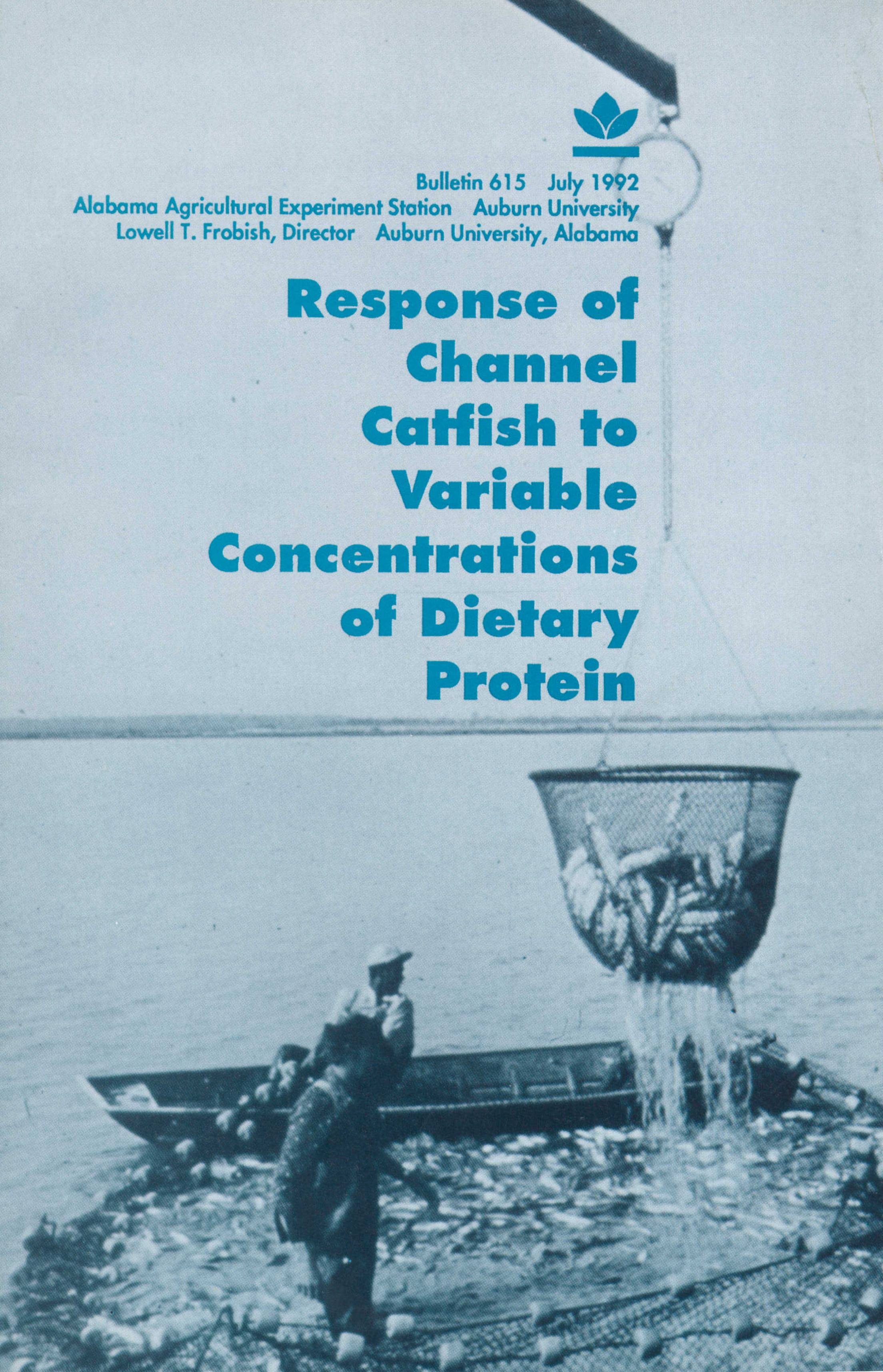
Bulletin 615 July 1992
Alabama Agricultural Experiment Station Auburn University
Lowell T. Frobish, Director Auburn University, Alabama

# Response of Channel Catfish to Variable Concentrations of Dietary Protein



# CONTENTS



FIRST PRINTING 3.5M, JULY 1992

# Response of Channel Catfish to Variable Concentrations of Dietary Protein

**Meng H. Li and Richard T. Lovell**

## INTRODUCTION

A NUMBER of studies have been conducted to determine the optimum dietary protein concentration for channel catfish *Ictalurus punctatus* in production ponds, and reported values have ranged from 25 to 45 percent *(8,11,13,14,15,16, 18,20,21)*. Reasons for this variation in the reported protein requirements are not clear but may be caused by differences in protein quality, energy content of the diet, fish size, or daily feed allowance *(9)*. The intensity of catfish culture has increased dramatically in the past decade, characterized by higher stocking rates and more generous daily feed allowances. With more liberal feeding, channel catfish might not require as high a percentage of protein in the diet as under restricted feeding.

Previous studies at the Alabama Agricultural Experiment Station *(14,15,16,18,20)* showed that 32 percent crude protein or more in practical catfish feeds provided for maximum weight gain; however, in those experiments feeding rate was restricted and usually reached a ceiling before the end of the growing season. Unrestricted or satiate feeding for the entire growing season might change the response of channel catfish to variable protein concentration in practical feeds.

Changing the protein percentage of the feed or daily feeding rate would be expected to change the composition of gain by the fish *(7)*; however, very little information is available on this. Recent concern for effects of body fat on sensory qualities of catfish flesh would indicate that an evaluation of effects of diet composition on composition of gain by channel catfish is in order.

A series of experiments was conducted at the Fisheries Research Unit of the Alabama Agricultural Experiment Station to address the following objectives: (1) evaluate effects of variable concentrations of dietary protein on weight gain, feed efficiency, protein efficiency, dressing percentage, and body composition for second- and third-year channel catfish fed to appetite in intensively-managed production ponds; (2) compare effects of various dietary protein concentrations fed at satiate and restricted feeding rates on weight gain, feed efficiency, dressing percentage, and body composition of second-year channel catfish; and (3) evaluate effects of dietary protein concentration on toxic nitrogenous wastes in intensively-managed catfish ponds.

## MATERIALS AND METHODS

### Experiment 1

***Second-year Fish***

Channel catfish fingerlings from the Alabama Agricultural Experiment Station, averaging 20.2 g, were stocked into 20 400-$m^2$ earthen ponds at a density of 13,590 fish per hectare and fed five experimental diets for 151 days.

The five practical-type diets containing 24, 28, 32, 36, and 40 percent protein were processed into extruded (floating) pellets (6-mm diameter) by a commercial feed manufacturer (MFC Services, Inc., Lumberton, Mississippi). The diets, table 1, were similar to those used commercially, with major ingredients being soybean meal, ground corn, and fish meal. Wheat middlings were substituted for some of the corn in the 24 percent protein diet to improve extrusion. Complete vitamin and trace mineral supplements were used. Protein concentration of the diets was adjusted by increasing protein percentage through substitution of a fixed ratio of soybean meal to fish meal (5:1) for corn. Energy concentration of the diets was not regulated; however, it only ranged from 3.09 to 3.17 kcal of digestible energy (DE) per gram of diet. Dicalcium phosphate was increased in the diets as fish meal decreased to meet the available phosphorus requirement of the fish. Essential amino acid requirements of channel catfish, as a percentage of dietary protein *(12)* were met in each diet. Crude protein in the diets was analyzed using the macro-Kjeldahl method *(2)*. DE was estimated from tabular values for individual diet ingredients *(12)*.

Each of the experimental diets was assigned randomly to four ponds. The fish were fed to satiation once daily from 6:30 to 7:30 p.m. throughout the growing season. Initially,

TABLE 1. INGREDIENT AND NUTRIENT COMPOSITION OF EXPERIMENTAL DIETS FED TO CHANNEL CATFISH IN EXPERIMENTAL PONDS

| Item | Protein percentage (Experiments 1 and 3) | | | | | Protein percentage (Experiment 2) | | |
|---|---|---|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | 40 | 26 | 32 | 38[1] |
| Ingredient (%): | | | | | | | | |
| Ground corn | 65.1 | 50.4 | 41.0 | 31.4 | 22.0 | 44.8 | 32.2 | 18.7 |
| Soybean meal, dehulled | 26.0 | 39.4 | 47.5 | 55.7 | 64.8 | 32.0 | 47.3 | 63.2 |
| Menhaden fish meal | 5.7 | 7.1 | 8.6 | 10.1 | 10.6 | 6.5 | 8.0 | 9.8 |
| Wheat middlings | 15.0 | .0 | .0 | .0 | .0 | 13.5 | 9.6 | 5.6 |
| Animal fat[2] | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Dicalcium phosphate | 1.55 | 1.45 | 1.30 | 1.15 | 1.00 | 1.5 | 1.3 | 1.0 |
| Trace mineral mix[3] | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| Fish vitamin mix[4] | .1 | .1 | .1 | .1 | .1 | .1 | .1 | .1 |
| Vitamin C[5] | .075 | .075 | .075 | .075 | .075 | .075 | .075 | .075 |
| Nutrient: | | | | | | | | |
| Crude protein, Pct. | 24.7 | 28.5 | 32.2 | 35.4 | 39.1 | 27.1 | 33.5 | 39.9 |
| DE, kcal/g diet[6] | 3.09 | 3.14 | 3.15 | 3.17 | 3.17 | 3.10 | 3.12 | 3.15 |
| Protein/DE ratio, mg/kcal | 79.9 | 90.7 | 102.2 | 111.6 | 123.3 | 87.4 | 103.1 | 126.6 |
| Sulfer amino acids, Pct. in protein[6] | 2.67 | 2.67 | 2.68 | 2.73 | 2.71 | 2.54 | 2.56 | 2.59 |
| Sulfer amino acid requirement[7], Pct. | 116.3 | 116.1 | 116.6 | 118.6 | 118.0 | 110.3 | 111.2 | 112.6 |
| Lysine, Pct. in protein[6] | 5.06 | 5.51 | 5.74 | 6.01 | 6.12 | 5.17 | 5.55 | 5.87 |
| Lysine requirement[7], Pct. | 99.5 | 108.3 | 112.8 | 118.1 | 120.3 | 101.6 | 109.0 | 115.4 |

[1] Designed protein percentage in the experimental diets.
[2] Sprayed on after processing.
[3] Trace mineral mix provided the following minerals per kilogram of feed: Zn, 150 mg; Fe, 44 mg; Mn, 25 mg; I, 5 mg; Cu, 3 mg; Co, 0.05 mg.
[4] Vitamin mix provided all of the following vitamins in the amounts presented per kilogram of feed: vitamin A, 4,000 I.U.; vitamin $D_3$, 2,000 I.U.; vitamin E, 50 mg; menadione, 10 mg; choline chloride, 500 mg; niacin, 80 mg; riboflavin, 12 mg; pyridoxine, 10 mg; thiamine, 10 mg; pantothenic acid, 32 mg; folic acid, 2 mg; vitamin $B_{12}$, 8 µg; ethoxyquin (antioxidant), 125 mg.
[5] As ethylcellulose-coated L-ascorbic acid (98 percent) from Roche Chemical, Nutley, New Jersey.
[6] Digestible energy (DE) and digestible amino acid content were estimated from tabular values for the diet ingredients (National Research Council, 1983).
[7] Amino acid requirements are from National Research Council (1983).

the fish were allowed to feed until feeding activity stopped (about 30 minutes), after which the remaining pellets were removed and counted to obtain an estimate of feed consumed. This amount was fed until feeding activity indicated that the allowance should be increased by about 10 percent; this was approximately every 3 to 5 days in the early part of the feeding period, and at greater intervals as the feeding period progressed. During the latter part of the feeding period, there was a decline in temperature and feed consumption decreased. Feed consumption, water temperature, and dissolved oxygen were recorded daily for each pond.

Two feeding rings (2-m diameter) made from 5-cm-diameter black plastic pipe with a 20-cm-deep screen attached to the ring were placed 2 m apart in each pond to retain the floating feed. A 0.25-kw lift-type aerator (Model AF-53, Air-O-Lator Co., Kansas City, Missouri) was set in each pond. All ponds were aerated between 8:30 p.m. to 8:00 a.m daily, beginning week 9 and continuing through week 20 of the feeding period. Total aerating time was approximately 5 hours per day.

At the end of the experiment, all fish were removed and total number and weight of fish in each pond were determined. Five fish from each pond were sampled to determine dressing percentage and body composition. Dressing percentage was weight of fish with head, skin, and viscera removed relative to weight of the whole fish. A fillet was taken from each dressed carcass and homogenized for analyses for protein (macro-Kjeldahl method), fat (modified Babcock method), and moisture (oven drying), using procedures of the Association of Official Analytical Chemists *(2)*. Analyses of variance with orthogonal contrasts and tests for regression among protein concentrations were conducted for weight gain, feed consumption, feed conversion, protein efficiency ratio, dressing percentage, and body composition *(19)*. Simple correlations between the measured variables also were performed.

### *Third-year Fish*

Channel catfish from the Alabama Agricultural Experiment Station, averaging 594 g, were stocked into 20 400-$m^2$ earthen ponds at a density of 4,942 fish per hectare and fed the same five experimental diets that were fed to second-year fish (previous study) to satiety for 141 days. Feeding procedures, pond management, and data collection and analyses were the same as described for the second-year fish. Orthogonal contrasts were made between second- and third-year fish for feed conversion, dressing percentage, body composition, and protein efficiency ratio.

## Experiment 2

A 2x3 factorial experiment, using two feeding regimes (satiate or restricted feeding) and three concentrations of dietary protein (26, 32, or 38 percent), was conducted during a 125-day growing season in 24 400-$m^2$ earthen ponds. Each treatment was assigned randomly to four ponds. Each pond was stocked with channel catfish fingerlings from the Alabama Agricultural Experiment Station, averaging 59.6 g, at a density of 13,590 fish per hectare. All ponds were aerated continuously from 1:00 to 7:00 a.m. daily, beginning week 8 and continuing through the end of the feeding period.

Three practical-type diets, table 1, similar to those used in Experiment 1, except for the protein concentrations, were prepared. Fish in all ponds were fed to satiation once daily from 6:30 to 7:30 p.m. until approximately week 9 of the feeding period when the fish were being fed approximately 60 kg per hectare per day. Then, the experimental ponds were randomly divided into two groups, one for satiate feeding and the other for restricted feeding. Satiate feeding management was similar to that described for Experiment 1, while feed allowance for fish in the restricted feeding group was held at 60 kg of feed per hectare per day for the remainder of the feeding period. During the latter part of the experiment, a decrease in temperature caused a decline in feed consumption by fish under satiate feeding.

Analysis of variance with orthogonal contrasts was used to test mean differences between satiate and restricted feeding and among dietary protein percentages. The same evaluations were made as in Experiment 1. Other pond management and data collection and analyses were the same as described for Experiment 1.

## Experiment 3

Nitrogenous waste compounds in the ponds and methemoglobin in the fish blood were measured during the feeding trial for third-year fish in Experiment 1. Water samples were collected biweekly at 3 p.m. (from week 9 to the end of the feeding period) from each pond and analyzed according to procedures of American Public Health Association et al. *(1)* for total ammonia-nitrogen (TAN) using the phenate method, nitrite-nitrogen ($NO_2^-$-N) using the diazotization method, chloride ($Cl^-$) using the mercuric nitrate method, and pH using a pH meter. The concentration of $NH_3$-N was calculated according to TAN concentration, temperature and pH *(4)*. Methemoglobin was measured in 10 fish from each pond at the time of harvest. Blood was drawn from the caudal artery into 2-ml evacuated blood collecting tubes (Becton Dickinson Vacutainer Systems, Rutherford, New Jersey), and the percentage methemoglobin was determined by procedures of Tietz *(22)*.

Analyses of variance with orthogonal contrasts and tests for regression among dietary protein concentrations were conducted for TAN, $NH_3$-N, $NO_2^-$-N, and methemoglobin *(19)*. Simple correlations between the measured variables also were performed.

## RESULTS

### Experiment 1

#### *Growth*

Maximum weight gain, table 2, by second-year fish was obtained with the lowest protein diet (24 percent); however, the effect of dietary protein concentration on weight gain was not significant ($P>0.10$). Maximum weight gain by third-year fish also was obtained with the 24 percent protein diet; dietary protein had a negative linear effect on weight gain ($P<0.001$).

#### *Feed Consumption and Feed Efficiency*

Mean maximum daily feed allowance for second-year fish was 85 kg per hectare, and for third-year fish was 105 kg per hectare. Dietary protein concentration had no effect on feed consumption, table 3, by second-year fish ($P>0.10$) and had a negative linear effect on feed consumption of third-year fish ($P<0.001$). Dietary protein concentration had no effect on feed conversion (feed per gain) in both year-groups ($P>0.10$).

TABLE 2. MEANS FOR FINAL WEIGHT AND WEIGHT GAIN OF CHANNEL CATFISH IN EXPERIMENT 1

| Pct. dietary protein | Final weight[1] (g/fish) | Weight gain[2] (g/fish) |
|---|---|---|
| Second-year fish | | |
| 24 | 517 | 497 |
| 28 | 481 | 461 |
| 32 | 462 | 442 |
| 36 | 475 | 455 |
| 40 | 507 | 487 |
| | | NS (P>0.10) |
| Third-year fish | | |
| 24 | 1,859 | 1,265 |
| 28 | 1,707 | 1,113 |
| 32 | 1,579 | 985 |
| 36 | 1,494 | 900 |
| 40 | 1,523 | 929 |
| | | L (P<0.001) |

[1] Mean initial weights were 20.2 and 594.0 g for second- and third-year fish, respectively.
[2] Standard errors for means for weight gain were 18.2 and 55.0 for second- and third-year fish, respectively. NS=no significant effect of dietary protein concentration; L=linear effect of dietary protein concentration.

TABLE 3. MEANS FOR FEED CONSUMPTION, FEED CONVERSION, AND PROTEIN EFFICIENCY RATIO (PER) FOR CHANNEL CATFISH IN EXPERIMENT 1

| Pct. dietary protein | Feed consumption[1] (g/fish) | Feed conversion[1] (feed/gain) | PER[1] (gain/ protein fed) |
|---|---|---|---|
| Second-year fish | | | |
| 24 | 713 | 1.43 | 2.82 |
| 28 | 678 | 1.47 | 2.39 |
| 32 | 607 | 1.38 | 2.27 |
| 36 | 636 | 1.40 | 2.02 |
| 40 | 662 | 1.35 | 1.90 |
| | NS (P>0.10) | NS (P>0.10) | L (P<0.001) |
| Third-year fish | | | |
| 24 | 2,315 | 1.83 | 2.31 |
| 28 | 2,057 | 1.85 | 1.93 |
| 32 | 1,751 | 1.78 | 1.75 |
| 36 | 1,742 | 1.94 | 1.47 |
| 40 | 1,717 | 1.86 | 1.41 |
| | L (P<0.001) | NS (P>0.10) | L (P<0.001) |

[1] Standard errors for means were 32.7, 0.04, and 0.07 for feed consumption, feed conversion, and PER for second-year fish, respectively, and were 106.2, 0.08, and 0.07 for feed consumption, feed conversion, and PER for third-year fish, respectively. NS=no significant effect of dietary protein concentration; L=linear effect of dietary protein concentration.

Weight gain was positively correlated with feed consumption by second-year fish (r=0.80, P<0.001), and third year fish (r=0.90, P<0.001). Mean feed conversion of 1.85 for third-year fish was higher, compared to 1.41 for second-year fish (P<0.001). Protein efficiency ratio (PER, gain per protein fed) decreased linearly with increasing dietary protein percentage for both year-groups (P<0.001). Mean PER of 2.28 for second-year fish was higher, compared to 1.77 for third-year fish (P<0.001).

### *Dressing Percentage and Body Composition*

Mean dressing percentage, table 4, of second-year fish increased as dietary protein increased from 24 to 36 percent and decreased as protein increased from 36 to 40 percent, showing a quadratic effect of dietary protein on dressing percentage (P<0.05). Dressing percentage for third-year fish was not affected by dietary protein concentration (P>0.10). Mean dressing percentage of 66.8 for third-year fish was higher than 60.0 for second-year fish (P<0.001). Fat content in muscle decreased linearly as dietary protein increased for both year-groups (P<0.05). The mean fat content of 9.6 percent in muscle of third-year fish was higher than the 7.3 percent for second-year fish (P<0.001). Protein and moisture

TABLE 4. MEANS FOR DRESSING PERCENTAGE AND FAT, PROTEIN, AND MOISTURE IN MUSCLE OF CHANNEL CATFISH IN EXPERIMENT 1

| Pct. dietary protein | Dressing pct.[1] | Pct. fat[1] | Pct. protein[1] | Pct. moist.[1] |
|---|---|---|---|---|
| Second-year fish | | | | |
| 24 | 59.5 | 8.3 | 16.5 | 74.2 |
| 28 | 60.2 | 8.1 | 16.9 | 74.5 |
| 32 | 60.8 | 6.7 | 17.2 | 75.5 |
| 36 | 61.0 | 6.5 | 16.9 | 75.8 |
| 40 | 58.3 | 7.0 | 17.5 | 74.8 |
| | Q (P<0.05) | L (P<0.05) | L (P<0.05) | L (P<0.10) |
| Third-year fish | | | | |
| 24 | 67.2 | 11.0 | 16.4 | 71.2 |
| 28 | 67.0 | 9.6 | 17.1 | 71.4 |
| 32 | 66.3 | 9.2 | 17.1 | 72.2 |
| 36 | 67.3 | 9.6 | 17.7 | 72.6 |
| 40 | 66.3 | 8.7 | 17.4 | 73.2 |
| | NS (P>0.10) | L (P<0.05) | L (P<0.05) | L (P<0.10) |

[1] Standard errors for means were 0.60, 0.53, 0.30, and 0.74 for second-year fish, and were 0.78, 0.51, 0.32, and 0.79 for third-year fish for dressing percentage and for fat, protein, and moisture content in muscle, respectively. Q=quadratic effect of dietary protein concentration; L=linear effect of dietary protein concentration; NS=no significant effect of dietary protein concentration.

in muscle increased with corresponding decreases in muscle fat ($P<0.01$) for both year-groups.

## Experiment 2

### *Growth*

Mean weight gain of 508 g for satiate feeding was higher than 410 g for restricted feeding ($P<0.001$). There was an interaction between feeding regime and dietary protein concentration for weight gain ($P<0.05$); weight gain, table 5, by fish fed to satiation decreased linearly as dietary protein content increased ($P<0.05$), while weight gain by fish under restricted feeding increased linearly with increasing dietary protein percentage ($P<0.05$).

TABLE 5. MEANS FOR FINAL WEIGHT AND WEIGHT GAIN FOR CHANNEL CATFISH IN EXPERIMENT 2

| Pct. dietary protein | Final weight[1] (g/fish) | Weight gain[2] (g/fish) |
|---|---|---|
| Satiate feeding | | |
| 26 | 593 | 533 |
| 32 | 562 | 502 |
| 38 | 539 | 479 |
| | | L ($P<0.05$) |
| Restricted feeding | | |
| 26 | 448 | 388 |
| 32 | 457 | 397 |
| 38 | 496 | 436 |
| | | L ($P<0.05$) |

[1] Mean initial weights was 59.6 g.
[2] Standard errors for mean for weight gain was 14.2. L=linear effect of dietary protein concentration.

### *Feed Consumption and Feed Efficiency*

Mean maximum feed allowance for satiate feeding, 120 kg per hectare per day, was reached near the end of the experiment, but under restricted feeding a feed allowance of 60 kg per hectare per day remained constant from week 9 to the end of the experiment. Under satiate feeding, feed consumption, table 6, decreased linearly as dietary protein percentage increased ($P<0.05$). Weight gain of fish fed to satiation was positively correlated with feed consumption ($r=0.92$, $P<0.01$). Feed consumption of restricted-fed fish was not different among dietary protein concentrations because the experimental design controlled the feed allowance.

Feed conversion (feed per gain) by fish under satiate feeding was 1.44 and was higher than 1.25 under restricted feeding (P<0.01). Feed conversion by fish under satiate feeding was not affected by dietary protein concentration (P>0.10), but under restricted feeding feed conversion decreased linearly as dietary protein percentage increased (P<0.05). Protein efficiency ratio (PER, weight gain per protein fed) under satiate feeding was 2.17, lower than that of 2.40 under restricted feeding (P<0.001), and decreased linearly as dietary protein concentration increased for both feeding regimes (P<0.001).

TABLE 6. MEANS FOR FEED CONSUMPTION, FEED CONVERSION, AND PROTEIN EFFICIENCY RATIO (PER) FOR CHANNEL CATFISH IN EXPERIMENT 2

| Pct. dietary protein | Feed consumption[1] (g/fish) | Feed conversion[1] (feed/gain) | PER[1] (gain/ protein fed) |
|---|---|---|---|
| Satiate feeding | | | |
| 26 | 783 | 1.47 | 2.51 |
| 32 | 706 | 1.40 | 2.13 |
| 38 | 696 | 1.46 | 1.72 |
| | L (P<0.05) | NS (P>0.10) | L (P<0.001) |
| Restricted feeding | | | |
| 26 | 511 | 1.32 | 2.81 |
| 32 | 487 | 1.23 | 2.44 |
| 38 | 528 | 1.21 | 2.07 |
| | | L (P<0.05) | L (P<0.001) |

[1] Standard errors for means were 23.4, 0.03, and 0.06 for feed consumption, feed conversion, and PER, respectively. L=linear effect of dietary protein concentration; NS=no significant effect of dietary protein concentration.

## *Dressing Percentage and Body Composition*

Mean dressing percentage for satiate feeding, 66.2, was higher than that for restricted feeding, 64.8 (P<0.01). Dressing percentage, table 7, increased as dietary protein increased from 26 to 32 percent and decreased as protein increased from 32 to 38 percent, showing a quadratic effect (P<0.05). Mean fat content in muscle was higher in fish fed to satiation than in those under restricted feeding (P<0.01), and decreased linearly for both feeding regimes as dietary protein increased (P<0.01). Fat in muscle for both satiate and restricted feeding regimes was inversely correlated with the protein per DE ratio of the diets ($r=-0.70$, $P<0.05$, for satiate feeding; $r=-0.74$, $P<0.05$, for restricted feeding). Protein and moisture content of fish muscle were not different between the two feeding regimes ($P>0.10$) and both increased linearly as dietary protein concentration increased ($P<0.01$). Protein and moisture varied inversely with fat content ($P<0.05$).

TABLE 7. MEANS FOR DRESSING PERCENTAGE AND FAT, PROTEIN, AND MOISTURE IN MUSCLE OF CHANNEL CATFISH IN EXPERIMENT 2

| Pct. dietary protein | Dressing pct.[1] | Pct. fat[1] | Pct. protein[1] | Pct. moist.[1] |
|---|---|---|---|---|
| Satiate feeding | | | | |
| 26 | 64.7 | 8.1 | 16.9 | 74.3 |
| 32 | 67.2 | 6.7 | 17.1 | 75.2 |
| 38 | 66.8 | 6.2 | 18.0 | 76.3 |
| | Q (P<0.05) | L (P<0.01) | L (P<0.01) | L (P<0.01) |
| Restricted feeding | | | | |
| 26 | 63.6 | 6.6 | 17.1 | 75.2 |
| 32 | 65.7 | 5.3 | 17.3 | 77.0 |
| 38 | 65.1 | 5.1 | 17.7 | 76.9 |
| | Q (P<0.05) | L (P<0.01) | L (P<0.01) | L (P<0.01) |

[1] Standard errors for means were 0.40, 0.50, 0.23, and 0.36 for dressing percentage and for fat, protein, and moisture content in muscle, respectively. Q=quadratic effect of dietary protein concentration; L=linear effect of dietary protein concentration.

## Experiment 3

### *Toxic Nitrogenous Wastes in Pond Water*

Means for concentrations of total ammonia-nitrogen (TAN), unionized ammonia-nitrogen ($NH_3$-N), and nitrite-nitrogen ($NO_2^-$-N) are presented in table 8. Measurements were made from week 9 to the end of the experiment, which covered the heavy feeding period. Total ammonia-nitrogen increased linearly as dietary protein concentration increased ($P<0.10$). There was positive correlation between TAN and total protein fed ($r=0.55$, $P<0.05$). Unionized ammonia-nitrogen, however, was not influenced by dietary protein concentration ($P>0.10$). Dietary protein concentration had a positive linear effect on $NO_2^-$-N concentration ($P<0.001$). Nitrite-nitrogen was positively correlated with total protein fed ($r=-0.80$, $P<0.001$) and TAN concentration in the pond water ($r=0.60$, $P<0.05$). There was no correlation between $NO_2^-$-N concentration and weight gain ($r=-0.34$, $P>0.10$). Chloride

TABLE 8. MEANS FOR TOTAL FEED AND PROTEIN FED, CONCENTRATIONS OF TOTAL AMMONIA-NITROGEN (TAN), UNIONIZED AMMONIA-NITROGEN ($NH_3$-N) AND NITRITE-NITROGEN ($NO_2^-$-N), AND $NO_2^-/Cl^-$ MOLAR RATIO IN PRODUCTION PONDS WITH CHANNEL CATFISH IN EXPERIMENT 3

| Pct. dietary protein | Total feed (kg/ha) | Total feed (kg/ha) | TAN[1] (mg/l) | $NH_3$-N[1] (mg/l) | $NO_2^-$-N[1] (mg/l) | $NO_2^-/Cl$[1,2] (mg/l) |
|---|---|---|---|---|---|---|
| 24 | 10,587 | 2,615 | 0.94 | 0.08 | 0.09 | 0.09 |
| 28 | 9,467 | 2,698 | 1.00 | .25 | .11 | .10 |
| 32 | 7,876 | 2,536 | .70 | .15 | .13 | .13 |
| 36 | 8,164 | 2,890 | 1.84 | .21 | .24 | .23 |
| 40 | 7,931 | 3,101 | 1.48 | .26 | .33 | .32 |
| | | | L ($P<0.10$) | NS ($P>0.10$) | L ($P<0.001$) | L ($P<0.001$) |

[1] Standard errors for means for TAN, $NH_3$-N, $NO_2^-$-N, and $NO_2^-/Cl^-$ were 0.30, 0.09, 0.08, and 0.08, respectively. L=linear effect of dietary protein concentration; NS=no significant effect of dietary protein concentration.

[2] Nitrite to chloride ratio was on molar basis. Chloride concentration was 2.6 mg/l.

concentration in the pond water, 2.6 +/- 0.2 mg per l, was not affected by diets. There were no overt signs of $NH_3$ or $NO_2^-$ toxicity in the fish, namely gill hyperplasia and dark coloration of the blood, respectively.

Percentage methemoglobin in the fish blood, which was measured at the termination of the experiment, was positively correlated with the $NO_2^-$ per $Cl^-$ molar ratio in the pond water measured at this time ($r=0.78$, $P<0.05$).

## DISCUSSION

Previous research has shown that maximum weight gain by channel catfish fed to marketable size often occurred when fish were fed diets containing 32 percent protein or above *(8,14,15,16,18,20)*, although some reports have indicated optimum weight gain at lower protein concentrations *(5,7,13,21)*. The reason for lack of consistency in response of channel catfish to the different concentrations of dietary protein in these studies has not been clear. Feeding rate could be a factor because when catfish were fed at less than satiation, especially during the latter phase of the feeding period, higher protein feeds were more productive than lower ones.

Prather and Lovell *(15)* fed second-year catfish (5,000 fish per hectare) with a maximum daily feed allowance of 34 kg per hectare, which was reached in mid-August and remained constant until the end of the growing season (mid-October), and found that fish fed 42 percent protein had greater weight gain than those fed 32 percent protein. Sun *(20)* fed second-year catfish (7,400 fish per hectare) with a maximum feed allowance of 39 kg per hectare per day, which was reached in mid-summer, and obtained better growth with 36 percent protein than that with 25 or 30 percent protein. Recently, Reis et al. *(16)* found higher production with second-year catfish fed 35 and 39 percent dietary protein than with fish fed 26 and 31 percent dietary protein; their diets and experimental conditions were similar to those in the present study; however, they fed at a lower rate. Possibly, in the studies of Hastings *(8)*, Prather and Lovell *(14,15)*, Reis et al. *(16)*, Rodriguez *(18)*, and Sun *(20)*, the fish were not fed to satiation and thus benefitted from the higher protein diets, whereas in the studies of Cacho *(5)*, Deru *(7)*, Page and Andrews *(13)*, and Tiemeier and Deyoe *(21)*, the fish were fed nearer to satiation and did not benefit from the higher protein diets. This possibility is supported by the study of Minton *(11)* who found that weight gain by second-year catfish was not significantly different when fish were fed dietary protein concentrations of 30 and 36 percent at satiate feeding but at 75 percent of satiate feeding fish fed the 30 percent protein diet had significantly less weight gain than fish fed the 36 percent protein diet. Mangalik *(10)* found that increasing protein in diets of satiate-fed small channel catfish (1 to 10 g) from 27 to 39 percent did not increase weight gain by the fish at a low digestible energy concentration, but when digestible energy was increased, feed consumption (and protein consumption) decreased and the fish fed the lower-protein diet grew less.

The interaction between feeding regime and dietary protein concentration on weight gain in Experiment 2 indicates that response of fish to different dietary protein concentrations is influenced by feeding rate, which might explain why the reported protein requirements of channel catfish grown to marketable size is so variable. Mangalik *(10)* established regression of dietary crude protein and DE for maximum growth on fish size. He found that 250 g channel catfish require 0.43 g of protein and 5 kcal of DE per 100 g body weight daily and demonstrated that this would be provided in a 27 percent protein diet with satiate feeding. In the present study, daily protein and DE allowances for second-year channel catfish fed the 24 percent protein diet at satiate feeding (Experiment 1) 1 week prior to harvest when feeding was maximum, were 0.42 g and 5.5 kcal per 100 g body weight of fish. Apparently, the second-year fish fed the 24 to 26 percent protein diets were obtaining sufficient protein and DE for maximum growth. Each of the diets in this study was sufficient in essential amino acids *(12)*.

The fact that weight gain was unchanged or decreased when dietary protein increased when the fish were fed to satiety indicates that when second- and third-year channel catfish are fed to near appetite, increasing dietary protein beyond 24 percent will not improve weight gain. In fact, the higher protein diets may suppress weight gain with highly intensive feeding. Feed consumption by third-year fish in Experiment 1 and second-year fish in Experiment 2 decreased linearly as dietary protein increased, which suggests that dietary protein may influence food intake of channel catfish under satiate feeding. Mangalik *(10)* found that dietary energy concentration had a primary effect on daily feed consumption by channel catfish but that protein also influenced level of food intake.

Also, the high-protein diets at satiate feeding might have had an adverse effect on water quality, which subsequently affected weight gain, by increasing nitrogenous wastes in the pond water. Total ammonia-nitrogen (TAN) increased as dietary protein increased, which agrees with Cole and Boyd *(6)* and Tucker et al. *(24)* who showed that TAN increased as feeding rate increased; however, $NH_3$-N, the toxic form of ammonia, was not significantly different among dietary protein concentrations. The mean afternoon $NH_3$-N concentration for the treatments (0.19 mg per l) was higher than the subacute toxicity level reported by Robinette *(17)*, but gill hyperplasia and other overt sign of $NH_3$-N toxicity were not observed. Nitrite-nitrogen ($NO_2^-$-N) concentration increased with increasing protein concentration in the diets.

The $NO_2^-$-N concentration in the highest protein treatment was 0.33 mg per l; Tomasso et al. *(23)* found that 0.30 mg $NO_2^-$-N per l caused 20 percent methemoglobin in blood of channel catfish. Bowser *(3)* reported that $Cl^-$ influence $NO_2^-$ toxicity and that a $NO_2^-/Cl^-$ molar ratio of 0.25 or higher was detrimental to catfish in commercial ponds. This $NO_2^-/Cl^-$ ratio was reached with the two highest protein treatments in this study (Experiment 3). Differences in amount of methemoglobin among treatments were not significant because of the large amount of variation in methemoglobin percentage among individual fish; however, there was a significant positive correlation between $NO_2^-/Cl^-$ ratio in the pond water and percentage methemoglobin in the fish blood. Although $NO_2^-/Cl^-$ ratio in the ponds increased with protein concentration of the diets to harmful levels, $NO_2^-$ might not have been the major cause of the reduction in fish growth rate as dietary protein increased because the greatest decrease in growth rate was between the two lowest protein diets, whereas the greatest increase in $NO_2^-$-N was at the higher protein concentrations.

Feed conversion was not significantly affected by protein concentration in the diet under satiate feeding. This is in marked contrast to results of Reis et al. *(16)* who fed similar diets and found that feed conversion decreased as dietary protein increased from 26 to 40 percent. Page and Andrews *(13)* and Prather and Lovell *(14,15)* also found a similar correlation between dietary protein percentage and feed efficiency. It is presumed that the fish in the other studies were not fed to satiety.

Results of this study show that under satiate feeding, growth rate is highly correlated with feed consumption instead of protein percentage in the diet. Under restricted feeding conditions, however, feed efficiency is improved as dietary protein increased. This indicates that when channel catfish are fed to appetite, they can obtain sufficient protein and energy in a diet containing 24 percent crude protein and 3.1 kcal DE per g of feed.

Larger channel catfish require more feed per kg of gain, which is of economic importance to commercial culture. This apparently is caused by the increase in body fat in the larger fish because weight gain as fat requires more energy than gain as muscle.

This study showed that muscle fat decreased as dietary protein increased, which agrees with the study of Reis et al. *(16)*. This apparently is caused by the decrease in DE per protein ratio of the diets *(7,13)*. The slightly higher fat content in fish fed low-protein diets might be undesirable to processing plants and consumers if it affects frozen keeping quality of the product. Sensory evaluation for consumer acceptance would be necessary to determine if this difference in muscle fat is important.

The third-year fish, which deposited more body fat, appeared to be more sensitive to the change in DE per protein ratio in the diets than the second-year fish. This is of economic importance to industry, especially when the processor pays the producer on a live weight basis.

Dressing percentage was not affected by dietary protein for third-year fish but was slightly higher for the lowest and highest protein diets for second-year fish. Reis et al. *(16)* found a similar decrease in dressing percentage with 26 and 40 percent protein diets, which they attributed to more visceral fat in the 26 and 40 percent protein-fed fish. They suggested that the increase in fat in the fish fed high-protein diets was caused by fish converting unused protein to lipid. Dressing percentage of third-year fish was higher than that of second-year fish because of the relatively larger size of muscle in the third-year (1.5 to 2.0 kg) fish.

This study indicates that practical catfish feeds containing 24 to 26 percent amino acid-balanced protein and 3.1 kcal of DE per g provide maximum growth with satiate feeding, while higher protein diets are necessary for maximum growth under restricted feeding. Commercial catfish farmers generally feed conservatively or below satiation, to avoid wasting feed *(9)*, so a dietary protein content above the minimum concentration used in this study would probably be recommended for most farm management programs presently used. However, by skillfully feeding to compensate for the daily variation in feed consumption by channel catfish *(11)*, feeding the fish at near appetite can allow reduction of protein in the feed, which would significantly impact feed cost. On the other hand, channel catfish fed low-protein diets have lower feed efficiency, dressing percentage, and higher muscle fat.

## CONCLUSIONS

Channel catfish fed to satiation for the entire growing season can obtain sufficient nutrients in a practical 24 to 26 percent protein diet for maximum growth. Satiate feeding will allow lower feed costs and higher yields, however, satiate feeding will cause higher level of management, poor feed conversion, and higher muscle fat. Second-year channel catfish have advantages over third-year fish in better feed efficiency and low muscle fat but the disadvantage of lower dressing yield. Increasing protein in the feed fed in intensively managed ponds increases nitrite concentration in the pond water.

## LITERATURE CITED

(1) AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORK ASSOCIATION, AND WATER POLLUTION CONTROL FEDERATION. 1989. Standard Methods for the Examination of Water and Wastewater, 17th edition, Washington, D.C.

(2) ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1984. Methods of Analysis. 14th edition, Arlington, Virginia.

(3) BOWSER, P. R. 1983. Brown Blood Disease in Channel Catfish. Info. Sheet 1314. Miss. Agr. and For. Exp. Sta.

(4) BOYD, C.E. 1990. Water Quality in Warmwater Fish Ponds. Ala. Agr. Exp. Sta.

(5) CACHO, 0. J. 1984. Effects of Fish Size and Dietary Protein Level on Growth, Feed Consumption and Feed Efficiency by Channel Catfish in Ponds. M.S. Thesis. Auburn Univ.

(6) COLE, C.B. AND C.E., BOYD. 1986. Feeding Rate, Water Quality, and Channel Catfish Production in Ponds. Prog. Fish-Cult. 48:25-29.

(7) DERU, J. 1985. Effects of Dietary Energy-protein Ratio on Composition of Gain by Channel Catfish and Autooxidation of the Fish in Frozen Storage. M.S. Thesis. Auburn Univ., AL.

(8) HASTINGS, W.H., 1967. Feed Formulation. Progress in Sport Fisheries Research. U.S. Dept. of Interior, Bur. Sport Fish. Wildl. Res. Publ. 39:137-139.

(9) LOVELL, R.T. 1988. Nutrition and Feeding of Fish. Van Nostrand Reinhold, New York.

(10) MANGALK, A. 1986. Dietary Energy Requirements of Channel Catfish. Ph.D. Dissertation. Auburn Univ., AL.

(11) MINTON, R.V. 1978. Responses of Channel Catfish Fed Diets of Two Nutrient Concentrations at Three Rates in Ponds. M.S. Thesis. Auburn Univ., AL.

(12) NATIONAL RESEARCH COUNCIL. 1983. Nutrient Requirements of Warmwater Fishes and Shellfishes. Revised Edition. Nat. Acad. Press. Washington, D.C. 102 pp.

(13) PAGE, J. W. AND J. W. ANDREWS. 1973. Interactions of Dietary Level of Protein and Energy on Channel Catfish, *Ictalurus Punctatus*. J. Nutr. 103:1339-1346.

(14) PRATHER, E. E. AND R.T. LOVELL. 1971. Effect of Vitamin Fortification in Auburn No. 2 Fish Feed. Proc. 25th Ann. Conf. Southeast. Assoc. Game and Fish Comm. 25:479-483.

(15) ________________. 1973. Response of Intensively Fed Channel Catfish to Diets Containing Various Protein-energy Ratios. Proc. 27th Ann. Conf. Southeast. Assoc. Game and Fish Comm. 27:455-459.

(16) REIS, L. M., E. M. REUTEBUCH, AND R. T. LOVELL. 1989. Protein-to-energy Ratios in Production Diets and Growth, Feed Conversion and Body Composition of Channel Catfish. Aquaculture 76:1-7.

(17) ROBINETTE, H. R. 1976. Effect of Selected Sublethal Levels of Ammonia on the Growth of Channel Catfish. Prog. Fish-Cult. 38:26-29.

(18) RODRIGUEZ, M. C. 1979. Effects of Decreasing the Protein Percentage in Diets Fed at Satiation Rates to Catfish in Ponds. M.S. Thesis. Auburn Univ., AL.

(19) STEEL, R. G. AND J. H. TORRIE. 1980. Principles and Procedures of Statistics. A Biometrical Approach. 2nd Edition. McGraw-Hill Book Company, New York.

(20) SUN, P. L. 1976. Effects of Increasing or Decreasing the Protein Percentage in Isocaloric Rations for Pond-raised Catfish during the Summer Growing Period. M.S. Thesis. Auburn Univ., AL.

(21) TIEMEIER, O. W. AND C. DEYOE. 1969. A Review of Techniques Used to Hatch and Rear Channel Catfish Fingerlings in Kansas and Proposed Restrictions on Nutritional Requirements. Trans. Kansas. Acad. Sci. 71(4) :491-503.

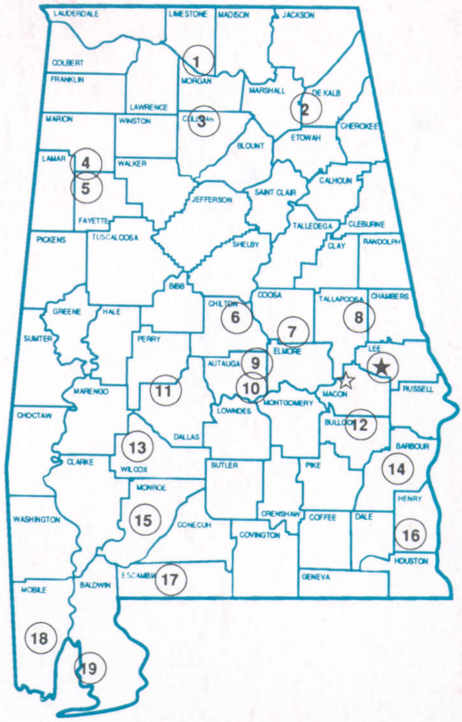
(22) TIETZ, N. W. 1970. Fundamentals of Clinical Chemistry. W. B. Saunders, Philadelphia, Pennsylvania.

(23) TOMASSO, J. R., B. A. SIMCO, AND K. B. DAVIS. 1979. Chloride Inhibition of Nitrite-induced Methemoglobin in Channel Catfish (Ictalurus ounctatus). J. Fish. Res. Board Can. 36(9):1141-1144.

(24) TUCKER, L. C, C. E. BOYD, AND E. W. MCCOY. 1979. Effects of Feeding Rate on Water Quality, Production of Channel Catfish, and Economic Returns. Trans. Am. Fish. Soc. 118:389-396.

## Alabama's Agricultural Experiment Station System
## AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.




## Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Chilton Area Horticulture Substation, Clanton.
7. Forestry Unit, Coosa County.
8. Piedmont Substation, Camp Hill.
9. Forestry Unit, Autauga County.
10. Prattville Experiment Field, Prattville.
11. Black Belt Substation, Marion Junction.
12. The Turnipseed-Ikenberry Place, Union Springs.
13. Lower Coastal Plain Substation, Camden.
14. Forestry Unit, Barbour County.
15. Monroeville Experiment Field, Monroeville.
16. Wiregrass Substation, Headland.
17. Brewton Experiment Field, Brewton.
18. Ornamental Horticulture Substation, Spring Hill.
19. Gulf Coast Substation, Fairhope.