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S-168 Annual Report 1983 Warmwater Aquaculture

Southern Region

Project Special Report

Southern Region Cooperative Research Project S-168 Annual Report 1983 Warmwater Aquaculture

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PROGRESS OF WORK AND PRINCIPAL ACCOMPLISHMENTS

The S-168 Technical Committee was organized to provide research information aimed at solving the common goals of warmwater aquaculturists in the Southern United States and adjacent regions. Major emphasis of the Technical Committee has been placed on the sharing of research findings and, where possible, the implementation of cooperative research projects among the various experiment stations and other agencies and institutions involved in the S-168 Project. In addition, the research plans of each unit involved in the Technical Committee are discussed at annual meetings. Discussions of future research plans provide a means by which duplication of effort can be avoided and related research can be coordinated to provide better use of funds while increasing the amount of useful information that is derived.

The stated objective of the S-168 Warmwater Aquaculture project is to develop and advance methods required for the rearing, processing, and marketing of warmwater aquatic animals with economic potential. Emphasis is being placed in the disciplines of culture systems, water quality, aquatic animal health, genetics and breeding, nutrition, economics and marketing, product development and quality assurance, technical assistance, and extension education programs.

In addition to providing research information through the traditional scientific literature, the S-168 Technical Committee is involved in the preparation of state-of-the-art publications which will be published as a part of the Southern Regional Cooperative Research Bulletin Series. At the time of this writing, there are bulletins being prepared on various culture systems, and a previously published bulletin, "Nutrition and Feeding of Channel Catfish," is being revised and updated. Subcommittees assigned the task of preparing additional bulletins will be formed during the course of the S-168 Project.

The S-168 Project was implemented in October 1981 and is scheduled for completion in September 1986. This report covers the accomplishments achieved under the project during 1983.

CULTURE SYSTEMS

Alabama

Mean net production and feed conversion ratio (FCR) for channel catfish grown in four 0.5- to 1.0-ha watershed ponds at 10,000/ha were 4,938 kg/ha and 1.81, respectively. Hybrid carp (bighead x silver) in polyculture at 625/ha produced an additional 1,220 kg/ha, without affecting yield of catfish. Three-year production of catfish from an 8.9-ha pond was 49,245 kg (trapping) and 19,397 kg (draining). Additional yield of hybrid carp and paddlefish was 10,422 kg.

Pond-matured and wild paddlefish females were equally responsive to inducing ovulation by injection; LHRH analog was more effective than paddlefish pituitary for ovulating females, and 1 million fry were produced. Food conversion ratios in polyculture ranged from 1.75 with catfish alone to 1.25 with catfish plus carp plus tilapia. Pelleted feed improved survival of *Macrobrachium rosenbergii* larvae 14 percent and growth 17 percent; survival was not affected by polyculture with tilapia. Growth of *Tilapia nilotica* was superior to that of *T. aurea* in both polyculture and monoculture ponds receiving swine waste; monoculture yields reached 2,156 kg/ha in 90 days. Silver carp stocked at 10,000/ha yielded 1,209 kg/ha in 150 days in ponds receiving treated domestic waste water. Adult *T. nilotica* gained 56 percent in a tank at 60/m^3 during 134 days; only nutrients from plankton in water from a catfish pond were available. Incubation of *T. aurea* and *T. nilotica* in cones and bottles indicated tripled water flow (0.5 to 1.4 l/minute), improved hatching rate, and allowed increased egg number. Food habits and morphology of bighead carp, silver carp, and their reciprocal hybrids were compared. Stomach contents of the parent species reflected a selectivity based on size of plankter; morphological characteristics and food habits of hybrids were intermediate to that of parents.

Arkansas

Adult *Tilapia aurea* were stocked in catfish production ponds to provide forage to the catfish in the fall. Catfish production in these ponds was higher than in control ponds, but catfish food conversion ratios were poorer. It was felt that by late summer the young tilapia grew large enough to consume catfish feed, and subsequently grew too large to be consumed by catfish.

Production of adult tilapia in ponds was compared with that in catfish monoculture ponds. Nine 0.1-ha ponds were each stocked with

1,000 mixed-size channel catfish in April. Three of these ponds were each stocked with three pairs of adult tilapia on June 1. Three other ponds were each stocked with six female and three male tilapia on July 6. The remaining three ponds served as catfish monoculture controls. Catfish in all ponds were fed to satiation up to a limit of 4.5 kg/pond/day, 6 days a week, with a 32 percent protein floating feed. Ponds were flushed with well water periodically. All ponds were seined at monthly intervals and enough larger catfish removed to reduce the standing crop to 2,270 kg/ha, based on an estimated 1.6:1 FCR.

The catfish monoculture ponds were harvested on November 9 after feeding had ceased. Production averaged 3,984 kg/ha with an FCE of 1.56:1.

A 1.6-ha pond was refilled with ground water during June, and two experiments with caged tilapia and catfish were initiated in July. In an 11-week study, blue tilapia were either fed to satiation 6 days per week or allowed to feed by means of demand feeders. Satiation-fed tilapia exhibited a significantly ($P = 0.05$) better FCR (1.6), but significantly lower weight gain (57 g) than demand-fed fish (2.3 and 98 g, respectively). For all cages, fish survival was high (92-100 percent), independent of feeding method.

Cages ($1 m^3$) were stocked with 200 and 400 channel catfish fingerlings per cage and fed a 32 percent protein ration to satiation 6 days per week from July 20 to October 25. Weight gain, FCR, and fish survival were not significantly affected at final average biomass of 34 and 65 kg/m^3 attained at the low and high densities, respectively.

Performance of fingerling and stocker size channel catfish fed with two types of pellets (25 percent protein) or not fed was examined during the 1982-83 winter season. Both sizes of fish performed best with a steam extruded pellet which was stable.

One-year-old bigmouth buffalo and their hybrids with smallmouth buffalo (BM X SM, SM X BM) reared together during 1982 were separated and restocked for second year grow-out at 250/ha in polyculture with channel catfish. Hybrid buffalo identification, based upon external morphology, was about 75 percent accurate for fish of 20 cm total length.

Three ponds, after 2 years of fish production, were planted with Centennial variety soybeans in July. Yields averaged 1,956 kg/ha after 131 days, with irrigation added before pod set.

Six ponds, planted with soybeans in 1982, were planted with Labelle variety rice in May. Red swamp crawfish broodstock were placed in these ponds during June at 67 kg/ha. Rice yield averaged 4,900 kg/ha (18 percent moisture) after a 141-day growing period.

Crawfish reproduction occurred in all ponds, which were flooded in October after rice harvest.

Mosquitofish (*Gambusia affinis*) may be commercially produced under monoculture or polyculture pond systems. Multiple harvests resulted in increased total yields compared to a single harvest and also provided fish when needed for mosquito control. Multiple harvests of mosquitofish significantly affected numbers per kg, size distribution, and sex ratio. Total fish/kg and female to male ratio increased during the production season. Intensively managed monoculture ponds with multiple harvests yielded 450 kg/ha. Mosquitofish yields in polyculture with channel catfish, bigmouth buffalo, and grass carp are approximately one-half those of monoculture systems, but with an additional production of 2,000 kg/ha from the companion species. Greater mosquitofish yields may be obtained in polyculture systems stocked with catfish over 150 mm, due to greater predation by 50-150 mm size catfish. In aquaria, the average gestation period for mosquitofish was 26 days and brood size was 40 fry. Females cannibalized 73 percent of their brood within 24 hours in aquaria.

Mosquitofish survival during transportation in tanks was accomplished by use of pure oxygen introduced at the rate of 2 l/minute, adding 0.2 percent NaCL by weight, and avoiding water turbulence. Twenty-four-hour air shipments at 50 g fish/1 water in plastic bags with oxygen are possible for adult mosquitofish. Mosquitofish were found to be highly efficacious on larvae of *Psorphora columbiae*, however, little efficacy was noted against *Anopheles quadrimaculatus* in tests conducted in commercial rice fields.

Kentucky

Winter culture trials with rainbow trout were begun in November 1983 in private farm ponds. Twelve thousand trout were stocked in floating cages to examine growth potential of two length groups at two stocking densities.

Louisiana

In crawfish studies, rice, volunteer vegetation, alligatorweed, and their combinations were tested as crawfish forages. Yields (kg/ha) of crawfish were: rice plus alligatorweed, 2,852; rice only, 2,652; and rice plus natural vegetation, 2,117. Three studies with prawns were completed: (1) Juvenile prawns were stocked into 18 ponds at 2,471/ha. Catfish fry were stocked into prawn ponds at 98,840/ha and 197,680/ha. Catfish fingerlings were stocked in prawn ponds at

37,065/ha and 74,130/ha. Catfish were fed daily in all ponds, but not prawns. Prawns fed on wastes and natural pond organisms. Dissolved oxygen levels were significantly ($P = .05$) lower in polyculture systems stocked with high densities of catfish. The pH, carbon dioxide, total ammonia nitrogen, and nitrite-nitrogen did not attain toxic levels in any ponds. (2) Juvenile or post-larval prawns were stocked into replicated ponds at 4,940/ha with catfish fingerlings at 7,410/ha. Catfish were fed daily. After a 106-day growing season PL's had 89 percent survival and averaged 33 g. Juveniles had 82 percent survival and averaged 39 g. (3) Four crops—rice, catfish, crawfish, and prawns—were grown in one plot in one year's time. Prawns stocked at 6,795/ha had 93 percent survival and averaged 41 g after 122 growing days.

Eighteen artificial baits were prepared and tested against shad in commercial ponds. Baits included various combinations of attractants including catfish meal, catfish protein hydrolysate, catfish oil, and menhaden meal; the binders were wheat or soya flour; the filler was bagasse, sand, and rice bran. Overall, the single best bait contained 12 percent catfish meal, 35 percent wheat flour, 27 percent bagasse, and 28 percent sand. This artificial bait caught an average of 470 g of crawfish for each trap set; shad caught 455 g per trap set. Of the 18 artificial baits, 12 caught an average of over 400 g per trap set. All baits pelleted easily since only one test bait contained catfish oil. When baits contained oil up to 15 percent, pelleting was difficult. The cost of artificial baits (ingredients only considered) ranged from $0.12 to $0.30 per kg. The cost of shad was $0.33 per kg.

Mississippi

Channel catfish culture research at the Mississippi Agricultural and Forestry Experiment Station, Delta Branch, Stoneville, Mississippi, has centered on the effects of stocking density and the combination of different size groups of fish on single season fish production in commercial fish ponds. All studies were conducted in 1.6-ha ponds. Fish were fed to satiation daily with a 32 percent protein floating fish feed. Dissolved oxygen (DO) was monitored closely and paddlewheel aerators were used whenever DO decreased to 2 p.p.m.

Single season production results were obtained for: (1) ponds stocked with fingerling catfish at densities of 10,000, 15,000, or 20,000 fish per hectare, (2) ponds stocked at a density of 15,000 fish per hectare with either fingerling catfish alone or in combination with subadult catfish and, (3) ponds stocked at 3,750 fish per hectare with

Age Group II channel catfish raised during their third summer of growth.

An increase in stocking density from 10,000 to 20,000 fingerling fish per hectare increased total production from 5,150 kg/ha to over 7,950 kg/ha and decreased the average fish weight at harvest from 0.59 to 0.45 kg. Feed conversions were 2.0 for all densities with conversion calculations including feed allotted on a winter feeding schedule of 1 percent estimated body weight, 3 days per week, from November 1982 to March 1983. At stocking densities of 15,000 and 20,000 fish per hectare, 25 to 40 percent of the fish stocked did not reach a harvestable size (0.34 kg) in a single growing season when 15-cm fingerlings were stocked in the spring.

Ponds stocked with 15,000 fingerling catfish per hectare yielded 5,850 kg/ha compared to 5,145 kg/ha for ponds stocked with fingerling and subadult (0.25 kg average weight) catfish. Competition between size groups for available food, a poorer feed conversion for larger catfish, or a combination of these or other factors resulted in an average feed conversion of 2.1 for production ponds stocked with both fingerling and subadult catfish and grown through the entire growing season. This compared to a 1.6 feed conversion for fish stocked as a single size group (fingerling) at the same density.

Age Group II channel catfish stocked at 3,750 fish per hectare yielded an average production of 2,745 kg/ha with a 2.2 feed conversion. More than 50 percent of the harvested fish attained a size of 1.4 kg. Voluntary feed consumption expressed as a percent of the estimated standing weight decreased from approximately 1.25 to 0.75 percent over the growing season.

Puerto Rico

The effects of initial size on final size and the competition between various size groups of all male hybrid tilapia were investigated at the Lajas Aquaculture Center. Triplicate ponds (0.07 ha) were stocked with either a single size group or mixed size group of fingerlings at a rate of 3,986 per hectare. The single size group was composed only of fish of 11-12 cm total length, while equal numbers of fish of 7-8 (small), 11-12 (medium), and 15-16 cm (large) made up the mixed group treatment. After 111 days, the average gain per fish for the single size group treatment was 286 g, while the small, medium, and large fish in the mixed size group treatment gained 215, 387, and 292 g, respectively. Growth curves, fish coloration, and condition indicate the "medium-single group" and "large-mixed group" fish consumed less food and/or expended energy on breeding behavior

during the first and second month, respectively. Such behavior resulted in depressed growth. These initial results indicate stocking mixed size groups may actually benefit the smaller fish rather than the larger fish as is the case for most other important cultured fishes. If this is true with other tilapias as well, stocking a few large males may improve yields of the other fish.

Production of prawns at 51 larvae/liter resulted in 55 percent survival to postlarvae. Stocking acclimated postlarvae in water with pH from 7.5 to 12.0 indicated that successfully higher pH values would kill the postlarvae. Further experimentation should prove a basis for predicting when to stock ponds with postlarvae.

Polyculture of 86-day-old *Macrobrachium rosenbergii* and rice indicated prawns would grow and mate in the rice ponds, but are difficult to harvest (25 percent capture). Yields of prawns stocked at 700 or 1,400 per hectare were not different.

Queen conchs were reared from eggs collected in the field. Larvae were cultured utilizing techniques adapted from bivalve culture by feeding phytoplankton cultures of *Isochrysis*, *Tetraselmis*, and *Thalassiosira*. Larval period varied from 12 to 22 days and length at metamorphosis from 1.1 to 1.8 mm. Juveniles were fed macroalgae in shallow pools initially and in troughs with flowing water. Maximum growth rates of 0.4 mm/day were recorded over a 200-day culture period.

Wire cages were more effective for holding juvenile spiny lobsters *Panulirus argus* than were tire cages. Average percent mortality was 1.8 ± 0.3 percent in wire cages, 26.7 ± 2.5 percent for horizontally placed tire cages, and 12.5 ± 0.7 percent for vertically placed tire cages.

Tennessee

Data collections from a study to evaluate polyculture of crayfish and tilapia indicated no adverse effects on growth when cultured together at different densities. Mean weight increments for tilapia were also not significant ($P = .05$). Behavioral interactions of crayfish, tilapia, and freshwater prawns were predominantly intraspecific; survival of crustaceans appeared to increase as their densities decreased. Predation of tilapia on crayfish was not observed; all mortalities of prawn and crayfish were attributed to cannibalism subsequent to molting. Further analysis of the data from the investigation of heat production from composting and its use in small-scale aquaculture indicated the steel heat exchanger extracted more heat from the compost than the copper exchanger. The design and fabrication of

the two heat exchangers were not comparable, thus accounting for these two metals functioning differently than anticipated. In addition, at flow rates of 1.0, 2.0, 3.0, and 4.0 l/minute, water in the steel heat exchanger increased an average of 8.1, 4.5, 3.2, and 3.2 C, respectively, while the increase for copper was 5.9, 3.1, 1.9, and 1.6 C, respectively.

A study was initiated to compare a commercially prepared fish ration to bermudagrass pellets (and possibly alfalfa) as the sole diet for the herbivorous white amur. A comparison of protein composition of each diet will be made along with the costs per unit production of fish cultured.

Texas

A 3:1 ration of *Penaeus vannaemei* to *P. stylirostris* in 0.1-ha ponds yielded a mean of 1,968 kg/ha. Of tested salinities, 25 p.p.t. was best for both species and 5 p.p.t. was the least favorable, especially for *P. stylirostris*. Damselfly larvae can be a significant predator of young shrimp.

Virgin Islands

Production of 397 kg was obtained when *T. aurea* were stocked at a rate of 1,200 in closed recirculating systems, containing 14 m^3 of water, and fed for 177 days. Total production was equivalent to 8.4 kg/l/minute of flow and 30.6 kg/m^3 of gravel biofilter volume. Total water and electrical consumption was 123 l and 8.7 kw-hr per kg of net production. Seventy-two tomato transplants, consisting of six hydroponic varieties (Vendor, Dombito, Jumbo, Laura, Perfecto, Tropic), were planted in the biofilters in each of six systems. No significant differences were obtained for treatments consisting of no nutrient supplementation and two levels of nutrient supplementation. Poor tomato growth occurred as the result of insect damage, early blight, high ammonia levels, and stem damage (girdling) caused by the action of wind and the gravel. Insect damage was eventually controlled by Orthene (acephate), an organic phosphate that is relatively nontoxic to fish. The tomato yield per system was 34 kg, of which 37 percent was marketable. Fruit cracking was the major problem. Vendor produced the highest yields.

T. aurea were stocked in cages at a rate of 400 fish/m^3 and fed for 145 days either manually twice a day or with demand feeders of 6 kg capacity. Demand feeding produced a significantly higher net yield (137 kg compared to 119 kg for manual feeding) and a significantly

lower feed conversion ratio (1.48 compared to 2.05). The demand feeders were refilled an average of 34 times compared to 285 manual feedings, which is equivalent to an 88 percent reduction in labor with the use of demand feeders.

Southern University

Current research involves laboratory studies of burrowing activity, long-term survival without food, and dietary vegetation preferences of newly hatched and small juvenile crawfishes, *Procambarus acutus acutus* and *P. clarkii.* Both species eat newly sprouted rice and ryegrass as well as alligator weed. Alligator weed is normally preferred over smart weed. *Procambarus clarkii* readily consumes water primrose but demonstrates no strong preference for it over alligator weed.

Tennessee Valley Authority

Two studies were conducted to evaluate corn stillage from an alcohol plant as a fertilizer/feed source for producing tilapia. Study I revealed that whole stillage fertility rates ranging from 7 to 14 g/m^2/day (dry matter basis) were sufficient to produce 222 to 228 g fish/m^2/day during a 46-day trial. Conversion of stillage dry matter (7 g/m^2/day) to fish was 1.45/1.0. During Study II, whole stillage was screened to produce solid and liquid fractions. At fertility rates of 10.5 g/m^2/day, net fish production averaged 3.51 and 3.23 g/m^2/day for the solid and liquid fractions, respectively. A feed control (Purina trout chow) yielded 6.3 g/m^2/day. In the stillage treatments, net fish production was correlated with net primary production.

Prawns *(Macrobrachium rosenbergii),* channel catfish, grass carp, hybrid carp *(Aristichthys nobilis* x *Hypophthalmichthys molitrix),* and tilapia were costocked into four replicate earthen ponds at densities of 20,000/ha, 10,000/ha, 125/ha, 500/ha, and 2,500/ha, respectively. Feed (32 percent catfish chow) was broadcast into the pond once a day at 1500 hours throughout the 133-day trial. Feeding rate was increased daily up to a maximum of 65 kg/ha/day. Net production (range, kg/ha) and survival values (range, percent) for the five costock animals were: prawns (316-533, 72.4-88.5 percent); channel catfish (1,154-1,719, 79-100 percent); grass carp (94-151, 100-100 percent); hybrid carp (481-580, 88-100 percent); tilapia (597-745, 92.5-97.5 percent). Total net production (mean ± 1SE) was 3,182.2 kg/ha ± 191 kg/ha. Feed conversion was 1.17/1.0.

Tests were conducted to determine the effectiveness of two types of chicken manure, chicken litter from broiler operations and liquid

manure from caged-layer operations, as fertilizers for producing tilapia. The highest rate of chicken litter, 12 g/m^2/day, produced 86.1 g tilapia/m^2 during the 30-day trial. This level of tilapia production did not differ ($P > .05$) from a fed control receiving a pelleted 37-percent protein ration. Fish production increased as fertility rate (broiler litter) increased from 1.5 g/m^2/day to 12 g/m^2/day. However, tilapia yield per unit of fertilizer input decreased as fertility rate increased. Similar trends in fish production resulted in treatments receiving caged-layer wastes. Net primary production, expressed as g 0_2/m^2/day, was also monitored in these tests.

Six 1.5 m^3 round tanks were stocked with 800 rainbow trout that averaged 45.0 g and 16.5 cm total length. Harvest density 84 days later was 73.8 kg/m^3. Fish averaged 145 g and 25 cm total length at harvest. Growth rate and survival were adequate, but food conversion and condition factor were less than satisfactory. It was concluded that sublethal levels of gas supersaturation caused chronic stress resulting in depressed performance.

A preliminary study on gas supersaturation involved two raceways stocked with approximately 10,000, 7-cm channel catfish at 0.23 fish/m^3. One raceway received gas supersaturated water (heated effluent), the other received water passed through a vertical packed column which removed supersaturated gases. Survival in the degassed raceway was significantly higher.

Approximately 10,000 white x striped bass averaging 4 cm were stocked in two raceways and two tanks at densities of 0.15 and 0.28 fish/m^3, respectively. After 93 days, 5,842 fish (80 percent survival) were harvested from the raceways and averaged 45 g and 15 cm total length. Tank fish were not harvested, but sampling indicated that they were twice the average weight of raceway fish; survival and food conversion were also enhanced in tanks.

A study is currently underway on the winter growth of white x striped bass in round tanks. Approximately 600 fish estimated at 340 g average are being cultured at temperatures from 12 to 18 C using a trout diet.

One hundred twenty-six paddlefish averaging 5.2 g and 10.0 cm total length were polycultured with 5,200 channel catfish fingerlings in one 17.1 m^3 raceway.

Fifty-eight paddlefish averaging 103 g and 34 cm total length were harvested 112 days later after being fed an artificial diet by hand and automatic feeders. Most mortalities were due to paddlefish sensitivity to recommended chemicals and treatment levels for channel catfish diseases.

U.S. Fish and Wildlife Service (Southeastern Fish Cultural Laboratory)

Gas supersaturation at very low levels has recently been implicated in loss of fish in some hatcheries. Total gas pressure was monitored in the morning and afternoon at the surface and bottom of warmwater ponds in Marion, Alabama, to determine the extent of gas saturation under natural conditions. Total gas pressure averaged 110 percent in the morning at the surface of non-aerated ponds and 110 percent in the afternoon in ponds with airlift at the surface and bottom, morning and afternoon, in both aerated and non-aerated ponds. No evidence of gas bubble disease was found in striped bass stocked into these ponds as 15-day-old fry and cultured for 42 days.

In other studies, researchers have compared oxytetracycline, Microtaggants, rare earth elements, and binary-coded wire tags for marking striped bass. Marking striped bass with oxytetracycline administered in the diet has not been effective. The mark cannot be consistently detected by fluorescence nor have reliable extraction and assay techniques been developed. Microtaggants have been withdrawn from the market by the 3-M Company and additional research on tagging striped bass with Microtaggants has been deferred. Rare earth elements administered in the diet are still under investigation, but it appears that background levels of rare earth elements vary locally and will have to be taken into account before this technique can be recommended. Retention of binary-coded wire tags in the nose of striped bass has been very poor; however, when placed in the cheek muscle, tag retention was 100 percent.

WATER QUALITY

Alabama

Oxygen-transfer rates for four tractor-powered emergency aerators were: blower-fan aerator, 12.1 kg 0_2/hour, Crisafulli pump and sprayer, 12.3 kg 0_2/hour; Airmaster aerator (centrifugual pump and sprayer), 21.3 kg 0_2/hour; paddlewheel aerator, 26.3 kg 0_2/hour. Times required for aerators to homogeneously mix salt in a 6,000-m^3 pond were: blower-fan aerator, 96 minutes; Crisafulli pump and sprayer, 94 minutes; paddlewheel aerator, 53 minutes; and Airmaster aerator, 38 minutes. The Airmaster aerator and the paddlewheel aerator did not differ in their abilities to transfer oxygen and circulate pond water ($P > .05$); they were both superior to the blower fan aerator and the Crisafulli pump and sprayer ($P > .01$).

Propeller-aspirator-pump aerators of 0.38, 1.50, and 2.24 KW transferred averages of 1.73 to 1.91 kg oxygen/KW-h in standardized oxygen transfer tests (tap water; 20 C; 0 mg/1 dissolved oxygen) conducted in a shallow basin (1.04 m of water depth). In comparison tests, spray-type surface aerators transferred 1.34 to 1.41 kg oxygen/KW-h and a diffuse-air system transferred 1.08 kg oxygen/KW-h.

Ponds at Auburn University, Alabama, stocked with 10,600 channel catfish, *Ictalurus punctatus*, per hectare that were fed at rates up to 66 kg feed/hectare per day, received water exchanges totaling 0, 1, 2, or 4 pond volumes between July and September. Although feeding rate was high enough to impair water quality, concentrations of dissolved oxygen, total ammonia nitrogen, nitrite-nitrogen, and chemical oxygen demand did not differ ($P > .05$) among treatments, and fish production was not increased by water exchange ($P > .05$).

Average depths of 35 ponds were computed by reliable mapping techniques. Assuming that average depths by mapping were accurate, averages of relative errors by other procedures were: Maximum depth x 0.4, 12.6 percent; transects, 9 percent; and S-pattern, 5.4 percent. The S-pattern required fewer soundings and was the most reliable. If mapping is not feasible, 12 to 24 soundings made along an S-pattern over a pond will provide a suitable value of average depth for computing pond volume.

Louisiana

Water quality was measured in commercial crawfish ponds planted with rice or natural vegetation from October 1982 through May 1983. The pH, nitrate, BOD, total alkalinity, total hardness, ammonia,

chlorophyll *a*, total phosphorus, and temperature did not differ among ponds. The free carbon dioxide, total carbon dioxide, soluble inorganic phosphorus, and conductivity were greatest in naturally vegetated ponds. The nitrite, COD, turbidity, total nitrogen, and dissolved oxygen were highest in rice ponds. Water quality was poorest in November, April, and May. Only dissolved oxygen attained concentrations considered toxic to crawfish. The acute toxicity of ammonia, nitrite pH, and sulfides to *P. clarkii* and *P. a. acutus* are being determined in laboratory studies.

The insecticide carbofuran was applied at 0.5 kg ai/ha to three, 2.5-ha rice-crawfish plots. Three plots received no carbofuran. Mean crawfish yield from the six ponds was 2,570 kg/ha (ranges 1,278-4,329 kg/ha). The application of carbofuran resulted in a 942 kg/ha reduction in crawfish yield ($\bar{x}$ = 2,100 kg/ha) relative to plots in which no carbofuran was applied ($\bar{x}$ = 3,042 kg/ha). Carbofuran should not be used in rice-crawfish double-cropping systems when crawfish is the principal crop.

Puerto Rico

Six, 0.12-hectare ponds at the Lajas Aquaculture Center were sampled biweekly between June and December 1983. Water samples were analyzed for ammonia, nitrate, organic nitrogen, carbon dioxide, chemical oxygen demand (COD), and turbidity. Ponds with high feeding rates had poorer water quality than ponds with identical stocking rates but lower feeding rates. However, at no time during monitoring did dissolved oxygen concentrations drop below 2 mg/1 in any of the ponds. In general, the higher the feeding rate, the greater the COD (maximum value of 102 mg/1), total ammonia nitrogen, nitrite-nitrogen, organic nitrogen, and turbidity.

Water budget for June 1 through November 30, 1981, and for June 1 through November 30, 1983, were developed for small experimental fish ponds at the Lajas Aquaculture Center. During the study, totals in centimeters for inputs of water were: rainfall 74.3 and 51.6, and regulated additions 52 to 83 and 67 to 130 for 1981 and 1983, respectively. Losses of water in centimeters over the periods were: evaporation 52.1 and 52.5; seepage 77.5 to 108.8 and 79.9 to 130 for the 1981 and 1983 periods, respectively. Seepage, the major variable among ponds, was the most important factor governing inflows required to maintain water levels. Seepage loss based on 20 small ponds averaged 0.61 and 0.54 cm/day for 1981 and 1983 periods, respectively. The decline may be related to the increased soil nitrogen content.

The effects of wind on dissolved oxygen (DO) levels and soil nitrogen levels in ponds were evaluated over a 2-year period. Ponds with their deep end to the leeward have a higher DO level at the surface and at 1-m depth in the morning and early evening than those to the windward when COD's, stocking, and feeding rates are nearly identical. The transfer coefficient of oxygen was 27 percent greater in leeward ponds than windward ponds. Preliminary studies on soil N indicate that the percent increase of soil N is less in leeward ponds than windward ponds even when nutrient inputs are the same, resulting in slightly higher seepage losses.

GENETICS AND BREEDING

Alabama

Channel catfish broodstock were readied in 1983 for spawning in May 1984, and facilities were prepared for experimentation during June 1984 to June 1985 to determine the heritabilities for feed consumption and feed conversion efficiency in channel catfish and the genetic correlations between these two traits, thus enabling the definition of the appropriate selective breeding program for these two traits. A cross-fostering factorial design will be implemented, allowing computation of heritability estimates and partitioning of additive, dominance, and material components of variation

Isozyme allele frequencies of 16 largemouth bass populations from the Mobile Bay drainage and from three other drainages in Alabama indicated that there was a single stock of bass in the Mobile Bay drainage which was distinct from stocks in the other watersheds.

Allele frequencies at several biochemical loci were different between eight channel catfish lines selected for growth rate and their controls.

Communal evaluation in both monoculture and polyculture proved valid for catfish genetics research. MK-3 and Kansas select lines were the fastest growing catfish in a cooperative test of catfish from Southeastern research institutions. Genotype-environment interactions occurred among blue, channel, and hybrid fingerling catfish stocked at varying rates. As the number of plankton-feeding fish increased in polyculture ponds, the relative growth rate of two genetic lines of *Tilapia nilotica* changed ($r = -0.84$) indicating genotype-environment interactions.

Preliminary results from crossing various color phenotypes of red-gold tilapia indicated a multilocus, multiallele gene complex for color determination.

Attempts to sex reverse red-gold tilapia using 17 $\propto$ - methyltestosterone at 30 mg/kg of feed for 21 days produced greater than 85 percent males. Growth data indicated early transfer from treatment to grow-out facilities advantageous to prolonged hormone treatment.

Georgia

Selection responses were compared in four lines of channel catfish *(Ictalurus punctatus)* selected for: (1) large 40-week body weight (W^+), (2) large spawn weight (S^+), (3) small 40-week body weight and large spawn weight ($W^- S^+$), and (4) large 40-week body

weight and small spawn weight ($W^+ S^-$). Single-trait selection for 40-week body weight was most effective in increasing body weight and total length 9 and 28 months after selection was made. Joint selection for body weight and spawn weight ($W^+ S^-$) was not as effective as selection for body weight alone (W^+) on improving growth. Both lines were, however, more effective in growth improvement than S^+ and $W^- S^+$ lines. Selection for increased spawn weight (S^+ or $W^- S^+$) reduced subsequent growth severely. In another study, albino (A) and normally pigmented (N) channel catfish were compared for spawn characteristics, growth, survival, and dress-out percentages. N fish were superior to A fish in body weight and total length when cultured in tanks, ponds, and cages. A x A fish required 11 days longer to spawn and produced smaller egg masses that contained eggs of lighter weight with poorer hatchability than did N x N fish. The A fish had lower survival rates than did the N fish, but dress-out percentages were nearly equal. The A fish produced from N x N parents and reared with their N siblings in the same tank were superior in growth to a fish produced from A X A parents and reared with their A siblings. However, N fish reared with the A siblings were comparable in growth to the N fish from the all-N families.

Louisiana

Channel x blue and channel x white hybrids were produced by handstripping eggs from females. Fingerlings were grown in ponds and will be used in future growth studies. Selective breeding experiments with crawfish will concentrate on improvement of economically important traits. Experiments with freshwater prawns will estimate heritabilities for growth and body size traits.

Mississippi

Evaluation of the effect of inbreeding on resistance to nitrite toxicity was completed. No inbreeding depression was noted, but there was wide variability in resistance.

North Carolina

Genetic manipulation techniques are being employed to produce triploid and gynogenic striped bass for growout.

Puerto Rico

The effects of stunting on the growth of *Tilapia nilotica* are being investigated at the Lajas Aquaculture Center. Triplicate cages and two ponds were stocked with equal numbers of stunted and non-stunted tilapia fingerlings. The stunted and non-stunted fish were both from the same parental stocks and were 37 and 14 weeks old, respectively. Stunting was attained by varying feeding rates and stocking densities as necessary. In the cages, females averaged 15.8 and 17.9 g, and males 18.3 and 19.7 g for the stunted and non-stunted groups at stocking, respectively. In the communally stocked ponds, females averaged 11.2 and 12.3 g, and males 27.7 and 30.8 for these respective groups. Feeding rates during the trials were such to maximize growth rates. After 112 days in cages, the females gained 138 and 125 g, and males 170 and 181 g, for the stunted and non-stunted groups, respectively. After 101 days in ponds, females gained 57 and 64 g, and males 218 and 226 for the stunted and non-stunted groups, respectively. Growth rates were slightly lower for the stunted fish the first few weeks, but afterwards no difference was found. Compensatory gain by the stunted group was not observed.

Triplicate plastic pools were stocked separately with either *Tilapia aurea, T. hornorum, T. nilotica,* or Taiwanese red tilapia fingerlings (60 fish/pool) averaging 7.3, 5.7, 8.2, or 7.6 g, respectively. Three other plastic pools were stocked communally (mixed groups) with equal numbers of similarly sized fish of the above four groups. Fish were fed 32 percent protein sinking pellets at an initial rate of 5 percent and decreasing to 3.5 percent total body weight daily divided into two equal feedings. All the fish were harvested after 68 days. Gains in weight for separately stocked pools were 62.8, 59.8, 69.8, and 73.5 g, respectively. Males gained more than females for all groups in separate and communal cultures; however, a significant group by sex interaction existed. In separately stocked pools, males gained 23, 119, 76, and 43 percent more in weight than females for the above groups, respectively. Rankings of gains were the same for separately and communally stocked pools indicating that communal rearing may be an efficient means of performance testing tilapias.

Memphis State University

Fertilized eggs of *Ctenopharyngodon idella* were subjected to thermal shock and chromosomal analysis was done on gill epithelium of the fingerlings. Diploid, triploid, and mosaic individuals were

found. The mosaic fish had cells containing both 48 and 72 chromosomes.

Tennessee Valley Authority

Two-year-old *Tilapia aurea* were stocked into five small nylon hapas (1.2 m x 1.2 m x 2.7 m) at a density of 6 males and 6 females/hapa. Stocking weight of individual males and females averaged 415 g and 225 g, respectively. Eggs and sac fry (collectively seed) were removed from the buccal cavity of incubating females at 7- to 12-day intervals from July 3 to August 23. During the 50-day trial, 62,900 seed, representing 78 spawns, were collected from the 30 females. This corresponds to a fecundity of 9,300 seed/kg of female broodstock which is comparable to fecundity of channel catfish.

A strain of red tilapia with cold tolerance traits similar to *Tilapia aurea* has been developed through introgressive breeding, i.e., hybridization (female *T. aurea* x F-1 male red phenotype). Progeny of the F-1 backcross, consisting of approximately 50 percent normal and 50 percent red phenotype, survived for a greater length of time under conditions of ambient cooling than pure strains of *T. aurea* and *T. mossambica* ($P < .05$). There were no differences in cold tolerance between the normal and red phenotypes of the F-1 backcross population ($P > .05$). Reproductive success in the hybrid cross female *T. aurea* x male red tilapia (commercial strain) was low, averaging 52 eggs per female during a 28-day period. In comparison, egg production in the pure strain of *T. aurea* (female *T. aurea* x male *T. aurea)* and the F-1 backcross (female *T. aurea* x male F-1 red phenotype) averaged 251 and 352 eggs per female, respectively.

U.S. Fish and Wildlife Service (Fish Farming Experimental Station)

In the spring of 1982, channel catfish eggs were obtained from stocks located in Alabama, Arkansas, Louisiana, Oklahoma, Mississippi, and Missouri. The eggs, were hatched and fry were stocked and reared in 0.1-ha ponds. During April 1983, fingerlings from the six strains were stocked into 36, 0.1-ha ponds at duplicated rates of 500, 750, and 1,000 fish per pond. The fish were managed for maximum gain and survival during the 150-day feeding period. The strains will be evaluated on growth rates, feed utilization efficiencies, survivals, and dress-out percentages.

In an experiment to study the inheritance of nonspecific resistance to bacterial infections, serum complement levels have been established for two of the strains in terms of complement concentrations in

the serum; a range of 38 to 125 CH_{50} units/ml has been established. Individual fish with known levels of complement were challenged with *Edwardsiella ictaluri* and there proved to be no relationship between complement level and resistance to challenge in the two groups.

AQUATIC ANIMAL HEALTH

Alabama

There were 353 fish cases reviewed for diagnosis. Etiologies were: virus (22); bacteria (127); fungi (3); parasites (71); and miscellaneous (130). Bacterial drug resistance was 89 percent for sulfa drugs, 7 percent to 19 percent for the tetracyclines, and 7 percent for nitrofurans. Pathogenicity of several parasites of catfish was determined. *Aeromonas hydrophila* and *Flexibacter columnaris* were the main causes of disease in several state fish hatcheries. Seven cell lines were started from five species of fish with passages ranging from grass carp ovary in passage 10 to golden shiner ovary in passage 28. A *Streptococcus* isolated from marine fish has been characterized and determined to be a new species. Largemouth bass immunized against bass tape worm showed some resistance to establishment of plerocercoids. Average length of plerocercoids in immunized bass was half that of those in non-immunized bass. Cutrine-Plus used at 15 mg/l for 1 hour eliminated the cilated protozoan *Trichodina* from channel catfish. Catfish exposed to 5 mg/l nitrite in a continuous flow tank were more susceptible to bacterial infection that unexposed controls; antibody production was lower in exposed fish.

Average antibody titer of channel catfish vaccinated with *Edwardsiella ictaluri* and held at 12 C had a peak average antibody titer of 1:70 at day 30; by day 60 the average titer had dropped to 1:14. Upon challenge, the low temperature vaccinated fish receiving 0.6 mg bacteria showed 60 percent mortality. The low temperature vaccinated fish receiving 0.3 mg bacteria had no mortalities, while the controls suffered a 40 percent mortality rate. The fish held at the high temperature had 80 percent mortality among the vaccinated fish; the non-vaccinated controls had 100 percent mortality.

A severe anemia occurred in cultured channel catfish in Alabama and Georgia in 1983; apparently the anemia was caused by the feed. Although the toxic substance in the feed has not been identified, it was shown that feeds contained no pesticides, heavy metals, hydroxides, or known mycotoxins that could possibly have caused the anemia. Experimental inducement of severe anemia by the feed was demonstrated in cage-cultured channel catfish during a 4-week study. Severely anemic fish had hematocrits as low as 2.0 to 5.0, while the average hematocrit was 25.8 in 37 control fish. Hemoglobin concentrations and erythrocyte counts were lower in affected fish than controls and clotting time of the blood was greater in test fish. Mor-

tality during the study was 9 percent in the test fish compared to 0.5 percent in the controls.

Two females receiving virus the day of stocking spawned and two females were successfully handstripped. To date, no virus has been detected from any of the offspring.

Several of the broodstock had neutralization against 100 $TCID_{50}$ of CCV prior to injection with virus. Fish receiving injections of CCV did have increased levels of neutralization against 100 $TCID_{50}$ over time.

One group of channel catfish fingerlings from a CCV-positive suspect female and a second group of fingerlings from a CCV-negative suspect female were injected with CCV and held at 23 C and 30 C, with and without aeration. Non-injected fish from each group were held in similar conditions. Clinical signs of CCV disease developed in all injected groups at 23 C and 30 C and in aerated and non-aerated treatments, but CCV did not develop in non-injected populations regardless of the environmental conditions. The disease developed quickly at 30°C regardless of DO, where mortality was 98 percent at 5 days, compared to a mortality of 50 percent after 28 days at 23 C.

A survey of dry prawns and white sardines, white bait, oil sardines, and *Lactarius* obtained from the Mangalore fish market indicated that *Vibrio parahaemolyticus* can sometimes be recovered from dry fishes. However, under experimental conditions, *V. parahaemolyticus* in fish did not survive the process of sun-drying and survival of *V. parahaemolyticus* smeared on dry fish appeared to be less than 2 hours.

A study of 56 samples of raw prawns, 50 samples of processed prawns, and 57 samples of frozen prawns from five prawn processing factories around Mangalore for the levels of *Vibrio parahaemolyticus* revealed that most of these samples carry a load of < 10/g. None of the samples had counts > 102/g indicating that the prawn processing factories are able to meet the ICMBF suggested limit of 10^2 *V. parahaemolyticus*/g for frozen prawns.

Proteases of *Aeromonas* spp and *Pseudomonas* spp isolated from mackerel were analyzed for hydrolysis of fish muscle. Both organisms produced good proteolytic activity. *Aeromonas* produced protease best at pH 7 while *Pseudomonas* production was more active at pH 5.2. A temperature of 25-30°C was most favorable. Approximately 55-65 percent of fish protein was hydrolyzed within 24 hours.

Louisiana

Procedures for the detoxification of *Aeromonas hydrophila* proteases and hemolysin were evaluated using formalin, glutaraldehyde, chloroform, and heat. The proteases required a two-step procedure with formalin and heat to maintain immunogenicity, while the hemolysin could be toxoided by heating.

Scanning and transmission electron microscopy indicated that *Acineta sp.* attaches to the cuticle of crawfish gills by means of an acellular disc of material distinct from that of which the lorica is constructed. No host response was evident.

Toxicity levels of several chemotherapeutic agents were determined for freshwater prawns. *Macrobrachium rosenbergii* 24-hour LC_{50} values were 3.8 and 3.2 mg/l for $KMn0_4$ using larvae and post-larval prawns, respectively, 1.0 mg/l for cutrine using larvae, 0.32 for copper sulfate using post-larvae, and 260 mg/l for formalin using post-larvae. Furanace was non-toxic at doses less than 16 mg/l for both larvae and post-larvae.

A systemic streptococcol infection in cultured bullfrogs in Brazil was characterized by vecrotizing splenitis and hepatitis with hepatic and renal hemorrage. A non-hemolytic Group B *Streptococcus* appeared to be the cause of the lesions and the stimulus for splenic reticulo endothelial hyperplasia. Stress may have played a major factor in disease development.

South Carolina

Glass eels and elver stages of American eel *(Anguilla rostrata)* were examined monthly for parasites. Glass eels (n = 225) harbored 5 species of parasites and elvers (n = 225) 11 species. *Myxidium giardi* was the most frequently encountered parasite in glass eels (43.6 percent) and elvers (60.4 percent). Percent occurrence of *M. giardi* was significantly ($P < .05$) greater in elvers.

Occurrence (percentage) and intensity (parasites/infected eel) of *Trichodina* sp. were 10.7 percent and 3.8 for eels and 17.7 percent and 5.0 for elvers. Occurrence and intensity of *Trichodina* sp. remained below levels found on wild elvers and elvers treated prophylactically with 100 mg/l formalin for 1 hour before stocking ponds. Prophylactic treatment with formalin appeared to provide some long-term protection against *Trichodina* sp.

U.S. Fish and Wildlife Service (Fish Farming Experimental Station)

Fish and Wildlife Service personnel, working with scientists at universities, state fish and game agencies, and researchers from other countries often collaborate in the identification and description of new species

A visceral microsporean, which causes bulging cysts in fathead minnows, was recently found in hatchery fish from Colorado. It had been reported only two other times—in feral fish in Ontario and in Quebec. Histological and electron micrographical studies in collaboration with other researchers showed the parasite is a species of *Glugea*—it will be named *Glugea pimephales.* In another cooperative effort an epistylid protozoan that causes grossly visible lesions in catfish, bluegills, goldfish, and several other fishes has been identified as *Herteropolaria colisarum.* This is a new distribution record for this parasite.

A new species of *Sanguinicola,* closely related to *S. davisi* Wales, has been found in brook trout. This is the first fish hatchery epizootic of blood reported east of the Rocky Mountains, and the first epizootic of this type reported in brook trout.

Hyperplasia of the gills of channel catfish cultured in ponds continues to cause fish losses in Arkansas, Mississippi, and several other states. This disease is commonly known as "hamburger gill disease." Tests to determine whether the disease or condition (toxin or toxin producers) could be transferred to healthy fish put in contact with soils from ponds in which the pathology was observed, were inconclusive. Histopathological studies revealed small sporozoan-like organisms in the lamellar and filament tissues—other workers consider this an early state of *Henneguya* cyst.

Of the several chemicals tested this year, chlorine dioxide, copper sulfate, and Cutrine® appeared promising for controlling certain disease organisms. Chlorine dioxide was tested on tilapia infected with *Flexibacter columnaris.* This compound at 250 p.p.m. (active ingredient) effectively immobilized the bacterial cells after an exposure of 1 hour. In 24 hours a few viable *F. columnaris* colonies were observed on treated fish, however, reduction in the infection level was evident.

An 18-hour static water treatment using 1.5 p.p.m. copper sulfate (total alkalinity of water - approximately 200 p.p.m.) reduced the levels of the parasite *Ambiphyra* on the gills of catfish by about 60 percent. Copper sulfate would be suitable for applications requiring only a reduction in *Ambiphrya* load.

A single treatment of 3.3 p.p.m. Cutrine on channel catfish, a labeled fishery algicide, was as effective in controlling *Ichthyophthir-*

ius multifilis as were four, 1.5-p.p.m. copper sulfate treatments given on alternate days in static waters. Savings in the quantity of chemicals required and in the application effort would result if additional tests confirm these studies.

NUTRITION

Alabama

Channel catfish of mixed sizes (12-220 g) stocked in earthen ponds were fed 32 or 36 percent protein diets at restricted or satiation rates for a 6-month growing season. Protein percentage did not influence growth rate. Growth rate was less for the restricted-fed fish; however, feed efficiency was also less.

Channel catfish fed ascorbic acid (AA) deficient diets showed lower natural immune responses, as measured by phagocytosis and serum complement activity, than those fed 30 mg/kg of AA. Increasing AA to 60, 150, or 300 mg/kg did not increase immune responses, but increasing to 3,000 mg/kg significantly increased complement activity as well as survival against infection with *Edwardsiella tarda.*

Channel catfish with an initial size of 5 g required 30 mg/kg of dietary ascorbic acid (AA) to prevent scoliosis and lordosis but 60 mg/kg for normal growth. Channel catfish beginning at 25 g required not more than 30 mg/kg for normal growth and bone development. This indicates that the AA requirement decreases as fish size increases.

Florida pompano *(Trachinotus carolinus)* were fed diets containing 12, 8, 4, or 0 percent fish oil. Those fed 8 percent oil gained most, probably because this amount supplied necessary fatty acids and the proper balance of energy with other nutrients. The 0 percent oil diet was probably deficient in essential fatty acids, as indicated by atrophied gills. The 12 percent oil diet probably contained too much energy and suppressed food intake.

A feeding study has been initiated to determine the effects of dietary level of metabolizable energy on food consumption, energy and protein intake, energy and protein gain, and energy and protein efficiency in small fingerling channel catfish (< g). Subsequent studies will be conducted with two larger sizes of fish (10 g and 100 g).

Mississippi

Channel catfish fingerlings, grown in aquaria and ponds, were fed 3 levels of vitamin E. Fish fed 33 g of vitamin E/ton of feed had better feed conversion in ponds and better weight gain and feed conversions in aquaria.

Requirements for zinc, selenium, and manganese were determined as: 150 mg Zn/kg diet, 2.25 mg Se/kg diet, and 2.4 mg/Mn/kg diet.

Puerto Rico

Male *Tilapia nilotica* fingerling were raised to harvestable size in cages by feeding three times a day a pelleted feed at 100, 85, 70, 55, or 40 percent of satiation. Respective average weight gain-food consumption was 349-465, 313-399, 277-329, 233-251, and 173-186. Weight gain decreased with increasing food restriction, but not in a linear fashion. The fish fed at 40 percent of satiation gained 24 percent less than the fish fed 55 percent of satiation; these gained 15 percent less than those fed 70 percent of satiation. Although the fish fed at 40 percent of satiation had the best food conversion ratio, feeding tilapia in cages below 55 percent of satiation did not improve weight gain relative to unit of food intake. Fish fed at the same level of satiation but with access to natural foods gained more than those without access. This occurred regardless of total nutrient input to the pond. Changing to a less restrictive feeding program (55 percent changed to 70 percent of satiation) resulted in faster growth relative to control fish maintained at the less restrictive level. Tilapia appear to adapt to restricted feeding by increasing gastric capacity and food utilization. To maximize weight gain while minimizing water quality problems, it is recommended to feed *T. nilotica* at 70 and 85 percent of satiation in ponds and cages, respectively.

South Carolina

Digestibilities of purified carbohydrates by blue tilapia *(Tilapia aurea)* were determined in laboratory feeding trials using extruded diets containing 1 percent chromic oxide. Fish were acclimated to temperatures of 23, 26, and 29 C. A separate study was conducted to calculate the error associated with fecal leaching from trough-collected feces. Fecal chromic oxide increased 1.35 percent per hour in the water. Menhaden meal acted as the carbohydrate carrier. Digestibility of fish meal was 69 percent and did not vary with temperature. Carbohydrate digestibilities were: dextrose, 98 percent; sucrose, 99 percent; and starch, 100 percent. There were no temperature effects. Cellulose was not digested, and did in fact lower overall diet digestibility. At 23, 26, and 29 C, cellulose digestibility averaged -15, -17, and -19 percent, respectively.

Texas

Studies to determine the optimum protein to energy ratio for fingerling redfish have been conducted. These studies indicate that the

protein requirement for fingerling redfish reared in low salinity water (5 p.p.t.) is 35 percent with an optimum PE ratio of 90-120 mg/kcal.

A series of studies to evaluate cottonseed products in channel catfish feeds was conducted. Glanded cottonseed meal, fullfat, glandless cottonseed flour, and defatted cottonseed flour and meal were substituted for soybean and peanut meals in catfish diets. The performance of catfish in both aquaria and pond studies indicated that defatted, glandless cottonseed meal was an adequate protein source for catfish. Edible portion gossypol levels are currently being determined. Similar studies with *Tilapia aurea* indicated that the cotton proteins were not as suitable as soybean and peanut meal.

Studies on the calcium requirement of *T. aurea* in calcium-free water have been conducted. Under these conditions, it was estimated that the calcium requirement is less than 0.65 percent of the dry diet. Growth, feed conversion, and bone composition data were used to make the estimate.

Feeding studies with brood channel catfish have been terminated. The final study in which the effects of feeding commercial feeds containing either fish meal or meat and bone meal as animal protein sources has been completed. The data were inconclusive because of the erratic spawning behavior of the broodfish. This behavior was attributed to the unusual weather conditions which occurred during the spawning season.

Several studies on the lipid requirements of channel catfish and blue tilapia were conducted. Growth and food conversion of blue tilapia fed 10 percent lipid diets were significantly better on menhaden oil than on beef tallow. Performance on catfish oil did not differ significantly from that on either menhaden oil or soybean oil. Tilapia performed well on fat-free diets, and there was little improvement when diets containing 4, 6, 8, 10, 12, or 14 percent soybean oil were compared with a fat-free control diet. Indications from experiments run with diets containing highly purified fatty acid esters were that linolenic acid family acids may not be required by blue tilapia and that linoleic acid family fatty acids may provide essential fatty acid activity. Synthesis of oleic acid *de novo* was indicated in the latter study.

Channel catfish fry maintained on a fat-free diet from first feeding to an age of 5 months showed *de novo* synthesis of saturated fatty acids and oleic acid. After 10 weeks on the fat-free diet, no docosahexaenoic acid could be detected in the fish. High levels of linoleic acid were once thought to cause growth depression in channel cat-

fish. When purified linoleic acid was fed to fingerling channel catfish, good growth was obtained up to a level of 2.5 percent dietary linoleic inclusion. Higher levels led to poorer growth, but were somewhat higher than those which might be found in any commercial catfish feed. Studies on the vitamin C requirements of blue tilapia revealed that a level of 50 mg/kg of feed will provide protection against pathology in that species. In order to obtain the desired level of ascorbic acid in finished feeds, however, it is recommended that formulation include 400 to 500 mg/kg of vitamin C because of its heat labile nature which subjects it to processing losses.

East Carolina University

Studies underway include effects of protein/energy ratios in diets of eels and striped bass hybrids.

U.S. Fish and Wildlife Service (Southeastern Fish Cultural Laboratory)

Aplastic anemia, also known as white-lip or no-blood disease, was reported in about 50 cases in Alabama in 1983. Eleven catfish diets were tested on channel catfish fry and sub-adults under laboratory conditions. Anemia was not detected in sub-adults, but did develop in fry maintained in flow-through tanks receiving 20 C well water when fry were fed 6 of the 11 diets. The incidence of anemia ranged from 0.16 to 11.1 percent and anemic conditions (hematocrit 11.7 ± 5.2 percent) were corrected (hematocrit 28.3 ± 0.7 percent) when fish were placed on new diets. The time of day when channel catfish were fed influences body composition. Visceral body fat was significantly greater in fish fed a single meal at 1630 hours as compared to fish fed at 0730 hours. When fish were fed half of their daily ration at 0730 hours and half at 1630 hours, visceral body fat was intermediate between that of fish fed in the morning and those fed in the afternoon. Additional work is underway to further explore the fattening responses of fish as a function of the time of day of feeding and the season of the year.

PRODUCT DEVELOPMENT AND QUALITY ASSURANCE

Alabama

Channel catfish were collected from 12 ponds in Alabama and from 6 ponds in Mississippi from April through October and evaluated for off-flavors sensorily and instrumentally. Generally, flavor was acceptable in fish from almost all ponds from April through July. From late August through September, approximately one-half of the fish from ponds in both states had unacceptable flavor. The dominant flavors were subtle muddiness, mustiness, and sewage (or fecal). Feeding or stocking rates did not seem to affect incidence or intensity of off-flavor. Both geosmin and 2-methyl-isoborneol were found in the muddy- and musty-flavored fish.

2-methyl-isoborneol, a muddy-flavored compound produced in the pond environment, has been isolated and identified in muddy-flavored channel catfish from commercial ponds. Occurrence and concentration in the fish are less than for geosmin, which has previously been identified and associated with earthy-musty off-flavor.

Objective and sensory testing for geosmin flavor in channel catfish agree very well ($R^2 = 0.70$, $P < .01$). Trained judges could detect geosmin in fish flesh spiked with geosmin as well as in fish from commercial ponds containing approximately 8-10 mg/kg of geosmin, which is the level considered unacceptable.

Amount of fat in flesh of cultured catfish was related to size and feeding method in ponds containing multiple-size fish. Fish averaging 1.1 kg weight contained 12.1 percent carcass fat, those averaging 0.5 kg contained 11.2 percent fat, and those averaging 0.23 kg contained 7.9 percent fat if diet-restricted or 9.5 percent fat if fed to satiation. Feeding method did not influence carcass fat in two larger groups of fish.

Radiolabeled geosmin (trans-1-20-dimethyl-trans-9-decalol) will be used to measure rate and mechanisms of absorption of this off-flavor compound by channel catfish from the water or diet. Storage site of geosmin in tissues of the fish and rate of release will also be measured. Relationship between concentration in the environment and fish can be determined. Geosmin, which is not commercially available, has been synthesized in the laboratory; the present efforts are to label one of the methyl groups with tritium (H^3).

Mississippi

A study of the effects of stocking rate (10,000, 15,000, and 20,000 fish/ha, packing, and storage temperature (-17C and -12C) was completed. No differences were found with any variable. The fish were stable and palatable at the end of 12 months of storage.

Puerto Rico

The effects of post-harvest methods on fish quality were evaluated for tilapia. Harvested tilapia were placed in a water and ice mixture or water at ambient temperature prior to evisceration. Tilapia in the water and ice mixture attained a final pH 18 percent lower than the fish in the water-only treatment. Organoleptic evaluations revealed a firmer cooked product for the fish that had a lower pH upon storage.

Fish quality was evaluated for tilapia that were raised on either (1) natural foods alone, (2) a pelleted feed alone fed at 100, 85, 70, 55, or 40 percent of satiation, or (3) natural foods at high or low nutrient input levels in combination with the pelleted diet fed at 40 percent satiation. The lowest mean body weight per 2-cm length group, lowest crude protein, lowest body fat, and highest moisture content occurred in fish that fed only on natural foods. Weight per 2-cm length group increased with increasing food intake. However, the fish that had access to natural food in the high nutrient ponds in combination with a feed fed at 40 percent of satiation and the fish fed at 85 percent of satiation showed no significant differences in deheading, eviscerating, or body composition. Organoleptic evaluations revealed no differences related to feed type or storage time.

U.S. Department of Agriculture

Catfish processing waste utilization studies were conducted. Freshly extracted oils from raw offal stored for 6 months at 22 C exhibited no change in free fatty acid (FFA) content. Oils extracted from various stored offal samples contained FFA values of 93.1 percent after 4 days at 22 C, 21.6 percent after 42 days at 4 C, and 12.4 percent after 72 days at -7 C. Fatty acid composition of these oils showed only slight variance from fresh-extracted offal oil. Oils obtained by several processing methods (rendering, alcohol extraction, indigenous liquefaction) had the same oils with the highest FFA content (5.3 percent). In catfish offal enzyme studies, a heterogeneous protein fraction was isolated that had approximately a 200-fold greater specific activity than dry acetone-insoluble equivalent frac-

tion. Acid proteases were found in all visceral tissues, with the stomach having the highest specific and total activity. Significant activities in the liver and kidneys indicate the offal liquefaction by endogeneous acid proteases is due to tissue as well as gastric proteases. Processing studies were continued with catfish offal being liquefied in pilot scale equipment designed and constructed in New Orleans. On-the-farm simulation runs were conducted. Processing variables were shown to alter the amounts of free essential amino acids without changing total amino acid content. Liquefied catfish protein (LCP) appears to be a good source of nutrients for inclusion in animal feedstuffs. Addition of molasses to LCP prevented spoilage at room temperature for over 1 year.

PHYSIOLOGY

Memphis State University

Bony fish produce only the IgM class of antibody. A method is described for the isolation and purification of channel catfish *(Ictalurus punctatus)* immunoglobulin M from immune channel catfish serum using a combination of sodium sulfate precipitation, DEAE-Sephacel anion-exchange chromatography, and Sepharose 6B gel filtration. Specificity of the purified channel catfish IgM was shown by agglutination testing and by immunoelectrophoresis. This should also be a feasible method for the purification of IgM from other teleost fish species.

The influence of the eyes and pineal gland of locomotor activity rhythms of channel catfish and the extent to which varying light intensity altered these activity rhythms were evaluated. Locomotor activity was measured in normal, blinded, pinealectomized, and pinealectomized-blinded channel catfish exposed to a 12:12 light/dark photoperiod of decreasing light intensities (7,500, 125, and 0.7 lux). Normal, blinded, and pinealectomized fish exhibited nocturnal activity patterns which corresponded with the exogenous photoperiod. Fish without lateral eyes and pineal gland did not entrain to the photoperiod but had arrhythmic activity patterns. Neither treatment nor light intensity affected total locomotor activity. Blinding or pinealectomy decreased the level of dark-period activity at low light intensities, but the effect of light intensity was not observed in normal and pinealectomized-blinded fish. Normal and blinded fish under constant light or constant dark exhibited arrhythmic activity. The pineal gland functions as an extraretinal light receptor in channel catfish.

Channel catfish were stressed by close confinement in a net for periods up to 24 hours. Plasma corticosteriod concentrations increased from 0.8 ± 0.3 ug/100 ml (mean ± S.E.) to a peak of 5.7 ± ug/100 ml after 6 hours, then declined by 24 hours. Leucocrit decreased during the first 6 hours, owing to a decline in lymphocyte numbers, then increased by 12 hours. Hematocrit did not vary significantly during the 24-hour period.

Oral administration of 12-B-estradiol or 17-∝-ethynltestoterone to sexually undifferentiated channel catfish during the first 21 days after yolk-sac absorption resulted in the production of 100 percent females. The androgen was effective at doses of 6 to 600 ug/g of feed but not at 0.6 ug/g.

Three types of basophils in the pituitary of channel catfish were distinguished by location, staining, reaction, age of differentiation, and annual change in size. TSH cells were located primarily in the dorso-lateral proximal pars distalis, differentiated early, and were largest in winter. Proximal pars distalis gonadotrophs were only present in adult fish, were largest during the spring when the gonads were developing, and were designated maturational gonadotrophs. Pars intermedia gonadotrophs differentiated in immature fish, increased in cell size during autumn when gametogenesis occurs, and were designated gametogenic gonadotrophs.

Levels of plasma corticosteroids and chloride were studied in rainbow trout *(Salmo gairdneri)*, lake trout *(Salvelinus namaycush)*, and Atlantic salmon *(S. salar)* after 6 hours of confinement in a shallow dipnet. Plasma corticosteroids increased more sharply in rainbow trout than in the other species during the confinement, and returned to resting levels more slowly. Plasma chloride levels decreased significantly from resting levels in both rainbow trout and Atlantic salmon confined for 6 hours and had not recovered 12 hours after release from the dipnet; very little effect was observed in lake trout. Both plasma corticosteriod and chloride dynamics appear to vary widely in closely-related species. The differences do not appear to be related to ease of maintaining the species in captivity.

ECONOMICS AND MARKETING

Alabama

Food size catfish were stored in four, 0.5-ha holding ponds to allow year-round marketing. A total of 19,530 kg of catfish was sold at $2.02/kg in the local live fish market. A total of 14,983 kg was sold at $1.58/kg to live haulers. Mean daily sale (96 days) at the local live fish market was 202 kg/day. Other species sold were 5,989 kg of Chinese carp at $1.03/kg, 322 kg of tilapia at $2.20/kg, and 672 kg of bluegill at $1.19/kg.

Kentucky

A collaborative trout and catfish market survey with the Kentucky Department of Agriculture was completed and a publication prepared and distributed.

Major activities in 1983 were as follows: mail and field survey questionnaires were developed to assess fishing activities and marketing potential at recreational fish-out operations in Kentucky; assistance was provided by marketing specialists from Auburn University. Mail and field surveys of Kentucky fish-out operations were conducted during the summer months; survey work was completed in September. Two publications are planned from this work: a directory of fish-out operations in Kentucky and an analysis of the potential of existing pay lakes as market outlets for Kentucky fish producers.

Mississippi

Cash flow schedules were computed for three farm situations and three financial situations. Analysis could be tailored for individual situations with specific costs, prices, and financial situations.

Texas

Gulf killifish *(Fundulus grandis)* grew in 80 days from 0.2 g to marketable bait size of 3 g in fertilized ponds, but required 100 to 107 days in ponds receiving 33 percent protein minnow meal. Cost of fertilizer ($195/ha) was less than for food ($301/ha), and labor cost for fertilizing weekly was much less than for feeding daily. Mean harvest averaged 22,795 fish in fertilized-only ponds and 24,420 in fed-only ponds. At $0.07 each delivered to bait dealers, they were worth

$15,956 and $17,094/ha, respectively. Shrimp migration from a once-through cooling lake over a drop structure into Trinity Bay, Texas, was monitored for a year. Significantly more shrimp passed over the drop structure nocturnally than diurnally. Although the surface of the lake was above high tide level, more shrimp left on ebbing than incoming tides. An estimated 11 million shrimp passed over the drop structure during the year which would have had a retail bait value of $935,000.

PLANS FOR 1984

The 1984 meeting of the S-168 Technical Committee will be held during June 18-21 at the University of Puerto Rico, Mayaguez, and at the University of the Virgin Islands, St. Croix. Sub-committee meetings in each of the subject areas identified for research by the Technical Committee will address current research activities and directions for future research. A focus of the 1984 meeting will be on the need for additional Southern Regional Cooperative Research Bulletins in the subject areas of tilapia, freshwater shrimp, crawfish, and chinese carp. Updating of earlier bulletins from S-83 will be considered; that for nutrition and feeding of channel catfish is underway and will be completed during 1984. Continuation of the series of SRCR Bulletins of aquacultural subject matter is an essential aspect of the Warmwater Aquaculture project. The bulletin provides the aquacultural community the latest available information on a variety of subjects in a concise form.

APPENDIX I, OTHER PARTICIPATING TECHNICAL COMMITTEE MEMBERS

Agricultural Experiment Stations

ALABAMA
R. Allison
C.E. Boyd
R.A. Dunham
J.M. Grizzle
P.H. Klesius
J.A. Plumb
E.E. Prather
W.A. Rogers
R.O. Smitherman

ARKANSAS
C.J. Haskins
W.R. Robinson
E.L. Torrans

LOUISIANA
R.P. Romaire
R.L. Thune
W.B. Wolters

MISSISSIPPI
G.R. Ammerman
R.L. Busch
W.E. Poe
H.R. Robinette

C.S. Tucker
J.E. Waldrop
R.P. Wilson

NORTH CAROLINA
D.J. Delmont
W.W. Hassler
M.T. Huish
J.H. Kerby

PUERTO RICO
J.M. Kubaryk

SOUTH CAROLINA
A.G. Eversole

TENNESSEE
R.J. Strange

TEXAS
D.H. Lewis
E.H. Robinson
R.K. Strawn

VIRGIN ISLANDS
A. Nair

Other Agencies and Institutions

EAST CAROLINA
M. Gallagher

MEMPHIS STATE UNIVERSITY
M.L. Beck
C.J. Biggers
K.B. Davis
D.D. Ourth

SOUTHERN UNIVERSITY
J. Huner

TENNESSEE VALLEY AUTHORITY
C.M. Collins
B. Kingsley

U.S. DEPARTMENT OF AGRICULTURE
D. Freeman

U.S. FISH AND WILDLIFE SERVICE
T. Brandt
D.C. Greenland
G.I. Hoffman
J.M. Martin
A.J. Mitchell
N.C. Parker
D.L. Tacket

APPENDIX II, PUBLICATIONS

Alabama

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