INCORPORATING ARTIFICIAL FEED WITH LIVE FEED (ARTEMIA) IN MARCROBRACHIUM ROSENBERGII POST LARVAL SHRIMP PRODUCTION

Hardin Aaron Jn Pierre
Fisheries Department
Pointe Seraphine, Castries, Saint Lucia
Hardinjpierre@hotmail.com

Supervisor:
Professor Òlafur Sigurgeirsson
Department of Aquaculture and Fish Biology, Holar University College
olisig@holar.is

ABSTRACT

This paper investigates the incorporation of artificial feed with live feed (artemia) in the early stages of *Macrobrachium rosenbergii* post larval production in Saint Lucia. Special focus is on reducing the costs of live feed. Experimental protocols have been designed to be carried out back in Saint- Lucia using a recirculation system set up to test various types of artificial feed, both local and commercial, in combination with live feed. Information has been studied and documented to gain overview of current practices with respect to *M. rosenbergii* post-larval production in Saint Lucia and abroad. It is shown that there is a room for improvement in the current processes involved with post larval culture in Saint Lucia compared to what is being done abroad. Currently, live feeds are not prepared and enriched with essential nutrients like lipids and vitamins. Prepared diets are also lacking many of the essential nutrients needed for good larval growth and survival. Many artificial diets still do not perform as well as using artemia. Artificial diets have recorded survival rates of 40-50%, where live feed diets (artemia) have survival rates upwards of 62-70%. This work aims to improve economic aspects of Saint Lucian Hatchery operations, particularly when it comes to reducing the costs of live feed used in the production of *M. rosenbergii* post larvae.

Key words: *Macrobrachium rosenbergii*, live feed (artemia), artificial feed.

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1 INTRODUCTION

1.1 Background

Aquaculture in Saint Lucia has seen slow but steady development since the early 1960s when tilapia was raised in small earthen ponds (Felix, 1997). In recent times there has been a shift in focus in the aquaculture sector with more species being introduced more intense culture (Clayton & Brennan, 1999; Felix, 1997). Aquaculture production has been increasing in Saint Lucia since the 1990s as a result of one of the key industries, bananas, in the country crashing. Since then, the government turned to aquaculture to help cushion the fallout (Mayett *et al.* 2014; Felix, 1997).

The St Lucian government through the Department of Fisheries (DOF), aquaculture unit with the aid of funding and expertise from external sources like the Taiwanese, Chinese and Japanese governments in recent times have intensified their efforts on aquaculture development (Myvett *et al*., 2014; Felix, 1997). This has led to a renewed drive carried out by the St Lucian government and several landowners who previously used their lands for banana farming are now utilizing their lands for freshwater shrimp and tilapia culture. Saint Lucia has not only seen an increase in freshwater aquaculture but also in marine aquaculture with the cultivation of sea moss and sea algae (Myvett *et al*., 2014).

Aquaculture in Saint Lucia has not had rapid expansion as is observed in Asian countries over the last 10-15 years, production has been increasing steadily over time (Myvett *et al*., 2014; Alessandro *et al*., 2003; Clayton & Brennan, 1999). However, there is still a huge potential for aquaculture development and expansion in Saint Lucia because of the availability of suitable lands and steady supply of clean running water (FAO 2014; Alessandro *et al*., 2003; Shleser *et al*.,1992).

There are two species being cultured by farmers in Saint Lucia. They are the giant freshwater prawn *Macrobrachium rosenbergii* and the Nile tilapia *Oreochromis niloticus* and its red hybrid (Aquaculture Brochure 2013; Felix 1997). In addition, the species of sea moss and sea algae grown are *Eucheuma cottonii* and *Gracilaria debilis* (Zemke & Smith, 2003). The giant freshwater prawn and Nile tilapia was introduced to Saint Lucia by the Taiwanese governments in the mid to late 1980s. The Taiwanese also brought their expertise on the culture of those freshwater fish species. As a result of this, along with government subsidies, aquaculture production has seen a steady increase over the last 10 years (FAO 2016; Myvett *et al*., 2014; Alessandro *et al*., 2003).

The government of Saint Lucia through the aquaculture unit of the Department of Fisheries manage two hatcheries which provides tilapia fingerlings and giant freshwater prawn post larvae to farmers for culture. The government also manages a sea moss nursery for the purpose of research and stocking farmers with plants. The aquaculture unit also provides technical advice and expertise to aquaculture farmers whenever they need it (Aquaculture Brochure, 2013).

1.2 Problems and Rationale

Aquaculture in St Lucia faces many challenges which may not only affect its expansion but ultimately its sustainability. Some of the key sustainability and development issues include;

high costs of operations including high pond construction costs, lack of readily available finance for aquaculture farmers (loans, grants), the procurement of a nutritional viable feed and government policies. Aquaculture continues to be a very lucrative and profitable industry despite said challenges. One form of aquaculture, the shrimp aquaculture, has seen its revenues continue to rise over the past decade (Saint Lucia Government, 2018).

The price of giant freshwater prawn *Macrobrachium rosenbergii* has been increasing steadily over the past few years which has resulted in more farmers coming into its production. This is encouraging for the development of the fishery but poses some problems to the government of Saint Lucia. The main challenge faced is in production cost of macrobrachium post larvae with regards to the use of live feeds in the start feeding process (Saint Lucia Government, 2018). Live feeds are very expensive and can be scarce at times. This feed issues seems to be a universal problem (David *et al*., 2018).

Hatcheries which produce *Macrobrachium rosenbergii* post larvae are dependent to a large extent on the use of live feed like *Artemia nauplii* (Sahu *et al*.,2015). As a result of the increase in the worldwide demand for artemia for the use in post larval shrimp production and marine fish larvae start feeding, its high costs pose a very big problem for developing countries (Sahu *et al*., 2015; Leger *et al*., 1986). The high costs of artemia in the production of post larvae is the main problem facing the government ran hatcheries in Saint Lucia that solely rely on artemia for its post larval production. At present, artemia cost accounts for 60-70% of the total production costs of shrimp post larvae in Saint Lucia (Saint Lucia Government, 2018).

As a result of this, shrimp farmers in Saint Lucia have experienced breaks in their production due to unavailability or delayed supply of shrimp post larvae. On many occasions The aquaculture unit have had to delay production of post larvae resulting in loss of revenue by farmers. This issue needs to be addressed by looking for alternative feed sources or ways of feeding in the post larval shrimp production. This would not only ensure the profitability of shrimp farming in Saint Lucia but also its short- and long-term sustainability.

For *M. rosenbergii* there have been many research and trials carried out since the 1980s with substituting larval diets (rotifers and artemia) with diet enrichment, microencapsulated, micro coated or micro bound diets with limited success (Sahu *et al*.,2015; Kolkovski, 2013; Tucker, 2012). Studies so far have confirmed that it is possible to have some reduction in the reliance on live feeds (artemia use) in the production of post larval shrimp. However other diets are unable to fully replace the use of live feeds (Holt, 2011). In order to address this problem, the government of St Lucia through the aquaculture unit needs to investigate ways of reducing the amount of artemia needed in the production of shrimp post larvae by incorporating the use artificial feeds with artemia or/and using other live feeds which are inexpensive and reasonable to grow (rotifers, other zooplankton) in the area.

This study will investigate ways of cutting cost and the amount of artemia required to produce a batch of *Macrobrachium rosenbergii* shrimp post larvae by focusing on incorporating artificial feeds and other live feeds which meets the nutritional requirements of the post larvae.

1.3 Research objectives

The production of *Macrobrachium rosenbergii* post larvae in Saint Lucia biggest setback is its cost of live feed used in the production process. The cost of good quality *Artemia nauplii* continues to rise and will only cause further delays in sourcing it for production. As a result, there need to be research into ways of reducing the amount of artemia needed for production. This type of knowledge will help stop delays in production of post larvae, help in reducing the

cost of production and ultimately helping in making shrimp farming in Saint Lucia more efficient and sustainable. The study objectives are:

1.3.1 General objective

To investigate incorporation of artificial feed along with live feed (artemia) to reduce the cost of feed in the early stages of *Macrobrachium rosenbergii* post larval shrimp production

1.3.2 Specific Objectives

To review the availability of artificial feed suitable for *Macrobrachium rosenbergii* post larval culture.

To review the practice of *M. rosenbergii* larval culture in other countries, particularly in terms of feed used (homemade feed and commercial feed), feeding practice and weaning process from life feed to dry feed to post larval stage.

Design an experimental protocol for the experiments, which will be carried out in Saint Lucia.

Design small scale experimental recirculation system for feed trials (or other variables) and evaluate its construction and running cost.

2 LITERATURE REVIEW

2.1 World Aquaculture Production

Aquaculture is the management and cultivation of both aquatic plants and animals for various reasons including recreation, food and profit generation (Harrell 2004; Frankic 2003; Stickney 1994). It is one of the fastest growing sectors in food production. In the year 2014 there was 73.8 million tonnes of fish produced at an estimated value of USD 160.2 billion (Ahmed, 2016; FAO, 2016).

The global wild fish caught has not increased since the early 1990s and has remained at around 90 to 95 million tonnes per year to present (Richie & Roser, 2019). As illustrated in figure 1, aquaculture in comparison is growing at a very rapid rate, from 1990 up till 2015 aquaculture production has increased up to 50- fold to over 100 million tonnes per year (Richie & Roser 2019; FAO 2018).

Aquaculture production is expected to continue to play a very major role in easing pressure off wild fish stocks along with meeting the increased demands of sea food and fish proteins (Richie & Roser 2019).

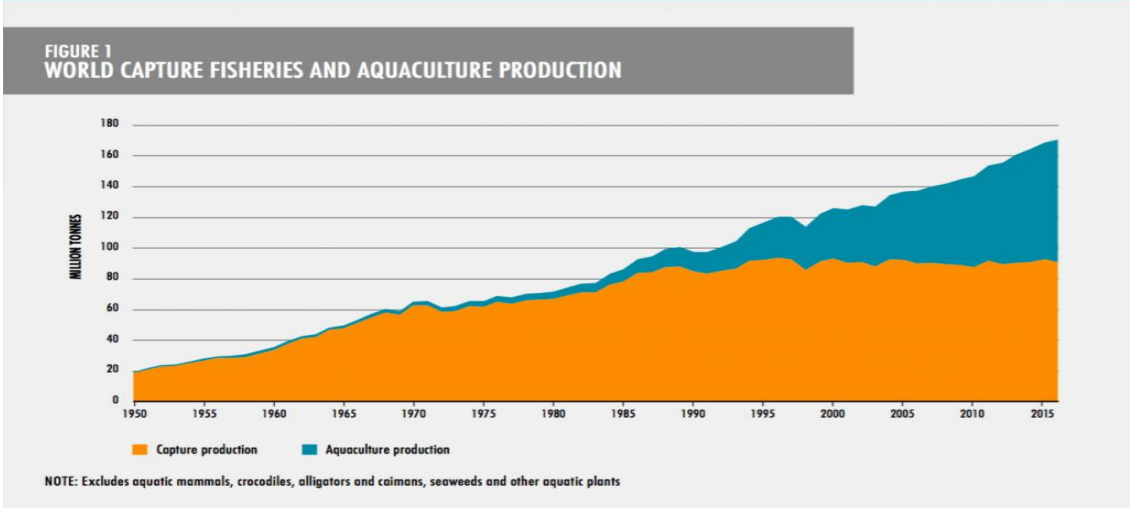

Figure 1. Global capture fisheries and aquaculture production 1950–2015 **(**FAO, 2018)

China contributes to over 60% of the aquaculture supply worldwide with almost 64 million tonnes produced in 2017 with an estimated value of USD 96.12 billion (figure 2). Many of the top aquaculture producers have also increased their production compared to previous years. Aquaculture production is expected to increase over the next few years both in China and worldwide as countries increase their efforts to meet the demands for animal fish proteins (Wee, 2019).

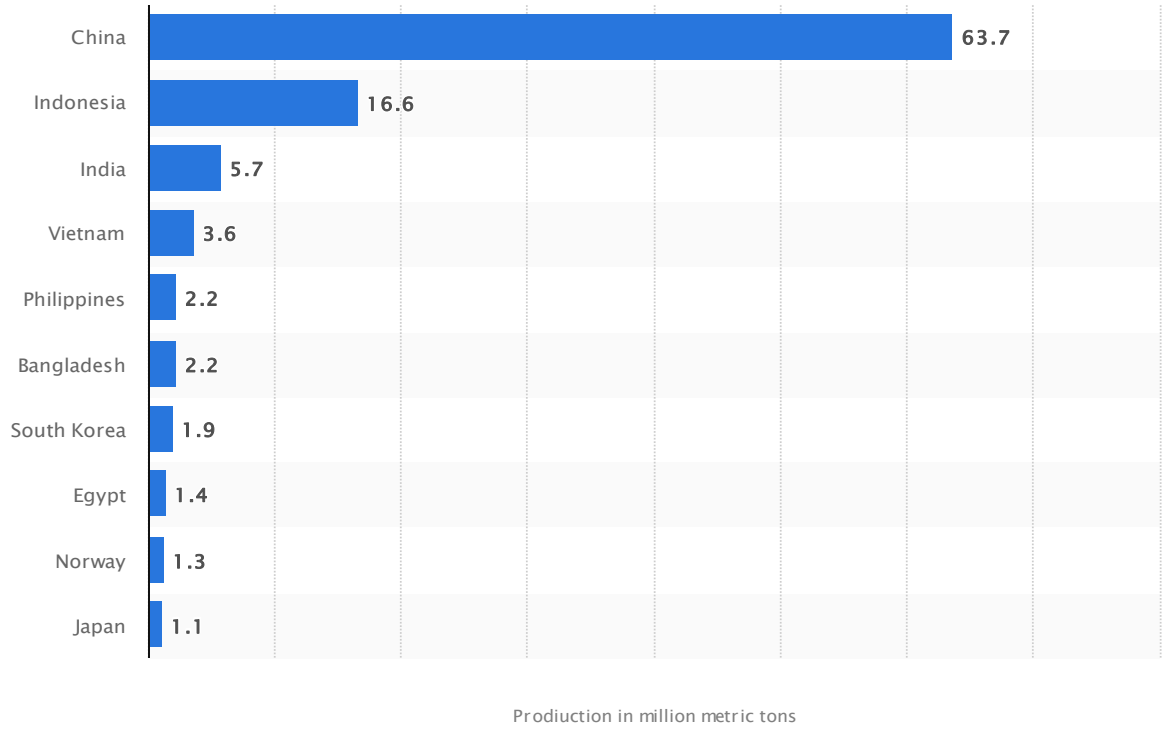

Figure 2. Top 10 Aquaculture producers in the World 2017 (Agriculture and Food Sector Insights, 2018)

2.2 Aquaculture in the Caribbean

World aquaculture production increased by an annual rate of 6.2% in 2000-2012, this is an increase from 32.4 million tonnes to 66.6 million tonnes. Africa experienced fastest growth of

11.7% with Latin America and the Caribbean came in second with a growth rate of 10% (FAO, 2014; Towers, 2014). Although aquaculture development is increasing in the region, it only contributes 0.05% or 3351.6 tonnes to the world's aquaculture production (Ewing, 2019; FAO, 2016).

In the years 2008- 2012, Latin America and the Caribbean accounted for only 2.9% of global aquaculture production (FAO, 2014; Myvett, 2014 *et al*.; Towers, 2014). This low number is a result of the aquaculture sector being underdeveloped in the CARICOM/CARIBBEAN region (Ewing, 2019; Moffitt, 2014; Myvett *et al*., 2014; Towers, 2014). Still, major aquaculture development has taken place in some of the more developed countries in the Caribbean like Jamaica and Belize (Myvett, 2014). These two countries are the region's top aquaculture producers. Other countries in the region like Guyana, Haiti, Suriname, Trinidad and Tobago and Saint Lucia have placed more attention and resources into developing aquaculture in their countries (Myvett, 2014; Towers, 2014).

Aquaculture in the Caribbean involves a few culture methods and culture species (figure 3). Pond culture is practiced in the farming of penaeid shrimp (*Penaeus* spp.), giant freshwater prawn (*Macrobrachium* spp.), tilapia (*Oreochromis* spp.), various carp species and cachama *(Colossoma macropomum*). There is also algae culture of *Eucheuma* spp. and *Gracelaria* spp. in Saint Lucia and Grenada and the culture of Mangrove Oyster (*Crassostrea rhizophorae*).

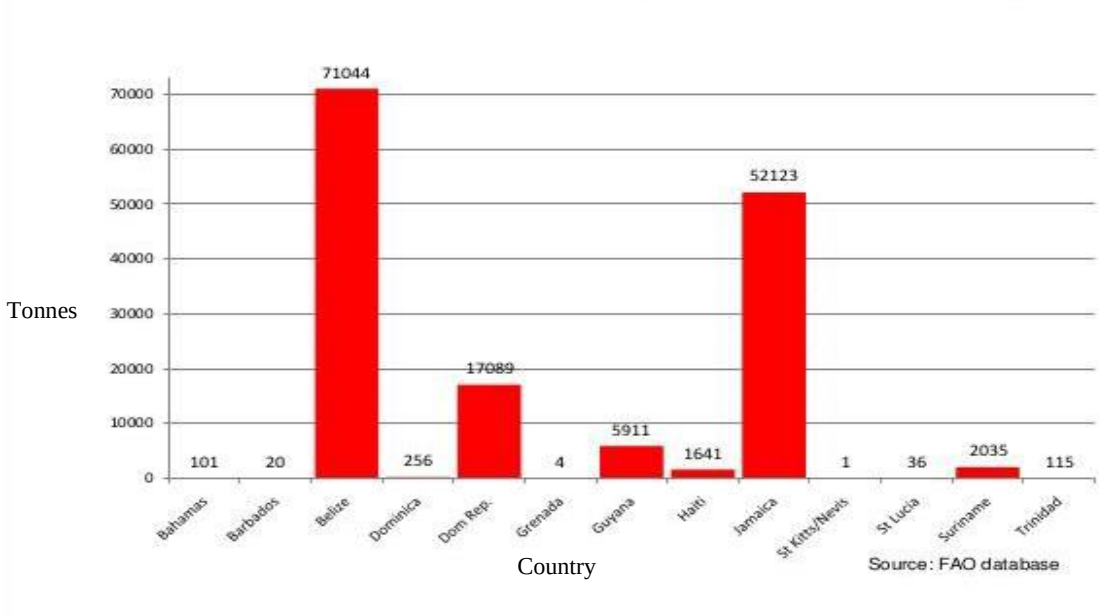

Figure 3. Aquaculture Production by Country in The Caribbean 2000-2012 (Myvett *et al*., 2014)

With the increase in the demand of fish and fish products within the region, along with most of its fish stocks being fished to an unsustainable level it is even more important to focus on aquaculture development within the region. However, aquaculture development in the Caribbean to date still has a long way to go, there is huge potential to increase the aquaculture production in the Caribbean (Ewing, 2019; University of California, 2019).

About half of all the fish supplied in the region is imported, causing trade imbalances as the dependence on fish imports continues to increase in many of the small islands in the region. Governments need to provide the necessary resources to develop the existing aquaculture infrastructure within in their countries to help solve tackle low production in aquaculture and

reduce the import of fish. New forms of aquaculture like cage culture of marine species like cobia could be explored. This form of aquaculture could provide economic viable sector while reducing the pressures on their marine ecosystems and helping increase its production (University of California, 2019; Myvett *et al*., 2014).

2.3 Fresh Water Aquaculture in Saint Lucia

Although aquaculture has been practiced in Saint Lucia since the 1960s, aquaculture production only intensified in the late 1980s- the mid-1990s (Felix, 1997), although the total production is still limited in volume. The introduction can be attributed to two freshwater culture species, the Nile Tilapia (*Oreochromis niloticus*) along its red hybrid and the giant freshwater prawn (*Macrobrachium rosenbergii*), by the Taiwanese Governments (Aquaculture Brochure, 2013; Felix, 1997).

Production of Nile tilapia has been steadily increasing from 2010-2016. Nile tilapia and giant freshwater prawn production were at their highest in the year 2016 (15.27 tonnes and 11.87 tonnes respectively). Both species experienced a drop in production the following year 2017 (9.09 tonnes of tilapia and 4.36 tonnes of freshwater prawn).

Nile tilapia production dropped that same year as a result of flooding of the tilapia fingerling ponds after a storm, resulting in loss of many of the fish fingerlings (figure 4).

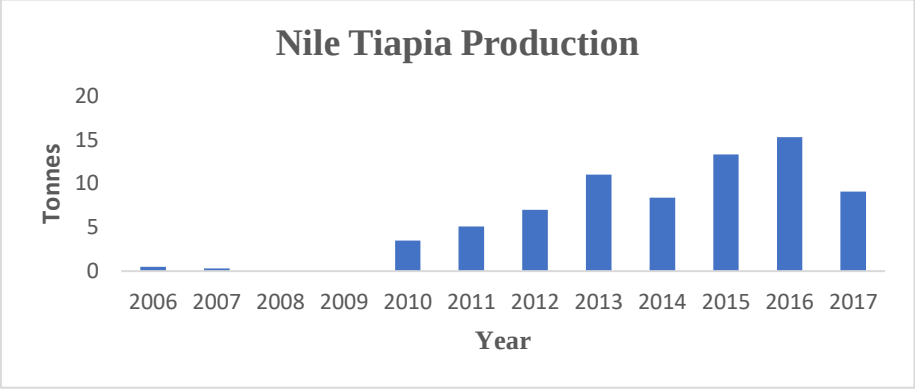

Figure 4. Saint Lucia Production of Nile Tilapia (*Oreochromis niloticus*) (MT) 2006-2017 (FAO, 2019)

The drop in freshwater prawn production in 2017 was a result of a smaller number of post larval shrimp produced at the government hatcheries (figure 5). As a result, not all famers were able to be stock their ponds for grow out and those who were stocked received lower numbers of post larvae than in a normal year.

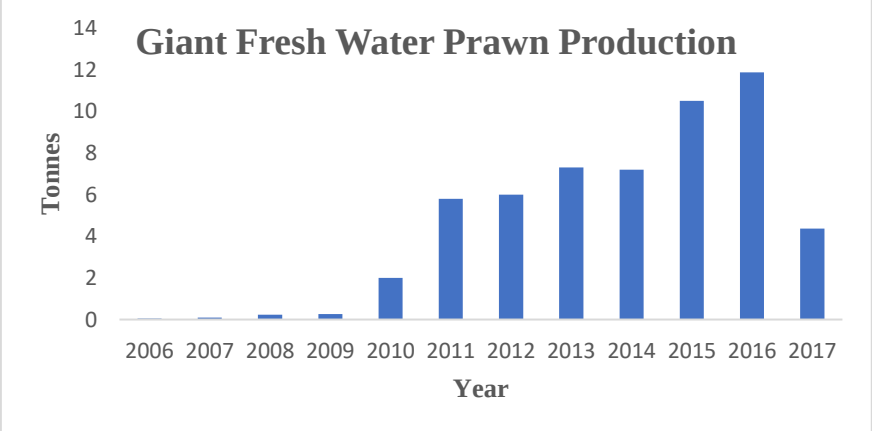

Figure 5. Saint Lucia Production of Giant Freshwater Prawn (*Macrobrachium rosenbergii*) (MT) 2006 to 2017 (FAO, 2019)

2.3.1 Locations of Giant Freshwater Prawn Farms in Saint Lucia

Giant freshwater prawn farms in Saint Lucia are scattered throughout the island, close to water sources (rivers and streams). Most farmers get water to their ponds using pumps or by damming the water and directing the water to their ponds. Currently there are 22 aquaculture farms engaged in culture of giant freshwater prawns on the island, as indicated in figure 6 (Government of Saint Lucia, 2018).

Figure 6. Map of Saint- Lucia Showing the Locations of Prawn Farms (Google Earth, 2018)

2.3.2 Problems Facing Macrobrachium rosenbergii Aquaculture in Saint Lucia

Giant freshwater prawn farming has been very good for the development of aquaculture in Saint Lucia and is typically a profitable venture for farmers. It does however face some major challenges which could affect its future development and sustainability (Government of Saint Lucia, 2018; FAO, 2016; Mayvett, 2014). Post-larval shrimp are produced by the government and provided to farmers at a subsidized price (Aquaculture Brochure, 2013).

An issue that continues to affect aquaculture farmers in Saint Lucia is high costs of pond construction. Most of the heavy equipment used in pond construction are rented with operators charging hourly rates. This can make pond construction cost very high. Acquiring land to get into aquaculture production is possible but availability of cash support through loans and grants are difficult to source. Many lending institutes consider aquaculture ventures as high risk and agricultural lands as low value and rarely receive loans to persons who want to use agricultural lands as security (Government of Saint Lucia, 2018; Taiwanese technical mission, 2016).

The quality of roads to reach aquaculture farms are deplorable. As a result, farmers often experience difficulties in accessing their farms, especially when it rains. This can cause major delays in harvests, breaks in feeding and receiving seed stock. Saint Lucia still has hundreds of acres of lands involved in banana cultivation. The use of various pesticides and herbicides on those farms could contaminate the nearby water intakes/rivers which are also used by shrimp farmers (Government of Saint Lucia, 2018).

Presently, there are no forms of aquaculture feed produced in Saint Lucia. All feeds are imported from Latin or North American countries. Imported feed is expensive, increase the production costs for shrimp farmers and reduce the profitability of their operations (Government of Saint Lucia, 2018; Myvett *et al*., 2014).

All issues mentioned so far are important and have major impact on the development of freshwater prawn aquaculture in Sant Lucia. However, the biggest limitation for shrimp culture in Saint Lucia is in the production of post larval shrimp. All post-larval shrimp are produced at the government hatcheries and then sold at subsidized prices to farmers for stocking. Government hatcheries are heavily dependant on the use of live feed (*Artemia nauplii*) in feeding shrimp larvae especially in the early stages of production (first 14-18 days). Artemia is not produced in Saint Lucia and must be imported from the United States at a high cost. In 2017, 250,000 post larvae of *Macrobrachium rosenbergii* cost the government 2,134 USD worth of *Artemia nauplii* ($1692 (3cases of artemia) + $442 shipping).

3 METHODOLOGY

This overview will focus on the first 14 days of the *Macrobracium rosenbergii* post-larval life cycle where the demand for live feed is at the highest.

3.1 Study design

First the necessary literature is reviewed to find out which artificial feed is on the market for shrimps and evaluate which diets meet the nutritional requirements for *Macrobrachium rosenbergii* post larvae.

Observation of the common procedure in freshwater shrimp larvae first feeding and weaning protocols in different areas/countries is undertaken through a desk study. Comparisons are made to common procedure in Saint Lucia.

Experimental protocols are designed to test 4 different start feeding approach, using artemia, dry feed and two weaning procedures. Additionally, an estimate of its potential effect on production cost of larvae. This will be done by studying experimental setup and conditions.

Design and evaluation of small-scale RAS system for experimental purposes is made by investigation of small-scale RAS in use and the functionality will be studied by learning process (reading/ discussion).

3.2 Study Area

St Lucia is an island located in the Eastern Caribbean at coordinates 13° 54 N, 060°58 W (figure 7), with an approximate population of 178,744 as of 2017 (St Lucia 2016 census). It forms part of the Windward Islands group of the Lesser Antilles and has a total area of 616 sq. km or 238 sq. miles (Jennings, 2009). The capital of Saint Lucia is Castries; it has a mountainous terrain and a tropical climate (Jennings, 2009).

Figure 7. Location of Saint Lucia **(**Jennings 2009)

The study will take place in one of the two government owned fish and shrimp hatcheries in Saint Lucia. This facility is called Beausejour prawn facility. This facility is in the south of the island in an area called Beausejour (Figure 8), Vieux-Fort coordinates 13° 45' N, 060° 58' W.

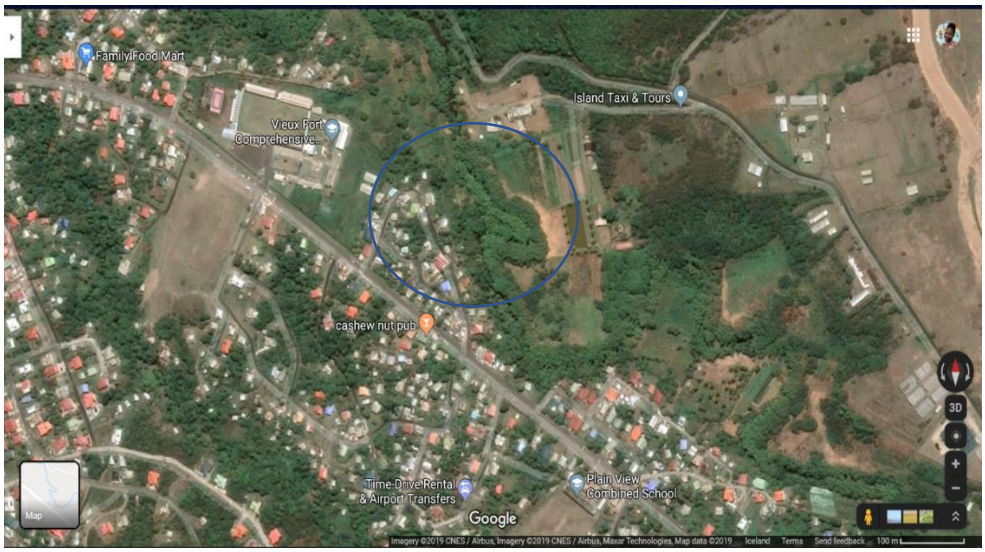

Figure 8. Map showing Location of Hatchery where Feed Experiment will take place-Bonsejour Prawn Farm (Google Maps, 2019)

4 A REVIEW ON THE AVAILABILITY OF ARTIFICIAL FEED SUITABLE FOR *MACROBRACHIUM ROSENBERGII* POST LARVAL CULTURE

4.1.1 What is the Giant Freshwater Prawn (Macrobrachium rosenbergii)?

M. rosenbergii or giant freshwater prawn, is a commercially important species of freshwater prawn (FAO, 2020; New, 2010). *M. rosenbergii* can grow to lengths of over 30cm or 12 inches and are mostly brownish to light blue in colour (FAO, 2020; New, 2010). Juvenile *M. rosenbergii* may have a greenish colour with faint vertical stripes. The rostrum contains 11 to 14 dorsal teeth and 8 to 11 ventral teeth. The first pair of walking legs are called pereiopods and are thin and elongated, ending with chelipeds or delicate claws which are used for feeding (FAO, 2020; New, 2010; Chowdhury, 1993). Its second pair of walking legs are much larger and powerful, especially in male *M. rosenbergii* (figure 9). The colour of the claws in the males of this species varies according to their social dominance (FAO, 2020; Almohsen, 2009; Chowdhury, 1993).

Female *M. rosenbergii* can be distinguished from the males by their larger abdomens and smaller second periopods, or walking legs. Genital openings are located on the area containing the fifth periopods (walking legs) in males and the third periopods in females (FAO, 2020; New, 2010; Chowdury, 1993).

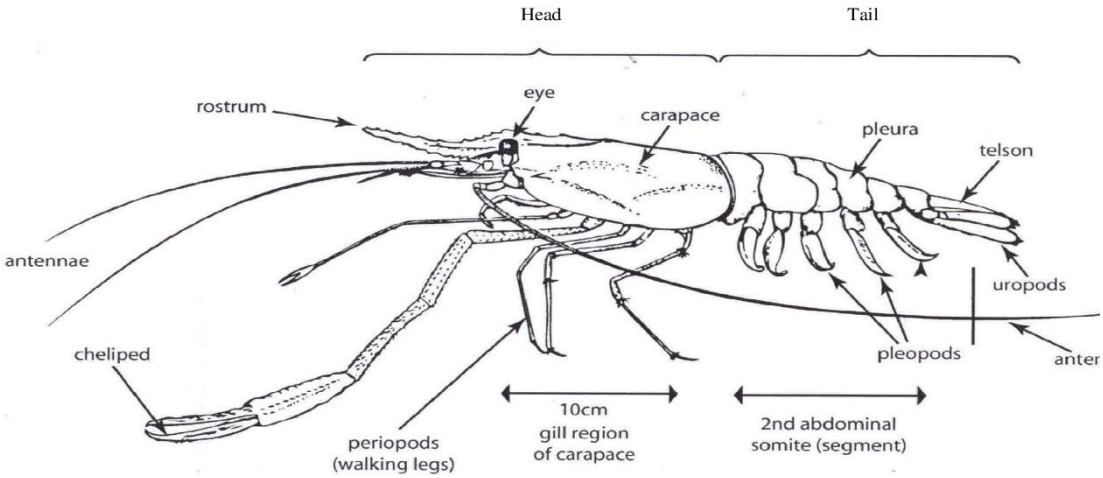

Figure 9. Anatomy of *M. rosenbergii* (Almohsen, 2009)

4.1.2 Background and Distribution of M. rosenbergii

M. rosenbergii is native to the Indo-Pacific and is a very popular aquatic food in the region, and in Europe and North America (FAO, 2020; New, 2012; Chowdury, 1993). Giant freshwater prawns were first reared by Thai farmers in the early 1950s by collecting seed from the wild (FAO, 2020; New, 2012; New, 2009; Chowdury 1993). *M. rosenbergii* grows very fast and can withstand temperature and salinity changes and it can be cultured in ponds.

Thai farmers experienced low production as a result of their dependence on collecting seeds in the nature (New, 2012; Chowdury, 1993). The intensification of *M. rosenbergii* culture is depended upon the availability of seed. Because of the interest by farmers in Southeast Asia to culture this species, a hatchery industry developed (Chowdury 1993).

Dr. S. W. Ling, a Taiwanese scientist discovered that *M. rosenbergii*, although being a freshwater species, completed its larvae phase in brackish water. He developed the green water

method of seed production. In the wild, *M. rosenbergii* spawns in estuaries and journey upstream after a month (FAO, 2020; New, 2012; Chowdury, 1993).

In recent years many advances have been made in hatchery technology. We have seen the abandoning of the green water method being replaced with the clear water method. Recirculation systems are generally used in the production of *M. rosenbergii* post-larvae (FAO, 2020; Chowdury, 1993).

There are 150 species of *Macrobrachium* found in the world, twenty-seven of those species are grown commercially and are found in Asia and the Pacific (New, 2009; Chowdury, 1993). Most species live in freshwater with a few living in brackish water at the mouths of rivers and estuaries (FAO, 2020; New, 2012; Chowdury, 1993).

M.rosenbergii has been the most researched species of *Marcrobrachium* and has also been introduced to many other countries for commercial culture. In 1972, Fujimura and Okamoto were successful in producing post-larvae of *M. rosenbergii* in large numbers in Hawaii (Chowdury, 1993). The Taiwanese government successfully produced *M. rosenbergii* post larvae in Saint -Lucia in the mid- 1980s (Felix, 1997). Presently, *M. rosenbergii* is being cultured successfully all over the world, in countries in the Caribbean, Central and South America and North America (FAO, 2020; Chowdury, 1993).

4.1.3 The Life Cycle of M. rosenbergii

There are four stages in the life cycle of *M. rosenbergii* (figure10). They are viz (egg), larva, juvenile and adult stages. Freshwater prawns moult just like other crustaceans. The number of moults and duration of intermoult are dependent upon the environment, particularly temperature and the availability of food (FAO, 2020; Chowdury, 1993).

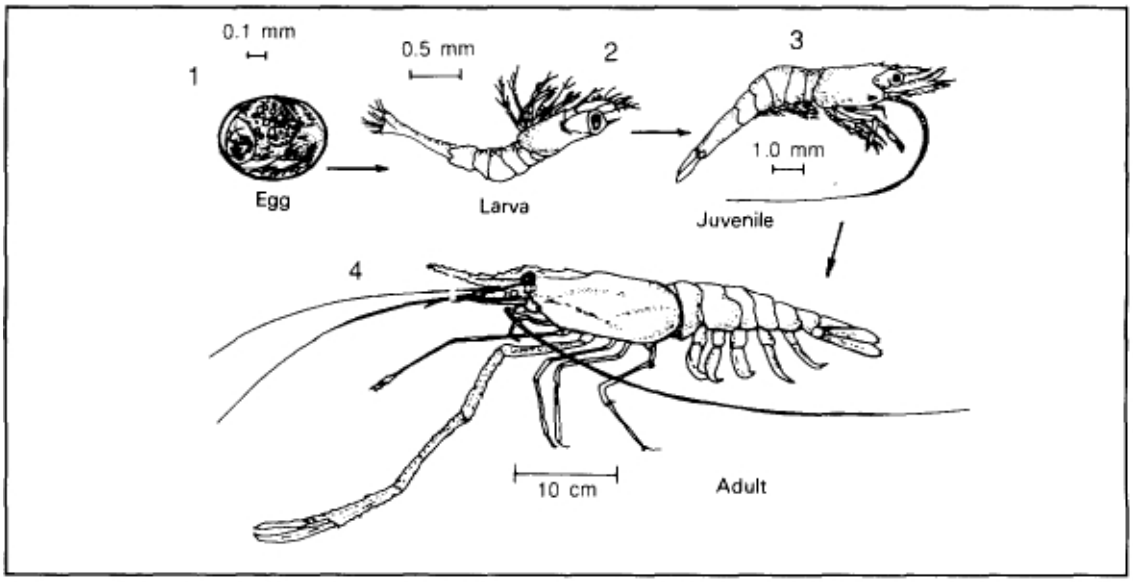

Figure 10. Life cycle of M. rosenbergii (Corteel *et al*, 2013)

In the wild *Macrobrachium rosenbergii* mate all year round. However, because of environmental reasons like climate, the peak mating takes place during certain periods of the year (FAO, 2020; Kamaruding, 2017). *M. rosenbergii* peak mating coincides with the warmer periods. This occurs to assure that the required temperatures of 28°C-30°C to enable the post larval process is met (FAO, 2020; Kamaruding, 2017).

A female prawn with mature gonads copulates just after moulting and mates with a male prawn with a hard shell. During the mating process, the male prawn deposits spermatophore on the

underside of the thorax of the female located between her walking legs (FAO, 2020; Kamaruding, 2017; Chowdury, 1993). A female prawn releases eggs within a few hours to a few days after copulation. The number of eggs released is dependent upon the size of the female prawn (FAO, 2020; Kamaruding, 2017). A full mature female of 50-100g can carry 50,000-100,000 eggs (Habashy, 2011; Cavalli, 2001; Chowdury; 2017).

As the eggs are extruded, they are fertilized by the sperm stored in the spermatophore. Fertilized eggs are then transferred to a brood chamber located on the underside of the female and held in place by a thin membrane. The eggs are kept aerated by the movements of the abdominal appendages. Fertilised eggs are incubated in this manner for 21 days and then hatch. Under hatchery conditions, it has been observed that hatching takes place 20 days after copulation but may take 25 to 30 days if the water temperature is below 25°C (FAO, 2020; Habashy, 2011; Chowdury, 1997).

Ovaries can ripen again even while a female is carrying eggs. As soon as hatching is completed, a female can release eggs again. Freshwater prawns can lay twice a month. The eggs of the prawn are 0.6- 0.7 mm in length and are bright orange in colour but become grey two to three days before hatching (FAO, 2012; Chowdury, 1997).

Larvae hatch at night. Newly hatched larvae swim with their heads down and jump when they reach the surface. Newly hatched larvae need brackish water to survive. Although they are hatched in brackish water, larvae will die if they are not placed in fresh water two to three days after hatching. Wild *M. rosenbergii* larvae generally feed on zooplankton, small insects, and other small aquatic invertebrates (FAO, 2020; Kamaruding, 2017; Chowdury, 1997).

Larvae in hatcheries are commonly fed with *Artemia nauplii* for the entire 28-36-day cycle until they reach post-larvae stage. Artemia is then incorporated with artificial feed after 2 to 3 weeks or when larvae have reached more advanced stages of development. Under hatchery conditions, after larvae have undergone metamorphosis to post-larvae, the salinity of the water is gradually reduced over a period of a week until they are in only freshwater. In the wild they go through the same salinity shift, the post-larvae swim towards freshwater canals and rivers (FAO, 2020; Chowdury, 1997).

4.2 Global production of the giant freshwater prawn, *Macrobrachium rosenbergii*

The true world production figures of giant freshwater prawns submitted to FAO maybe underestimated. This is as a result of a large quantity of prawns being sold in local markets by small prawn farms and these figures may not be included in statistical data (New, 2012).

At the end of 1980, giant freshwater prawn annual global production was only 2,861 tonnes. Most of this output was from Vietnam, Mexico, Thailand and the USA (New, 2012; FAO, 2011). The farming of giant freshwater prawns has expanded since the 1980s. As of 2011, global production has increased by more than 80 times as much as in 1980 (from 2,861 tonnes to 229,419 tonnes) (New, 2012; FAO, 2011).

Table 1 shows all the countries that reported farmed production of giant freshwater prawns in 1980 and 2009. Thailand and Vietnam first reported the production of giant freshwater prawns to FAO in 1975, Myanmar in 1997, Taiwan 1982, India 1989, Bangladesh 1995 and China 1996. The largest current producer is China. The production has increased rapidly from when first reported in 1996 until 2001. China's production fell slightly in 2002 and 2003 but has continued to rise until present day. Chinese production has reached 145,000 tonnes by 2009. They produced no farmed giant freshwater prawns at all in 1980 (New, 2012; FAO, 2011).

Table 1. Comparison of volume of farmed giant river prawns per country (Macrobrachium rosenbergii) produced in 1980 and 2009 (Farook, 2018; New, 2012)

Country	Giant freshwater prawn, *Macrobrachium rosenbergii* production in year (MT)	
	1980	2009
China	0	144,467
Bangladesh	0	26,137
Thailand	113	32,175
Indonesia	0	696
Taiwan	0	7,470
India	0	6,600
Vietnam	1,560	7,700
Myanmar	4	2,881
Philippines	0	29
Malaysia	48	552
Brazil	273	100
Others	863	7,342
Total	**2,861**	**229,419**

Thailand experienced an upturn and downturn in the production of giant freshwater prawns from 1980 until 2002 as the result of a major UNDP/FAO project (1977-1980). This development in production is as a result of competition for resources with rice farming and the farming of marine shrimp. Thai production of giant freshwater prawn more than doubled between 2002 (15,393 t) and 2004 (32,583t) and has remained at elevated levels since. In future, there could be an increase in the production of giant freshwater prawn in Thailand as the government aims to reduce its dependency on the production of whiteleg shrimp (*Litopenaeus vannamei*) (New, 2012; FAO, 2011).

Bangladesh annual giant freshwater prawn production has increased every year from 1995 until 2009. Production as of 2009 was 26,000 tonnes. Bangladesh is currently the third largest producer of farmed giant freshwater prawn (*M. rosenbergii*). However, this is not the trend for all the top producers of giant freshwater prawn. Giant freshwater prawn production has declined quite significantly from its peak in 2005 of 43,000 t (New, 2012; FAO, 2011, New 2008). Diseases and water quality problems are responsible for such a drop in production. Production fell to 12,800 t in 2008 and 6,600 in 2009. Consequently, many farmers have turned to the production of alternative species (New, 2012; FAO, 2011).

Annual production levels of giant freshwater prawns are similar in Vietnam and Taiwan. Vietnam appears to be at an average of between 7,000 and 8,000t and production in Taiwan fell by 25% in 2009 when compared to 2008 (New, 2012; FAO, 2011).

Production in Myanmar is close to 2,900t a year. Production of giant freshwater prawns in Malaysia has expanded greatly in 2009 compared to 2008. Although production increased in 2009 (552t) this was still less than 50% if the peak level achieved in 2000 (1,338t). Giant freshwater p,rawn production in Indonesia remained around the 1,000t a year mark in 2005 through to 2008, production has declined in 2009 (New, 2012).

When compared to Asia, the production of giant freshwater in other countries is very small. Output from the Caribbean and the Americas has failed to expand. Ecuador and Mexico produced several hundred tonnes in 1980 but have reported little or no production in 2009. Although *M. rosenbergii* production has great potential in Brazil, its production is on the decline. Current production in Brazil is about one seventh of the level reported in the early 1990s (New, 2012). There has been a tremendous interest in the seasonal production of *M. rosenbergii* temperate regions of the United States. However, the US production of giant freshwater prawns is still very small (less than 200 tonnes a year), although production may be underestimated (New, 2012; FAO, 2011).

Total global production of giant freshwater prawn peaked at 229,000 tonnes in 2009 and could have been higher if not for problems experienced in India (table 2) (New, 2012). China produced 63% of the global production of giant freshwater prawns followed by Thailand with 14%, India, Taiwan and Vietnam with about 3% each and Myanmar with 1% (New, 2012; Farook *et al*., 2019).

Global value of giant freshwater prawns reached US$1.21 billion in 2009. Comparing the value of production in 1984 (USD 71.0 million) with the value of production in 2009 shows that value has not risen that much as compared to the production. The value was 17 times greater in 2009 compared to 1984 but expansion factor was 20 times greater in 2009 when compared to 1984 (New, 2012).

4.2.1 Giant Freshwater Prawn Recent Production

Recent reports have indicated that in some countries giant freshwater prawn is a very important crustacean subspecies and continues to contribute to global prawn aquaculture (Farook, 2018). Great interest is focused on improving the productivity of this species especially when it comes to feed at the larval stages (Sarman *et al*., 2018; Luan *et al.*, 2012; Kovalenko *et al.*, 2002).

Table 2. Global production status of *M. rosenbergii* from 2010 to 2016 **(**Farook, 2018)

Country	Giant freshwater prawn, *Macrobrachium rosenbergii* production in year (MT)						
	2010	2011	2012	2013	2014	2015	2016
China	125,203	122,933	124,713	117,402	127,204	129,452	132,678
Bangladesh	30,636	39,868	45,162	43,713	45,167	42,523	46,189
Thailand	25,606	21,079.9	18,702	18,168	18,000	16,218	14,950
Indonesia	10,725	10,145	13,775	13,773	13,609	14,122	11,708
Taiwan	6,318	6,460	6,759	6,774	8,557	6,580	6,437
India	6,568	3,721	4,269	-	3,545	7,989	10,152
Vietnam	4,246	5,813	5,885	4,785	5,674	7,014	7,014
Myanmar	2,881	4,233	4,355	872	800	2,329	13,545
Philippines	1,418	1,625	1,487	1,676	1,682	1,486	1,299

Malaysia	619	334	413.28	457	398	268	390
Brazil	100	100	100	100	100	100	100
Others	396	657	603	461	402	380	318
Total	214,716	216,968	226,203	208,180	225,138	228,960	244,780

M. rosenbergii production has been increasing steadily over the past 17 years among the major producers (figure 11). However apart from Malaysia, which showed a significant increase in production from 2016 to 2017, the increase has been steady but not drastic. There may be several reasons for this ranging from competition by other fish species to government policy. The main issue plaguing this species culture is that of costs related to post-larval production (FAO, 2020; Farook, 2018).

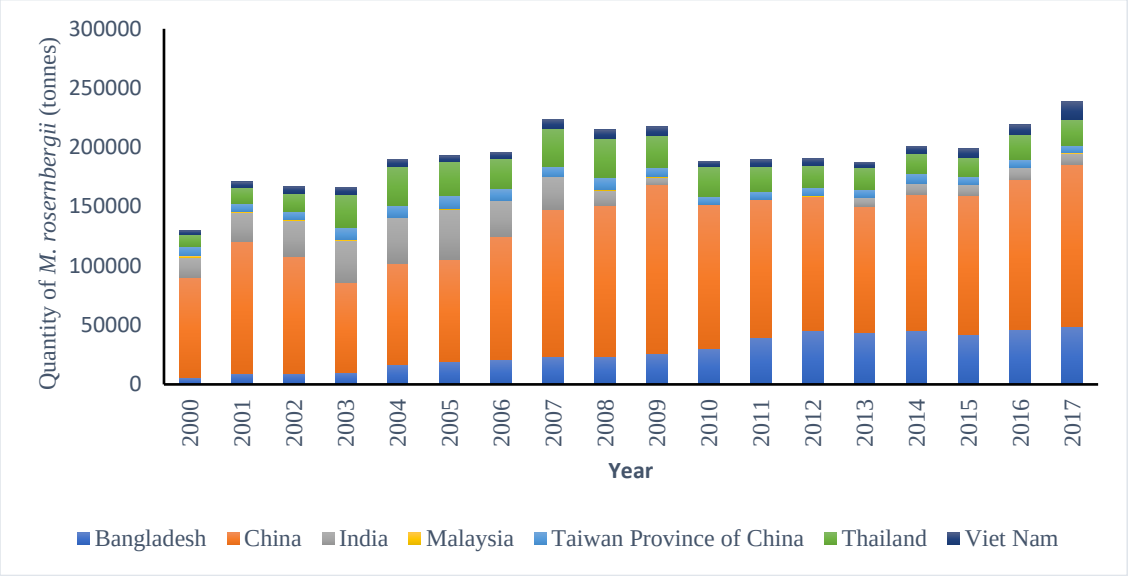

Figure 11. Top Producers of *M. rosenbergii* 2000-2017 (FAO, 2019)

5 NUTRITIONAL REQUIREMENTS FOR *M. ROSENBERGII* POST-LARVAE

Nutritional requirements of *M. rosenbergii* post-larvae have not been standardized but during the last decade there has been some knowledge gained. This has led to increased sustainability in post larval production and of *Macrobrachium rosenbergii* culture in general (FAO, 2004-2020; New & Valenti, 2000).

Giant freshwater prawn larvae are capable of digest various diets of plant and animal origin (FAO, 2004-2020; Mitra *et al* 2005). *M. rosenbergii* post-larvae requires nutrients such as proteins (amino acids), lipids (essential fatty acids, cholesterol), energy sources (lipids, proteins and carbohydrates), vitamins and minerals for their daily metabolism (Roustaian *et al*., 2007).

The prawn larvae have higher protein and lipid requirement than post larvae and on-growing prawns (figure 12). As a result, larvae are reared with *Artemia nauplii* containing 55% protein and 21% lipid (Nesara, 2018; FAO, 2004-2020; New & Valenti, 2000). *Artemia nauplii* is normally enriched with highly unsaturated fatty acids and other nutrients before it is fed to

larvae (Nesara, 2018). A high protein content is required for all the larval stages of *M. rosenbergii*. The nutritional formulation should reflect the larval amino acid composition to fulfil their requirement (Nesara, 2018; FAO, 2004-2020). Amino acid requirements range between 13.4-16.6% and 9.7-11.5% for glutamic acid and phenylalanine (with cystine). Amino acid relative need is lower in tryptophan (1.4-1.6%), methionine (1.4-2.7%) and histidine (2.9-4.2%) (Nesara, 2018).

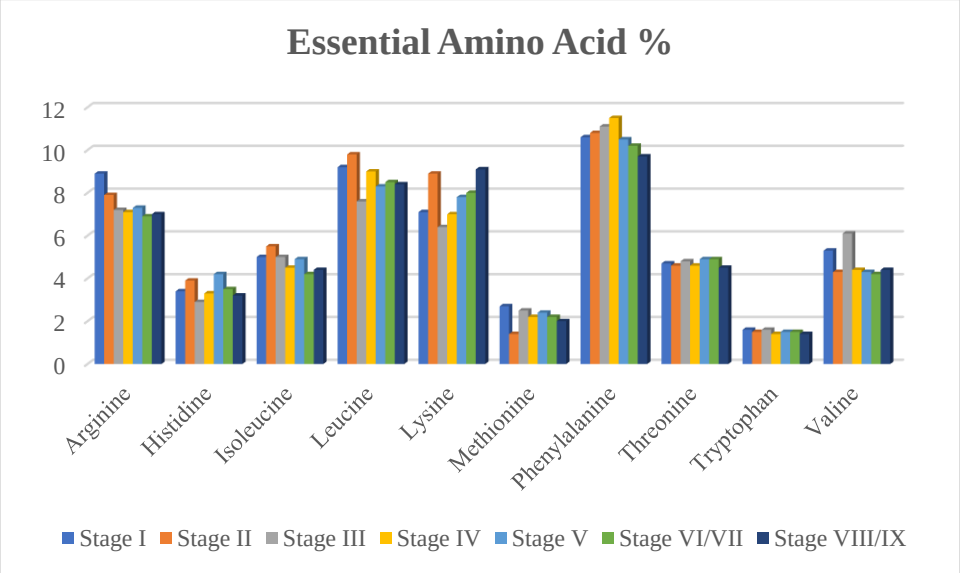

Figure 12. Essential Amino Acid % over the various larval stages of M. rosenbergii (Roustaian, 2007)

Carbohydrates play important role in glycogen storage, formation of steroids and fatty acids. Carbohydrates are also the fundaments in the chitin synthesis. Chitin is the main substance in the exoskeleton of crustaceans. Carbohydrates requirements in the diet of *M. rosenbergii* larvae depends on the stage of larval development. The development of amylase used to breakdown carbohydrates continue as the larvae grows, improving its ability to utilize carbohydrates as a source of energy. As *M. rosenbergii* larvae age, they can produce more amylase and utilize higher carbohydrate level in their diet (Nesara, 2018; New, 2012; FAO, 2004-2020).

M. rosenbergii larval cycle has 11 stages of development from larvae to post-larvae. Larvae can utilize various sources of carbohydrates efficiently at the latter stages in their life cycle, from stage 8 to post larvae at stage 11. Carbohydrates in the form of complex polysaccharides are more effective sources of energy (Nesara, 2018; Mukhopadhyay *et al*., 2003).

M. rosenbergii larval feeds like artemia are not effective sources of carbohydrates or lipids. As a result, the lipid levels in larval diets could be as low as 5%. The lipid requirements for *M. rosenbergii* larvae ranges from 4-8% in the diet but most of this in needed in the latter stages of the larval cycle (stage 8-11) (Nesara, 2018; FAO, 2004-2020; Rangacharyulu, 1999). To fulfil the lipid requirements, hatcheries need to enrich artemia with linoleic (18:2n6) or linolenic acid (18:3n3) (Nesara, 2018; FAO, 2004-2020). Dietary levels of 0.075% of linoleic and linolenic acid are known to increase the weight gain and feed efficiency of larvae at the latter stages (Nesara, 2018; Mitra *et al*., 2005; FAO, 2004-2020).

Larval dietary requirements for cholesterol is 0.3-0.6 %. Unlike marine shrimp feeds, there is no need for high levels of purified cholesterol in freshwater larval prawn feeds, granted that the feed ingredients have enough levels of phytosterols (Nesara, 2018; Mitra *et al*., 2005). High

levels of cholesterol are more important for mature giant freshwater prawn as they play important part in egg maturation and affect egg quality (Nesara, 2018).

Vitamin requirements for *M. rosenbergii* larvae are like that of other crustacean species. Vitamins are added to the diets of *M. rosenbergii* larvae after the 2nd to 3rd weeks of their cycle in small quantities to encourage normal growth (Nesara, 2018; FAO, 2004-2020). Research has been conducted to indicate that vitamin C is beneficial in the early stages of the post larval cycle (Nesara, 2018; FAO, 2004-2020). Artemia is enriched in some cases with C as early as the 3rd day of the *M. rosenbergii* post larval cycle (Merchie *et al*., 1995). Vitamin C and vitamin D added in small amounts can reduce stress levels and improve the immune system of *M. rosenbergii* larvae (Nesara, 2018; FAO, 2004-2020). An increase in mortality of larvae have been observed when vitamins are not added in their diet. There is still need for more research to find out what are the exact causes (D'Abramo, 1998).

Not much is known on the quantitative mineral requirements of *M. rosenbergii* larvae. A dietary supply of calcium seems to improve growth but is probably in relation to the water hardness. There is need for more research in this area. There seems to be lack of information on the mineral requirements and its effects in both marine shrimp and freshwater prawn (Nesara, 2018; FAO, 2004-2020).

5.1.1 Artemia use in Aquaculture

Artemia is an organism that is very closely related to a giant shrimp and are from the order anostraca of the class phylum, crustacea and arthropoda (FAO, 2020; Das *et al*., 2012; Bengston *et al*., 1991).

Artemia, or brine shrimp, are zooplankton, like daphnia and copepods. They are used as live feed for marine finfish, in ornamental aquaculture, and in shrimp and other crustacean larval culture (Das *et al*., 2012; Pillay & Kutty, 2005). Artemia can be used in various forms, as decapsulated eggs, frozen nauplii or freshly hatched from dried cysts. More than 50 strains of artemia are found worldwide. There are several brands and various qualities of brine shrimp cysts sold commercially worldwide. Most of the worlds harvest (about 90 %) is obtained from the Great Salt Lake in Utah (Litvinenko, 2015; ,Treece 2000). A gram of high quality Artemia cysts normally hatch 200,000- 300,000 nauplii (Das *et al*., 2012; Treece, 2000).

There are various live feeds used in shrimp hatcheries butaArtemia is the most common and widely used. Traditionally the commercial production of artemia has been centralized to a few selected locations. However, as a result of the increasing demand and high market prices for artemia, it has now been transplanted to places and new environments where significant quantities of cysts can be harvested. Although there could be other live animal feeds that maybe more nutritionally viable than artemia, its ease and speed of hatching (cysts) makes it much acceptable and convenient for hatcheries (Das *et al*., 2012; Kutty, 2005).

Artemia as a live feed source in shrimp larvae culture has several advantages. The biggest of these is that it is a live food which can be produced from dry storable powder (figure 13). Dormant artemia cysts hatch when put in sea water of about 35ppt of a temperature of 25–30°C and pH of 8–9. It gains its metabolic activity in 24 hours and release nauplii larvae. These larvae are normally about 0.4 mm in length (figure 14). Another advantage of artemia is that it contains a relatively high nutritive value along with a high conversion efficiency. Artemia could be used as feed in all its life stages: egg, nauplii, juveniles, sub-adult stages (Das *et al*., 2012).

Artemia is used as the sole diet for various fish species in many commercial aquaculture hatcheries. Frozen artemia nauplii is used in ornamental fish industry, and by fish breeders and

aquaculturists. Artemia use is not only confined to aquaculture but is also used as a food additive for livestock and in pharmaceutical products. It is also used to produce protein rich foods in the poultry industry (Zarei, 2013) and even consumed by humans. Because of its vast use, artemia trading is increasing around the world (Litvinenko, 2015; Das *et al*., 2012).

One of the main factors which influences the suitability of artemia for hatchery fish is the size of nauplii. The size of artemia nauplii varies depending on its geographical location/source. This characteristic is evident in strains of artemia found in India. They do not perform well in local shrimp hatcheries as a result, and cysts need to be imported (Das *et al*., 2012). Some strains of artemia may be better for different species as opposed to others, that is some may do well with fish species like fish fry and some may do better with shrimp species (Das *et al*., 2012; Lim *et al*., 2003).

Artemia is an excellent food source for many cultured marine and freshwater fish species. One the major constraints for using Artemia as live feed is how its nutritional quality varies. However, there are ways to solve such a problem, to address issues associated with the size and energy content of the different strains of artemia hatchery technicians should: ensure that they choose the right strains, that use decapsulated cysts, storing the cysts correctly and using better feeding strategies (incorporating artificial feeds) (Browdy, 2017). More detailed methods to increase the nutritional value of Artemia will be mentioned later in this paper.

Figure 13. Unhatched Artemia Cysts (Brine Shrimp Eggs). (Alibaba.com)

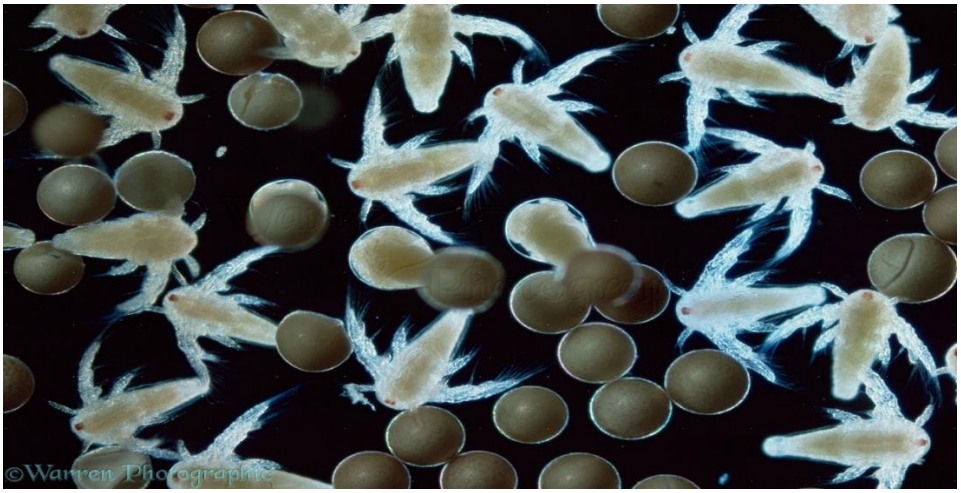

Figure 14. Newly hatched Artemia Nauplii and unhatched cysts. (Warren Photographic)

Most research and data of the nutritional composition of artemia is relative in value. In depth analysis of artemia shows that nutritional value of cysts can change considerably with the strain, batch life and stage along with the harvest season. However, the main nutrients found in artemia include proteins, (amino acids) lipids, vitamins and trace amounts of minerals (table 3) (Vahabzadeh, 2015; Browdy, 2009; Maldonado, 2004).

Lipids have been the most documented nutrient found in artemia since it was identified in the mid to late 1970s and early 1980s. Research has shown that the concentration of essential fatty acids 20:5 n-3 (eicosapentaenoic acid, EPA) found in artemia nauplii determined its nutritional value for the larvae of different species of marine fish and crustaceans (Browdy, 2009; Lavens, 2007; Pillay, 2005). The level of essential fatty acids varies very greatly in amount from strain to strain and batch to bath of artemia. Another fatty acid, docosahexaenoic acid (DHA: 22:6 n-3) is lacking or can be found in very small amounts in artemia. As a result of the deficiencies in essential fatty acids in artemia, techniques have been developed to improve the lipid content of various types (strains) of artemia (Browdy, 2009; Lavens, 2007; Pillay, 2005).

Amino acids levels are the highest nutrient content of artemia. Although there may be different concentrations of amino acids at different life stages and strains of artemia, the differences are usually less pronounced than lipid content (Browdy, 2009; Lavens, 2007). As a result of the low molecular weight of the peptides and free amino acids found in artemia nauplii, along with the high solubility, this makes it highly digestible by young larvae (Browdy, 2009; Lavens, 2007).

The mineral requirements of freshwater and marine shrimp larvae are not fully known, and it is assumed that their mineral requirements are met by the water they drink. Several minerals are found in artemia but at quite low amounts (Lavens, 2007). Vitamins C and E are present in both dormant and freshly hatched artemia cysts although their concentrations may depend upon the strains of artemia along with their geographical locations (Lavens, 2007)

Table 3. Nutrient Composition different strains of Artemia Nauplii (Maldonado, 2005)

Proximal composition (% dry basis) of the Artemia *adult biomass*

Composition (%)	Real de Salinas (rice brand and *T. suecica*)	Real de Salinas (wild)	Texcoco, México[1] (wet *Spirulina*)	San Francisco Bay, USA[2] (dry *Spirulina*)	San Francisco Bay, USA[3] (rice brand)
Protein	53.1	50.3	58.4	62.5	13.69
Lipids	10.6	4.0	7.2	10.8	6.54
Ash	15.4	33.9	8.7	19.1	10.77
Fiber	0.32	0.1	2.1	-	-
Nitrogen free extract (NFE)	20.5	11.7	21.2	-	60.70

Artemia nauplii contains more proteins (amino acids) when compared to other live feed sources like rotifers (table 4) (Mamaliga 2006). It is also bigger in size than various other forms of live feeds, as a result it is easier to catch and consumed by the *M. rosenbergii* larvae (Mamaliga, 2009).

Table 4. Protein (amino acid) composition % of Artemia and Rotifer**. (**Mamaliga 2009)

Amino acids	Rotifer	*Artemia* nauplii	*Acartia clausi*
Arginine	7.08	7.21	8.57
Histidine	1.61	3.14	3.50
Isoleucine	5.01	5.08	2.17
Leucine	9.12	8.81	9.92
Lysine	10.29	10.20	11.04
Methionine	2.92	1.98	1.98
Phenylalanine	4.69	5.26	1.05
Threonine	3.41	3.94	2.50
Cystine	—	—	0.07
Valine	7.92	6.74	9.57
Total EAA	52.05	52.36	50.37
Alanine	7.18	7.86	11.12
Asparctic acid	9.21	9.20	9.57
Glutamic acid	13.72	10.45	11.10
Glycine	6.92	6.31	4.25
Serine	5.18	5.94	6.37
Tyrosine	3.92	5.29	6.31
Total NEAA	46.13	45.05	48.72
Total	98.18	97.41	99.09

5.1.2 Artificial feed suitable for Macrobrachium rosenbergii post larval culture.

Giant freshwater prawn aquaculture has huge potential for generating revenue and employment for persons from all social status (Yan, 2019; Shailender, 2013; Rangappa, 2011). Giant freshwater prawn farming in most instances is environmentally sustainable since farmers stock at low densities (New, 2010). Most of the seeds used for the farming of *M. rosenbergii* is obtained from hatcheries (Shailender, 2013). Hatchery operators depend very heavily upon using live artemia nauplii only or combined with other prepared diets (Sahu *et al*., 2015). Artemia production and use in hatcheries requires facilities, maintenance expenses and labour in order to produce it safely and constantly (Sahu *et al*., 2015; Kazawa, 1989).

As a result of the increasing demand for artemia worldwide, cost of artemia and supply at times very scarce, especially in developing countries (Sahu *et al*., 2015). Many hatcheries in order to reduce feed costs do not operate at max capacity (Sahu, 2015; Shailender, 2013). *M. rosenbergii* larval production has failed to increase in some countries because of disease, competition, introduction of new species (in the case of India). One reoccurring problem is that of the price and availability of artemia nauplii (Sahu, 2015; Shailender, 2013).

Artemia nauplii as a live food source in the culture of *M. rosenbergii* larvae is not only a constraint because of costs and scarcity. Various authors have shown that artemia nauplii in some cases does not suit optimally to produce *M. rosenbergii* post larvae (Shailender, 2013; Lavens, 2007). Some authors have documented that artemia nauplii do not fully meet the nutritional requirements of giant freshwater prawns during the last larval stages. As a result, it is recommended hatcheries use supplemental diets like egg custard and pelleted feeds (Shailender, 2013; New 2010).

Also, a result of the issues faced using artemia, it is necessary to develop microparticulate diets as a substitute for live foods to further increase the productivity of healthy seed for shrimp culture (Sahu, 2015; Kazawa, 1989). Different types of microparticulate diets are categorized into three groups, micro-encapsulated diet, micro-bound diet and microcoated. Micro-diets are also important in not only developing alternative diets but in order to partially replace artemia. Consequently, it is important to know the protein content of artificial diets and the chemical

composition and stability in general (Roustaian *et al*., 2007). A careful analysis of chemical composition at the various life stages of *M. rosenbergii* would help in creating an artificial feed which meets their nutritional needs (figure 15) (Roustaian, 2007).

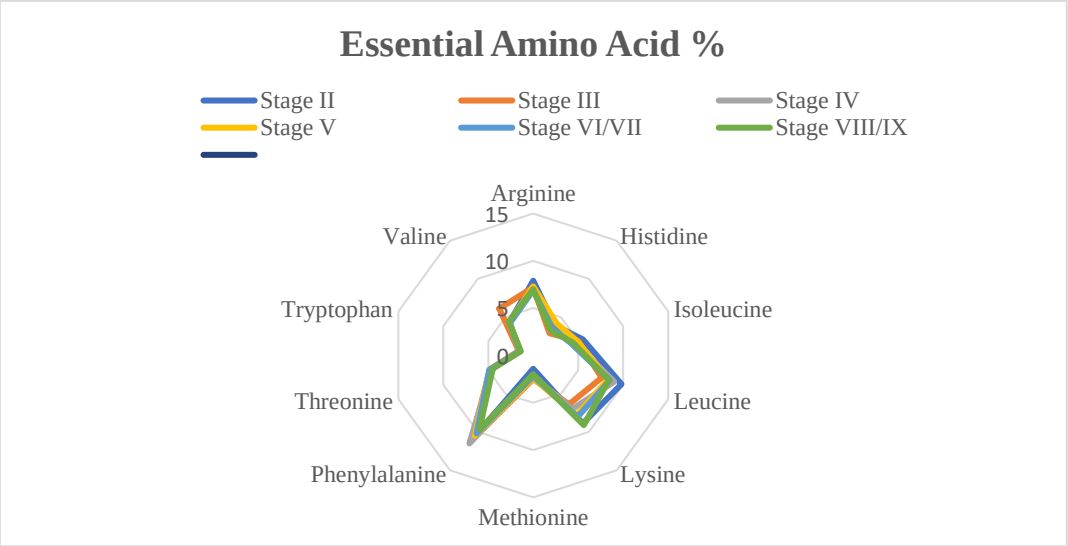

Figure 15. Essential Amino Acids of M. rosenbergii at different larval stages of development. (Roustaian et al., 2007)

Many attempts have been made to create nutritionally complete micro-bound, microcoated, or microencapsulated larval diets which are beneficial to *M. rosenbergii* larvae. Those diets however have achieved limited success and most times cannot serve as a complete substitute for artemia nauplii (Sahu *et al.*, 2015).

Research has shown that other penaeid larvae exhibits good survival and developmental growth rates when they are cultured with rotifers or microencapsulated diets but *M. rosenbergii* larvae do not respond positively to total artemia nauplii replacement (Sahu *et al*., 2015; Lavens *et al*., 2007). A successful replacement of artemia nauplii for *M. rosenbergii* larvae is not only dependent upon nutritional values but various factors like larvae behaviour, mechanical and physical processes during feeding, which needs to be known and documented (Sahu *et al*., 2015; Shailender, 2013). Food size, how larvae capture the food, how it is accepted and how efficiently it is digested at the different larval stages are all important considerations. Hence the food particle size, texture and density of replacement diet/inert food would affect selection and ingestion by larvae (Shailender, 2013; Kovalenko, 2002).

Diets and feed management in *M. rosenbergii* hatcheries are the result of empirical observations. This is because not much is known about the feeding behaviour and the nutritional needs of larvae (Shailender, 2013). The particle size of inert food is specific for each larval stage. In the first 8 stages of *M. rosenbergii* larvae life cycle, food particle size is between 400 to 500 µm in length. They can consume bigger food particles in the latter stages from 9 - 11 (Shailender, 2013; New, 2010).

A suitable micro diet for *M. rosenbergii* larvae is dependent upon having enough physical characteristics and nutritional composition at all stages of larval development. One important factor which could influence the type of artificial diets used for larval culture is the type of culture system employed, whether using RAS systems or another system. There are also disagreement on from which larval stages should artificial/ supplemental feeds be offered (Shailender, 2013).

Artificial feeds in the form of microencapsulated diets have been tested on several shrimp larvae species including *M. rosenbergii*. It was observed that there was a higher survival rate when *M. rosenbergii* larvae was fed with free particulates, live feeds (68%) than artificial/microencapsulated diets (40-50%). Growth is slower as well with artificial diets than live feed diets, unless artificial diets are incorporated with algal supplement. Microbound diets, however, are more successful than microencapsulated diets and higher survival rates recorded in larvae as well. Microparticulate diets still do not perform as well as live feed diets (artemia) (Shailender, 2013; Kovalenko, 2002). The survival rates of *M. rosenbergii* larvae when fed with microparticulate diets are between 45-50%. Survival rates of larvae when fed with artemia is 65-70% (Shailender, 2013; Kovalenko, 2002).

6 GLOBAL REVIEW OF *M. ROSENBERGII* LARVAL CULTURE

6.1 *M. rosenbergii* feeds used in larval culture

Macrobrachium rosenbergii larvae in the early stages are unable to directly collect food by themselves. As a result, feed in the form of live artemia nauplii (brine shrimp) are commonly used as diet in hatcheries worldwide. This small crustacean is rich in proteins. When enriched it is also a rich source of lipids and vitamins. Presently, there are no effective commercial feed substitutes found to replace artemia nauplii completely from the initial larval feeding.

Artemia nauplii must be fed to shrimp larvae as soon as possible after hatching, they are most nutritious when they still contain their yolk sac. Enrichment with essential fatty acids must be done immediately and fed to shrimp larvae with 6 hours after hatching to avoid them from using up their protein content (D'Abramo *et al*., 2003). It is important to collect the artemia nauplii with as little of the hatched shells as possible. Shells may contaminate the water containing the larvae, also if shells eaten by larvae it could also kill them. A new batch of artemia needs to be fed daily to avoid feeding larvae with nauplii which have depleted their nutritional value and risk any chance of contaminated artemia being fed also.

In addition to live feed, *M. rosenbergii* larvae is supplied with artificial feed/supplemental diet as well (table 5). Artificial feeds/ prepared hatchery feeds can be given when larvae are 14 days and onwards, and the amount of artemia nauplii given could be reduced by about 2.5 brine shrimp nauplii per ml (D'Abramo *et al*., 2003; Chowdhury, 1993).

Other diets used in the larval and post-larvae stage of giant freshwater prawn are squid and squilla meal at 14% which can result in increasing growth and has no negative effects on the survival of larvae. It is important to introduce this diet when larvae are 2- 3 weeks old (Nesara 2018). Special care and attention need to be taken when administering this feed to avoid contamination of larval tanks through over feeding (Nesara 2018, D'Abramo *et al* 2003, Chowdhury 1993).

Table 5. Prepared hatchery feed for M. rosenbergii larvae (D'Abramo et al., 2003; Chowdhury, 1993).

Ingredient	Amount
Powdered Milk	60g
Corn Flour	20g
Egg (2 nos.)	70g
Cod liver oil	3.5ml
Vitamin mix	2g
Agar Powder	4g
Tetracycline (antibiotic)	0.50g

In consideration of the protein requirements of larvae, the ingredients listed in table 5 are used to prepare artificial feed. Those ingredients are mixed using a blender, then steamed to prepare a custard. After this mix is cooled it is again grinded in a blender. When feeding this artificial feed to *M. rosenbergii* larvae, particles which are too large and too fine should be removed by wet screening (FAO, 2004-2020; D'Abramo *et al*., 2003; Chowdhury, 1993).

It is not required that larvae are fed with artemia nauplii on the day of hatching. From the 2nd day to the 10th day, a density of artemia nauplii of 5 BSN (brine shrimp nauplii)/ ml should be maintained. This is done by adding newly hatched artemia nauplii in the morning and the evening. Live artemia needs to be fed frequently from sunrise to sunset, instead of one or two feedings over a long period of time (D'Abramo *et al*., 2003). Without frequent feeding, the nutritional value of uneaten artemia decreases overtime. This is as a result of the nutrients found in their yolk sac being absorbed to satisfy their growth requirements and metabolic needs (D'Abramo *et al*., 2003).

The amount of artemia nauplii fed is cut by half when larvae are being fed prepared feed (FAO, 2004-2020; D'Abramo *et al*., 2003; Chowdhury, 1993). The total amount of artemia nauplii added is dependent upon the volume of water in the tank being fed and the number of larvae. A tank of 100- 250 litres of water will require 4.3 kg of artemia cysts for a 50-day rearing cycle (FAO, 2004-2020; Aflalo *et al*., 2006; Chowdury, 1993). Before feeding, the number of artemia nauplii need to be determined so the amount given could be adjusted to get desired level (FAO, 2004-2020; D'Abramo *et al*., 2003; Aflalo *et al*., 2006).

When using prepared feeds there are several factors that needs to be considered: The size of the particles should correspond with the size of the larvae (table 6). Overfeeding could contaminate the water causing high mortality of larvae. Underfeeding could cause stress, malnutrition and encourage cannibalism which would affect growth. The water quality and

cleanliness of tanks needs to be checked before feeding. The best way to administer prepared feeds is to follow the following steps:

- Turn off aeration
- Hand feed and observe to make sure all larvae are actively feeding
- When done, resume aeration (D'Abram *et al*., 2003; Chowdhury, 1993)

*Recirculating Aquaculture systems (RAS) are used in hatcheries abroad. Those systems have several advantages from maximizing space to creating hygienic conditions for the M. rosenbergii post larval process (Suantika *et al*., 2018).

Table 6. Stage-dependent feeding rates for Artemia nauplii and for the supplemental diet and recommended particle size of supplemental diet (D'Abramo *et al*., 2003)

Day of cycle	Stage index	*Artemia* per larva		Supplemental feed		Particle size	Flushing screen
		a.m.	p.m.	Upper	Lower		
		no.	*no.*	*mg*	*mg*	*µm*	*µm*
1	1	0	0	-	-	-	
2	1.5	3	3	-	-	-	
3	1.8	3	3	-	-	-	
4	2.2	9	8	-	-	-	
5	2.7	10	9	-	-	-	
6	3.2	12	10	-	-	-	300
7	4.0	16	14	(0.08)	(0.08)	300-500	
8	4.8	22	20	(0.09)	(0.08)		
9	5.4	27	23	(0.11)	(0.11)		
10	5.6	32	28	(0.18)	(0.15)		
11	6.4	38	32	0.3	0.2	500-700	500
12	6.9	42	38	0.38	0.25		
13	7.2	47	43	0.43	0.3		
14	7.9	49	45	0.55	0.4		
15	8.3	51	47	0.65	0.5	700-900	700
16	8.9	53	48	0.75	0.6		
17	9.1	54	51	0.8	0.6		
18	9.6	54	51	1.1	0.6	900-1200	
19	9.8	56	54	1.2	0.75		
20	1st Postlarvae	58	58	1.2	0.8		
21		65	65	1	0.8		
22		58	58	1	0.9		
23		58	58	0.85	0.9		
24		56	56	0.85	0.8		
25		53	53	0.75	0.7		
PL		62	62	0	0.3		

Carefully observing the behaviour of larvae during hand feeding prevents overfeeding and helps in detecting health problems (FAO, 2004-2020; D'Abramo *et al*., 2003; Chowdhury, 1993).

The older larvae get the amount of feed given should be increased. When larvae are first fed with prepared feed after the 10-14th day, a tank od 100-250 litres should be given 15-30g/tank. As time progresses the rate could be increased to 100g/tank/feeding. A whole larval cycle nay requires 6-8 kg of prepared feed. From the 10th day onwards of feeding prepared feeds, the particle size could be gradually increased up to 1mm as the larvae grow (FAO, 2004-2020; D'Abramo *et al*., 2003; Chowdhury, 1993).

6.2 *M. rosenbergii* feeds used in larval culture (in Saint Lucia)

The production of *M. rosenbergii* post larvae in Saint Lucia relies heavily on artemia nauplii as the main larval feed source. Larvae are fed with newly hatched artemia from the 2nd day to until when they are metasomatized into post-larvae. Artemia cysts have till now not been decapsulated before hatching.

M. rosenbergii post larvae are fed with prepared feeds and artemia nauplii after 14 days till they turn to post-larvae. The prepared feed however is slightly different from what is used in hatcheries abroad (table 7).

Table 7. Prepared Feed in Saint Lucia.

Ingredient	Amount
Powdered/ liquid Infant Formula (0-6months) months)	40-60g
Eggs (3)	105g
Cod-liver oil	4ml

A mixture of infant baby formula is mixed with eggs and cod-liver oil. Infant baby formula is used to add more proteins to the larval diet. Proteins are one of the main nutrients which is vital in the *M. rosenbergii* post larval cycle, for the growth and survival. Cod-liver oil is added to this supplemental feed to add vital lipids needed for larvae in the aim to provide them with the right nutrients, helping them reach to the post larval stage.

This mixture is blended and then steamed until it solidifies. The solidified mixture is then crushed using a piece of mesh or wet screening. The crushed solution is then putted in about ¼ litre of water which will be fed to *M. rosenbergii* larvae.

Technicians observe larvae when feeding. This is done to determine if there is enough feed in the tanks. The feed will be adjusted if needed. Caution needs to be taken with this prepared feed as over feeding could contaminate the water and cause health problems and mortalities. About ¼ of the water in larval tanks is changed daily when feeding prepared feeds and live feeds to improve water quality. At present, recirculating aquaculture systems (RAS) are not being used at the hatcheries in Saint Lucia in the production of *M. rosenbergii* post larvae. Using RAS might be a good alternative, aiming for stable and optimal growth conditions for the shrimp larvae.

7 DESIGN OF EXPERIMENTAL PROTOCOLS TO BE CARRIED OUT IN SAINT LUCIA.

7.1 Recirculating Aquaculture System (RAS)

Old systems used in the production of *M. rosenbergii* post larvae had several constraints including unstable water quality and very high susceptibility to infectious diseases which would reduce on post larval shrimp productivity. A closed recirculating aquaculture system (RAS) helps reduce many of those problems (Suantika *et al*., 2018).

RAS technology ensures an efficient use of water due to the water treatment process through water circulation along RAS components. This system includes biological filtration units which can solve problems which may arise from having high levels of organic matter in the system. The system also reduces the risk of infection by pathogenic bacteria that may exist in untreated water (Suantika *et al*., 2018).

Recirculating aquaculture systems are important in aquaculture. They make it easier to control the conditions of culture of any species and provide balanced and stable conditions (Timmons *et al*., 2018). The use of RAS has been successfully applied in hatcheries all over the world to allow for more stable culture conditions, water quality, improved hygiene and effective and

efficient use of water resources in *M. rosenbergii* post larvae aquaculture production (Suantika *et al*., 2018).

7.2 Experimental system (RAS)

The experiment will be conducted on the Bonsejour Prawn farm hatchery in Saint Lucia. The hatchery is set up with heaters, the lighting is reduced, and the building is closed to help in the regulation of temperature and to mimic the culture conditions in the natural environment.

Nine (9) black cylindrical tanks of 12L each will be filled with brackish water of salinity 12ppt containing shrimp larvae and will be fitted with a central 40mm drain at the bottom in order to effectively drain the waste from each tank when necessary. Tanks will be elevated on building blocks in a 3x3 formation. Each tank will be supplied with a heater (if necessary) to maintain a temperature of 28°C throughout the length of the experiment.

One (1) 250L tank will be filled with brackish water of salinity 12ppt and kept at 28°C using the heater. This water will be used for water exchanges throughout the length of the experiment. One (1) 150L tank with brackish water of salinity 12ppt will be used to put buried females for collection of larvae after spawning. Two (2) 12L tanks containing brackish water of 28ppt salinity will be used to hatch artemia.

7.2.1 Aeration and Circulation

A 1.1 KW side channel blower will be used and run continuously throughout the length of the experiment. It will be fed into a ring of 40 mm black irrigation piping, which will aid equal pressure and ensure each individual tank receives equal aeration and mixing. From the 40 mm ring, a 15 mm black irrigation pipe will be run into the bottom of each tank and attached to the aeration ring. This aeration ring will consist of a 1940 mm long piece of 15 mm irrigation pipe bent into a ring, with individual holes made with a pin every 25 mm along the length of the pipe.

This ring will fit around the inner perimeter of the tank, producing a ring of bubbles additionally aiding in mixing, and will be anchored in place with two stones. To ensure that the water quality will be uniform and homogenized throughout the tanks, 9 airlift pumps will be constructed using 15 mm polyvinyl chloride (PVC) pipes, with air fed from the 40 mm air ring using micro tubing commonly used in drip irrigation systems.

These air lift pumps will be inter-leading from one tank to the next and will have an output of 3-6 litres per minute each. In anticipation for the case of a blockage of an airlift pump, a connection between adjacent tanks will be made using 32 mm flexible pipe, just above the 12 L water level of the tanks, in order to even out the water and prevent tanks from overflowing. Also, this will be accompanied with a recirculation system to ensure maximum water availability, aerating and usage. This system also supplies brood tank, water exchange tank and tanks used to hatch artemia with aeration. A sump tank will be built to trap excrements and protein skimmer will be added to collect and expel smaller suspended solids. A biofilter will be constructed to work on nitrogen excretion. A biofilter volume of $1m^3$ is presumed to have enough capacity for de-nitrifying the water from such a small biomass. The biofilter media will be small plastic biofilter particles with high surface/volume ratio. An aerator is connected to the biofilter. The maturation period (establishment of biofilm) for the biofilter is 3-4 weeks.

7.3 Experimental Design

Buried *Macrobrachium rosenbergii* females will be taken from the brood pond at the facility. Females of eggs of a dark brown colour will be collected, this is an indication of egg maturity, as illustrated in figure 16 (hatches within 1-2 days). Adult females weighing 50-100 grams

could produce up to 50,000 -100,000 larvae (Rafiqul *et al*.,1993). Buried females will be placed in spawning where they will be observed over the next few days to collect larvae after spawning.

Figure 16. Buried Macrobrachium rosenbergii with eggs at 2 stages of maturity (Rafiqul et al., 1993)

Newly hatched larvae will be collected and counted, a total of 9,000 larvae are needed for this experiment. Newly hatched larvae are about 1mm in size (Rafiqul *et al*., 1993). Larvae will be stocked in triplicates of 1,000 larvae per tank of 12L water holding capacity as recommended stocking densities for *Macrobrachium rosenbergii* post larvae is 100/L respectively. Shrimp larvae will be stocked separately in tanks A_1, A_2, A_3 which is treatment 1 (control), tanks B_1, B_2, B_3 for treatment 2 and tanks C_1, C_2, C_3 for treatment 3.

7.3.1 Tank Management

The system will be checked at least four times a day for the first 13 days of the experiment, with feeding taking place throughout the day with amount of feed used being recorded. A special effort will be made to individually observe each tank and check for unconventional behaviour indicating distress and poor health, to ensure the well-being of the shrimp larvae.

One fifth (20%) of the water in the tank 2.4L will be exchanged every day (2) days over the length of this experiment with the last exchange being done on the 12th day of the experiment. This is the recommendation for recirculating systems. In the case of normal systems at least 50% of the water would have to be exchanged (D'Abramo *et al*., 2003; Chowdhury, 1993).

7.3.2 Mortalities

If possible, mortalities will be removed from respective tanks, without being replaced. Numbers of mortalities will be recorded, along with the date and tank of origin. Mortality will be calculated in percentage.

$$\text{Mortality} = \frac{\text{initial number} - \text{final number}}{\text{Initial number}} \times 100$$

7.3.3 Feeding

Shrimp larvae will be fed experimental feeds alone, where treatment 1 (control) will be fed a diet of only artemia nauplii. Treatment 2 will be fed with a mixture of live feed (artemia nauplii) and artificial feed. Treatment 3 will be fed with only artificial feed. All tanks will be fed the same amount of feed throughout the experiment, in treatment 2 artemia and live feed will be fed in equal portions. Larvae will be fed in satiation (ad lib.) and feed adjusted accordingly to ensure every tank gets equal amounts of feed.

It is generally recommended that artemia nauplii be fed to larvae from the second to the 10th day. The density of artemia nauplii needs to be kept at 5 brine shrimp nauplii/ml. This level is maintained by constantly adding newly hatched nauplii in the morning and evening or throughout the day (D'Abramo *et al*., 2003; Chowdhury, 1993).

Quantity of artemia added is dependent upon the volume of water in the tank. A 5-T tank (100-250 litre) needs 4.3kg of artemia cysts over a 50-day cycle (D'Abramo *et al*., 2003; Chowdhury 1993). The necessary calculations for artemia needed for our experiment will be done. Larval mortality is important to calculate the amount of feed that needs to fed daily and the utilization of artemia. Feed provided must be adjusted according to the number of (live) larvae in the tank.

Artemia numbers are counted using a 250ml beaker and numbers are estimated according to the numbers collected (D'Abramo *et al*., 2003; Chowdhury, 1993).

7.3.4 Sampling

Shrimp larvae will be sampled from each tank on two (2) occasions throughout the experiment, at the start of the experiment and at the end of the experiment. On the first day of the experiment shrimp larvae will be collected from spawning tank where they will be counted in 250ml containers. This is the best way to get a good estimate of the numbers needed (Rafiqul *et al*., 1993). The correct number of shrimp (1,000 per tank) will then be placed in each tank to start the experiment.

On the 14th day shrimp in individual tanks will be netted and placed in a white circular container (5-gallon capacity) where they will be observed for signs metamorphosis of the 8th stage of the post larval cycle which is expected after 14 days (figure 17). At this stage the pleopods with setae have developed for the first time (figure 18). The numbers (ratio) of shrimp which have moulted to this stage will be taken for each tank used in the experiment. Larvae will not be fed on sampling days to reduce stress.

Figure 17. Pleopods with setae at the 8th stage of post larval growth (Lindqvist, 2002)

Figure 18. Shrimp Larvae at 8th stage where Pleopods with setae first appear (Lindqvist, 2002)

7.4 Statistical Analysis

Data from this experiment will be subjected to one-way Analysis of Variance (ANOVA) using SPSS software version 22 and difference between means of the variables will be detected and separated using Duncan's Multiple Range Tests. The RAS for the experiment is presented graphically in figure 19, below.

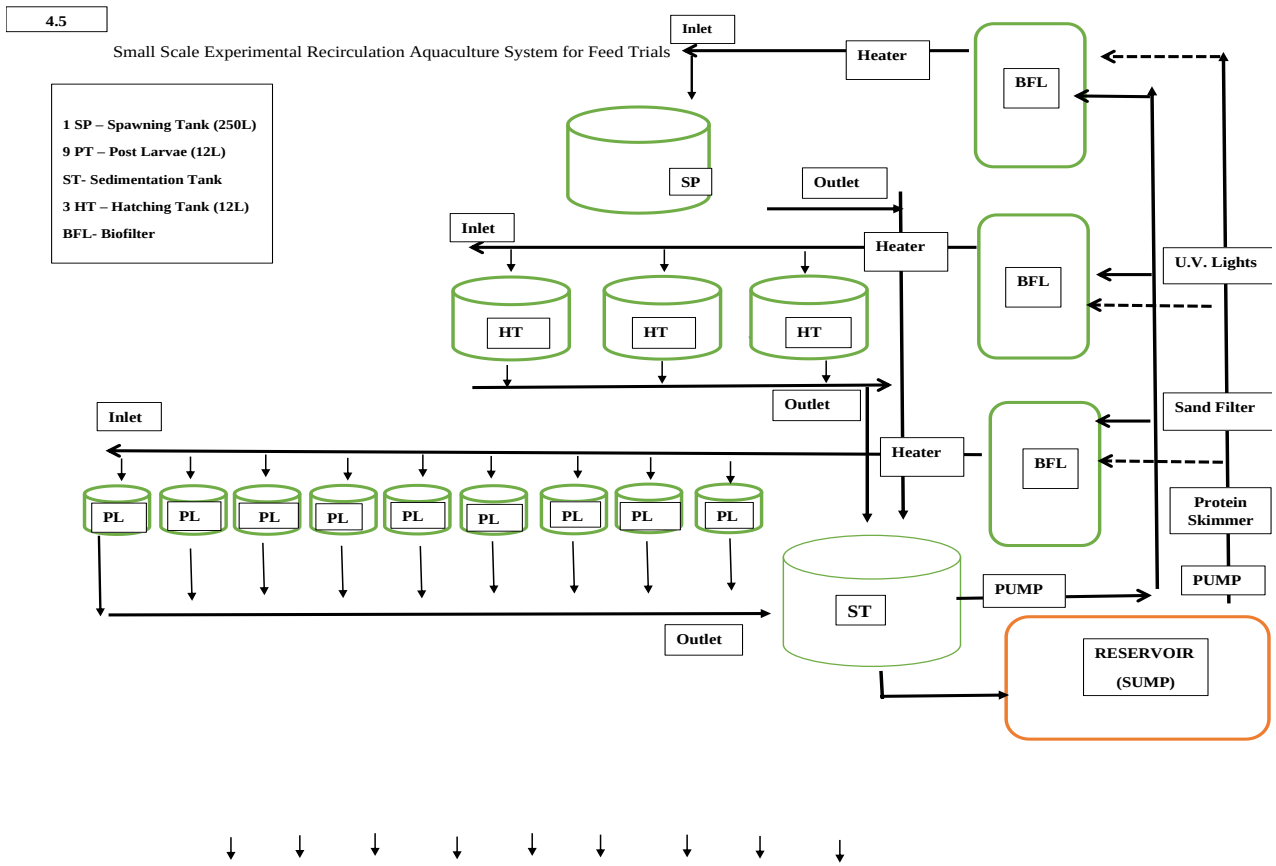

Figure 19. Small Scale Experimental Recirculation Aquaculture (RAS) System for Feed Trials.

The costs of establishing a RAS for this experiment are outlined in table 8 below.

Table 8. Prices of main components of small-scale RAS for experiments and culture

ITEM	NUMBERS NEEDED	COST (USD)
Pump	2	$83
Protein Skimmer	1	$101
U.V. Lights	1	$194
Biofilters	3	$120
Heaters	3	$86
Spawning Tank (150L)	1	$100
Hatching Tanks (12L)	3	$144
Sedimentation Tank (250L)	1	$253
Reservoir/sump(1000L)	1	$584
Post Larval Tanks (12 L)	9	$431
Air Blower	1	$283
Portable ammonia tester	1	$180
Dissolved Oxygen Meter	1	$79
Salinity Meter	1	$40
Feed (Shrimp Flake)	1 five-gallon Bucket	**$107**
Brine shrimp	1 case (12 cans)	**$564**
TOTAL		**$3,349**

7.5 Recirculating (closed) system explained

M. rosenbergii post larval culture needs to be conducted in tanks indirect of natural sources of light with similar intensity of a typical morning or early afternoon. They should also be conducted in tanks of dark coloration. The darker the tanks the higher the survival of *M. rosenbergii* larvae. Larvae are light sensitive in the early stages of their cycle (Yasharian *et al*., 2005). Hatcheries should never use only artificial lighting as a light source. Natural lighting should be complimented with artificial lighting only on occasions when lighting is interrupted or not enough (D'Abramo *et al*., 2003; Chowdhury, 1993).

Clearwater (minimal algal growth) recirculating systems are recommended for larval culture at temperatures of 28-30 °C maintained using water heaters (see figure 20). The water needs to be at a salinity of 12-15(ppt). In a recirculating system water is collected for this system from a reservoir (sump), passes through a sand filter with the assistance of a pump through a protein skimmer (D'Abramo *et al*., 2003). A protein skimmer is a simple device used to remove organic compounds such as food and other waste particles from water, by counter-current of water and air, creating foam. Water then passes through an ultraviolet light unit and biological filters before this water goes into the larval, spawning and hatching tanks. A biological filter (biofilter) is used to remove nitrogenous wastes (ammonia nitrate) which would be very toxic if it accumulates in high concentrations. Biofilters are made of high surface-area substrate which contains bacterial populations which grow and oxidize ammonia (FAO, 2004-2012; D'Abramo *et al*., 2003; Golz, 1995). Ammonia is one of the principle waste products of larval prawns and in accumulated amounts are toxic to prawn larvae. This ammonia is oxidized by those bacteria into nitrate which is non- toxic (D'Abramo *et al*., 2003).

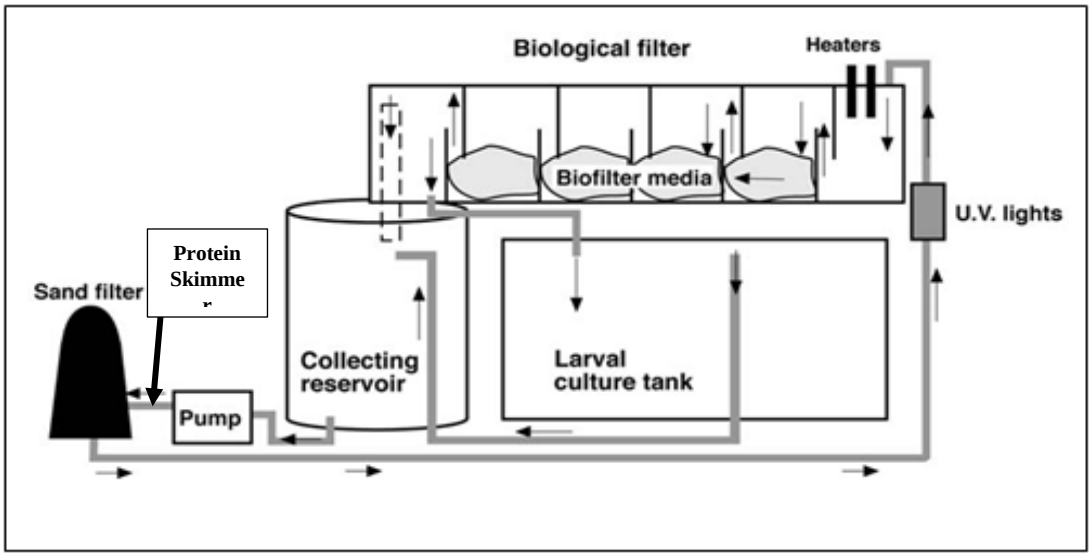

Figure 20. Main components of RAS (D'Abramo *et al* 2003)

- Water then settles into the various tanks:
- The spawning tanks where the buried females will be kept.
- The post larval tanks
- Hatching tanks (for brine shrimp)
- Sedimentation tank (after water has passed through all the tanks).

Water from all the tanks will be pumped into the sedimentation tank which would then be pumped back to the reservoir and the process repeats itself to the completion of the experiment.

Water is heated by a series of heaters or there is the option to heat the water in the reservoir to reduce heating costs. Water is also well-aerated, for stripping out CO_2 and ensure high saturation of oxygen. All tanks are fed by lines which provide oxygen at the desired levels in all the tanks used in the experiment/system.

* There are key instruments which need to be used with any recirculation system, they are: 1. Salinity meter. 2. Dissolved Oxygen meter. 3. Portable ammonia tester.

8 CONCLUSION AND RECOMMENDATIONS

Giant freshwater prawn is a profitable species and its production could be increased much more as this species grow out phase is fairly well researched and documented. Many hatcheries continue to experience problems with cutting down on their costs of production of *M. rosenbergii* post larvae, specifically when it comes to feed costs. Artemia nauplii as a live feed is the main live feed can prove very costly scarce.

With such issues associated with the use of artemia in the production of post-larvae, many hatcheries in developing countries have not been able to consistently produce. This is evident from the drop in production of farmed giant freshwater prawn form many of those countries in the Caribbean and Latin America. Saint Lucia is no exception to this trend. However, it is worth noting that *M. rosenbergii* farming is profitable. There are several key issues in the culture of post-larvae for stocking which needs to be researched and addressed in order to ensure the future sustainability and growth of this culture species in Saint Lucia.

Research conducted with regards to the suitable feed for *M. rosenbergii* post-larvae have proven that the best feed for the production process is artemia nauplii. Although it can be expensive and scarce at times, this live feed source is extremely hard to replace. Marcel and Valenti (2014) indicated that other types of feed are not as easily accepted by *M. rosenbergii* post larvae. They also indicated however that it is possible to maximize the use of artemia nauplii by incorporating the feeding with other types of inert diets and preparation methods.

Enrichment and decapsulation of artemia are methods which are not being practiced currently at Saint Lucian hatcheries and those practices needs to be looked at. Decapsulating cysts before hatching has several advantages, to include reducing the wates (hatched shells) in larval tanks reducing the risk of larvae consuming shells which could prove a danger to the survival of larvae. Decapsulation would also prevent the artemia nauplii from exerting too much energy and nutrients in when hatch reducing their nutritional value to the *M. rosenbergii* larvae. Enriching hatched artemia to improve its nutritional value is an important practice. According to Prusińska *et al*. (2015) although artemia nauplii has many advantages one key disadvantage is that it lacks high quantities of essential fatty acids and vitamins which are important in the development of fish and shrimp larvae. Enrichment maximizes the utilization of artemia.

Prepared feeds combined with artemia during the latter stages of the *M. rosenbergii* larval cycle must be improved in Saint Lucian hatcheries. At present said feeds are lacking or do not have enough of the required nutrients to encourage effective growth of larvae. Following or adjusting the formula used in many hatcheries in major giant freshwater prawn producing countries would help improving the current diet of larvae.

The importance of a recirculation system in the production of *M. rosenbergii* post larvae cannot be overlooked. Presently the recirculation systems in Saint Lucia are not functioning as they should and at times not in function. This could lead to water quality issues, a longer post-larval cycle, more labour intensive and less survival and larval quality. A fully functioning and

effectively controlled recirculation system would improve the delivery of both live and prepared feeds to shrimp larvae allowing better maximization of nutrients. Such systems also encourage sustainable larval culture because of better water quality, and decreasing labour, power, and feed cost.

There is still a lot of work which must be done when it comes to larval feeds, both live and artificial. It is crucial to explore those issues extensively, paying more attention to the nutritional requirements for *M. rosenbergii* larvae and delivery of artificial feeds. Many scientists have researched artificial feeds and live feeds in *M. rosenbergii* larval culture but not much is known of the nutrients and their functions.

Not much is known about the larval cycle of *M. rosenbergii* in the wild. Wickins (2004) showed that wild *M. rosenbergii* larvae reach post-larvae in 22-25 days compared to 33- 45 in hatchery conditions. This difference might, at least partly, be due to more differenced and nutritious diet sources in the wild. A better understanding of conditions faced by wild larvae could help hatcheries reduce their production cycle and improve the larvae production in general. If enough information is gained from this type of research, this would benefit commercial hatcheries in reducing their reliance upon both live and prepared feeds in production of *M. rosenbergii*. There is also a need for more research to be done in studying other species of macrobrachium. Native species of macrobrachium can do very well at both larval and grow out stages. A better overview of the natural life stages could help aquaculturist to adjust their culture methods to improve/ deal with feed and other issues affecting *M. rosenbergii* post larval production.

Funding from external donors have dried up and the government is no longer able to continue the subsidization of this venture in Saint Lucia. A lot of what was learnt from this paper could help in preparing proposals to source finance from external donors and NGOs. The issue of artemia costs is not only unique to Saint Lucia. Many of the top producers do experience the same issues. Saint Lucia however does not have many of the resources and has no other species to fall back into. As a result, this issue needs to be addressed to ensure the survival of the giant freshwater prawn industry. Government need to put resources into finding ways to reduce the cost and dependence associated the use of artemia in the larval stages of *M. rosenbergii* production

Whatever is decided one thing that can be agreed upon is that this issue must be addressed before it is too late.

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Summum attingitur nitendo: The Top is reached by striving

Dedication

This work is dedicated to my daughter Nikiege Louisy. My motivation and my strength. Je t'aime