; Zarain-Herzberg et al., 2006).

#### ***Nutrition.***

As shrimp production methods have shifted to semi intensive and intensive methods, more reliance has been placed on formulated diets. This frequently constitutes the largest component of the operating costs of shrimp farms and has been the impetus behind research into the development of efficient and economical feeds. During the last decade knowledge of the nutritional requirements of penaeid prawns has increased greatly and inclusion levels have been defined for many major components of the diet

(Table 2).(See reviews by Lim and Akiyama, 1995; Conklin, 1997; D'Abramo, 1997; Harrison, 1997; Teshima, 1997; Chen, 1998).

**Table 2: Recommended nutritional composition of shrimp feeds for different size ranges (Akiyama, 1992).**

<i>Nutrient</i>	<i>Shrimp size (grams)</i>		
	<i>0-3</i>	<i>3-15</i>	<i>15-40</i>
Protein minimum	40	38	36
Lipid minimum	6.2	5.8	5.5
Maximum	7.2	6.8	6.5
Fiber	3.	4.	4.
Ash	15	15	15
Calcium	2.3	2.3	2.3
Phosphorus –available	0.8	0.8	0.8
Potassium- minimum	0.9	0.9	0.9
Lysine minimum	2.12	2.01	1.91
Arginine – minimum	2.32	2.20	2.09
Threonine- minimum	1.44	1.37	1.30
Methionine – minimum	0.96	0.91	0.86
Methionine/Cysteine minimum	1.44	1.37	1.30
Phospholipid – minimum	1.0	1.0	1.0
Cholesterol –minimum	0.35	0.3	0.25
20:5n-3 – minimum	0.4	0.4	0.4
22:6n-3 minimum	0.4	0.4	0.4

Optimum levels of inclusion for dietary protein for penaeids has been determined to be about 40%, and quantitative inclusion requirements have also been determined for several individual amino acids (Chen et al., 1992a and b; Millamena et al. 1993) and vitamins (Chen et. al., 1991; Chen and Hwang, 1992; Shiau and Lung, 1993; Shiau and Hsu, 1994; Shiau and Liu, 1994; Shiau and Suen, 1994; Chen, 1998).

Penaeids utilize disaccharides and polysaccharides sugars better than monosaccharides, with optimal inclusion levels of 20-30% (Alava and Pascual, 1987; Shiau and Peng, 1991). Levels of lipids above 10% have been associated with significant reductions in the growth rates of penaeids (Akiyama, 1992), and nutritional studies have suggested best penaeid performance at dietary levels of between 5 to 10% (Lim and Akiyama, 1995; D'Abramo, 1997). Penaeids have limited or no ability to synthesize the highly unsaturated fatty acids (HUFAs) 20:5n-3 and 22:6n-3 (Akiyama, 1992; Lim and Akiyama, 1995; D'Abramo, 1997). Addition levels of both HUFAs of 0.5 to 1% of diet has been recommended for optimal growth and survival (Lim and Akiyama, 1995).

### **Disease**

Many of the organisms causing diseases in aquaculture are opportunistic pathogens which are part of the natural fauna and flora of the environment and include bacteria, viruses, fungi and protozoans. The increased susceptibility to disease found in aquacultured animals is a consequence of impairment of their immune defence mechanisms arising from poor management, poor water quality or food. This is

particularly so in the intensive hatchery and nursery rearing systems in which the conditions enhance the development and transmission of the diseases. Diseases caused by bacteria and viruses in particular, continue to be responsible for severe losses in shrimp and bivalve cultures and some of the control measures in use are discussed below.

In addition to practical preventive management such as routine disinfection of hatchery equipment and water supply as well as trans-shipment sanitation, bacterial control methods also include the use of chemotherapy such as formalin, hydrogen peroxide, iodophores, chlorine and methylene blue. However, the use of these chemicals often depend on the host having a higher tolerance threshold level to the substance than the target organism. These differences are often marginal, and vary with particular physiological and environmental factors. The widespread use of powerful antibiotics, while useful, has unfortunately been demonstrated to lead to the creation of antibiotic resistance in some strains of bacteria.

#### *Immune enhancement:*

The use of immunostimulants such as  $\beta$  1,3-glucans (Vargas-Albores, 1995), and killed bacterial suspensions (vaccines) (Raa et al. 1996; Alabi et al., 1999b; 2000) resulting in enhancements of the shrimp immune system has been demonstrated. Such methods have been recommended for enhancing the immune system of the shrimp just prior to expected periods of stress or handling.

#### *Manipulation of the bacterial flora and use of probiotics*

The use of microbially matured water (water with a wider diversity of established, non-opportunistic bacteria) has been demonstrated to increase survival in larval shrimp (Alabi et al., 1997; 1999a) and halibut (Skjermo et al., 1997; 1999). This, together with the use of selected, beneficial bacteria (probiotics) (Verschuere et al., 2000) are in wide use today in fish and shellfish hatcheries and prawn farms. Other researchers have interrupted the bacterial signaling pathways used to communicate between individual cells (quorum sensing), and thereby stopping the switch to virulence by the bacteria and preventing disease (Misciatelli et al., 1998).

At least ten serious virus diseases have affected farmed penaeid prawns. These are white spot disease (WSB), yellow head disease, (YHD), baculoviral midgut gland necrosis (BMN), monodon baculovirus disease (MBV), taura syndrome virus (TSV), infectious hypodermal and haematopoietic necrosis virus (IHHNV), hepatopancreatic parvo-like virus (HPV), lymphoid organ vacuolization virus (LOVV), baculovirus penaei (BP), lymphoidal parvo-like virus (LOPV), maurilyan virus (MOV) and laem singh virus (LSNV). (for reviews please see Lighter, 1992; Flegel, 2006).

Viral infections cannot be treated by drugs but can be managed by screening for viral pathogens in broodstock and postlarvae, by adopting good farming practices such as regulated stocking, feeding protocols and effective pond management. However, outbreaks of shrimp viruses may still occur due to sudden changes in water quality and poor pond bottom environments. More seriously, several viruses appear to have been spread geographically by the importation of infected stock. Stopping the further spread of these serious diseases requires the effective use of quarantine and effective screening techniques. The use of nauplii from specific pathogen free broodstock has also been useful in controlling the incidence of viral infections in shrimp culture.

### **Processing and Marketing:**

Bivalves may be sold live in shell or shucked and fresh, frozen or smoked. If the bivalves are grown in coliform – free waters, they are washed and graded. They may also be held in flowing seawater to eliminate sand and mud from the mantle cavity. A period of depuration in disinfected seawater is required for bivalves that have been grown in coliform contaminated waters. Ajani (1980) reported that mangrove oysters in Nigeria are steamed, dried, drained rinsed, salted and smoked before sale. Such methods have the advantage of reducing or eliminating bacterial contamination (Angell, 1980). Many foreign buyers often prefer to eat the oysters raw and so, a period of depuration in disinfected sea water is required for bivalves that are destined for export and grown in contaminated waters.

Immediately after harvesting, shrimp are cleaned and transported in refrigerated trucks (Figure 7) to processing facilities where they are cleaned and sorted into various grades for export. Many importing countries have requirements on the amount of chemical residues that may be found in shrimp. There are also food safety requirements including certification, traceability and environmental sustainability.

Sanitary standards are high in all the major importing countries especially with regard to antibiotic and chemical residues and as part of the worldwide marketing strategy, major processors and exporters have adopted hazard analysis critical control points (HACCP) and ISO quality control systems.



**Figure 7: Transport of harvested shrimp to processing facility**

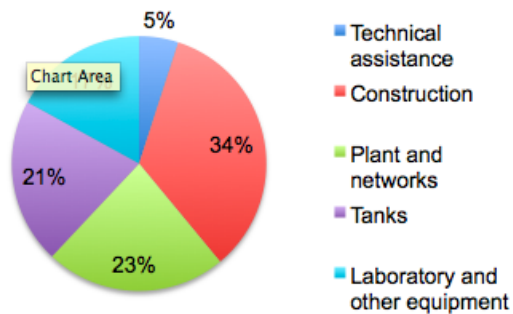
### **ECONOMICS**

A shellfish venture is a business like any other and a careful financial and risk analysis should be made examining all aspects of the business, possible crop failures and variabilities in pricing prior to proceeding.

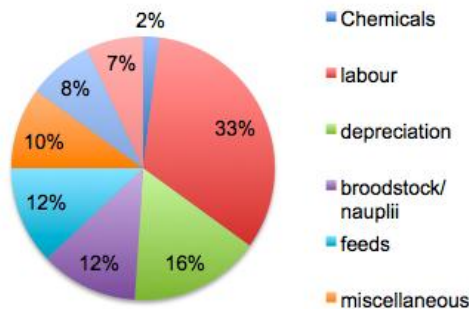


Hatcheries may exist as stand-alone units, when they must be financially viable, or as part of integrated units in which case, the security of seed supply is often the overriding concern. With the exception of *P. japonicas* in France at a reported cost of US\$25 per 1000 PLs, production costs for *P. vannamei* and *P. monodon* have ranged from US\$3.24 to US\$9.00 per thousand (Wilkenfield, 1992, cited in Wilkins and Lee, 2002).

Construction costs are the major cost factor in penaeid hatchery fixed costs (Figure 8), while labour is the highest cost for the operating costs (Figure 9) (Wilkins and Lee, 2002).



**Figure 8: Proportionate investment costs for a shrimp or prawn hatchery (Wilkins and Lee, 2002)**



**Figure 9: Proportionate operational production costs for a shrimp hatchery (Wilkins and Lee, 2002)**

Published data for commercial bivalve hatcheries are limited but are expected to be similar to costs obtained in penaeid hatcheries.

Construction costs are the greatest component of fixed costs in establishing a shrimp farm, ranging between 44 – 81% of total fixed costs (Wilkins and Lee, 2002; Liao and Liao, 2006). Depending on the mode of operation (extensive or intensive), the major operating cost components are feed and seed, which between them account for 50–70% of operating expenditures. Analyzing data from several shrimp producing countries, Wickins and Lee (2002) reported that geographic location was among the most important factors in cost of production, with the high operating costs in industrialized and newly industrialized countries and the limitations of growth imposed by climate in several countries being major factors in the costs of shrimp production. Liao and Liao (2006) analyzed the financial performance of Taiwanese tiger shrimp (*P. monodon*) and white shrimp (*P. vannamei*) farms, using the ratio of the net returns to the total costs to assess the profitability of farming both species (Table 3).

The 0.42 ratio obtained in 2001 indicates a return of 42 cents for every dollar invested. The loss of 8 cents per dollar obtained with tiger shrimp reared in 1992 was attributed to differences in production levels, prices and costs of production of these two species. As seen in Table 3, the returns to capital were generally higher when raising white shrimp than tiger shrimp.

Afinowi (1985) did an economic analysis of mangrove oyster production in the Niger Delta. Using similar methods on the data of this researcher revealed potential returns of either -0.20 kobo per naira invested or +84 kobo per naira invested depending on whether wooden trays or longer lasting, plastic trays were used.

In conclusion, Nigeria has significant advantages which favour the development of shellfish mariculture industry. The future success of this industry will require support in the form of education and training which are required to address the shortage of skilled technicians and researchers in the new field, and research to improve production methods, stock development, disease identification and control methods, and nutrition. Techniques exist for rearing all stages of the commonly cultured species, which can be adapted to work in Nigeria. It must be noted however, that these techniques were developed for use in countries with different infrastructure, climatic and labour environments compared to Nigeria and the products may prospectively not competitively produced in Nigeria without refinement. Developing a sustainable industry will also require guidelines to avoid potential multiuser conflicts and environmental degradation and ensure compliance with international food safety regulations while providing employment and taxation revenues to the government.

Although production may be the immediate focus of the development of the industry, detailed economic analysis needs to be conducted to identify potential market sizes and develop effective marketing strategies for each target product.

Table 3: Annual costs and returns per hectare of *P. monodon* and *P. vannamei* cultured in Taiwan over several years

<b>Items</b>	<b><i>Penaeus vannamei</i></b>							<b><i>Penaeus monodon</i></b>		
	1990	1991	1992	1993	1994	1995	1996	1999	2000	2001
<b>Operating costs</b>										
Seed	\$72,652	\$38,376	\$51,666	\$49,853	\$44,590	\$57,374	\$55,466	\$154,805	\$111,333	\$73,000
Feed	\$221,948	\$210,192	\$126,841	\$155,206	\$180,050	\$173,987	\$226,369	\$264,257	\$248,298	\$317,000
Drugs	\$7,093	\$10,212	\$9,583	\$11,859	\$11,930	\$12,129	\$18,454	\$19,814	\$17,891	\$18,720
Electricity and water	\$58,434	\$44,104	\$48,026	\$47,335	\$52,180	\$76,118	\$55,883	\$126,478	\$123,280	\$131,000
Wages	\$20,634	\$24,115	\$17,057	\$16,635	\$48,862	\$12,696	\$28,276	\$58,965	\$39,661	\$50,920
Others	\$37,772	\$14,454	\$129,749	\$7,652	\$11,388	\$10,924	\$15,494	\$5,666	\$14,625	\$12,240
Total Variable costs	\$418,533	\$341,453	\$382,922	\$288,540	\$349,000	\$343,228	\$399,942	\$629,985	\$555,088	\$602,880
<b>Fixed costs</b>										
depreciation	\$89,297	\$63,211	\$39,463	\$45,351	\$95,066	\$36,908	\$30,277	\$75,000	\$44,000	\$67,000
Land Rent	\$455	\$4,566	\$8,572	\$6,126	\$6,266	\$5,023	\$10,299	\$10,029	\$11,295	\$1,960
Pond Maintenance	\$29,083	\$22,787	\$21,745	\$20,883	\$19,370	\$17,882	\$25,854	\$47,053	\$27,108	\$19,320
Equipment maintenance	\$11,017	\$12,890	\$12,949	\$11,098	\$19,083	\$13,226	\$24,124	\$20,666	\$37,680	\$31,760
Others	\$6,300	\$10,074	\$11,993	\$11,160	\$17,177	\$25,559	\$14,483	\$105,285	\$99,245	\$32,420
Total Fixed costs	\$136,152	\$113,528	\$94,722	\$94,618	\$156,962	\$98,598	\$105,037	\$258,033	\$219,328	\$152,460
Grand total costs	\$554,685	\$454,981	\$477,644	\$383,158	\$505,962	\$441,826	\$504,979	\$888,018	\$774,416	\$755,340

Gross returns	\$518,542	\$511,506	\$439,959	\$393,277	\$588,129	\$559,711	\$803,022	\$2,129,000	\$909,000	\$1,072,000
Variable costs	\$418,533	\$341,453	\$382,922	\$288,540	\$349,000	\$343,228	\$399,942	\$629,985	\$555,088	\$602,880
Fixed costs	\$136,152	\$113,528	\$94,722	\$94,618	\$156,962	\$98,598	\$105,037	\$258,033	\$219,328	\$152,460
Total costs	\$554,685	\$454,981	\$477,644	\$383,158	\$505,962	\$441,826	\$504,979	\$888,018	\$774,416	\$377,644
Net returns	-\$36,143	\$56,525	-\$37,685	\$10,119	\$82,167	\$117,885	\$298,043	\$1,240,982	\$134,584	\$316,660
Efficiency ratio										
Gross returns/total cost	0.93	1.12	0.92	1.03	1.16	1.27	1.59	2.40	1.17	1.42
Net returns/total costs	-0.07	0.12	-0.08	0.03	0.16	0.27	0.59	1.40	0.17	0.42



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