The Use of a High Energy Feed for the Improvement of Trout Farm Effluents

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Chapter 1. Introduction

A number of factors have played a part in the recent growth and expansion of the aquaculture industry. This trend can be explained by an increased demand for low fa food coupled with a diminished supply of wild stock (Yoo *et al*, 1995). This growth in the aquaculture industry is expected to continue well into the 21st century. This expansion and growth has been coupled with an intensified amount of attention from environmental regulators. Although the discharges of trout raising facilities can be characterized as a high flow with a low solids content, the use of such high quality water resources has caught the attention of environmental regulatory agencies. The water quality parameters currently regulated by Virginia Department of Environmental Quality (VDEQ) include total suspended solids (TSS), settleable solids (SS), dissolved oxygen (DO), 5-day biochemical oxygen demand (BOD_5), total ammonia nitrogen (TAN), and total Kjeldahl nitrogen (TKN).

Although several efforts have been made to reduce the loadings of these contaminants, several studies have proven that aquaculture facilities must not only address the issues mentioned above; but must also acknowledge future regulations which may limit nutrient discharges. For example, facilities in Europe and Northern Idaho are currently regulated for phosphorus discharges.

Although the release of TKN and/or TAN are/is currently regulated und er some Virginia Pollution Discharge Elimination Systems (VPDES) permits, standards for all nitrogen species and phosphorus have not yet been generally applied.

1.1 Current Virginia Environmental Regulations

In order to understand the regulatory limits that the Virginia aquaculture facilities currently face, a summary of permit limits for two Virginia facilities is provided in Table 1.

Table 1.
VPDES discharge limits for Farms A and B.

Parameter	Farm A	Farm B
TSS (mg/L) avg./max.	10.0/15.0	10.0/15.0
SS (mg/L) avg./max.	NL/1.8	0.1/0.5
BOD_5 (mg/L)	10.0 (avg.)	NL
TAN (mg/L)	1.8	NL
pH	6.0 – 9.0	6.0 – 9.0
Dissolved Oxygen (mg/L) min.	6.6	NL

NL – Not regulated

These current regulations do not include limits for phosphorus, but it must be noted that these permits are subject to review and revision on a 5-year basis. Because o this, high discharges of phosphorus must not be ignored.

Although the discharges from the farms considered in this study complied with the regulations summarized in Table 1, the aquatic diversity in the receiving waters o these farms has been adversely affected, as shown through studies conducted by the VDEQ between the span of June 1995 and July 1996. These studies concluded that the waste loadings from the aquaculture facilities were impacting downstream water quality and benthic macroinvertebrates. A comparable study in North Carolina yielded similar results (Loch *et al*, 1996).

1.2 Research Objectives

The first objective was to observe the operations within two facilities and relate these processes to effluent water quality. Initial visits indicated that both of these raceway-style facilities have high, single-pass flows with low pollutant concentrations over a 24-hour period. These flows are much more difficult to treat than a low flow, highly concentrated waste stream (Summerfelt, 1998). Another key observation made at the two facilities was that solids spikes occurred encountered during feeding and harvesting. Another concern at each facility was the lack of space available for the implementation o several treatment options.

The second objective was to investigate the use of a high energy feed to reduce the solids content in raceway effluents. Because a high energy feed has a greater amoun of nutritional content per unit mass fed, less input is needed. Additionally, this feed is more digestible, so more of the feed is incorporated into fish biomass while less fecal matter is produced. By comparing the effluents of basins using high energy feed to those receiving a standard grower, these theories were tested.

The third objective of this study was to compare nitrogen (total Kjeldahl nitrogen and total ammonia nitrogen) levels in these different effluents. Although a previous study has shown that basins receiving high energy feeds produce elevated effluent levels of nitrogen (Heinen *et al*, 1996), a site specific analysis for the two facilities in this stud was deemed necessary.

In order to maintain anonymity for the two facilities that participated in this study, they are designated as Farm A and Farm B.

Chapter 2. Methods and Materials – Farm A

2.1 Site Description – Farm A

The characteristics of these two farms are listed in Table 2. Essentially, the onl differences between Farms A and B are the modern construction (concrete basins and drained sediment traps) and the increased attention given to basin cleaning at Farm B.

Table 2.
Site characteristics for Farms A and B.

	Farm A	Farm B
Avg. production (kgs./year)	80,000 – 115,000	55,000 – 82,000
Fish types	Rainbow, Brook, Brown	Rainbow, Brook, Brown
Feeding practice	Manually measured and fed	Manually measured and fed
Raceway construction	Earthen and concrete ponds	Earthen and concrete ponds
Flow range (gpm)	6,760 – 7,630	2,750 – 3,200
Source water	Spring	Spring
Manpower	4 – 6 employees	4 – 6 employees
Water Treatment	Sediment traps	Weekly basin cleanings, Sediment traps

2.2 Sampling and Monitoring - Farm A

At Farm A, sampling and monitoring was conducted on a monthly basis. Both grab and composite samples were taken at the facility influents, within designated raceways, and at the facility effluents. This work was conducted from September of 1997 to April of 1998. During this time, additional efforts were made to set up a pilot scale experiment comparing the effluents from basins receiving a standard trout grower to those from a high energy feed basin.

2.3 Experimental Setup – Farm A

In February of 1998, two similar size rectangular basins at Farm A were set aside for the experiment. These two basins were situated next to each other, and had similar constructions. Each basin was approximately 32 meters long, 2.4 meters wide, and 0.5 meters deep. Both shared a common concrete wall, and had earthen bottoms. In order to ensure that the amount of flow entering each basin was comparable, several flow measurements were taken using weir readings at the discharges of these basins. Comparing results of this approach to those from a calibrated flow measuring device checked the validity of these measurements. For this, a Swoffer velocity meter was used. On two separate occasions, values obtained from weir readings were within 2.5% o those using the velocity meter. These small differences ensured that flows could be measured as the flow passed over these weirs. Using this procedure, it was determined that influent flow rates at each basin were at comparable levels throughout the study.

On February 9th, 1998, a total of 8000 brown trout weighing 2352 pounds were equally split into these two basins described above. A final inventory was taken by the facility manager to ensure an equal split. This inventory showed that each basin contained 4000 brown trout weighing 1176 pounds, giving an average fish size of 3.4 fish/pound. This initial size was used to calculate initial feeding rates for these basins. One basin (designated SG) received a standard trout grower, while the other basin (designated HE) was fed a high energy trout grower. A simple schematic showing these basins is provided in Figure 1. Ziegler Brothers, Inc supplied both feeds. The makeup of the different feeds is shown in Table 3.

Table 3.
Nutritional content of a standard grower and a high energy trout grower (Technical information, Zeigler Brothers, Inc., 1998)

	Standard Trout Growe	High Energy Grower
Guaranteed Analysis		
Protein, %	38.0 (minimum)	42.0 (minimum)
Fat, %	8.0 (minimum)	18.0 (minimum)
Fiber, %	4.0 (maximum)	4.0 (maximum)
Moisture, %	9.0 (maximum)	12.0 (maximum)
Ash, %	12.0 (maximum)	10.0 (maximum)
Calculated Analysis		
Digestible Energy (kcal/kg)	3,050	4,270
Metabolizable Energy (kcal/kg)	2,670	4,000
Protein Digestibility, %	90.00	92.50
Nitrogen, %	6.080	6.720
Phosphorus, %	0.86	0.88

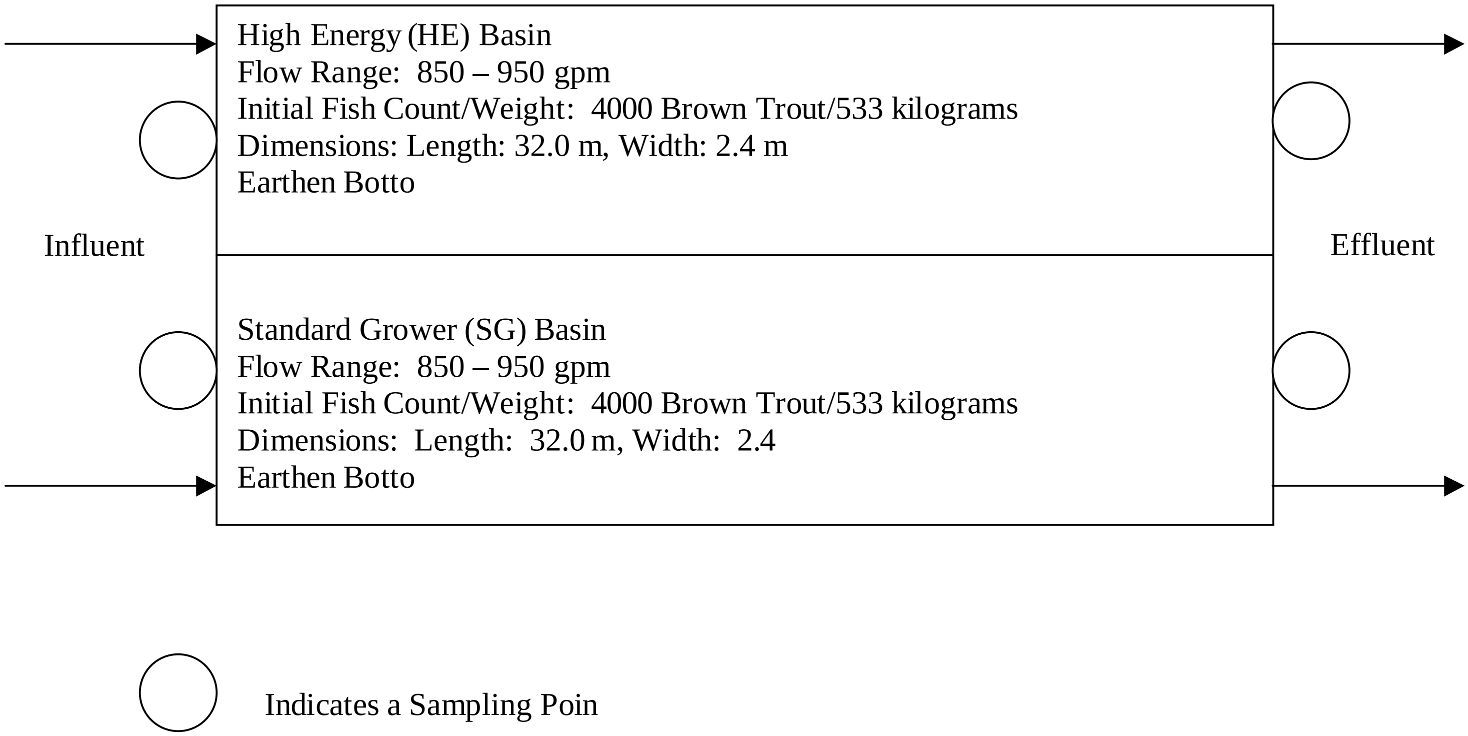

Figure 1. Schematic of experimental basins at Farm A.

Based on the amount of fish in each basin, the feeding rates were determined b using a suggested feeding guide supplied by Ziegler Brothers, Inc. Since these suggested feeding rates are based on fish size and number, the amounts were subject to change after monthly inventories were taken. The fish were fed half of their allotted feed once in the morning, and again in the afternoon. On February 9th, 1998, this feeding schedule was implemented. On February th, 1998, a periodic sampling and monitoring program was initiated.

2.4 Fish Inventories/Feed Records – Farm A

In order to accurately compare the amount of solids produced in each basin, detailed records of fish densities and feed inputs were kept for each basin. This was done in order to normalize effluent pollutants to the amount of feed input and account for differences between each basin. A difference in these required feed amounts stemmed from the relatively higher energy and nutrient content of the high energy feed. Because of this difference, less feed per pound of fish is required for the basin receiving the high energy feed. Fish densities for a given date could be calculated from daily feed input, feed conversion rates, stocking and harvesting events, and daily mortality rates. Although a number of assumptions were made in calculating fish densities, the final results were checked against monthly fish inventories conducted at the site.

2.5 Sampling and Monitoring of Experimental Basins – Farm A

TSS, TKN, and TAN analyses were all conducted in accordance with the 19th edition of Standard Methods (1995). The particle count analyses were performed using a HIAC/ROYCO Model PC-320 Automatic Particle Size Analyzer. Water temperature and DO content were measured using a Yellow Springs Instruments, Inc. Model 57 Meter with a Model 5905 BOD Probe. bi-weekly sampling and monitoring program lasted from February 10th, 1998, to August 28th, 1998. During each sampling event, several grab samples were taken at each sampling station, while an ISCO 24-hour composit sampler was placed at each of the two basins' point of discharge.

Chapter 3. Results - Farm A

3.1 TSS Discharges

When comparing simply the TSS levels of the two different effluents, discharges from the high energy basin tended to have lower concentrations of solids than the standard grower basin. Although a statistical analysis showed no significant difference between influent solids content at the 95% confidence level, TSS levels in the standard grower basin discharges exceeded those of the high energy basin in over 83 percent of the trials (n=43). From a statistical standpoint, TSS discharges from the standard grower basin were significantly greater than those from the high energy basin at the 95% confidence level. Figure 2 shows each basin's TSS discharges during this sampling period. The average for the standard grower basin discharges was 5.0 $\pm$ 4.5 mg/L TSS, while the high energy basin discharges averaged 1.8 $\pm$ 2.2 mg/L TSS. Figure 3 shows a

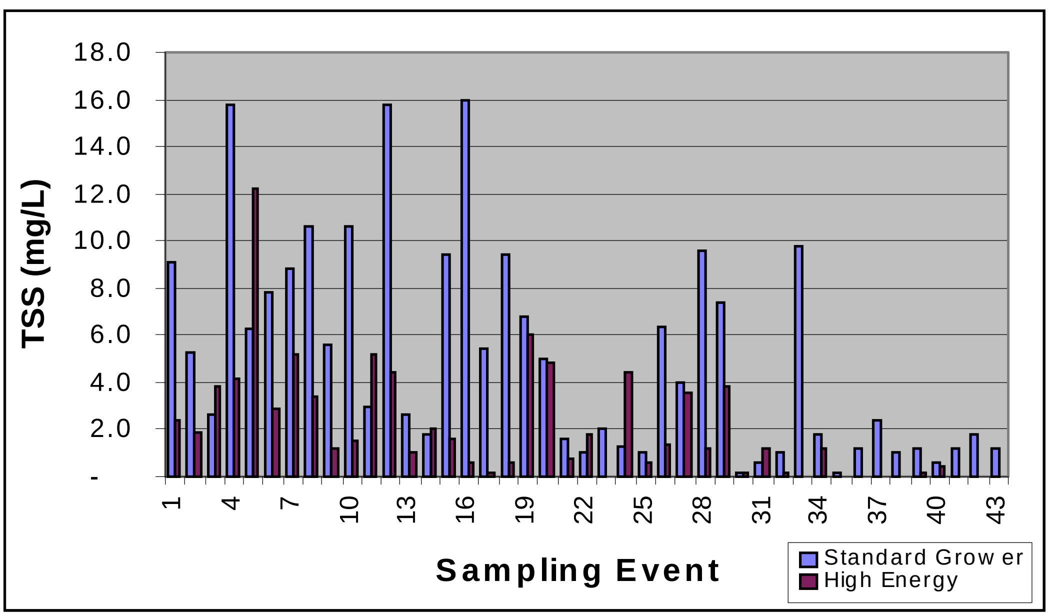

Figure 2. Effluent TSS levels for a standard grower basin and a high energy basin at Farm A.

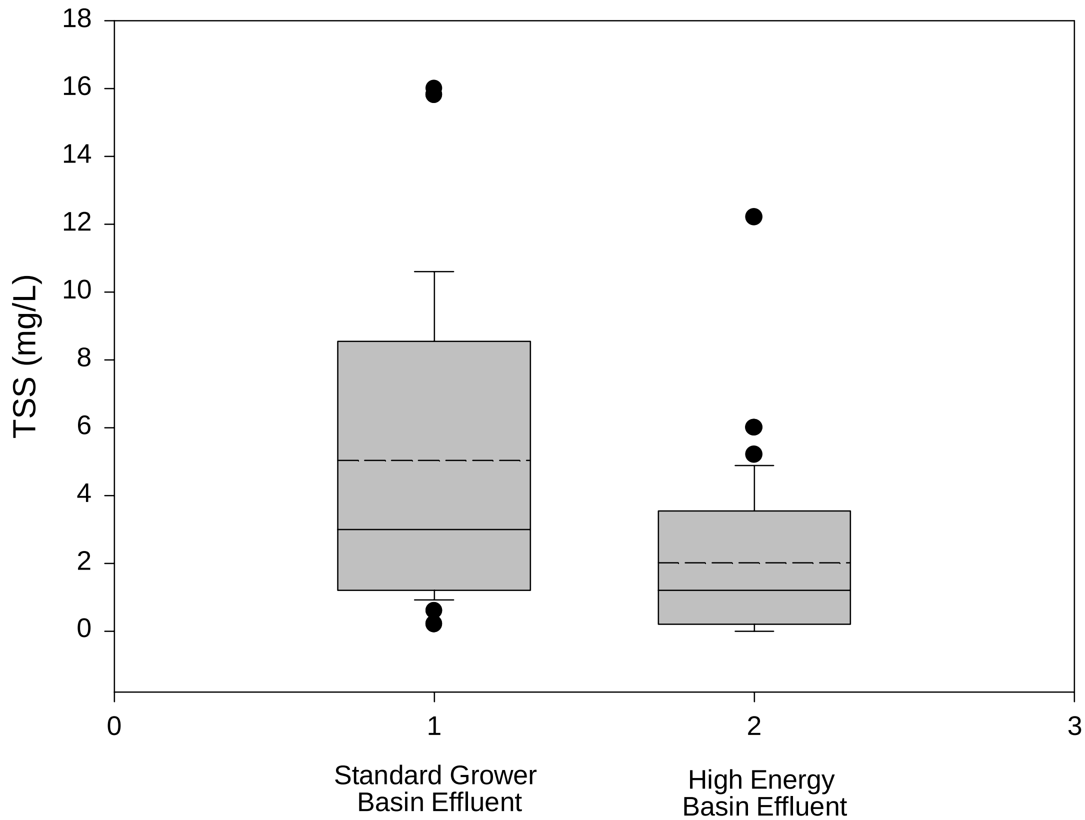

Figure 3. Box plot showing the statistical values for the standard grower feed basin effluents and the high energy feed basin effluents at Farm A

box plot outlining these results. These data were collected between the dates of February 10, 1998 to August 14, 1998. After this period, the basin originally receiving the standard trout grower was switched to the high energy feed. On August 28th, a number of samples were taken to observe any significant differences from the original trend. On this date, the TSS levels of the former standard grower basin exceeded that of the other basin only 5 out of 9 sampling events. The average for the basin previously receiving the standard grower was 0.4 ± 0.6 mg/L TSS.

On four separate occasions, a 24 hour composite sample was taken at the end of each basin to measure the average TSS discharges over a single day. The average for the standard grower basin composites was 4.9 mg/L TSS, while the high energy basin composites averaged 1.9 mg/L TSS.

The data were normalized in order to account for the larger amount of feed given to the standard grower basin. This revealed that in over 74 percent of samples taken, normalized values for the standard grower basin exceeded that of the high energy basin. Figure 4 displays these results. The monthly averages of the normalized data were also taken. This is shown in Figure 5.

Another analysis of the solids data for Farm A was the measurement of the TSS production within each basin. Subtracting influent TSS from effluent TSS made an estimate of solids contributed by waste feed and fecal matter. Figure 6 illustrates these differences.

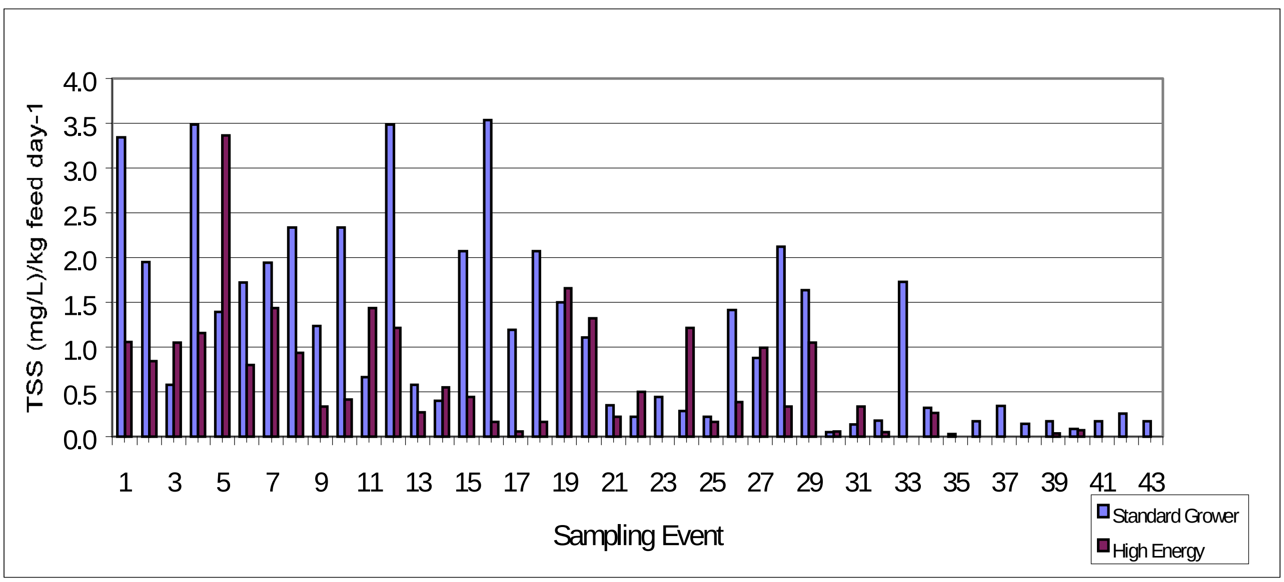

Figure 4. Effluent TSS values per kg. of feed given daily for the standard grower and high energy basins at Farm A

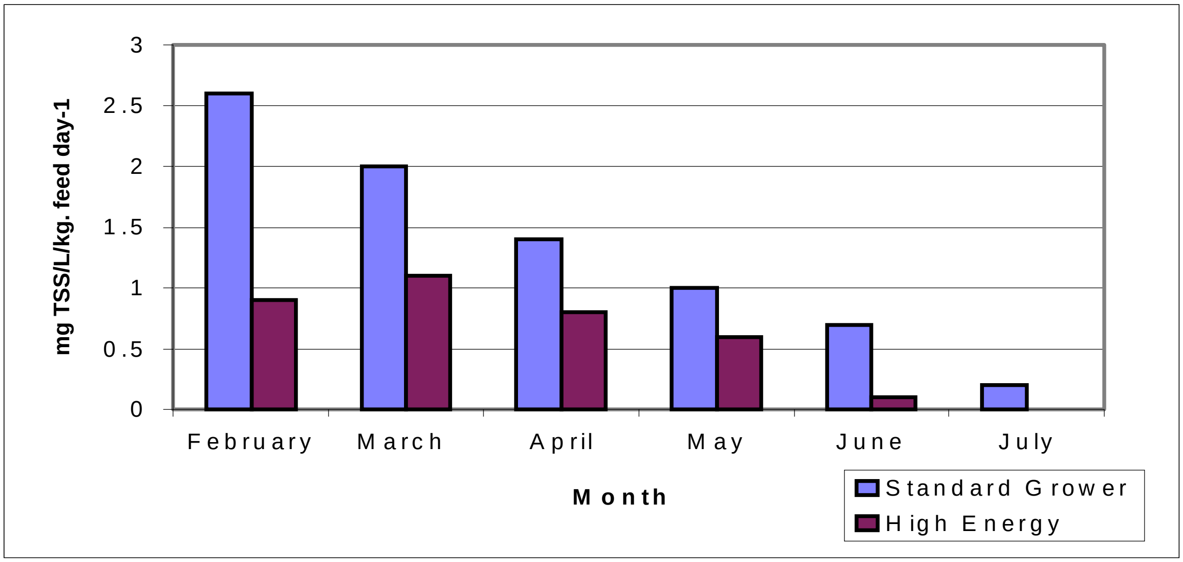

Figure 5. Monthly averages for normalized TSS discharges at Farm A.

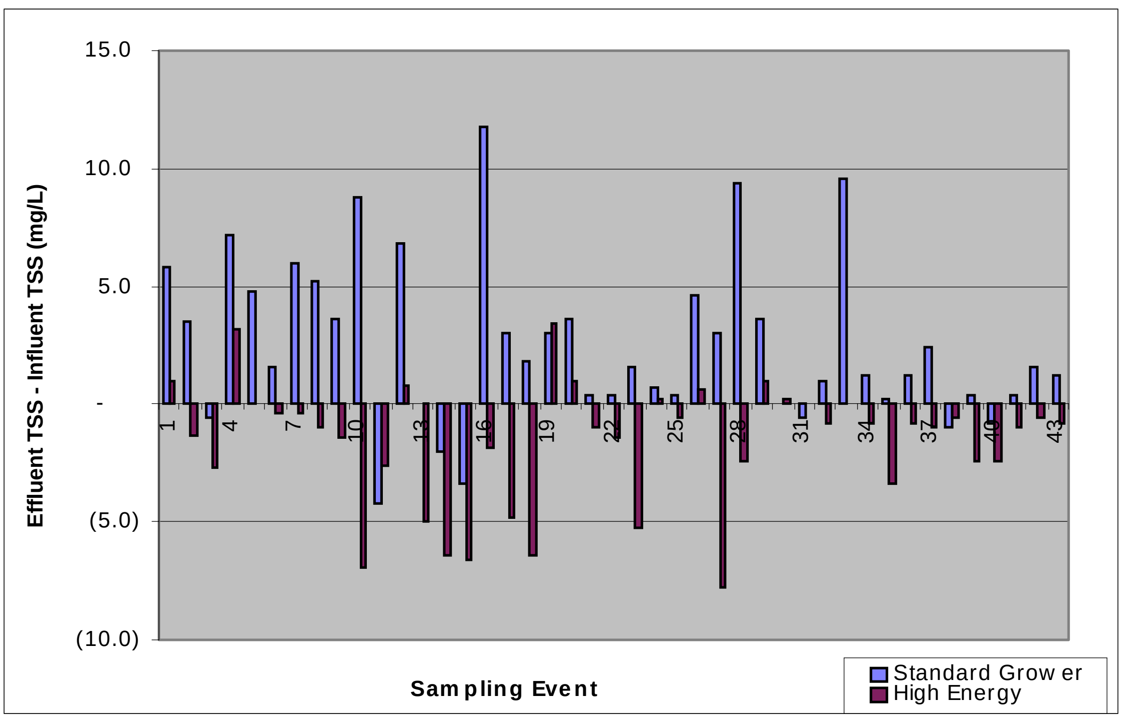

Figure 6. Net TSS production within a standard grower basin and a high energy basin.

3.2 Particle Counts

By analyzing samples with a HIAC Model PC-320 Automatic Particle Size analyzer, the size distribution of solids in the effluents was compared. Cripps (1995), in a previous study, demonstrated that typical aquaculture effluents contain a large percentage of relatively minute particles. TSS size distribution, of course, impacts on the performance of a treatment option. The values for the first of two different trials were plotted to compare particle distributions. The results are shown in Figures 7 and 8. The results for the second trial were similar to that of the first

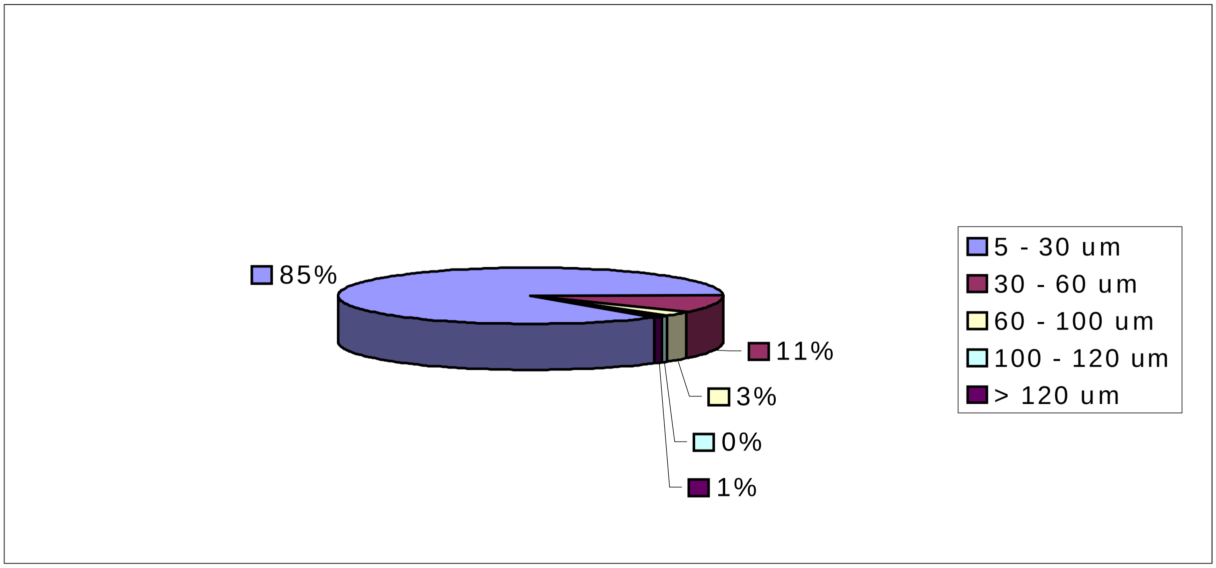

Figure 7. Particle size distribution of the standard grower basin effluent.
(average TSS = 4.2 mg/L)

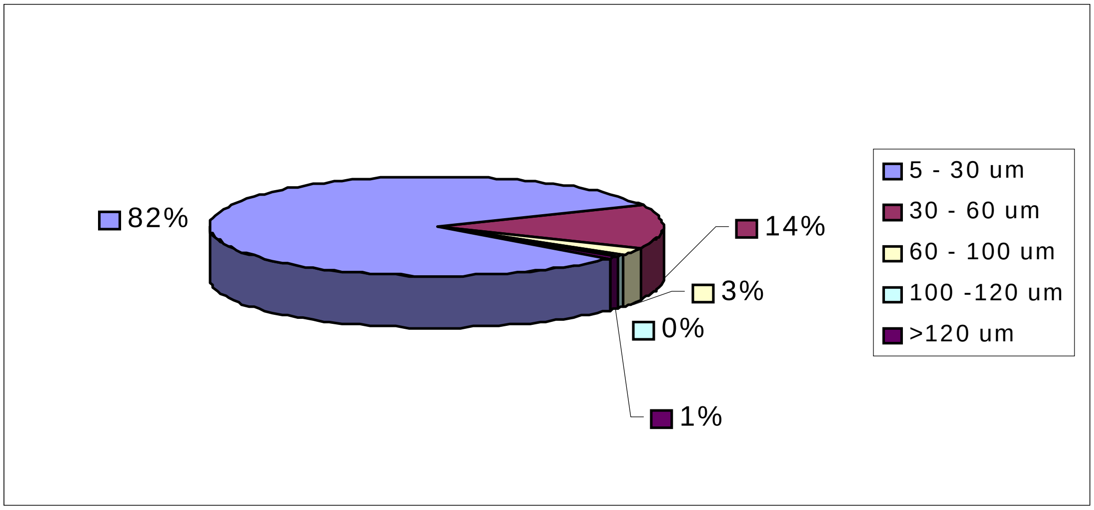

Figure 8. Particle size distribution of the high energy basin effluent (average TSS = 2.9 mg/L)

From this, it can be seen that the two effluents had similar particle size distributions. The most apparent characteristic of both effluents is the high proportion of solids in the 5 – 30 micron range.

3.3 Nitrogen

In comparing total nitrogen (in terms of TKN) for the two effluents, it was found that effluents from the high energy basin were susceptible to spikes. A comparison between the two effluents is shown in Figure 9. The average TKN level for the standard grower basin was 3.2 $\pm$ 1.8 mg/L while the high energy basin was slightly higher at 3.8 $\pm$ 3.0 mg/L. TAN values did not significantly differ between the two basins. The average TAN level for the standard grower basin was 0.8 $\pm$ 0.2 mg/L, while the high energy was slightly lower at 0.6 $\pm$ 0.3 mg/L. The TAN values for both basins at each sampling poin are shown in Figure 10.

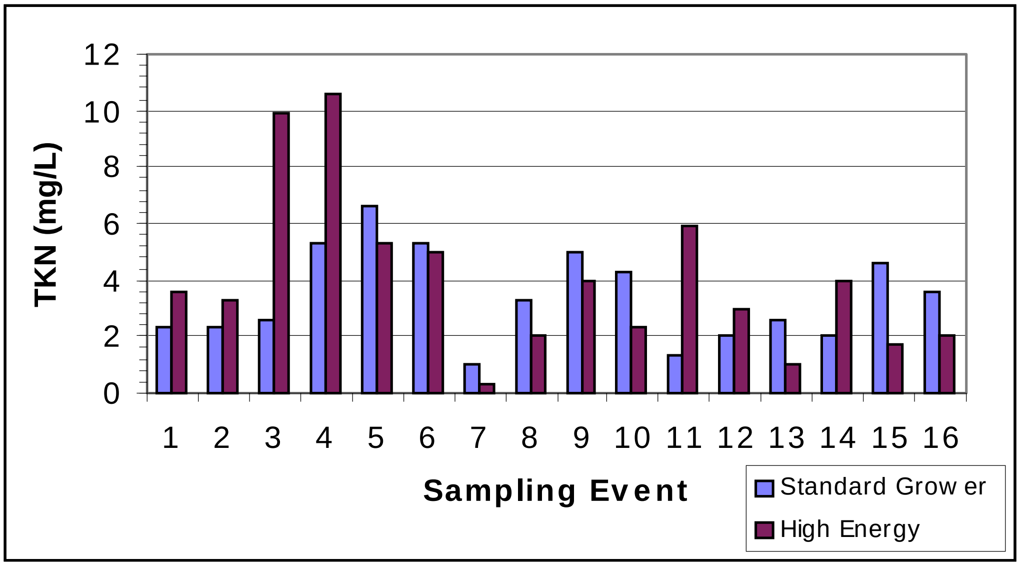

Figure 9. Effluent TKN values for a standard grower basin and a high energy basin.

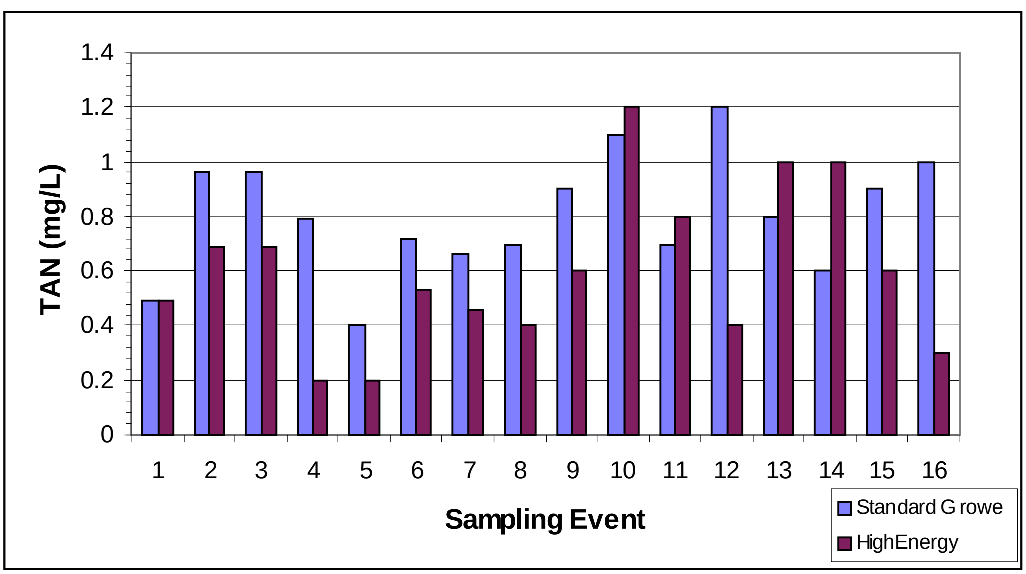

Figure 10. Effluent TAN values for a standard grower basin and a high energy basin.