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Case study: The rise and demise of the commercial shrimp farm, Amatikulu Prawns (Pty) Ltd., 1989 to 2004 (Kwazulu Natal, South Africa)

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Summary

Amatikulu Prawns (Pty) Ltd operated as a commercial shrimp farm from 1989 to 2004 when market forces made producing shrimp unviable and the farm closed. The farm established the technical requirements from the existing scientific literature, consultancy, training courses and visits to other commercial farms. The farm had two sites (10 ha and 24 ha), two hatcheries, a HACCP-certified processing plant and a feed mill.

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Background

The Amatikulu Prawn Research Unit was associated with 'prawn' culture research and development (in South Africa, the term 'prawn' is used for shrimp). During the 1970's work was funded by the Fisheries Development Corporation of South Africa (abolished, 1987), mainly on *Fenneropenaeus indicus* (Colvin, 1975; Read, 1977; Gerhardt, 1978; Emmerson, 1980a; Emmerson, 1980b; Emmerson and Andrews, 1981; Emmerson, 1983, 1984; Emmerson et al., 1983; Hecht and Britz, 1990) and *Macrobrachium rosenbergii* was imported in 1981 from an aquaculture operation in Mauritius (S. Myburgh, Amatikulu Prawns, pers. comm.). Amatikulu Prawns (Pty) Ltd was established in 1981, originally with the intent of farming with *M. rosenbergii*. This initial effort to commercialize the research on shrimp culture was not successful and the company started the commercial production of freshwater ornamental fish.

Interest in commercial shrimp farming by the owner, Stephanus Myburgh, led to the basic requirements of shrimp culture being established by the author in 1989. Algal culture and larval rearing trials were undertaken with *Penaeus monodon* and *F. indicus*. In March 1991 the construction of ponds began for a pilot 6-ha intensive farm; funded by a loan from the Industrial Development Corporation (IDC). By the summer of 1991 the first ponds were stocked with *P. monodon*. Before starting with the venture a full review of the literature was undertaken. In particular, site requirements (Chiu, 1988), engineering (Bose et al., 1991), maturation and spawning, hatchery and algal production, nursery and growout and nutrition and feed manufacture were investigated. During the history of the farm, the author traveled widely in order to increase knowledge and background – this included visits to Texas A&M, USA (Shrimp Faming Short Course), Bigelow Labs (algal culture), Taiwan (Tungkang Marine Laboratory and Commercial Feed, President Feeds, Hanaqua feeds (R Young, P Chiang)) and hatchery and growout equipment suppliers, (Team Aqua, Nan Rong, Taiaqua Co. LTD.), Thailand; hatchery (Phuket, Suwannasarn Enterprise (Dawn Suwannasarn)) and growout farms (Nakorn region, Bangkok Aquaculture Farm Co., Ltd (Michael Chen, Han Li-Yu)), Ecuador, hatcheries, with a consultant, Ken Chien, and Hawaii (Oceanic Institute, feed consultancy). A further 4 ha of growout facility was added in 1997. The switch to *F. indicus* was a commercial necessity due to a deterioration in quality and lowered availability (Envirofish, 2009) of wild *P. monodon* broodstock from our source on the offshore Tugela Bank. *F. indicus* on the other hand were plentiful, comprising 80% of the catch and spawned easily.

Amatikulu Prawns (Lat: 29° 4'36.04"S; Long: 31°38'46.32"E) took ownership of the neighbouring Mtunzini Prawns (Lat: 28°56'58.02"S; Long: 31°46'9.11"E) from the IDC in October 1997. At this time, Amatikulu Prawns comprised of 10 ha of ponds and Mtunzini with 53 ponds amounting to 24 ha. Mtunzini had been in operation since 1993 and had its own hatchery that was kept in operation, while the processing and feed production was done on the Amatikulu site. The Amatikulu site had a higher salinity profile (generally over 15 ppt) compared to Mtunzini (generally below 15 ppt).

Shrimp prices declined dramatically after 2000 and expansion was identified as the only remedy to reduce production costs. Various investment options were explored, but no further funding was secured, and the management closed the farm after the June 2004 harvest, as entering the next season would have led to bankruptcy. This case study therefore covers 15 years of commercial production.

Description

Introduction

This case study will outline some of the shrimp farming technology that was successful at Amatikulu and Mtunzini. Each unit's standard operating procedure and technology will be briefly outlined. Any particular difficulties will also be identified. An analysis will then look at what led to the closure of the farm and what could have made the farm viable and competitive in the new market environment.

Employment on the two farms

All staff employed on the farm were South Africans; the majority being Zulus from the local community. Stephanus Myburgh, the owner, was a dynamic businessman, always looking for potential projects, so the Amatikulu site also had tropical freshwater fish, aquarium plants and cow hide ‘dog chews’ and fish flake production under the same ownership, but managed separately.

Descriptions of production systems/farms

Amatikulu Prawns Pty Ltd owned and managed 2 sites, Amatikulu Prawns and Mtunzini Prawns. The Amatikulu site had four ponds of 0.5 ha, four of 1 ha and two of 2 ha. Two sets of nursery tunnels (PL12 to 1 g) were not utilized in production, as direct stocking of PL12 gave higher overall survival and growth rates. The soil was very sandy, with a high rate of seepage. Water was pumped 24 h a day from the Amatikulu river estuary, which was generally a high salinity estuary, but with large salinity changes from 5 ppt to 35 ppt with tidal exchange and during heavy rains; yet well within the salinity range tolerated by P. monodon (Cheng and Liao, 1986) and F. indicus. Water was delivered using two electrical 3 phase centrifugal KSB pumps (Model ETA250/40, 90kW motor, 1480 rpm) each delivering about 220 L/sec. The 2-ha ponds were as easy to manage as a 0.5 hectare pond.

The Mtunzini site had 53 ponds, of which 51 were usually in production. Each pond was approximately 0.5 ha. Soil was silty clay that led to turbidity in some ponds making secchi disk estimates difficult (Jamu et al., 1999). Water was pumped using two electrical (90kW, 1460 rpm), three phase, two stage axial flow Monax pumps (Howden Pumps, (now Denorco Pty Ltd) delivering up to 330 L/sec. Water from the Umlalazi river estuary and was usually below 15 ppt. We set 4 ppt as our minimum acceptable salinity for F. indicus.

Hatchery

There were operational hatcheries on both sites. A survival of 33% from nauplius to stocking at PL12 was considered acceptable. Larval rearing tanks for rearing from nauplius to PL4 were 7 and 10 metric tonnes. Postlarval rearing to PL12 were 30 and 40 metric tonnes.

Table showing Amatikulu hatchery performance for 2000

2000 STOCKING, AMATIKULU - hatchery performance						
TOTALS						
	13,210,690	52,510,060	21,511,071	28,68,051		
POND	STOCKED	NAUPLII	PL4	PL12	%PL4:N	% Stocked:N
G1	733,276	2,539,716	1,231,576	733,276	48	29
G2	727,771	2,218,200	1,553,497	727,771	70	33
G3	893,703	2,970,000	1,994,418	673,471	67	30
G4	738,301	1,351,326	1,099,350	322,359	81	55
G5	2,383,773	12,934,905	7,877,788	411,174	61	18
I1	2,727,017	5,692,460	2,727,017	0	48	48

I2	685,871	1,027,000	685,871	0	67	67
I3	706,446	1,377,000	727,021	0	53	51
I4	967,077	3,318,666	967,077	0	29	29
I5	2,647,457	10,369,406	2,647,457	0	26	26
LOST		0				
SPAWNERS		2536		Nauplii/Spawn.	29302	
SPAWNS		1792		PL4/Spawn.	12004	
NAUPLII		52,510,060		Broodstock Selection success %		71 %
SURVIVAL: N-PL4		41 %				
SURVIVAL: N-stock, PL12		25 %				

Maturation and spawning

The principles described by Simon (1982) were largely applied for our prawn maturation facility. Biosecurity measures were applied where possible (FAO, 2003). Broodstock were initially collected from commercial trawlers operating on the Tugela bank. We would go out by ski-boat and collect gravid shrimp and males that came in with the trawl net after each 4-h trawl. Minimum handling and stress ensured maximum survival, which was generally over 75%. On good days we could collect 60 *P. monodon* and about 200 *F. indicus* females. Broodstock responded best if brought straight into warm (28°C), clean, aerated, biologically filtered full sea water (36 ppt). Attempts made to trawl from a ski-boat were not successful. We also used ‘over-wintered’ pond-reared broodstock. *F. indicus* become gravid quite easily in outdoor ponds with temperatures above 23°C and salinities above 20 ppt. This was achieved on the grower pellet produced on site, so long as the pond had a strong diatom bloom. Using cast nets we selected gravid females and recently mated females (soft with large visible, white spermatophore plugs in the thelycum). We would replace 25% of our females weekly and ensure the maturation male to female ratio was 1:2. We emerged from a cold winter into our hatchery season, so our broodstock were overwintered (18°C) and came into condition in September. All ponds had to be stocked by mid-December, allowing at least 4 to 6 months of growout before the onset of winter in May.

Broodstock in the ponds can become gravid from around 20 g and are definitely mature by 35 g. Mating takes place after molting in the ponds. At least 10% of females would be gravid and close to spawning, making an outdoor pond a very reliable source of broodstock. Densities of 15-20/m^2 did not seem to detrimentally affect the process of mating and egg development.

Wild broodstock produced at least 100,000 robust nauplii per female. Pond-reared females, started the season at around 20,000 nauplii per female and slowly increased to 50,000 per female.

The maturation system consisted of a closed recirculation system with a separate biological filter. This was superior to flow-through systems in terms of spawning, egg production, nauplii production and hatching rates (Millamena, 1991). Our four 6-m^3 black tanks were smaller than any described in the literature, however spawning was reliable and predictable. The tanks were 4.35 m long, with rounded ends (0.7 m radius) and 1.5 m wide. This design allowed us to check every female visually with a submersible torch from one side of the tank and not lose any potential spawns. Stress and disturbance of the shrimp was minimal. Maturation ponds were maintained at a depth of 1 m, illuminated by low intensity green light and salinity was above 30 ppt. The light was supplied by eight 240-cm (8-ft) fluorescent tubes under a white plastic cover painted green. Aeration was through one air ring (50 cm diameter) and an aspiration system on the water into the tank (Moore and Boyd, 1984). This maintained high oxygen levels and promoted nitrification in the biological filter.

Up to 15 large females and nine males Penaeus monodon were held in each tank (4/m²), which is within the range recommended by Primavera (1988). Spawning ceased in winter when temperatures dropped to 21-22°C. We switched to Fenneropenaeus indicus after two years of production, increasing their density due to their smaller size, holding 60 females and 30 males in each tank. In 1993 we experimented with P. japonicus broodstock brought by the owner in damp sawdust from Spain. These were a bit small and we only ran one larval rearing cycle. In 1995 we collected some P. japonicus from a site off St Lucia. We spawned these and stocked one pond. These yielded about 500 kg of 5-g shrimp. They developed a disease that forced us to harvest them. Microscopically, they had various epicommensal parasites on the gills, such as filamentous bacteria, Stentor-like creatures, ciliates. etc. Their gills looked brown and shrimp started to weaken and die. The initial problem was probably dietary, as their growth had slowed dramatically on the home-made diet.

Table showing maturation parameters

Parameter	**Optimal range or condition**
Salinity- 'oceanic'	28-36 ppt (Treece, 2001)
Temperature, *P. monodon*	27 to 30°C +/- 2º C
Temperature, *F. indicus*	25 to 29°C
pH	(7.8 lowest) 8.0 to 8.3
Light (photoperiod)	Dim, green/blue, 14L, 10D (Treece, 2001; Gandy, 2007)
Nutrition	Fresh marine feeds, pellets (Madmac from http://www.aquafauna.com/)
Nitrogen ammonia (TAN, mg/l); nitrite	Below 0.3 ppm[a] NH_4^+; 0.1 ppm NO_2^- (Chen and Chin, 1988; Huguenin and Colt, 1989)
Water exchange, no biofilter	Flow through: 250 to 300% per day
Recirculated water exchange	5 to 10% per day; 60% recirculated/hr (to reduce ammonia in tanks)
Organic material	Filtration must remove organic solids
Tank colour	Generally only black is used.
Human activity and machine noise	All disturbances should be minimized.
Tank shape	Round or oval, 20+ m^2.
Sex ratio (Males : Females)	1:2 or 1:1
Stocking density	As low as practically possible 5 to 16/m². (Depends on prawn weight)
Water depth	35 cm to 1 m; no obstructions to upset mating and

	spawning.
Eyestalk ablation for hormone cycles	*P. monodon* - yes; *F. merguiensis, F. indicus* - not essential.
Broodstock weight	*F. indicus* (15 g minimum), above 35 g is good for females, 25 g for males. *P. monodon* (50g minimum), ideally above 100 g for females and above 60 g for males.

Note a: Various sources report maturation ammonia levels as actual (<0.5 ppm (Paibulkichakul et al., 2008); 0.36 (Peixoto et al., 2003) or ideal levels (0.02 mg/L (Treece and Fox,); 0.01 mg/L (Huguenin and Colt, 1989). Practically, 0.1 mg/L should be attainable.

The shrimp were fed at least four times daily, at 06h00, 12h00, 17h00 and if necessary at 21h00. We had to watch for overfeeding, especially if uneaten pellets began to affect water quality and overload the biological filter. Uneaten feed was vacuumed off the bottom in the morning and afternoon. A basket to catch uneaten food which washed into the filter was cleaned daily and a net filter to catch the bulk of the faeces was cleaned whenever necessary. The filter medium was crushed oyster shells and old fish nets.

Mixed diets of formulated pellets and fresh feeds appear to work best. Broodstock should get a mix of feeds that includes some form of commercial maturation pellet and fresh (frozen) feeds such as:

• Squid, octopus – 5 to 10% of biomass per day
• Oysters, clams, mussels – 3 to 6% per day
• Sardine – 3 to 6% per day
• Enriched adult *Artemia*, *Artemia* biomass or krill – 3 to 6% per day
• Dry formulated maturation feeds – 1 to 2% per day.
• Local feeds such as sand shrimp (Calianassa krausi)

Our schedule entailed feeding 10% of biomass as fresh (wet) feeds and 2% of biomass as a pellet per day. If this was eaten, we would increase the feed, or add another feed. Arce et al. (2000) fed 24 to 28% of biomass per day (0830, 1100, 1330, and 1600). Babu et al. (2001) fed 15-20% of bodyweight. Briggs (2003) feeds as much as 35 to 40% of body weight per day, feeding 6 to 8 times per day. Briggs emphasizes satiation feeding to prevent the quality of the nauplii and larvae declining. Broodstock need to maintain their nutritional status. Some agents of dry feeds are promoting higher percentages of formulated feeds (5%), which lowers the fresh feed requirement (1% dry = 5% wet). Treece and Fox (1993) would calculate the tank biomass (average weight x total number) and start feeding at 3.75% per day on a ‘dry weight basis (DWB)’. When feeding wet feeds like squid, they would multiply this DWB proportion by 5, terming this the ‘wet weight factor (WWF)’. By observation, one can quickly see if the prawns are eating all the food fed, so the method of calculating the amount to feed only gives an initial estimate.

Formulated pelleted diets (‘Madmac’) provide specific vitamins, minerals, antioxidants, carotenoids, cholesterol, phospholipids and fatty acids to the diet (Millamena, 1989).

Unilateral eyestalk ablation was performed on Penaeus monodon once the shrimp had sufficiently recovered after collection from the trawlers; usually within a week. This was achieved by slicing the eyestalk with a razor and squeezing the contents out. With *F. indicus* eyestalk ablation was not necessary.

The water quality used for spawning was important (One micron filtered, UV irradiated seawater, 30–36 ppt, 28°C, light aeration, 1 to 4.5 P. monodon (Pironet et al, 1999) and 3 to 6 F. indicus females per m^2.

Many hatcheries still spawn in smaller individual tanks (better biosecurity), but many commercial hatcheries now spawn in tanks that hold many spawners. Mass spawning tanks are about 40 cm deep and 1 m x 3 m. This gives an area of 3 m2 per tank and a volume of 1.2 m^3. *F. indicus* broodstock are held here at between 3 and 6 per m^2 (one female per 200 to 400 L). Densities of over 6 per m^2 tend to foul the water. Typically, good spawns will deliver 60,000 nauplii per female or between 600,000 and 1.2 million nauplii per tank. Larger tanks can be used (8 m3). With *Penaeus monodon*, between one (500 g) and five (100 g) broodstock would be the recommended maximum. Breeders were selected according to their gonad stage (Solis, 1988) and on the presence of two distinct lobes lateral to the central gonad in the first abdominal segment. Spawning usually occurred soon after sunset and never in the day. Spawners were returned to the same maturation tanks the next day.

Eggs were siphoned out through a mesh (#60 = 260 µm) to remove faeces, rinsed in a malachite green solution and moved to clean water of the same quality. The net to catch the eggs is less than 150 µm (Note: A#155 nitex screen is used). Egg diameter reported for various species is fairly consistent (e.g., 260 to 280 µm, P. japonicus, 270 to 310 µm, P. monodon). These eggs were then stirred every hour until they hatched later in the day. Hatching rates were, however, highly variable (Menasveta et al., 1989).

The following day, nauplii were counted, harvested through a fine mesh, rinsed in malachite green and transferred to the larval rearing tanks with water of the same quality. Here they would remain with very light aeration until they changed to zoea 1 the following day. 10 ppm EDTA was applied to spawning and larval rearing water (Utting and Helm, 1985).

In later years, nauplii were allowed to hatch in the spawning tanks and remained there until transfer to the larval rearing tanks the following day. Nauplii were carefully netted out and then rinsed for 1 to 2 min in a 100 ppm (1 ml into 10 L) Argentyne iodine solution (Argent Laboratories). This iodine disinfectant has 10% of a polymeric-iodine complex as the active ingredient (provides 1% minimum titratable iodine = 1% free iodine). A second rinse in formalin (100 ppm for 30 seconds) was sometimes also applied.

Larval rearing and feeding

We managed two hatcheries. The Amatikulu hatchery was built into the facilities of the defunct Fisheries Development Corporation. The Mtunzini hatchery was based on an Asian *P. monodon* and *Skeletonema costatum* hatchery design. We used its ten *S. costatum* tanks (10 m^3) for larval rearing and its 40 m^3 tanks to rear postlarvae from PL4 to PL12. The flow in both hatcheries was maturation to spawning to larval reading, nauplius to PL4 to PL4 to PL12 to stocking to growout ponds (0.5 to 2 ha).

The hatchery layout allowed isolation of different units and one set of larval rearing tanks to be shut down and sterilized while the other still operated fully. Ideally, the *Artemia* production should be in its own isolated area. Water from storage tanks could flow down for use at the hatchery.
Developmental stages are easily distinguished and were monitored from zoea 1 onwards (Pan and Yu, 1990; FAO, 1968). Other factors in addition to environment of the larvae and the nutritional quality of the algae appeared to affect the success and failure of larval rearing cycles. Kuban et al. (1985) suggests that a variety of factors may be influence larval survival, including inherent larval variability resulting from differences during vitellogenesis. We did not succeed in identifying causes of strong and weak nauplii, but wild broodstock produced the most viable nauplii and postlarvae. Expected survival from nauplius to 10-12 days postlarvae was at least 35%.

Larval feeding was typically as in the table below, representing one million larvae stocked at 100 per L in a larval rearing tank (LRT) and similar to that described in the FAO (2007) Penaeus monodon manual.

Table showing larval feeding of formulated feeds, *Artemia* and two species of live algae

Stage (mesh) micron	Grams formulated feed (dry)	Artemia nauplii (grams per million	Algae concentration (Chaetoceros), [Tetraselmis]

		animals)	**x 1000**
Z1: (250) 20 – 60	24		(50 –100)
Z2: (250) 20 – 100	36		(100), [5]
Z3: (200) 60 – 100	36		(100), [10]
M1: (200) 60 – 100	60		(100), [10]
M2: (200) 60 – 100	78	40	(100), [10]
M3: (150) 100 – 200	90	80	(100), [15]
PL1: (150) 100 – 200	96	100	(80), [15]
PL2: (150) 100 – 200	108	200	(80), [10]
PL3: (100) 100 – 200	132	300	(80)
PL4: (100) 200 – 300	150	300	(80)
PL5: (100) 200 – 300	162	300	(80)
PL6: (100) 200 – 300	174	400	(80)
PL7: (56) 200 – 300	180	500	(80)
PL8: (56) 200 – 300	204	400	(80)
PL9: (56) 200 – 300	228	300	(80)
PL10: (56) 200 – 300	252	200	(80)
PL11: (56) 200 – 300	294	200	(80)
PL12: (30) 300 – 500	300	200	(80)
PL13: (30) 300 – 500	stock		(80)

Tetraselmis suecica as used in commercial hatcheries in Ecuador also proved highly successful in our hatchery. Algal densities in the larval rearing were checked with the aid of a Neubauer Haemacytometer. Densities of *T. suecica* used were above 10,000 cells per mL for late zoea 1 and zoea 2, 20,000 cells per mL for the mysis stages and a final maximum of 40,000 cells per mL for PL1 (Loya-Javellana, 1989). By P12 the guts of the post larvae were no longer green. *T. suecica* was produced in outdoor tanks. We also used Cyclopeeze as an Artemia replacement.

Chaetoceros gracilis, *C. muelleri*, *C. simplex* and *C. calcitrans* (CSIRO, 2009) are diatoms smaller than *T. suecica* that we used in larval rearing. We used 45,000 cells/ml as our absolute minimum diatom algal cell concentration during larval rearing although we generally maintained the concentrations for *Chaetoceros muelleri* at 100,000 cells/ml. *Artemia nauplii* were fed from the PL2 onwards. *C. simplex* was tested due to its higher temperature tolerance and was found suitable. The *Artemia* brands we used came from Great Salt Lake (GSL) in the USA and Bohai Sea in China. GSL *Artemia* has an average 20:5w3 fatty acid level of 1.12% (Webster and Lovell, 1990). *Artemia* cysts were hatched in full sea water at 28°C and 90% hatched within 18 h. We used a case (12 x 1 lb cans) per million postlarvae.

Water quality

Disease problems were avoided by maintaining good water quality through filtration and UV sterilization, by the provision of adequate high quality live and artificial feeds and good biosecurity management. Our hatchery water source was initially the Amatikulu estuary, but later, we pumped full seawater from a 5-m deep beach wellpoint.

Estuarine water treatment

Water was pumped with a centrifugal pump or 1.5 kW Speck swimming pool pumps on spring tides when salinities were over 28 ppt. With estuarine water, crab, barnacle and oyster larvae, fish such as gobies, sea slugs and cucumbers, all came in through the inlet to the first of three 130 m3 settling tanks. Water siphons to the second and then the third tank, removing much of the silt. This water was then siphoned down to two serial sand filters with 5 grades of sand. Water passed through the sand filters by gravity at a rate of 2 m3 per h and then collected in a 30-m3 pond. At this stage the water had been filtered to less than 10 µm by the sand filters. It was then pumped through the sand filters again and then through a diatomaceous earth filter (DE) to another storage tank for storage, heating and polishing. Before using the water it was again passed through the DE filter, filtered to 1 µm and UV sterilized. Routine larval rearing tank disinfection with 12% hypochlorite at 200 ppm for 24 h was sometimes applied between larval rearing cycles.

Beach wellpoint water treatment

Water from a beach wellpoint, using a Grundfos submersible pump, was of exceptional quality, filtered, full seawater (30 to 36 ppt). If incorrectly placed the wellpoint salinity would be too low or become fresh during rains, so placement as close to the low tide level and the wellpoint depth were important for a stable wellpoint. Two wellpoint types were used. In one, a submersible pump was dropped down a vertical 150 mm diameter PVC pipe sunk its full 6-m length down into the sand. The last metre of the pipe was slotted (approx 1 mm or screened with a stainless steel mesh of 0.2 to 0.5 mm (U.S. Mesh 35). Delivery to the hatchery was via a 50 mm HDPE pipe. In a larger wellpoint configuration, a number of wellpoints are sunk and connected to a manifold linked to a self priming pump higher up the beach.

Water from the wellpoint did not require further filtration and simply passed through small 20 µm and 1 µm prefilters linked to a UV sterilizer before going into the hatchery system.

Parameters measured

The only larval water quality parameters we monitored regularly were temperature (27-30°C), pH (7.8-8.5) and salinity (27-36 ppt) and emphasis was on prevention rather than cure, with regular water exchanges to avoid problems. EDTA was maintained at a concentration of 10 ppm throughout the larval rearing cycle as this was found to improve survival (Licop, 1988). It was noted that a high percentage prawn larvae sometimes died after feeding algae, and this was soon linked to the high pH of the algae cultures (=>9). The pH of the algae was then routinely brought down to 8.4 with CO_2 or NaH_2CO_3 before feeding. In the maturation facility, ammonia, nitrite and nitrate levels were also monitored.

Algae production

Algal production requires producing enough algae of a suitable nutritional value. We kept pure cultures of the species which we thought would be useful. In Ecuador many hatcheries used a combination of *Chaetoceros gracilis* and *Tetraselmis suecica* and we used these two species as well. Later we used *C. muelleri*. Over the years we also isolated local species and experimented with *Chaetoceros simplex*, *C. calcitrans*, *Skeletonema costatum*, *Thalassiosira pseudonana*, *T. weissflogii* and *Isochrysis* sp. (T.ISO).

The techniques for intensive algal culture are covered by Fox (1983). We used the F/2 nutrient medium of Guillard (1975) for all our algal cultures, which is now modified as the L-1 medium (Guillard, personal communication 1991). When using the L-1 medium, we only adjusted the elements listed in the F/2 medium and did not add the additional elements listed.

We found the pH of mass cultures of algae, especially Tetraselmis suecica, rising to unacceptable levels, near 10, and introduced CO_2 gas at 40-1001/h. into the air system. This served to keep the pH at 8.2 and increased the algal growth rate. Sodium bicarbonate was also used to lower algae pH levels.

Hatchery diseases

No serious diseases were encountered in the hatchery phase. Epicommensal or ectocommensal protozoa (Treece and Fox, 1993) were the most serious consistent problem. High densities of ciliates would also sometimes occur. Sterilization of tanks and equipment between cycles and staff disinfecting their hands with chlorine or iodine (FAO, 2007) was the best way to prevent various forms of contamination or disease incidence. A hand wash and foot bath was placed at each unit (maturation, algae production, larval rearing, microscope room) and staff used these on entering and exiting these units. The hatchery was managed with Standard Operating Procedures (SOPs) (FAO, 2003) similar to HACCP (Jahncke et al., 2002) for each job function. An activity was defined as follows:

Critical Control Point (CCP)	**Significant Hazard(s) (important dangers)**	**Critical Limits for each Preventive Measure**	**Monitoring (check) What**	**Monitoring (check) How**	**Monitoring (check) Frequency**	**Monitoring (check) Who**	**Corrective Action(s) (what to do to correct)**	**Records**	**Verification Company Manager's check**
Activity, e.g. nauplii washing is a critical activity that can seriously impact the success of the whole hatchery if it is not done with great care and attention.	Possible human and animal related problems caused by activity. E.g. rough handling, temperature variations, wrong concentration of iodine, both high and low, salinity of different waters etc.	The parameters, such as time, concentration of chemical etc. required to be safe. E.g. temperature range allowed, iodine dosage per 10 L, handling method taught etc.	Precisely what to check during this activity. E.g. iodine concentration added as mL per 10 L, wash time for nauplii in seconds, water temperatures of nauplii tanks, rinse bucket and rinse water etc.	How to do action, including tools to use, e.g. thermometer, looking, measuring etc.	How frequently should particular monitoring action take place? Often, during activity, before activity, constant monitoring or at a specific time period.	Who, by name, is responsible for the correct implementation? This then also becomes a training tool and job description built into a database for easy access. If this process fails, there is a person to identify and retrain on the procedure to correct error.	If a parameter is exceeded, how is this corrected? This outlines how to fix an identified problem. E.g. rough handling of nauplii out of water requires retraining.	List of records to be used and kept during this activity. Record keeping is essential for future reference and statistics.	How can this control of the CCP be verified for correct implementation and procedure? Often, this is simply by inspection of staff at work.

Such detailed procedures take time to develop, but once established, greatly enhance and speed up the training of new staff. Additionally, experienced staff can review and advise improvements to the controls, so that there is a continual process of improvement.

Nursery and growout nursery

In the first years, we implemented a nursery phase to one gram between the hatchery and the growout ponds. We soon abandoned this as both survival and initial growth rates were better with direct stocking to growout ponds, but the choice is debatable (Stern and Letellier, 1992). In our nursery tunnels, we generally stocked postlarvae at between PL6 (6-day-old postlarvae) and PL10. In this protected environment survival was acceptable. Salinities were generally high, usually above 25 ppt. During the period in the nursery, postlarvae go through further morphological changes up to about PL20 or 30 and expected survival is around 47.7% (Bages and Sloane, 1981). We stocked our postlarvae at 600/m². We later found that with direct stocking of PL12 we could expect an overall survival of 50 to 65%.

At stocking, salinity, pH and temperature acclimation were important, requiring a change of 1 ppt per 20 to 30 min and pure oxygen cylinders to boost oxygen levels to saturation during the acclimation process.

We also shipped postlarvae (PL10 to PL20) to growout farms in Seychelles and Maputo in 1993. Various methods were used by these customers to determine the quality of our postlarvae, such as 4-7 rostral teeth, muscle to gut ratio of greater than 4:1, and stress tests. For shipments we packed our PL10 - PL20's at a density of 800 to 1250 per L.

Over the 1994 to 1995 season, we also attempted growout through winter, stocking our ponds from pond-reared broodstock in April. This trial showed overwintering is not worthwhile as it appeared to slow the prawn's summer growth rate. We tried this again at Mtunzini over the 1998 to 1999 season. FCR's attained were high and difficult to manage. These shrimp entered winter at over 10 g.

Other ponds stocked just before winter showed that growth rates could recover after winter, but FCR's were very difficult to manage over the long growout period.

Growout

Our pond design was similar to that of Jung and Co (1988). We had an open concrete inlet water canal, called a flume linked by 400 m of pipe to the pump station, with pond filling achieved by an open flume outlet, controlled by wooden slabs at the feeder canal sill (Estilo, 1988). Our wooden slabs were vertical, but horizontal planks could also be used.

No pollution affecting the prawns was noted during the growout period and tests for cholera were always negative. During the history of the farm, *Microsporidia* sp. (Toubiana, 2004) infection was a common problem, affecting a percentage of some ponds each season.

Between crops the ponds were dried, accumulated sludge was removed by first piling it into rows manually and then is using an excavator or dozer. The ponds were then ploughed or tilled to about 15 centimetres. 500 to 1,000 kg of lime would be applied before tilling. Ponds would be fertilized with a combination of organic (usually chicken manure purchased from local chicken farms) and inorganic fertilizers (urea and super phosphate).

The nutrient ratio for diatoms is C:Si:N:P = 106:15:16:1 (Brzezinski , 1985). A ratio of N: P of around 20:1 is reportedly for good diatom blooms (The Redfield ratio) (Fox, 2008; FAO, 1987d; Boyd and Tucker, 1998).

Urea is 45% nitrogen and super phosphate is 46% P, so for every 10 kg of urea, we added 500 g of phosphate. Infertile waters need 20 kg N/ha and 1 kg P/ha two or more times per week. Where waters are more fertile, the amounts may be reduced by 50% or more, but the 20:1 ratio of N: P should be maintained in brackish water. Fertilization should be suspended when plankton blooms become dense (<35 cm) during periods of heavy feed applications. Typically, in our 1-ha ponds, we would start with 10 kg urea and 0.5 kg phosphate, and 500 kg of chicken manure at pond filling. This would be followed by 3 kg urea and 150 g phosphates daily. The algal bloom and zooplankton would be allowed to develop for two weeks before stocking postlarvae. An ideal secchi disk reading for stocking was set at 30 to 35 cm.

Feed and feeding

Once the correct growout conditions are established, feed quality (FAO, 1987b) and feed management (ASEAN, 1998) become the most important factors leading to success and profits. Overfeeding lowers feed conversion ratios (FCR's) and reduces water and sediment quality. Deterioration of the pond environment leads to increased shrimp stress, slowed growth rates and increased inputs such as aeration and water exchanges. This process begins with purchasing or manufacturing feed of the correct quality. Shrimp were fed four times daily (06:00, 12:00, 18:00, and 24:00). Feed was applied by hand from paddle boats.

Shrimp were weighed weekly and a guideline feed schedule produce for the following week. Feed trays needed to be empty on this feed schedule, while the target standard growth curve needed to be attained. Plots of feed and growth assisted in setting the next week's feeding programme. Until 2004 the standard feed curve was

Shrimp weight = -4.8393312+0.14932493 x day of culture (from 0.6 g and heavier)
Feed as percentage of biomass = 100 × (10^(-1.05 - 0.446 × LOG(shrimp weight in grams)) × 0.8 (modified from Green et al., 1997a, 1997b)

Later consultancy in Iran and data from Emadi et al. (2006) and Gholizadeh and Liasi (2006) allowed a modification for these curves. Growth should be based on shrimp weight rather than day of culture, so

Shrimp weight (g) = 40 × (1 - EXP(-0.013 × (DOC + 9)))^3.5

We started producing moist pellets (Image 13) and eventually installed our own custom made pelletizer (Agrifeed Systems, South Africa) with a 3-stage conditioner.

Moist pellets were dried in a heated wind tunnel before feeding, while with the pelletizer we had a pellet drier. Our formula hardly changed throughout the years of production. In 1999 we received some consultancy on our growout and maturation feed formulation and feed manufacture process from Warren Dominy of the Oceanic Institute. We produced each week's requirement on demand, so did not store large food reserves. We also imported feeds from suppliers such as President Feeds (Taiwan)) (1992/3 season). Green Label Feeds (Taiwan) (2003) and CP Feeds (Thailand)(1992/3 season). Our first crop of 10 tonnes of *P. monodon* in the 1991/2 season was reared on a homemade feed, using a Taiwanese moist pellet mill. When shipments of imported feed were delayed in 1992 for both us and our neighbours at Mtunzini, we had to resort to producing our moist pellet feed for both sites and did not import feed again until a trial in 2003 to test feed conversion ratios (FCR's). Green Label Feed was used in South Africa for the whole growout season in 2003 to 2004. This was a strategic decision, with the expectation of investors coming into the company, and the possibility of the feed supplier assisting in a larger feed mill in South Africa. Also, with the South African Rand being strong relative to the US $ in 2003 and 2004, it became cheaper to import feed at US $900 per metric tonne than to produce our own feed on site.

FCR's were on average about 0.3 to 0.4 better with imported feeds. Day 138 was 30 April; the beginning of winter temperatures.

Yield: 10.6T (2-ha pond) FCR: 2.0

Partial harvests started on day 155, causing zero growth as the larger shrimp are selectively cropped off by the nets.

Net Survival: 62% (after deducting stocking mortality)

By 2003, we had implemented the idea of a visual 'standard feed curve', based on feed as a percentage of biomass, and used to optimize FCR. For a good FCR, feeding needed to be below this.

Feeding trays (5 per Ha) were used in the ponds to monitor feed consumption, with the emphasis being that it was better to under feed than overfeed, improving water quality and the food conversion ratio. Feeding was managed by weekly graphical plots of growth against a standard growth curve and feed against a standard feed curve. This allowed a review of the pond supervisors feed management. A feed program was generated each week as a feed guide that was largely followed. If the feed program did not lead to empty feed trays, feed would be adjusted for the following week.

A sample of 50 shrimp was randomly selected, either from 'pull nets' or cast nets. The whole 50 would be weighed quickly in a bucket zeroed with a wad of tissue paper. The bucket and now wet paper would be reweighed after returning the shrimp to the pond and deducted off the first weight. If the average shrimp weight was obviously too high or low, the sample would be redone.

Pond management

The maintenance of good water quality through water exchange, aeration, correct stocking densities, correct feeding, and control of algal densities are important.

We used paddlewheels (Team Aqua) during growout. 2 HP paddlewheels deliver about 3.79 kgO2 per hour (Vinatea and Carvalho, 2007). We used 4 to 5 two horsepower (1.5 kW) paddlewheels per hectare pond or roughly one 2 HP paddlewheel per tonne of prawns. This was eventually translated into one HP of paddlewheel aeration per 10 kg of feed (7,000 kg final yield with 2% feed per day = 140 kg per day = 14 HP aeration = 7 paddlewheels). Up to 50 kg per ha of feed can be fed without aeration. Aeration using paddlewheels should be started before the oxygen level drops below 4 ppm as this is the minimum optimum dissolved oxygen (DO) level (Madenjian, 1990) and over midday to break up pond temperature stratification and to prevent supersaturation. The lethal DO for shrimp is close to 1 ppm (Allan and Maguire, 1991).

Water changes were made when the secchi disk depths drop below 30 cm. Healthy levels of phytoplankton, preferably diatoms, are promoted as these produce 10 times more oxygen than they consume, and remove micronutrients such as ammonia. Safe total ammonia and nitrite levels for larval P. monodon are reported at 1.15 mg/L (Chin and Chen, 1987) and 1.36 mg/L (Chen and Chin, 1988) respectively, while in intensive ponds at the end of growout, typical levels are 0.645–0.86 mg/L and 0.083 – 0.97 mg/L ,respectively (Tookwinas and Songsangjinda, 1999; Arnold et al., 2006). Nitrite toxicity increases with lowered salinity. Lin and Chen (2003) estimated the ‘safe level’ for nitrite when rearing L. vannamei juveniles at different salinities to be 6.1, 15.2 and 25.7 mg/L in 15, 25 and 35 g/L, respectively. Total ammonia concentrations of 5.88 mg NH4 per L have lead to mortalities in shrimp ponds (Gonzalez Feliz et al., 2007). Average water exchange was around 15% per day.

Cloudy weather leading to greatly reduced photosynthesis and lowered oxygen production is a typical water management problem. On some nights, critical oxygen levels could be approached. The best remedy was to rapidly drain 20% of the pond water, bringing the water level to the compensation depth (Boney, 1976) of the phytoplankton as algae below this depth are net consumers of oxygen (Piedrahita, 1991). The water column is one of the biggest consumers of oxygen.

Additionally the availability of nutrients to algae should be enhanced. Oxygen levels are in this way maintained. With a secchi depth of 26 cm, the compensation depth is about 52 cm. Algae deeper than this are in darkness.

Harvesting and processing

The most important aspect of shrimp harvesting is HACCP standard (e.g. National Seafood HACCP Alliance, 2001) quality assurance of this highly perishable product (Gorga and Ronsivalli, 1988). This requires very controlled post harvest handling and cold chain, maintaining product temperatures as close to 0°C as possible. Harvests were done through drain and partial harvesting. The shrimp would be starved with at least 3 feeds being skipped before the harvest. The processing plant could only handle 2 metric tonnes per day, so a 1-ha pond would be harvested 3 to 4 times to complete.

Partial harvesting

Partial harvest nets were used from up to 2 months before the final harvest to crop off the larger shrimp in the pond. Up to 4 nets were placed in a selected pond.

Shrimp were not fed for 3 to 4 feeds before partial harvests and would migrate in shoals looking for food. Up to 500 kg could be caught in a net, especially over sunset, so nets were checked every hour after placement in a pond.

Drain harvesting

The pond with the lowest percentage of soft moulted prawns (<4%) would be selected and drained to a depth of 60 cm without removing the screens. The harvest drain would also be cleaned of sludge. The screen was then removed and the water drained through a harvest bag net on the monk or gate (Cruz, 1983). The harvest net was a long sock, about 4 m long, tied closed at the end. Batches of shrimp were released from the cod end into deep hand-nets so that staff could handle 50 to 100 kg at a time. Harvesting would commence after sunset and each team on each site had to harvest one metric tonne before going home. When still alive the manually harvested shrimp were emptied, killed and rinsed in an iced-chilled seawater bin (<4°C). Shrimp were then weighed into 15-kg units in plastic crates. These crates were placed in an iced, chilled bath with metabisulfite for 5 min, removed to a drainage platform, covered with a layer of crushed or flaked ice and loaded into a refrigerated truck for transport to the processing plant. The processing plant was on the Amatikulu site, so for the Mtunzini product this was a trip of about 15 km. Product was loaded into a 6-m reefer container set to -4°C that served as a chiller and processing started at 7.00 am the next day. We used 20 kg of sodium metabisulfite in 500 L of water, with a dip of 10 min to reduce melanization (black spot) of the exoskeleton and appendages and bacteria such as Vibrio cholerae (Karithikeyan, 1999; Januário and Dykes, 2005).

Once packed the prawns were rapidly frozen to -20°C. For a product with high quality shelf life, only 9 days at 0°C are available, most of which must be allocated to the retail outlet and the home. Effectively we therefore had one day at 0°C for harvesting and packing. The cold chain has to be maintained throughout, from initial handling and processing until purchase by the consumer.

Diseases and pests

We did not have serious disease problems. However, the following did occur.

• Chitinolytic bacteria are associated with diseases of invertebrates (West, 1988). Usually associated with some injury shrimp occasionally has black eroded spots on their exoskeletons (bacterial shell disease) (Bower, McGladdery and Price, 1994.). The frequency increased in winter when moults slowed. This product would be peeled and deveined.
• Necrotising hepatopancreas (NHP) -like disease (NACA, 2007) occurred in two seasons. This was treated effectively, but not eliminated with oxytetracycline included in the feed at 1.5 g per kg, followed by a 25-day withdrawal period before harvesting (Nogueira-Lima et al., 2006). Oxytetracycline is expensive and was only used prophylatically in the growout phase where a NHP-like pathogen was identified or suspected.
• Microsporidia (Toubiana et al., 2004; ASEAN, 1978; Sindermann, 1974) infections occurred in some of the shrimp in some ponds every year. Most would die before a few grams in size, but some would grow to harvest at 20 g.
• Cramped muscle syndrome (MacVey, 1983; ASEAN, 1978) or cramp tail would occur occasionally, but at insignificant levels. Its highest incidence was in July and August 1998 when we used one-year-old feed.
The approved treatments which we found useful were:

Chemical	**Treatment or application**	**Web link**
Formalin (2 to 5 ppm) x 1 or 2 treatments	Epicommensal protozoa in larval rearing (2 to 5 ppm) x 1 or 2 treatments x 4 hours), nauplii washing (100 to 300 ppm x 1 minute), broodstock (100 to 300 ppm x 1 minute)	Protea Industrial Chemicals
Oxytetracycline 1.5g per kilogram of feed x 7 days	NHP-like disease in growout	Sterkspruit Veterinary Clinic
Calcium hypochlorite	General sterilization	Coastal farmers

Quaternary ammonium compounds	Net and equipment sterilization	Protea Industrial Chemicals
Potassium permanganate (100 ppm)	Sterilization of floors, tanks, nets	Protea Industrial Chemicals
Teaseed cake (saponin) (20 ppm)	Kill fish in ponds	
Prefuran (0.7ppm) (10% furanace)	Shrimp eggs, nauplii and larval rearing	Argent Chemical Labs
Malachite green (use stopped early as it is a carcinogen)	Nauplii, eggs (0.15 ppm (Arthur Lavilla-Pitogo, and Subasinghe, 1996), broodstock	Protea Industrial Chemicals
Iodine	Nauplii, eggs (0.1 ppm) (Argentyne, 1 ml in 10 litres)	Argent Chemical Labs
EDTA water soluble (10 ppm)	Bind (chelating) heavy metals in larval rearing	Protea Industrial Chemicals
Urea, superphosphate, chicken manure	Pond fertilizers	Coastal farmers; (manure from chicken farms)
Sodium metasilicate	Promote diatom blooms in ponds,	Protea Industrial Chemicals
Sodium thiosulphate	Dechlorination, used occasionally	Protea Industrial Chemicals
Alken Clear-Flo 1006	Bacterial probiotic for growout and larval rearing	Alken Murray
Alken Clear-Flo 1100-50x	Bacterial probiotic for biofilters and larval rearing	Alken Murray
Guillard f/2 nutrient medium with L1 modifications to f/2 nutrients.	Marine algae culture, Chaetoceros, Tetraselmis.	Protea Industrial Chemicals (all ingredients)
Sodium metabisulphite	Reduce shrimp discolouration (melanization) and bacterial load	C.J. Petrow

Prefuran was subsequently banned for use, but is still commercially available.

We experienced no major or chronic diseases. We avoided routine prophylactic treatments except with bacterial probiotics (actually bioremediation products (Dr. S. Newman, Pers. Comm.)).

Water into the growout ponds was filtered with 90% shade cloth to remove vertebrate and invertebrate larvae entering the ponds. Teaseed cake was also applied before and during growout if fish were seen. It was especially important to prevent fish predators eating postlarvae and juveniles. However, occasionally we did get fish problems.

Table showing species often found in the growout ponds

Species name	**Common Name**	**Abundance**
Ambassis spp.	glassy	High

Chanos chanos	milkfish	Medium
Gilchristella aestuarius	estuarine round herring	High
Elpos machnata	springer	High
Thryssa vitrirostris	glass nose	Low
Glossogobius giurus	tank goby	Medium
Megalops cyprinoids	oxeye tarpon	Low
Muraenesox bagio	pike conger	Low
Thyrsoidea macrura	slender giant moray	Low
Platycephalus indicus	bartail flat head	Medium
Argyrosomus japonicus (A. hololepidotus)	kob	High
Pomadasys commersonni	spotted grunter	Low
Solea bleekeri	blackhand sole	Medium
Acanthopagrus berda	river bream	Medium
Diplodus sargus	blacktail	Low
Rhabdosargus auriventris	bigeye stumpnose	Low
Rhabdosargus holubi	Cape stumpnose	High
Rhabdosargus sarba	Natal stumpnose	High
Monodactylus falciformis	Cape moony	High
Oreochromis mossambicus	tilapia	High
Crocodylus niloticus	Nile crocodile	Two
	water tortoise/terrapin	Present
Uca sp. (Species not identified)	fiddler crab	in drainage
Penaeus monodon	tiger prawn	Low
Marsupenaeus japonicus	Kuruma prawn	Low
Fenneropenaeus indicus	Indian prawn	Medium
Scylla serrata	mangrove crab	High
Macrobrachium sp. and other small shrimp	freshwater prawn	Low-high

Scylla serrata was considered part of the crop and sold. It grew to well over the reported 360 g (Silva-Krott, 1995) during the growout period and may have predated on shrimp.

Tilapia adults would quickly produce juveniles, so were a pest if they got into the pond. It is speculated that they were dropped by birds.
The Mtunzini site had a population of otters. Their faeces appeared to indicate that they ate mostly crabs. The cob, *Argyrosomus japonicus* was commonly found at the Amatikulu site. It predated on shrimp, and so was a pest.

Another problem on both farms that occurred at the beginning of the growout cycle was the flourishing of filamentous algae that would have to be removed manually and separated from small shrimp (<1 g). As feed volumes increased and diatom blooms improved, this problem would disappear.

Nutrition and feed technology nutrition

Diet formulation

The optimum protein, carbohydrate energy, and lipid levels for *P. monodon* is fairly well established and there is comprehensive literature on the subject. For *F. indicus*, there is less data, but we managed to produce a viable diet for intensive culture conditions in a small feed mill on site.

The following feed formula (g per kg diet) was used successfully in the growout phase to produce intensive yields of up to 9,000 kg per ha. Although raw materials were sourced from local suppliers, products like soybean oilcake were generally imported.

F. indicus feed formulation and costs (2002)

Date of formulation: 03/05/2002	**cost per**	**raw material cost**	**Percent**	**Inclusion range**
Ingredient	**100kg**	**percent**	**Formula**	**(kg per metric tone)**
Fish meal (>65% protein when possible, Chilean, Peruvian, South African (Concentra Ltd., Oceana))	R 145.52	33.80	27.2	260 to 270
Soybean meal (>42% protein) (Imports from USA, Brazil, local Afgri)	R 82.80	19.23	30	270 to 300
Industrial wheat (>12% protein) Ngwane Mills S.A. (Pty) Ltd, Swaziland	R 52.43	12.18	28.4	250 to 286
Brewer's yeast (SA Breweries)	R 15.68	3.64	5.6	50 to 100
Fish oil (Oceana; Energy Oils (Pty) Ltd, Durban, S. A.)	R 10.00	2.32	2	16 to 20
Soya lecithin, crude (Crest Chemicals)	R 17.90	4.16	2	16 to 20
Ascorbic acid polyphosphate (vitamin C, Stay-C) (DSM Nutritional Products South Africa (Pty) Ltd, (was Roche))	R 13.03	3.03	0.1	1 to 4
Vitamin mixture (BASF, ADVIT)	R 12.80	2.97	0.4	4 to 8
Minerals (BASF, ADVIT)	R 1.41	0.33	0.2	1 to 2
Endox (commercial feed antioxidant) Kemin Industries South Africa	R 0.33	0.08	0.03	0.3
Mycocurb (anti fungal) (Kemin Industries South Africa)	R 0.62	0.14	0.06	0.6
Cholesterol, (33% pure) (Westbrook Lanolin (Argowax standard)(now Croda	R 40.00	9.29	0.1	1 to 10

Oleochemicals); Solvay Pharmaceuticals)				
Wheat gluten (C.J. Petrow; Crest Chemicals)	R 33.75	7.84	2.5	25 to 40
Mono calcium phosphate (Coastal farmers)	R 4.20	0.98	1.42	5 to 20
Methionine (BASF, ADVIT)	R 0.00	0.00	0	0 to 1
Raw material cost	**R 430.47**	**100.00**		
Raw materials as a % of feed costs			**75.82**	
Labour/wages	R 23.31	16.98		
Electricity	R 20.57	14.98		
Maintenance	R 17.14	12.48		
Transport	R 0.00	0.00		
Administration	R 20.57	14.98		
Interest	R 45.71	33.29		
Bags	R 10.00	7.28		
Production cost in ZAR	**137.314**		**24.18**	
Cost in ZAR per kilogram feed	**R 5.68**			
Exchange rate, US $:R	10			
Cost in US $ per kilogram feed	**$0.57**			

Currency in ZAR (R 9.6 to R11.6 ZAR to the US $ in 2002)

In general, we started at the higher levels and in the last years of operation, used the lower levels in the diet. This diet provided a protein level of over 40% and a lipid level between 5 and 6% (Sara, Gous and Bureau, 2009).

Vitamin and mineral mixture

Vitamins were included in the diet at 0.4% (4 kg vitamin mix per tonne of feed). The vitamin mixture was formulated by BASF Animal Nutrition according to our specification as below. This was one of the most economical vitamin mixes on the market, but our feed did not require storage and was used within 2 months.

Vitamin	Unit used	Amatikulu 2004
Thiamine (B1)	mg/kg	20
Riboflavin (B2)	mg/kg	16
Pyridoxine (B6)	mg/kg	20
Pantothenic acid (B5)	mg/kg	30
Niacin (B3)	mg/kg	26

Biotin	mg/kg	0.4
Inositol	mg/kg	120
Choline chloride	mg/kg	160
Folic acid	mg/kg	4
Cyanocobalamin (B12)	mg/kg	0.04
Ascorbic acid	mg/kg	Included separately
Retinol acetate, Vitamin A	IU/kg	4,000
Vitamin D3 (calciferol)	IU/kg	1,600
Vitamin E	mg/kg	33.35
Vitamin K	mg/kg	10

The mineral mix was included in the diet at one unit (1.5 kg) per metric tonne of feed. Mineral mix was supplied to specification by BASF Animal Nutrition.

Species:	**Unit**	***F. indicus***
Minerals	**Unit**	**Amatikulu , 2004**
Manganese	mg/kg	30
Zinc H_2O	mg/kg	165
Copper	mg/kg	51
Iodine	mg/kg	1.5
Cobalt	mg/kg	2.1
Iron	mg/kg	133.5
Magnesium	mg/kg	946.5
Selenium	mg/kg	0.75
Chromium	mg/kg	
Aluminium	mg/kg	
Calcium	%	[a]0.32
Phosphorus	%	[a]0.49
Potassium	%	
Sulphur	%	
Sodium	%	
Ca:P	ratio	

[a]From monocalcium phosphate at 2% inclusion in diet

Involvement of governmental and academic institutions

In terms of the legal requirements for shrimp aquaculture in South Africa, we required:

• A permit from the Department of Water Affairs and Forestry to pump water from the estuary (National Water Act).
• A permit to collect wild broodstock specifying species, numbers allowed and source of broodstock from Marine and Coastal Management (MCM).
• An import permit for broodstock originating from Mozambique (F. indicus and P. monodon) from the Department of Trade and industry and an MCM permit for these broodstock. We also had to test imported broodstock for white spot syndrome virus (WSSV) while in quarantine. We tested for viral disease at Molecular Diagnostic Services (Pty) Ltd in South Africa.
• A permit to collect Callianassa kraussi from the Amatikulu estuary (fresh food for broodstock maturation) from the MCM.
• A permit to run a processing plant facility from the MCM.
• A permit to farm shrimp on each site from the MCM.
• HACCP certification inspected by the South African Bureau of Standards. We had to pay a levy based on yield and supply a 2 kg box for testing on each visit.
• Special permission to open the Amatikulu estuary when it became too full at the beginning of each summer.
• We started our farming operations before EIA regulations were in place. New farms now need to follow EIA policy and procedures.

We had to keep detailed records and send reports to the MCM as a condition of the permits authorized.

Other than the process of legal compliance, as a private business, there was no active technical or scientific support for the industry, although had we requested it, it may have been forthcoming. Professor AT Forbes formed a 'Prawn Interest Group' (Biology Department of the University of Natal, Durban, in 1996), which was succeeded by the Prawn Fisheries and Development Association (1998), where we would meet at least twice per annum together with the trawling companies, bait shrimp fishery, representatives of the fishing industry, both estuarine and offshore, conservation and law enforcement bodies, the Marine and Coastal Management (MCM), university researchers and anybody else interested in the shrimp industry. This provided a forum for the exchange of views on a variety of aspects of the management of this resource, including trawling, farming, export/import, duties, uncontrolled imports, poaching and viral diseases on farms (Forbes and Demetriades, 2005).

The funding organization, the Industrial Development Corporation, although very supportive and constructive, was purely commercial. Envirofish did do a 'Project appraisal of Amatikulu prawn' (see http://www.envirofishafrica.co.za/projects.html) for the Development Bank of South Africa in 2001. Studies were done by honours students on the farm effluent and I supplied animals and facilities for research that led to a PhD on the nutrition of F. indicus (Sara, 2006). We also provided facilities for work on the mangrove crab for a few years that led to a PhD (Davies, 2003) and an MSc (Chrurchill, 2004).

Financial analysis of farm production

Production history

Although the target production was intensive, yields at 7000 kg per ha, this was seldom achieved.

Table showing production history for the Amatikulu and Mtunzini sites

	Prawn Production (kg)			Prawn Production (kg)			Amat...	Mtu...
Date	Amatikulu	Pond ha	kg/ha	Mtunzini	Pond ha	kg/ha	Species	Species
1992	10000	5.6	1786				*P. monodon*	
1993	17873	5.6	3192				*P. monodon*	
1994	17868	5.6	3191	48000	27	1761	*F. indicus*	P. m, P. i, P. j
1995	22344	5.6	3990	53445	27	1979	*F. indicus*	P. m, P. i
1996	34757	5.6	6207	54656	27	2024	*F. indicus*	F. i
1997	39479	9.6	4112	31363	27	1162	*F. indicus*	P. m, F. i.
1998	58618	9.6	6106	0	0		*F. indicus*	F. i
1999	69561	9.6	7246	55330	17	3255	*F. indicus*	F. i
2000	47172	9.6	4914	79669	19	4193	*F. indicus*	F. i
2001	38059	9.6	3964	82134	18	4693	*F. indicus*	F. i
2002	68700	9.6	7156	89000	22.5	3956	*F. indicus*	F. i
2003	59778	9.6	6227	75761	23	3294	*F. indicus*	F. i
2004	55000	9.6	5729	69661	23	3029	*F. indicus*	F. i

A temperate climate with cold winters meant that only one crop per annum could be produced. Pond water temperatures dropped to below 20°C in early May and slowly rose through August and September to above 23°C. Due to this, only one crop per annum was possible. This was the main factor leading to our inability to compete and remain viable when market prices fell.

Other factors that reduced production included:

• Theft was a major issue on both farms by a variety of thieves from the fisherman needing bait to professional gangs. It was difficult to stop on the Mtunzini site due to the sloping topography allowing hiding places. Often the only evidence of theft would be a few dropped shrimp, a wet point of exit and a change in the feed required and size profile of the pond. In two years at Amatikulu, thieves would arrive armed and two would shoot at the staff on site while their team of five took 20 min to net out shrimp. Product was recovered from a local butchery and the people involved identified, but the matter never got to court.
• Staff would dump feed at night into the ponds closest to the feed store and record the furthest ponds as fed.
• Pump problems would lead to lowered water quality forcing a reduction of feed.
• Fish predators had some impact (e.g. Argyrosomus japonicus) in some ponds in some years.
• Domesticated broodstock produced weaker shrimp lowering survival at times.

Sales figures

Most of our product was sold head-on. In the season ending in 2004, we achieved an average price of R54.26 (US $8.48) per kg, while in 2003, it was 51.60 (US $6.83), with a sales income of R7,860,954 and R6,984,909, respectively. About 20 metric tonnes of the 2004 sales was imported L. vannamei, so approximately R6,694.437 was due to sales from production. The range of products included head-on, tails, 'butterflied', 'peeled and deveined' (soft shell due to moulting), bait (microsporidia infected) and crabs.

Table showing sales records for the season ending 2003

Amatikulu & Mtunzini Prawns Production & Sales			
Sales by Inventory Code 01/07/2002 to 30/06/2003			
Product code & description	**Kilo**	**Rand**	**Per kg**
Item : 0002 - ZuluPrawns LM Head-on 30-40/kg Q2	74	6,474	R 87.49
Item : 0003 - ZuluPrawns LM Head-on 40-50/kg S1	411	29,589	R 71.99
Item : 0004 - ZuluPrawns LM Head-on 50-60/kg S2	216	13,122	R 60.75
Item : 0007 - ZuluPrawns LM Butterflied 30-40/kg Q2	1908	129,668	R 67.96
Item : 0008 - ZuluPrawns LM Butterflied 40-50/kg S1	10088	740,459	R 73.40
Item : 0009 - ZuluPrawns LM Butterflied 50-60/kg S2	49148	2,786,926	R 56.70
Item : 0010 - ZuluPrawns LM Butterflied 60-70/kg SS1	38977	1,593,148	R 40.87
Item : 0011 - ZuluPrawns LM Butterflied 70-80/kg SS2	4202	138,595	R 32.98
Item : 0012 - ZuluPrawns LM Headless 44-67/kg Q1/Q2	428	15,488	R 36.19
Item : 0013 - ZuluPrawns LM Headless 69-89/kg S1/S2	304	25,579	R 84.14
Item : 0014 - ZuluPrawns LM Headless 90-132/kg SS1/2/3	188	18,760	R 99.79
Item : 0015 - ZuluPrawns LM P&D 44-67 Q1/Q2	2204	189,261	R 85.87
Item : 0016 - ZuluPrawns LM P&D 68-89/kg S1/S2	150	10,704	R 71.36
Item : 0017 - ZuluPrawns LM P&D 90-132/kg SS1/2/3	1736	108,863	R 62.71
Item : 0018 - ZuluPrawns LM P&D 133-180/kg SSS	1791	91,792	R 51.25
Item : 0019 - LM Bait Prawns	1345	41,541	R 30.89
Item : 0020 - LM Live Prawns	29	87	R 3.00
Item : 0025 - ZuluPrawns LM H/O 60-70/kg SS1 500 g	1876	122,818	R 65.47
Item : 0026 - ZuluPrawns LM H/O 70-80/kg SS2 500 g	7635	548,020	R 71.78
Item : 0027 - ZuluPrawns LM Bflied 30-40/kg Q1 500 g	5929	297,304	R 50.14
Item : 0028 - ZuluPrawns LM Bflied 40-50/kg S1 500 g	880	35,064	R 39.85
Item : 0029 - ZuluPrawns LM Bflied 50-60/kg S2 500 g	1428	31,077	R 21.76
Item : 0030 - ZuluPrawns LM Bflied 60-70/kg SS1 500 g	181	7,045	R 38.92
Item : 0031 - ZuluPrawns LM P&D 90-132/kg SS1/2/3 250g	39	1,305	R 33.46

Item : 0032 - Crabs Medium	13	420	R 32.31
Item : 0033 - Crabs Small	232	1,800	R 7.76
GRAND TOTAL	131412	6,984,909	
Average sales price per kilogram: |Gross|Head-on|		R 53.15	R 51.60
Exchange rate	US $:Rand	8	
$ equivalent price per kg		$7.03	$6.83

Table showing sales figures for the year ending 2004

Amatikulu & Mtunzini Prawns Production & Sales			
Sales by Inventory Code 01/07/2003 to 30/06/2004			
Product code & description	**Kilo**	**Rand**	**Per kg**
Item : 0001 - ZuluPrawns LM Head-on Fresh	193	13,068	R 67.71
Item : 0002 - ZuluPrawns LM Head-on 30-40/kg Q2	2301	170,658	R 74.17
Item : 0003 - ZuluPrawns LM Head-on 40-50/kg S1	7624	461,174	R 60.49
Item : 0004 - ZuluPrawns LM Head-on 50-60/kg S2	8235	415,045	R 50.40
Item : 0005 - ZuluPrawns LM Head-on 60-70/kg SS1	3742	173,589	R 46.39
Item : 0006 - ZuluPrawns LM Head-on 70-80/kg SS2	1574	66,883	R 42.49
Item : 0007 - ZuluPrawns LM Butterflied 30-40/kg Q2	183	12,961	R 70.83
Item : 0008 - ZuluPrawns LM Butterflied 40-50/kg S1	22403	1,598,962	R 71.37
Item : 0009 - ZuluPrawns LM Butterflied 50-60/kg S2	39372	2,178,357	R 55.33
Item : 0010 - ZuluPrawns LM Butterflied 60-70/kg SS1	16226	749,761	R 46.21
Item : 0011 - ZuluPrawns LM Butterflied 70-80/kg SS2	2691	101,128	R 37.58
Item : 0012 - ZuluPrawns LM Headless 44-67/kg Q1/Q2	64	5,908	R 92.32
Item : 0013 - ZuluPrawns LM Headless 69-89/kg S1/S2	1290	93,482	R 72.47
Item : 0014 – ZuluPr. LM Headless 90-132/kg SS1/2/3	2567	190,647	R 74.27
Item : 0015 - ZuluPrawns LM P&D 44-67 Q1/Q2	1471	110,953	R 75.43
Item : 0016 - ZuluPrawns LM P&D 68-89/kg S1/S2	2627	197,648	R 75.24
Item : 0017 - ZuluPrawns LM P&D 90-132/kg SS1/2/3	4095	287379	R 70.18
Item : 0018 - ZuluPrawns LM P&D 133-180/kg SSS	4611	284,535	R 61.71
Item : 0019 - LM Bait Prawns	3995	171,523	R 42.93
Item : 0021 - ZuluPrawns LM Head-on 80-100/kg SS3	78	2,748	R 35.23

Item : 0022 - ZuluPrawns LM H/O 30-40/kg Q2 500 g	152	5,103	R 33.57
Item : 0023 - ZuluPrawns LM H/O 40-50/kg S1 500 g	12	474	R 39.47
Item : 0024 - ZuluPrawns LM H/O 50-60/kg S2 500g	22	713	R 32.40
Item : 0025 - ZuluPrawns LM H/O 60-70/kg SS1 500 g	1211	100,977	R 83.38
Item : 0026 - ZuluPrawns LM H/O 70-80/kg SS2 500 g	1315	102,672	R 78.08
Item : 0027 - ZuluPrawns LM Bflied 30-40/kg Q1 500 g	5818	347,884	R 59.79
Item : 0028 - ZuluPrawns LM Bflied 40-50/kg S1 500 g	45	1,778	R 39.52
Item : 0029 - ZuluPrawns LM Bflied 50-60/kg S2 500 g	503	11,147	R 22.16
Item : 0030 - ZuluPrawns LM Bflied 60-70/kg SS1 500 g	212	3,007	R 14.19
Item : 0032 - Crabs Medium	5	150	
Item : 0033 - Crabs Small	24	640	
GRAND TOTAL	134661	7,860,954	
Average sales price per kilogram: |Gross|Head-on|		R 58.38	R 54.26
Exchange rate	US $:Rand	6	
$ equivalent price per kilogram		$9.12	$8.48

Operating costs

Another factor was that our operating costs were high compared to international norms. While market prices were high, we were still profitable, but when the prices declined, we were under pressure to reduce costs. Financial models indicated that expansion under the same management cost structure reduced costs and so expansion plans were prepared. From about 2001, we were negotiating with potential investors and this continued after closure, but we were unable to secure the necessary funding for expansion.

Typical operating costs as in the below did not allow us many areas for cost cutting when prices declined. Improvements were possible in FCR, and did reduce our management costs, but with the prices of 2004, we became unviable.

Typical Cashflow Budget for Amatikulu and Mtunzini Prawns (Pty) Ltd. (modeled, not actuals)

		Year 9	Year 10	Year 11	Year 12
BEGINNING CASH BALANCE		100,000	100,000	100,000	100,000
Receipts:					
	Shrimp	1,058,548	1,058,548	1,058,548	1,058,548
	Sale of capital	1,767	0	3,050	937
TOTAL CASH INFLOW		1,160,315	1,158,548	1,161,598	1,159,485
Operating Expenses:					
	Postlarvae	18,662	18,662	18,662	18,662

	Fertilizer	2,948	2,948	2,948	2,948
	40% Protein Feed	219,699	219,699	219,699	219,699
	Pumping	27,962	27,962	27,962	27,962
	Aeration	22,719	22,719	22,719	22,719
	Ice	12,483	12,483	12,483	12,483
	Processing	28,711	28,711	28,711	28,711
	Pack & Grading	24,966	24,966	24,966	24,966
	Storage & Freight	13,002	13,002	13,002	13,002
	Full Time Labor	124,000	124,000	124,000	124,000
	Management Salaries	110,857	110,857	110,857	110,857
	Accountant, Audit, Admin Fees	19,000	19,000	19,000	19,000
	Legal Fees	2,000	2,000	2,000	2,000
	Bank charges	7,143	7,143	7,143	7,143
	Insurance Premium	9,000	9,000	9,000	9,000
	Marketing	7,143	7,143	7,143	7,143
	Repair of Buildings.	1,096	1,096	1,096	1,096
	Repair Mach, Equip, Ponds	38,665	38,665	38,665	38,665
	Repairs Storm Damage	2,023	2,023	2,023	2,023
	Utilities	1,400	1,400	1,400	1,400
	Supplies	2,800	2,800	2,800	2,800
	Property Tax, Levies	11,018	9,682	8,347	7,012
	Fuel	30,857	30,857	30,857	30,857
	Contingency	36,908	36,841	36,774	36,707
Total Operating Expenses		775,059	773,657	772,255	770,853
Capital Invest & Replace		20,624	0	9,372	75,618
Schedule of Debt Payments					
	Intermediate Principal	38,132	42,707	47,832	53,572
	Intermediate Interest	21,869	17,293	12,169	6,429
Income & Self-employ Taxes		1,857	1,857	1,857	1,857
TOTAL CASH OUTFLOW		857,540	835,515	843,485	908,329
AVAILABLE CASH		302,775	323,033	318,113	251,157

International prices reported on http://www.shrimpnews.com/ for 2004 and 2005 are given in the table below.

Table showing white prawn prices over 2004 and 2005 (US $)

Product as tails per pound (head-on count/kg)	**Aug 13th 2004 Gulf of Mexico Whites**	**December 3rd 2004 Gulf of Mexico Whites**	**April 1st 2005 Gulf of Mexico Whites**	**December 22nd 2005 Gulf of Mexico Whites**	**Source: www. Shrimpnews .com**
26/30	$4.20	$4.15	$4.20	$4.55	
31/35	$3.90	$3.85	$3.90	$4.20	
36/40	$3.30	$3.40	$3.65	$3.85	

The best price of US $4.55 per pound for tails is equivalent to a head-on price of $6.30 per kilogram. Our production costs could have been reduced by $2 per kg if we were simply able to produce two crops per annum, as illustrated in the table below.

Table showing break-even scenarios, one and two crops (hypothetical) per annum

One crop per annum, actual capability due to climate			
Break-even Production (kg, heads-off)	Year 10	Year 11	Year 12
To Cover Cash Costs	61,277	60,792	60,263
To Cover All Costs Before Taxes	65,907	65,423	64,893
To Cover All Cost Including Taxes	66,043	65,558	65,029
Break-even Price ($/kg, heads-off)			
To Cover Cash Costs	10.83	10.74	10.65
To Cover All Costs Before Taxes	11.65	11.56	11.47
To Cover All Cost Including Taxes	11.67	11.59	11.49
Break-even Production (kg, heads-on)			
To Cover Cash Costs	98,833	98,052	97,198
To Cover All Costs Before Taxes	106,301	105,520	104,666
To Cover All Cost Including Taxes	106,520	105,739	104,885
Break-even Price ($/kg) head on			
To Cover Cash Costs	6.71	6.66	6.60
To Cover All Costs Before Taxes	7.22	7.17	7.11
Two crops per annum scenario			

Break-even Production (kg, heads-off)	Year 10	Year 11	Year 12
To Cover Cash Costs	89,043	88,562	88,036
To Cover All Costs Before Taxes	93,673	93,192	92,667
To Cover All Cost Including Taxes	93,809	93,328	92,802
Break-even Price ($/kg, heads-off/tails)			
To Cover Cash Costs	7.87	7.83	7.78
To Cover All Costs Before Taxes	8.28	8.23	8.19
To Cover All Cost Including Taxes	8.29	8.25	8.20
Break-even Production (kg, heads-on)			
To Cover Cash Costs	143,617	142,842	141,994
To Cover All Costs Before Taxes	151,086	150,310	149,462
To Cover All Cost Including Taxes	151,305	150,529	149,681
Break-even Price ($/kg) head on			
To Cover Cash Costs	4.88	4.85	4.82
To Cover All Costs Before Taxes	5.13	5.11	5.08
To Cover All Cost Including Taxes	5.14	5.11	5.08

In July 2009, the 26/30 tails per pound prices are as in the table below, so it appears that we may have been able to survive the lower prices had we greatly improved efficiencies in various areas. However, we did not have the financial resources to maneuver. Achieving two crops per annum of shrimp was not possible due to the climate. We had been collecting pond-grown *Argyrosomus japonicus* so as to begin a winter crop of fish, but we did not have the financial or professional resources to properly pursue this option and the collected broodstock were stolen from the holding pond.

The director and owner of the farm, Mr. Stephanus Myburgh, was killed in a motor accident in 2002. His son put the farms up for sale at R11.5 million including stock in the ponds (140 metric tones) and creditors (1.5 million). We had been trying from before 2002 to secure extra funding, so by the harvest of 2004, we saw that without extra funding, some form of expansion and improved operational efficiencies, we would go bankrupt if we entered the 2005 season. Neither M. Myburgh nor I were prepared to risk bankruptcy, as to intentionally incur debts knowing that bankruptcy was likely was considered a criminal offence.

Table showing 2009 prices for 26/30 tails per pound of shrimp

Product, 26/30 tails per pound count	Price (US $, www.shrimpnews.com), July 3rd 2009
Bangladesh Tigers	$4.20 (same as 5.80 per kg head-on)
China Whites Easy Peel IQF	$3.80
Ecuador Whites Farmed	$3.85

Gulf of Mexico Whites	$3.75 (same as 5.20 per kg head-on)

Under the hypothetical scenario of improving feed conversion ratios to 1.7, halving the staff per hectare, reducing feed costs to US $600 per metric tonne, improving growout survival to 65% and increasing yields to 8.1 metric tonnes per ha as an average production, our cost structure with one crop per annum would have allowed us to produce at a cost of between US $4.62 and US $4.88 per kg head-on, allowing about US $1 per kg under the prevailing global price structure. Although this could have been a target, each of these would have been excellent achievements on their own and not achievable in one or two years.

Our average price achieved for head-on product was higher than the average market price for tails, but in 2004 the market also became flooded with cheap head-on tiger prawns from India. This coincided with the anti-dumping regulations that the USA imposed against a number of countries, including India after a petition by the Shrimp Trade Action Committee (ASTAC) in December 2003 (Bhattarcharyya, 2005). This was the final nail in the coffin for our local market. Some product that India could no longer send to the USA landed in South Africa at between US $4 and US $5 per kg for 20/30 count per kg head-on tiger prawns. In India, prices crashed from Rs. 450 to Rs. 600 to Rs. 220 per kg, while the cost of production was Rs. 250 (around US $5.50 in 2004) (Bhattarcharyya, 2005). Even to compete with such production costs from countries achieving two crops per annum required significant cost reductions. The impact was compounded by a weak US $ of between R6 and R7 to the US $. Product landed at US $5 per kg was costing importers R35 per kg for a bigger product than we produced at between US $6.6 and US $7.00 (R44) per kg. The generally low international prices, and strong Rand also made the export market less viable. As a cash-strapped company, investment and expansion was the only solution, but financial institutions work slowly. A process that began before 2002 with the international consulting group, Akvaplan-niva (Norway, http://www.akvaplan.niva.no/) employed by S. Myburgh and a black economic empowerment (BEE) investment team (Siyaya Fisheries, http://www.busrep.co.za/index.php?from=rss_&fArticleId=3423611) funded by KwaZulu-Nata Growth Fund (http://www.kzngrowthfund.co.za/default.aspx?pid=43), finally appeared to take shape in December 2005 when Rod McNeil was sub-contracted to design an intensive shrimp production system based on a new biofloc technology (see http://floc.aesweb.org/). However, sufficient funds could not be secured and this team disbanded a few months later in 2006. *Argyrosomus japonicus* is now being considered (July 2009) as a production species by the company that now owns the Mtunzini site. Viable broodstock have been held at the facility for about 2 years.

Conclusion

The purchase of the Mtunzini Prawns site in late 1989 allowed a rapid increase in overall production, but the design, pond layout and low average salinities of this farm made its management and attaining high yields more difficult than at Amatikulu. Together, the farms were viable until three factors coincided in 2004: the weakened US $, the lowered international shrimp prices and the arrival of cheap prawns in South Africa due to the USA anti-dumping legislation against some countries. Had there been some form of government support for this new industry assisting both academically, with research and development, and financially, the industry may have survived. In South Africa, shrimp can only be grown commercially outdoors from September to April, so a winter crop of some other species or covered structures for winter production would have been necessary to remain competitive internationally.

Three options available at the time of closure were:
1. Diversification through adding other cold-tolerant species such as *Argyrosomus japonicus*;
2. Increase in farm size and production per hectare;
3. Implementation of new technologies such as biofloc under tunnel structures.

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Appendix 1

Landed catches (to the nearest tonne) by the KZN crustacean trawl fishery, based on landing sheets received from the trawling companies and extracted from the MCM database (Sauer et al., 2002).

Catches	**Sector**	**1990**	**‘91**	**‘92**	**‘93**	**‘94**	**‘95**	**‘96**	**‘97**	**‘98**	**‘99**
White prawns	Inshore	82	99	85	50	43	20	55	12	103	72
Tiger prawns	Inshore	4	-	2	2	-	1	6	2	3	1
Pink prawns	Offshore	311	246	112	166	65	96	76	77	69	121
Langoustines	Offshore	52	51	70	83	46	55	58	78	49	50
Rock	Offshore	14	18	31	33	10	12	10	10	6	8

lobster											
Crabs	Offshore	74	186	187	138	80	98	82	113	100	73
Fishes	In/offshore	47	66	58	45	18	49	63	71	79	35
Cephalopods	In/offshore	28	28	32	24	9	26	22	21	16	32

Organizations

Oraganization	Type of organization	Address	Main Contanct	Website
Ecotao Enterprises cc	Consltants, shrimp aquaculture (technical assistance)	PO Box 1524, Stanger, 4450, South Africa.	Laurence Evans	www.ecotao.com
Amatikulu Prawns (Pty) Ltd	Growout, htchery, feedmill	Company closed in 2004		
Mtunzini Prawns (Pty) Ltd	Growout, hatchery	Company closed in 2004		

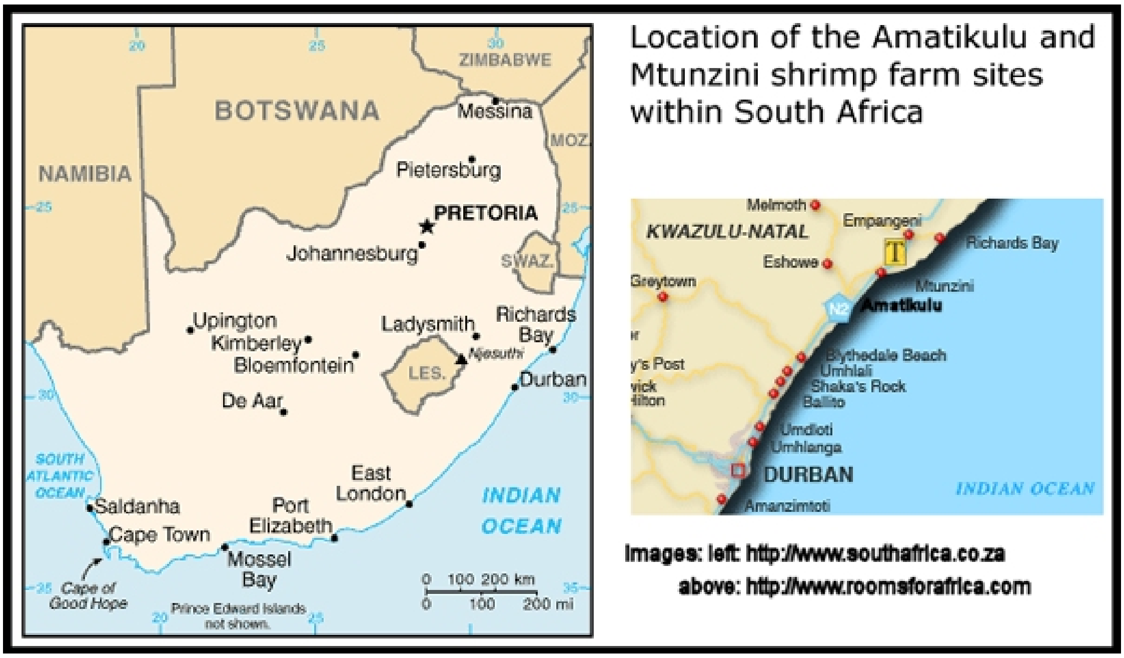
Links to Websites

NAME	ADDRESS (URL)
ADVIT – vitamin supplier	http://www.advit.co.za
AFGRI – oil and protein feeds	http://www.afgri-ir.co.za/glance_oil_protein.htm
Applied UV cc – ultraviolet water sterilizer merchant	http://www.applieduv.co.za/index2.shtml
Aquafauna Bio-Marine Inc	http://www.aquafauna.com/
Aquatic Animal Diseases Significant to Asia Pacific – necrotising hepatopancreas	http://library.enaca.org/Health/FieldGuide/html/cb001nhp.htm
Argent Laboratories	http://www.argent-labs.com/

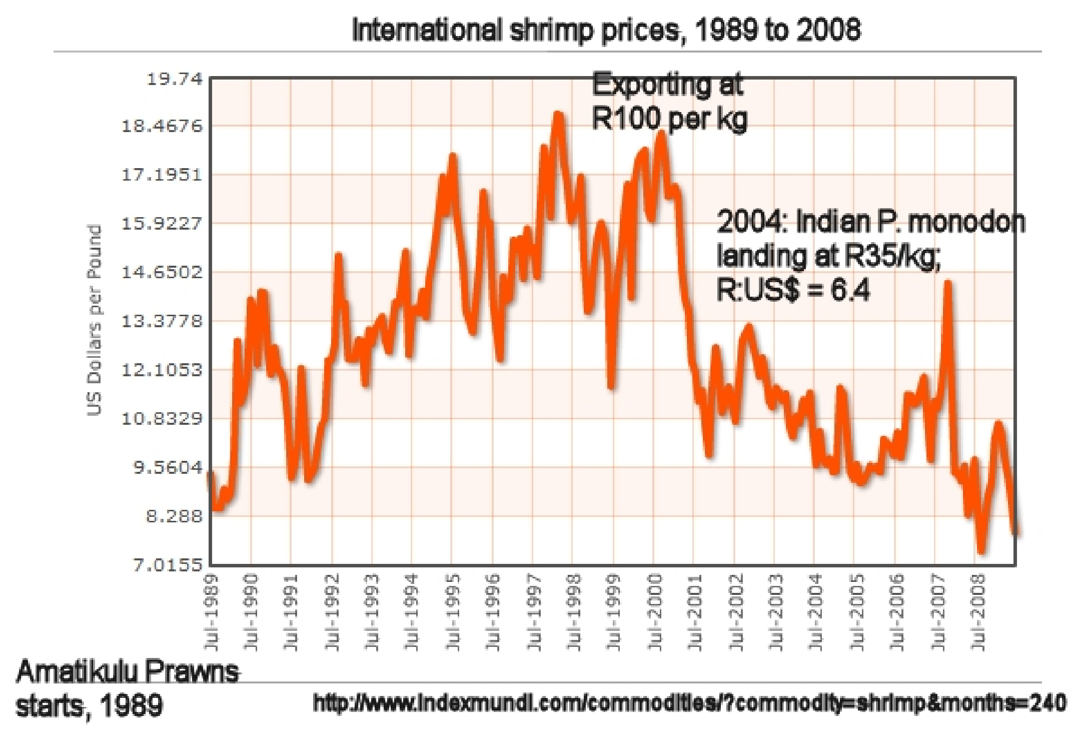
BASF Animal Nutrition, South Africa	http://www.advit.co.za/
Bridgelow Labs (algal culture)	http://ccmp.bigelow.org/
Coastal Management Office, South Africa	http://www.mcm-deat.gov.za/coastal/
Coastal's Farmers' Suppliers	http://www.coastals.co.za/
CP Feeds, Thailand	http://www.cpshrimp.com/pages/product/seafood/inside_aqua_files/framemain_animalfeed.htm
Crest Chemicals	http://www.crestchem.co.za/Website/Crest/Crest.nsf
Croda South Africa – cholesterol supplier	http://www.croda.co.za/
Cyclop-eeze	http://www.cyclop-eeze.com/index.php
Denorco Pty Ltd (pumps)	http://www.denorco.com/
Department of Water Affairs and Forestry, South Africa	http://www.dwaf.gov.za/
DSM Nutritional Products, South Africa	http://www.dsm.com/en_US/html/dnp/contacts_southafrica.htm
Endox, brand dry antioxidant, Kemin Industries, Sourth Africa	http://www.kemin.com/agrifoods/kana/products_services/feed_stability/endox
Energy Oil – fish oil supplier	http://www.energyoil.co.za/specialityproducts.htm
Envirofish	http://www.envirofishafrica.co.za/
Green Label Feeds, Taiwan	http://www.tradekey.com/profile_view/uid/927001.htm
Grundfos, pumps, South Africa	http://www.grundfos.co.za/
Industrial Development Corporation, South Africa	http://www.idc.co.za/
International HACCP Alliance	http://www.haccpalliance.org/sub/index.html
KDB Pumps	http://www.ksbpumps.co.za/
Molecular Diagnostic Services, South Africa	http://www.mdsafrica.net/site/default.asp
Oceana Group Ltd. – fish oil supplier	http://www.oceana.co.za/divisions/oceana_brands/fishoil.php
Oceanic Institute, Hawaii	http://www.ocean-institute.org/
OIE Disease Card on necrotising hepatopancreas	http://www.oie.int/aac/eng/Publicat/Cardsenglish/NHP%20disease%20card%20_draft_.pdf
President Feeds, Taiwan	http://unipresident.en.ecplaza.net/
South African Breweries Ltd	http://www.sablimited.co.za/sablimited/view/sablimited/en/page1
South African Bureau of Standards	https://www.sabs.co.za/
Speck pumps, South Africa	http://www.speck-pumps.co.za/code/home.htm

Team Aqua – paddle weeder supplier	http://www.aquaculture-product.com.tw/
Team Aqua Corporation	http://www.aquaculture-product.com.tw/
Texas A&M Shrimp Farming Short Course	http://texas-sea-grant.tamu.edu/Outreach/Short%20Course/shortcourse.html
Texas A&M University	http://www.tamu.edu/
Tungkang Marine Laboratory	http://www.tfrin.gov.tw/english/ot.htm
Wikipedia definition: HACCP	http://en.wikipedia.org/wiki/Hazard_Analysis_and_Critical_Control_Points

Illustrations



Location of the Amatikulu and Mtunzini shrimp farms in South Africa



International shrimp price trends, 1989 to 2004

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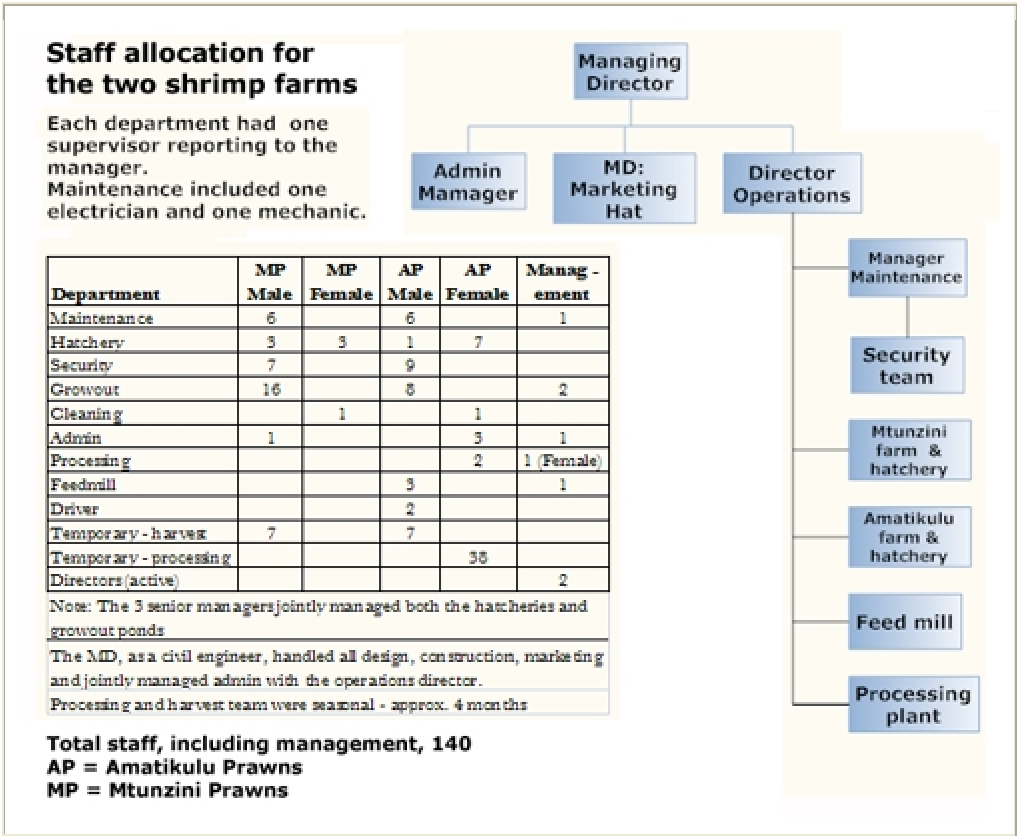
Aerial view of Amatikulu Prawns (Pty) Ltd. and the Amatikulu River estuary in 2005

©Guy Upfold



Department	MP Male	MP Female	AP Male	AP Female	Manag - ement
Maintenance	6		6		1
Hatchery	3	3	1	7	
Security	7		9		
Growout	16		8		2
Cleaning		1		1	
Admin	1			3	1
Processing				2	1 (Female)
Feedmill			3		1
Driver			2		
Temporary - harvest	7		7		
Temporary - processing				38	
Directors (active)					2

Note: The 3 senior managers jointly managed both the hatcheries and growout ponds

The MD, as a civil engineer, handled all design, construction, marketing and jointly managed admin with the operations director.

Processing and harvest team were seasonal - approx. 4 months

Departments and staff of the two shrimp farms

Aerial view of the Amatikulu Prawns site, 1998

©Guy Upfold

Aerial view of the Mtunzini Prawns site, 2001

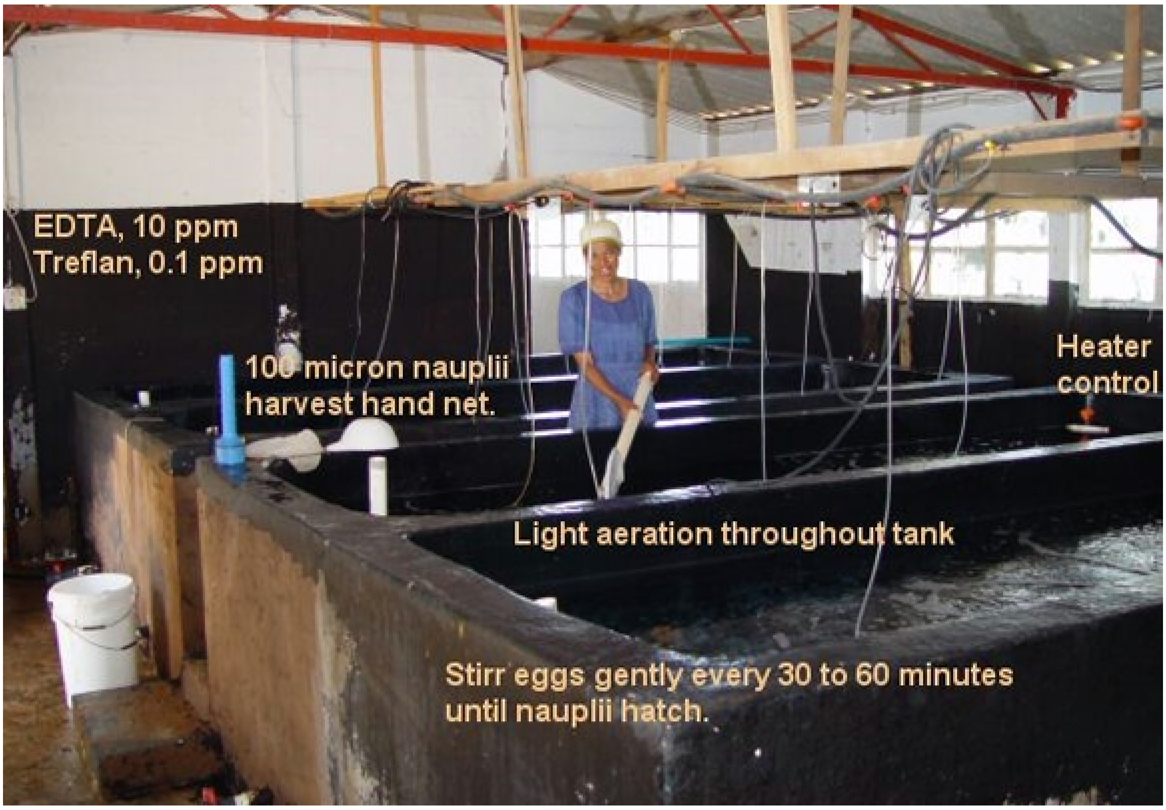
©Guy Upfold

Seven cubic metre larval rearing tanks lined with fibreglass

Forty metric tonne postlarval rearing tank

Gravid *F. indicus* ready to spawn

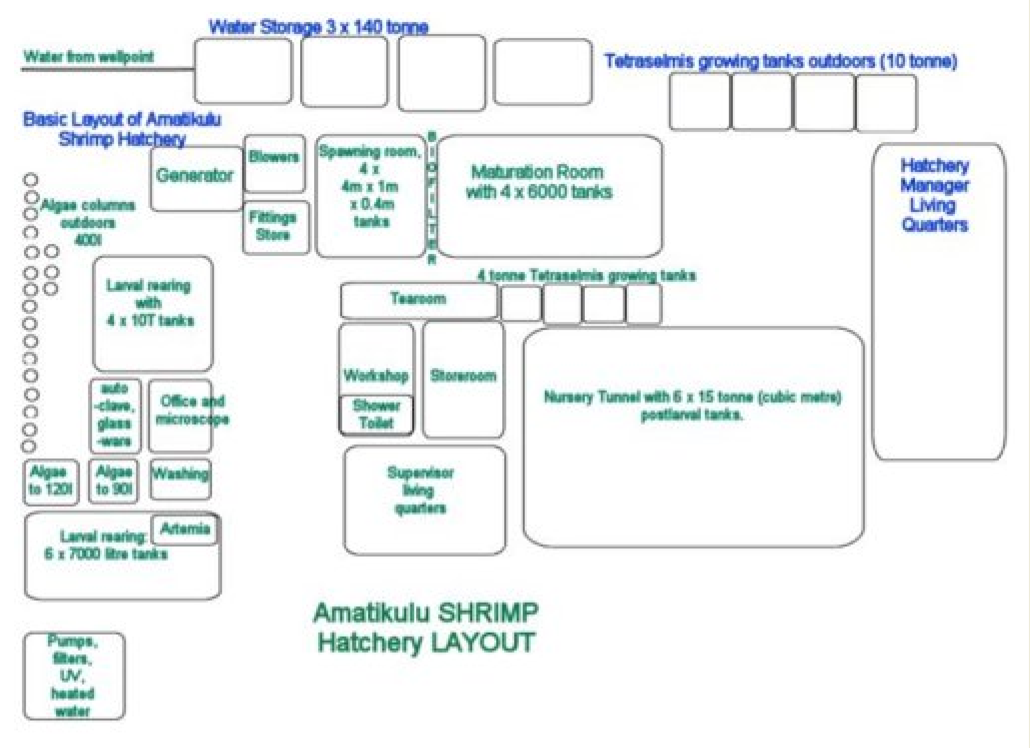
16-g, gravid *F. indicus*



Fibre-glass lines mass spawning tanks for *F. indicus* at Amatikulu

©Guy Upfold

Maturation tank at Amatikulu

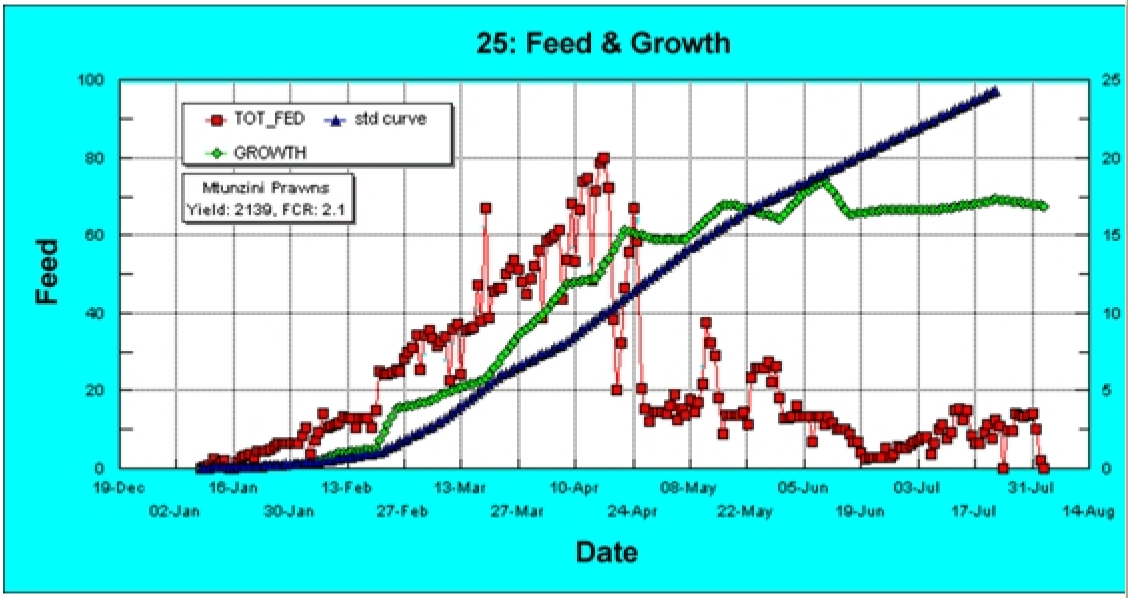


Hatchery layout plan allowing good biosecurity

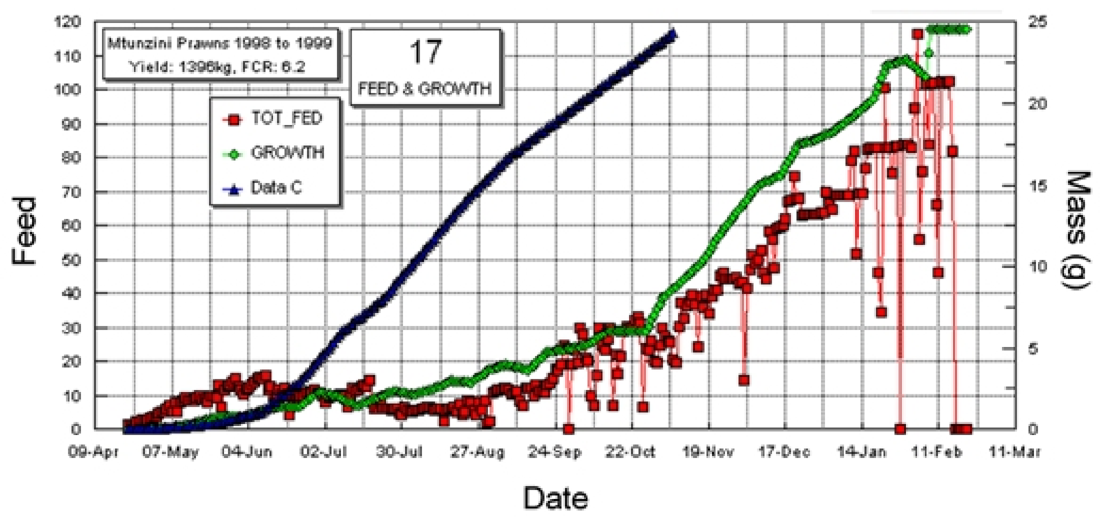
©Laurence Evans

Ten-cubic-metre *T. suecica* production tanks at Amatikulu, 2003

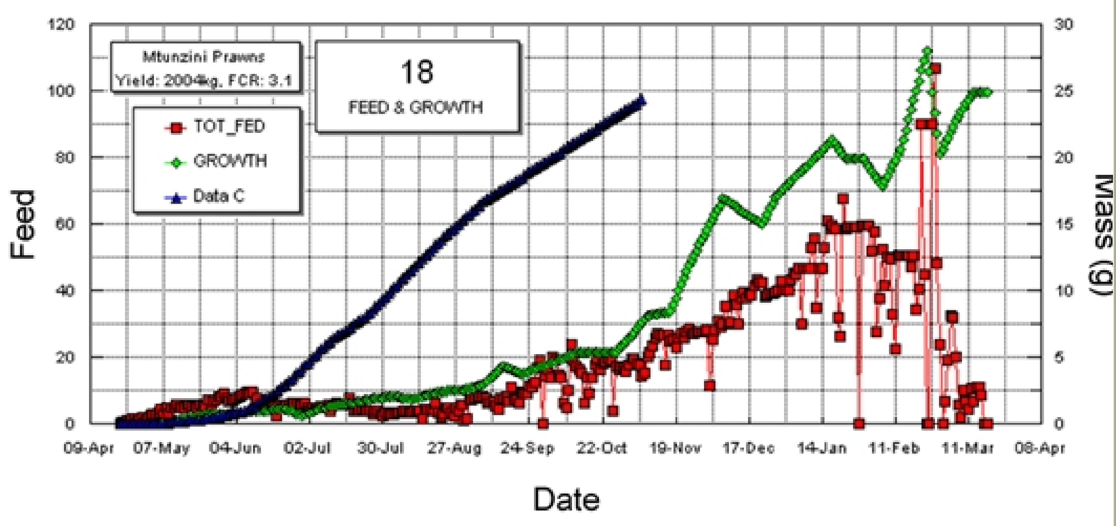
Stocking of postlarvae in 2-ha pond (note diatom bloom and filamentous algae at pond side)



Growth of juvenile, 10 gram shrimp through winter



Winter growout of postlarvae stocked before winter at Mtunzini



Feed and growth of *F. indicus* through winter at Mtunzini

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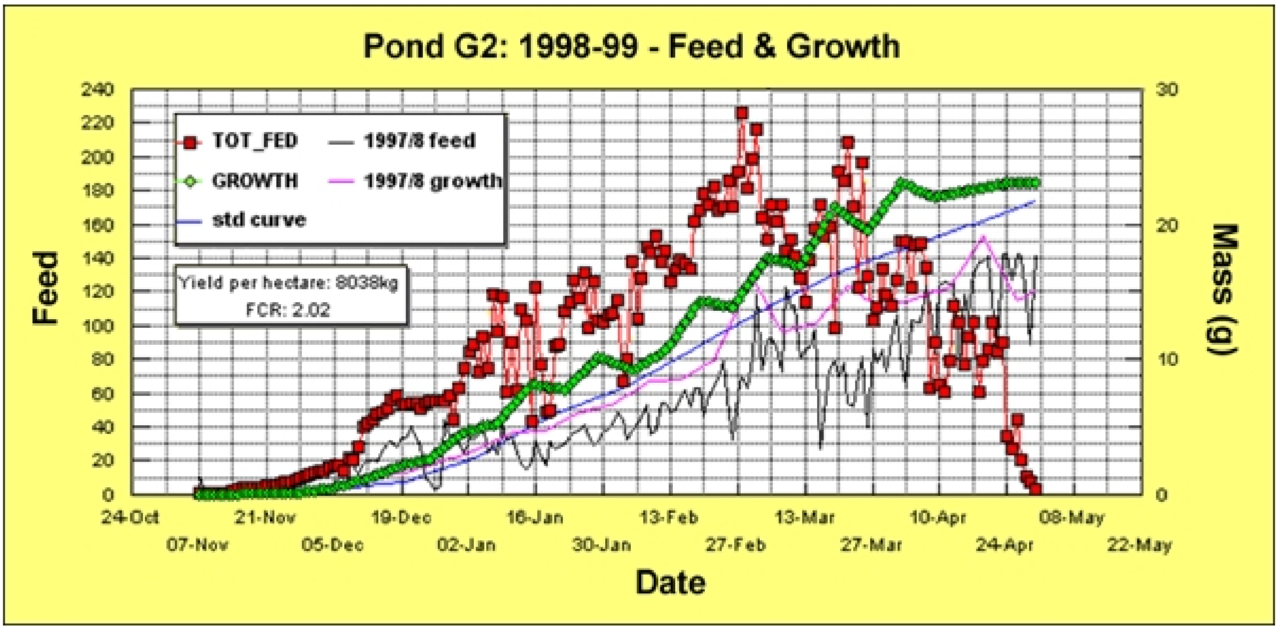
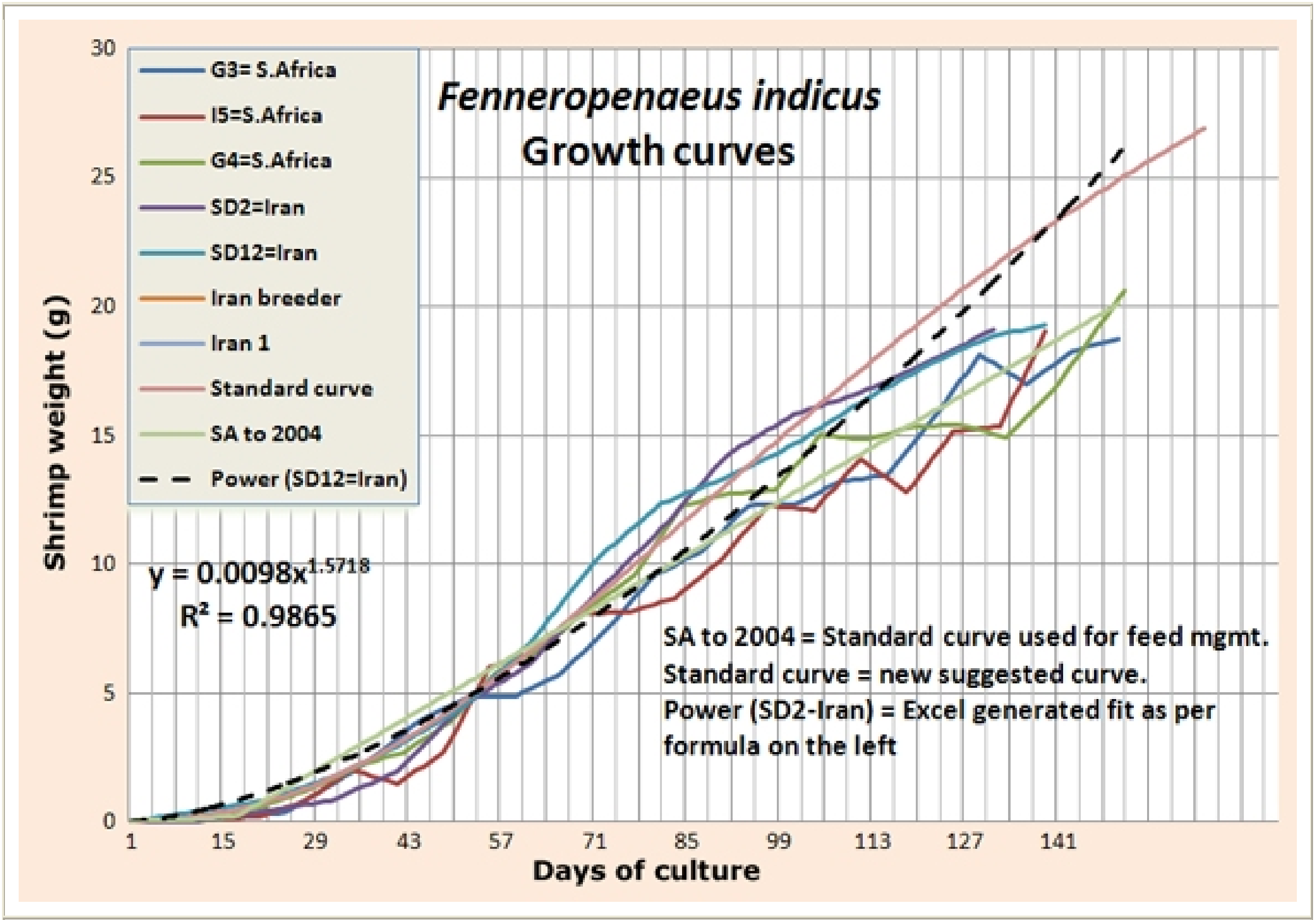
Manual piling of sludge. There were large amounts of sludge in some ponds, but others had very little sludge

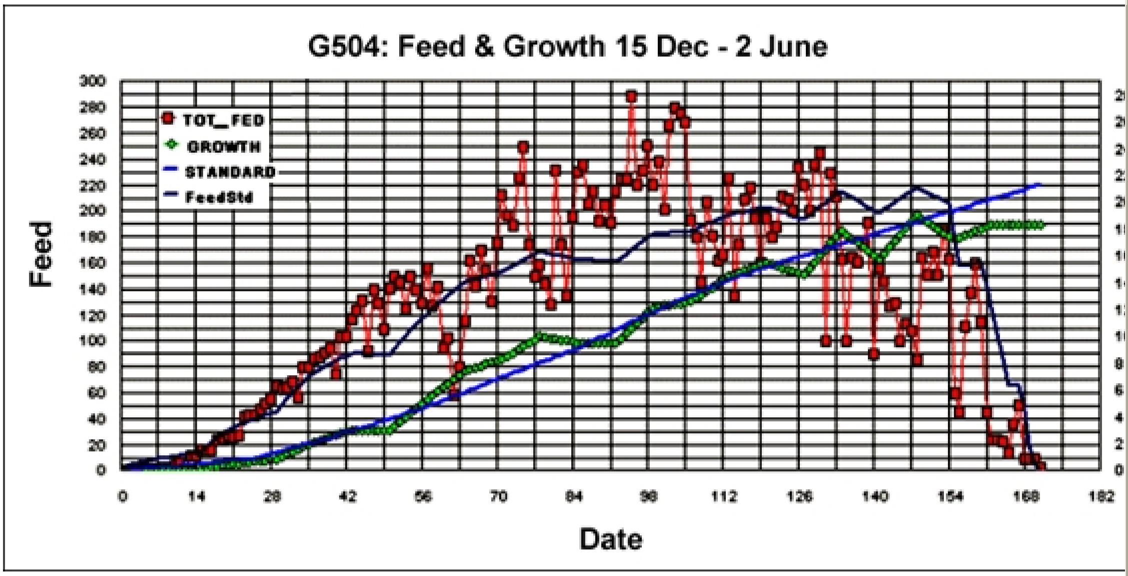


Ideal yield, shrimp weight and feed conversion ratio (FCR) attained in a one hectare pond at Amatikulu



Actual and theoretical growth curves for *F. indicus*

Moist pellet mincer



Growth and feed in a 2-ha pond in 2004

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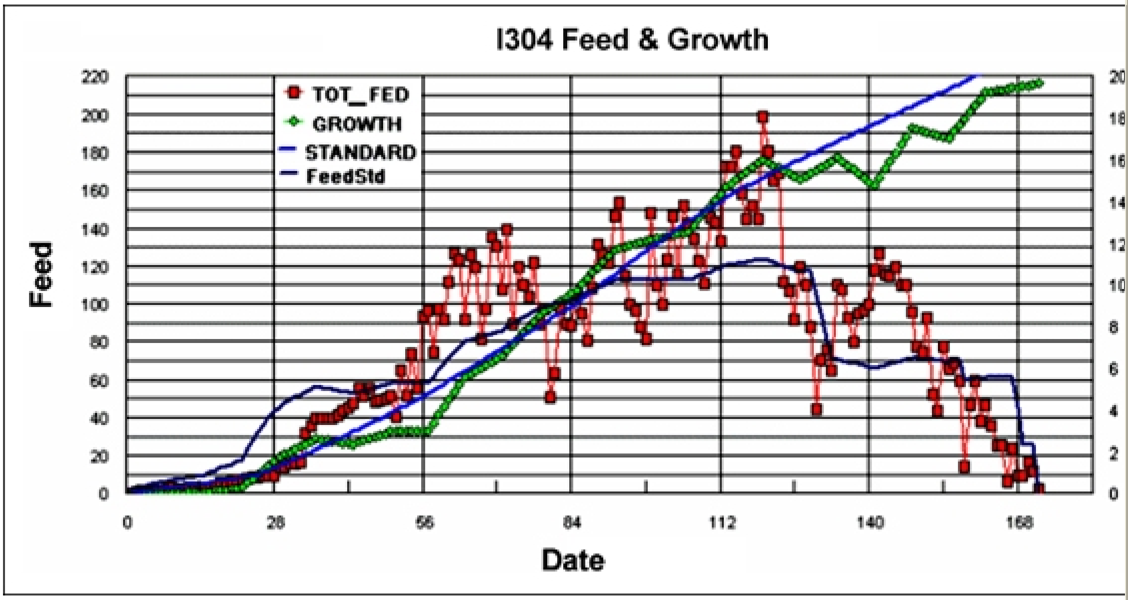

One-hectare pond feed and growth

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Sampling the shrimp population to estimate weekly growth

Sampling the shrimp population to estimate weekly growth

Preparing to remove shrimp from a partial harvest net

Parial harvest net

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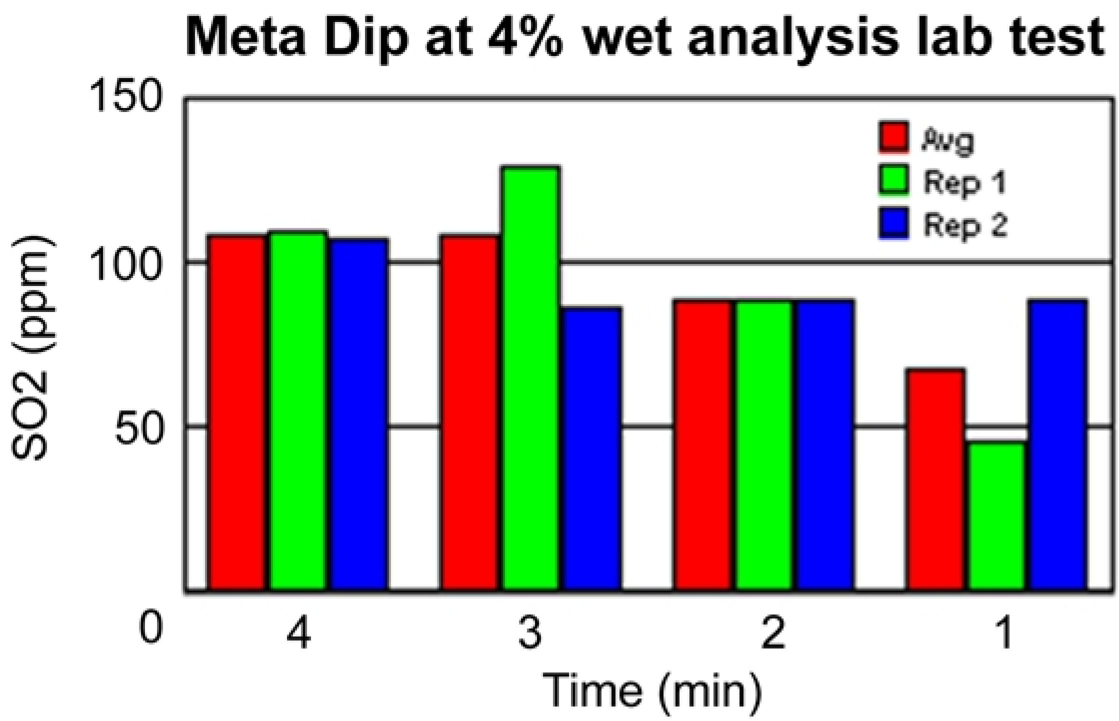
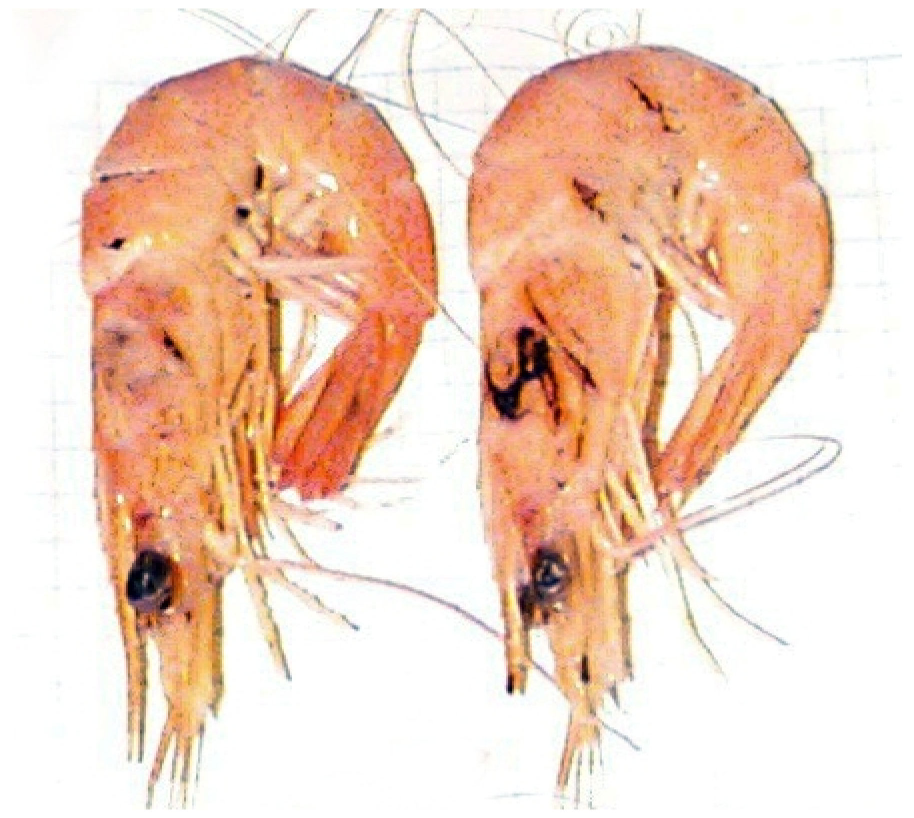


Sulfite on flesh of shrimp

Shrimp processing and boxing of product

Processing staff laying shrimp in boxes



Black spot on cooked shrimp; caused by injury in the pond, 1999 quality training by Empress

Microsporidia on shrimp, tail flesh turns white

Scylla serrata commonly found at Amatikulu and less frequently at Mtunzini

Scylla serrata commonly found at Amatikulu and less frequently at Mtunzini

©Guy Upfold

Some unwanted species from Amatikulu growout ponds

Tilapia bycatch from a growout pond at Mtunzini

Argyrosomus japonicus (mulloway) and filamentous algae from Amatikulu growout ponds

Pelletizer use to produce shrimp feed

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