Effects of Diet and Organic Fertilization on Water Quality and Benthic Macroinvertebrate Populations in Ponds Used to Culture Freshwater Prawn, *Macrobrachium rosenbergii*

Sankie J. Hill, Jr.
John D. Sedlacek
Paul A. Weston
James H. Tidwell
Kevin D. Davis
Wanda L. Knight

ABSTRACT. Effects of three diets: (1) complete diet; (2) supplemental diet (vitamin and mineral supplements not added); and (3) the supplemental diet with an adjunct organic fertilization regimen (using distiller's dried grains with solubles [DDGS]) on benthic macroinvertebrate populations and water quality in experimental ponds used to culture freshwater prawns, *Macrobrachium rosenbergii* were investigated. Benthic samples were taken from deep (1.5 m) and shallow (1.0 m) areas of each of nine 0.02-ha ponds every three weeks, using a 0.09-m^2 Ekman dredge. The abundance of gastro-

Sankie J. Hill, Jr., John D. Sedlacek, and Paul A. Weston, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601 USA.

James H. Tidwell, Aquaculture Research Center, Community Research Service, Kentucky State University, Frankfort, KY 40601 USA.

Kevin D. Davis, Department of Entomology, University of Kentucky, Lexington, KY 45056 USA.

Wanda L. Knight, Aquaculture Research Center, Community Research Service, Kentucky State University, Frankfort, KY 40601 USA.

Address correspondence to John D. Sedlacek.

Journal of Applied Aquaculture, Vol. 7(3) 1997

pods, oligochaetes, total non-insects, chironomids, total dipterans, total insects, and total macroinvertebrates was significantly higher ($P < 0.05$) in ponds receiving the complete diet, possibly due to lower predatory pressure by prawns or direct benefits of micronutrients. Total macroinvertebrate abundance was significantly decreased ($P < 0.05$) in ponds receiving supplemental diet (with and without organic fertilization), possibly due to increased predation by prawns to supplement the nutrition not provided by the lower quality diet. Organic fertilization significantly increased ($P < 0.05$) the abundance of oligochaetes and total macroinvertebrates. These data suggest that *M. rosenbergii* can adjust to reduced feed quality by increasing consumption of benthic fauna. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

INTRODUCTION

Freshwater prawns, *Macrobrachium rosenbergii*, are benthic omnivores. Their diet consists of aquatic insects and crustaceans, algae, mollusks, worms, fish, zooplankton, and other detrital matter (Wellborn 1985; MacLean et al. 1989; MacLean et al. 1994). Corbin et al. (1983) suggested that the major portion of macronutrients (i.e., protein) for cultivated freshwater prawns needs to be provided in prepared diets but that required levels of micronutrients (i.e., vitamins and minerals) could be obtained from natural productivity.

Feed constitutes 40 to 60% of the production costs of prawn (D'Abramo and Sheen 1991). Tidwell et al. (1993a and 1993b) demonstrated that fish meal in prawn diets could be replaced with less expensive plant proteins with no adverse effects on prawn growth. A better understanding of the role of natural productivity in prawn nutrition could lead to management strategies that selectively enhance desirable food organisms and lower feed costs by utilizing low-cost agricultural by-products as organic fertilizers.

This study was conducted to evaluate the effects of deleting certain dietary components, with and without organic pond fertilization, on water quality and macroinvertebrate populations in prawn ponds.

MATERIALS AND METHODS

Ponds

Nine 0.02-ha earthen ponds were drained in the spring of 1992, allowed to dry for two weeks, then were refilled on June 1, 1993, from a freshwater reservoir collecting runoff from the surrounding watershed. Water was filtered through a 385-μm mesh sock to prevent the introduction of macroinvertebrates from the reservoir. Water for replacing evaporative losses and flushing of ponds was also obtained from this reservoir.

Two applications of 10-34-0 liquid fertilizer (200 mL/pond) were added to all ponds to stimulate algal production (Tidwell et al. 1993a). Juvenile prawns averaging 0.5 g each were stocked into all ponds at 39,520/ha on June 5, 1993. Three replicate ponds were randomly assigned to each of the three nutritional strategies: (1) complete diet; (2) supplemental diet; and (3) supplemental diet with organic pond fertilization.

Feeds, Feeding, and Fertilizer

Both complete and supplemental diets were formulated to contain 32% crude protein. The complete diet contained 7.5% fish meal with vitamin and mineral premixes. In the supplemental diet, vitamin and mineral premixes were not added, and fish meal was replaced with distiller's dried grains with solubles (DDGS) and soybean meal (SBM) as reported in Tidwell et al. (1995). The third feeding regimen consisted of feeding the supplemental diet in conjunction with organic pond fertilization. The organic fertilizer used was unpelleted DDGS, applied every other day to achieve a total of 75 kg/ha/week. Prawns were fed 25 kg/ha/day of diet until they averaged a minimum of 5 g. At a size >5 g, prawns were fed a percentage of body weight according to a feeding schedule (D'Abramo et al. 1989) with the daily feed amount split into equal rations for morning (0900-1000) and afternoon (1500-1600) feedings.

Water Quality

Dissolved oxygen and water temperature were measured daily in the morning (0900) and afternoon (1530) with a YSI Model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio[1]). Ponds were aerated with electric vertical pump aerators if the overnight dissolved oxygen was predicted (graphically) to decline below 4.0 mg/L. The pH of each pond was determined daily at 1300, using an electronic pH meter (Hanna Instruments, Ltd., Mauritius). If the afternoon pH was measured to be ≥ 9.5, the pond was slowly flushed overnight with water from the reservoir. Total ammonia-nitrogen (TAN), nitrite-nitrogen (NO_2^-–N), and phosphorus (orthophosphate) was measured in each pond weekly with a Hach DR/2000

1. Use of trade or manufacturer's name does not imply endorsement.

spectrophotometer (Hach Company, Loveland, Colorado). Chlorophyll *a* was determined weekly by acetone extraction followed by spectrometry (Boyd 1979).

Benthos

Baseline benthic samples were taken from each pond 3 days prior to stocking of prawns according to Lind (1979). After stocking, benthic macroinvertebrate samples were taken at 3-week intervals. Two samples per pond were taken with a 0.09-m^2 Ekman dredge (Wildco, Saginaw, Michigan). One dredge sample each was taken 2 m from the perimeter of the shallow (1.0 m) and deep (1.5 m) ends of each pond. The sediment sample was sieved through a 20-L capacity U.S. Standard 35 mesh (0.5-mm mesh) sieving bucket and the contents preserved in 70% ethanol until identification and enumeration. If possible, benthic macroinvertebrates were identified to phylum, class, and order, and insects were identified to family and/or genus, using taxonomic keys of Needham and Needham (1966), Pennak (1978), Lehmkuhl (1979), and Merritt and Cummins (1984).

Statistical Analyses

Water quality parameters were assessed for block and treatment effects using ANOVA and Fisher's LSD test. Macroinvertebrate density data were extrapolated to one square meter before analyses and are presented as untransformed treatment means with $\log_{10}$ transformed mean separations. Benthic data were analyzed with ANOVA for block, depth, treatment effects, and their interactions, using the SAS GLM procedure and Fisher's LSD test (SAS 1988).

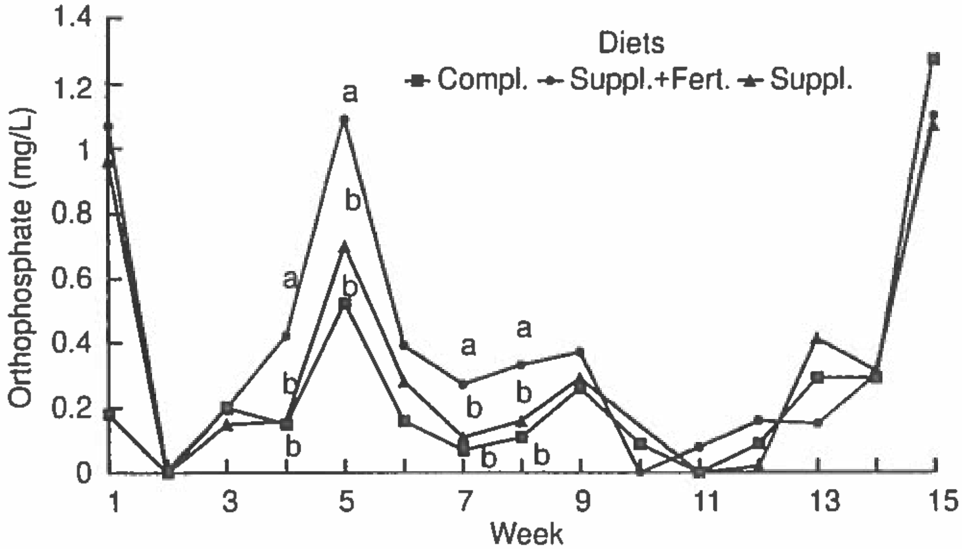
RESULTS AND DISCUSSION

Water Quality

Mean ± SE dissolved oxygen (morning and afternoon combined), water temperature, and pH for the entire study were 9.3 ± 0.5 mg/L, 27.0 ± 0.3°C, and 8.8 ± 0.2, respectively. Dissolved oxygen, water temperature, and pH were not significantly ($P > 0.05$) different among the three nutritional strategies.

Between weeks 4 and 8, orthophosphate concentrations were significantly higher in ponds receiving supplemental diet with organic fertilization (Figure 1). Chlorophyll *a* levels increased in all treatments after week

FIGURE 1. Orthophosphate concentrations associated with ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).



6 and corresponded with decreasing orthophosphate concentrations after week 5 (Figure 2). After week 11, chlorophyll *a* concentrations were not significantly higher in ponds receiving the complete diet or supplemental diet without fertilization than those in ponds with organic fertilization ($P > 0.05$).

Total ammonia-nitrogen (TAN) concentrations increased in all treatments after week 9 (Figure 3). At week 13, TAN was higher ($P < 0.05$) in ponds receiving the complete diet. The reason for higher TAN in ponds receiving the complete diet during this period is not known. Perhaps nitrogen contained in fish meal is more soluble than that in DDGS due to ingredient particle size.

Nitrite-nitrogen (NO_2^-–N) concentrations increased from weeks 10 and 13 in all treatments and was significantly higher in ponds receiving the complete diet ($P < 0.05$) (Figure 4). By week 14, NO_2^-–N concentration was significantly higher in ponds receiving the supplemental diet with organic fertilization. The increase in NO_2^-–N was correlated with a decrease in TAN. By week 16 NO_2^-–N concentrations in ponds receiving complete diet and supplemental diet with adjunct organic fertilization was significantly higher ($P < 0.05$) than those in ponds receiving supplemental diet only.

FIGURE 2. Chlorophyll *a* concentrations associated with ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of the three replications. No significant differences ($P > 0.05$) were found among treatments.

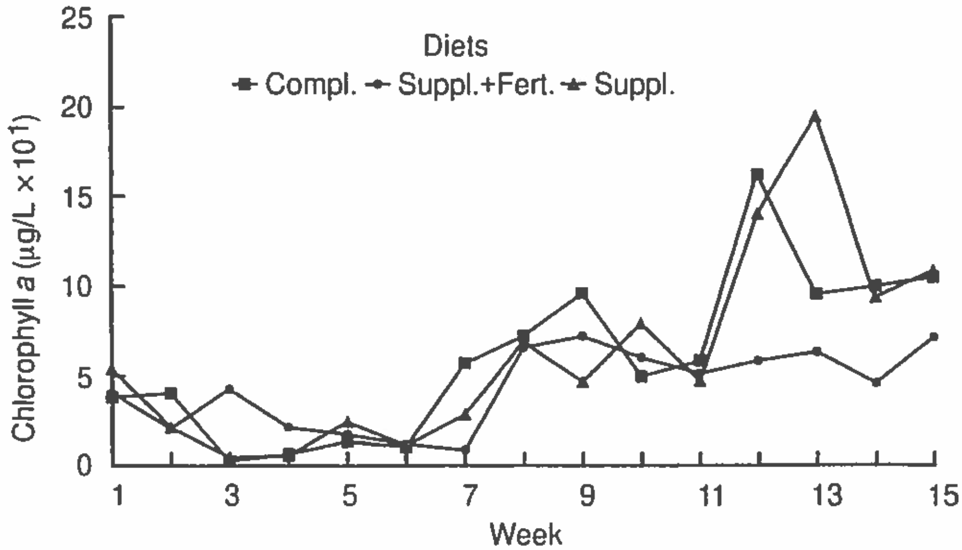


FIGURE 3. Total ammonia-nitrogen (TAN) concentrations associated with ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

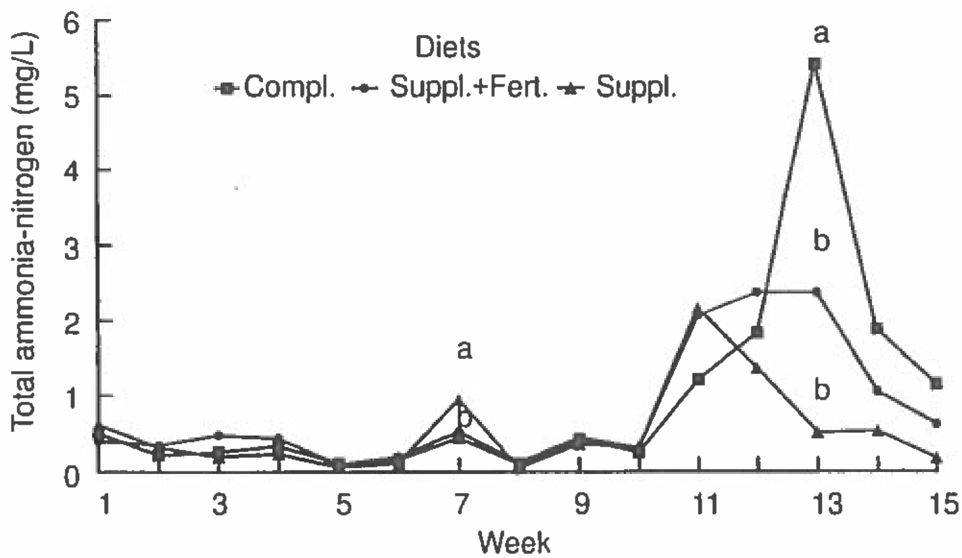
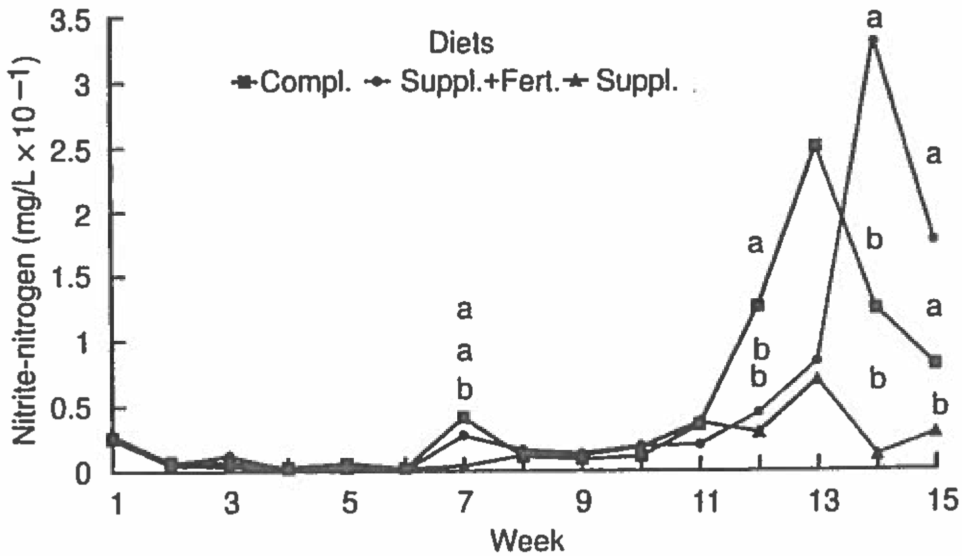


FIGURE 4. Nitrite-nitrogen (NO_2^-–N) concentration associated with ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).



Benthic Community

The numbers of gastropods, oligochaetes, total non-insects, chironomids, total dipterans, total insects, and total macroinvertebrates differed significantly ($P < 0.05$) among the three feeding regimens on at least three of the six sampling dates (Figures 5-11). Densities of these benthic taxa were consistently higher in ponds in which prawns were fed the complete diet versus supplemental diet plus fertilizer, ranging from 95% higher for chironomids (Figure 8) to 261% higher for oligochaetes (Figure 6). Densities of chironomids and oligochaetes were 280 and 281% higher, respectively, in ponds in which complete feed vs. supplemental feed was used. Ponds receiving adjunct organic fertilization had higher numbers of macroinvertebrates compared to those receiving supplemental diet only, with numerical differences ranging from 5% for oligochaetes (Figure 6) to 94% for chironomids (Figure 8), 89% for dipterans (Figure 9), and 96% for total insects (Figure 10).

Chironomid (Figure 8), total dipteran (Figure 9), and total insect densities (Figure 10) increased in the complete feed and supplemental feed with adjunct organic fertilization treatments from June 8 to July 7, 1993. Mean numbers of individuals decreased for oligochaetes, total non-insects, and

FIGURE 5. Abundance of Gastropoda in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

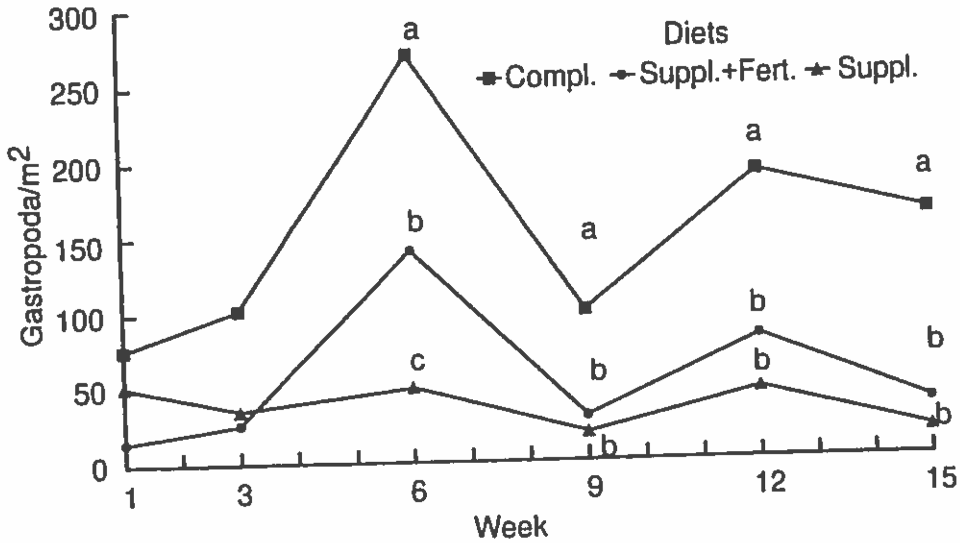


FIGURE 6. Abundance of Oligochaeta in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

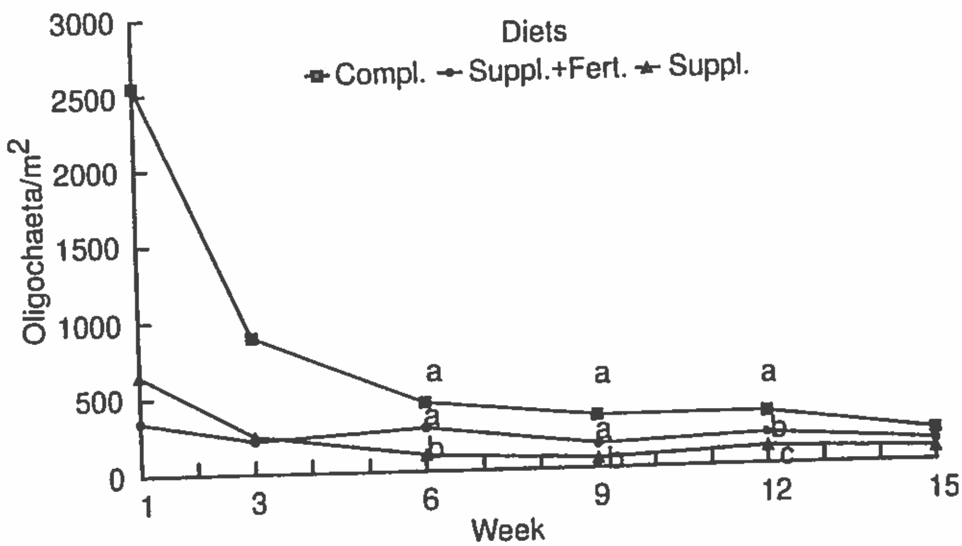


FIGURE 7. Abundance of non-insects in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

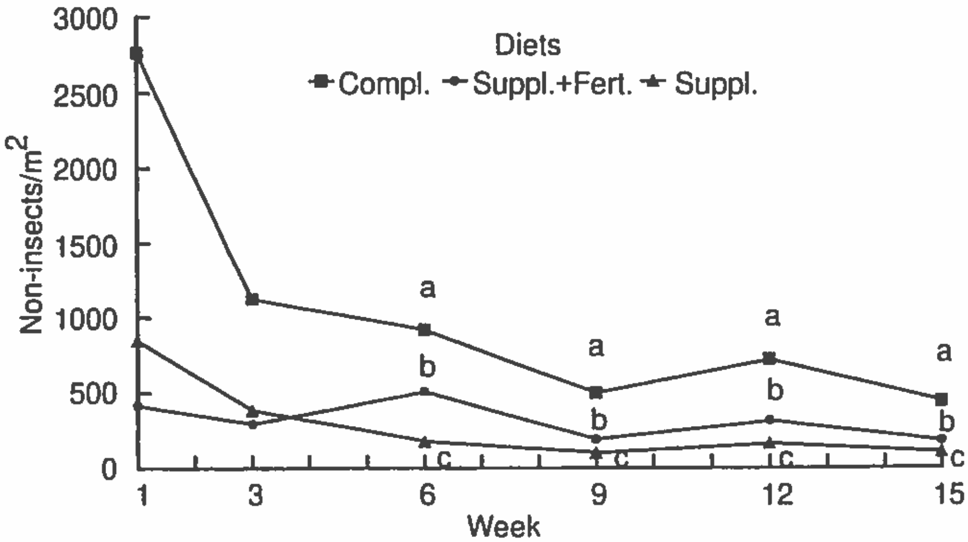


FIGURE 8. Abundance of Chironomidae in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

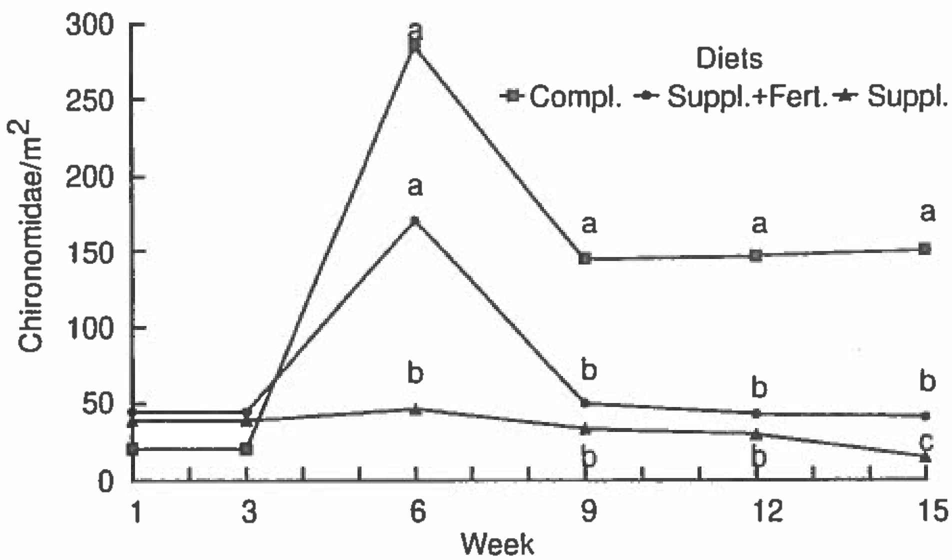


FIGURE 9. Abundance of Diptera in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

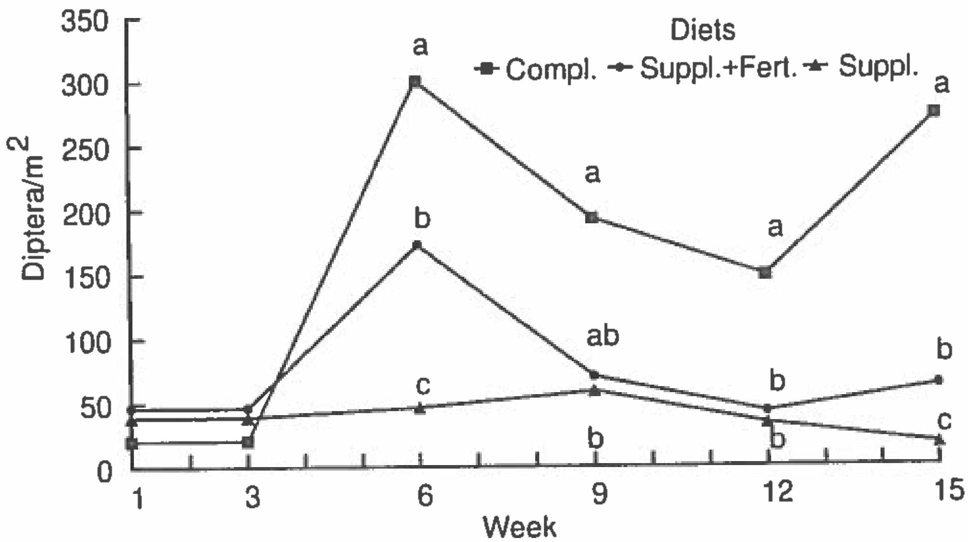


FIGURE 10. Abundance of insects in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

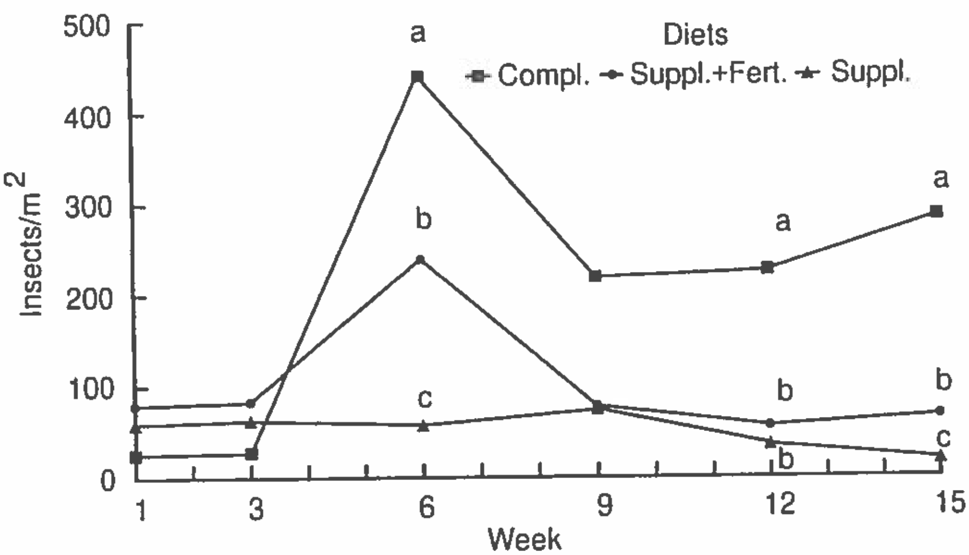
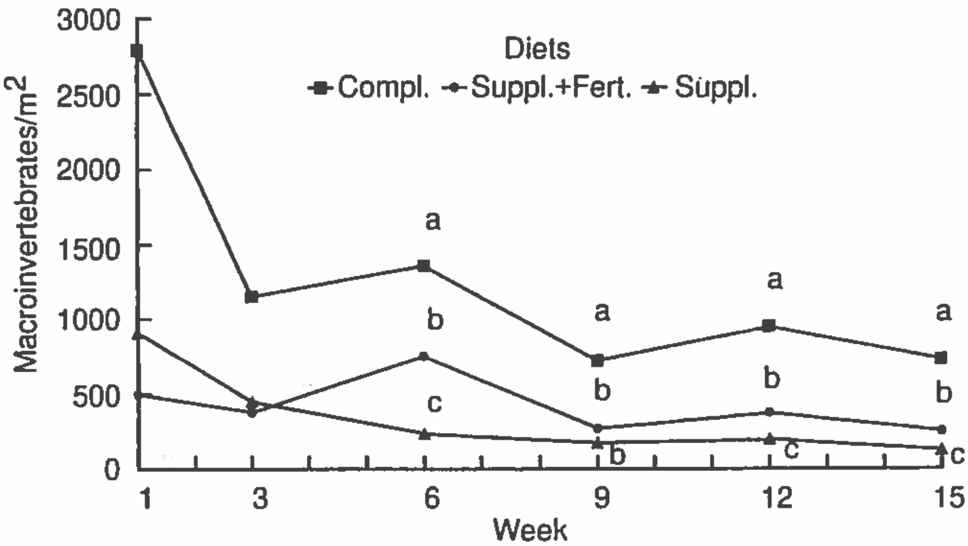


FIGURE 11. Abundance of total macroinvertebrates in ponds in which freshwater prawns, *M. rosenbergii*, were fed three different diets. Values are means of three replications. Means followed by different letters are significantly different ($P < 0.05$).

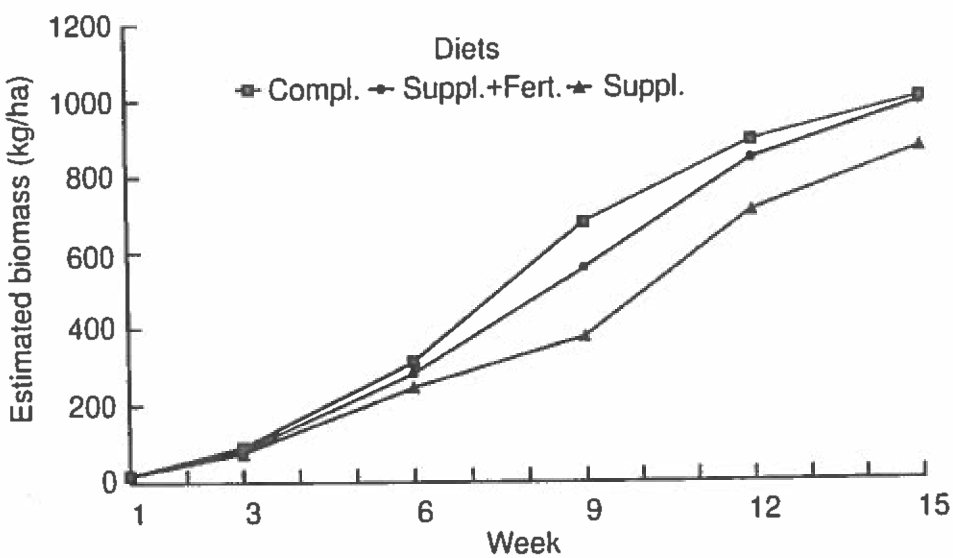


total macroinvertebrates with each successive sampling date (Figures 6, 7, and 11). Densities of gastropods, chironomids, total dipterans, and total insects generally decreased from observed peak densities on July 7 through the last sampling date on September 14 (Figures 5 and 8-10).

The higher abundance of benthic macroinvertebrates in ponds receiving complete diets could be due to increased levels of predation on benthic macroinvertebrates by prawns fed the supplemental diet in order to augment nutrients in lower quantities (i.e., vitamins, minerals, and certain amino acids). Differences could also be explained by increased macroinvertebrate survival and reproduction as a result of feeding on diet particles and the associated direct positive effects of micronutrients on macroinvertebrate populations. This seems less likely, due to the widely divergent feeding niches of these taxa (e.g., detritovores vs. carnivores). Thus, even though the evidence is circumstantial, it is our contention, like Tidwell et al. (1995), that the increased abundance of benthic macroinvertebrates in the more nutritionally complete ponds resulted indirectly from decreased predation by prawns. Food habits data to determine ingestion rates of invertebrate taxa by prawns in the different dietary treatments would be helpful. However, stomach analysis of crustaceans is difficult and often inconclusive, due to small stomach size, small size of prey items, mastication at time of ingestion, rapid catabolism in the stomach, relatively rapid rate of stomach emptying, and incidental ingestion of nutritionally unimportant items (Brown et al. 1992). The possibility of increased predation is supported by Weidenbach (1980) who found that prawns could adjust to the absence of feed pellets by increasing consumption of available vegetation. Hird et al. (1986) suggested that cannibalism in crustaceans may be a response to satisfying the dietary need for arginine. Tidwell et al. (1993b) reported that as fish meal levels in prawn diets decreased, dietary arginine became more limiting. In studies on alternative protein sources for common carp, *Cyprinus carpio* (L.), Spinelli et al. (1979) reported that Diptera larvae had arginine levels very similar to those in fish meal. In the present study, chironomids (which are Diptera larvae) showed a very pronounced response to the complete and supplemental diets.

Interestingly, estimated prawn biomass did not differ significantly among the three feeding regimens (Figure 12). However, as previously stated, significantly greater numbers of total macroinvertebrates and most individual taxa were found in ponds in which complete feeds were used rather than supplemental feed (Figures 5-11). These data suggest that *M. rosenbergii* can adjust to differences in diet quality by increasing their consumption of benthic fauna. This is consistent with aquarium studies

FIGURE 12. Estimated freshwater prawn, *M. rosenbergii*, biomass throughout the study period using three different diets. Values are means of three replications. No significant differences ($P > 0.05$) were found among treatments.



that revealed juvenile prawns (≥ 2 g) fed a variety of live foods grew as fast or faster than prawns fed a nutritionally-complete pelleted diet (Coyle et al. 1995). Further studies should be conducted to address this hypothesis, which could lead to selective management of beneficial natural food items with DDGS as an organic fertilizer and food item in prawn production.

ACKNOWLEDGMENTS

The authors thank Brad Mefford, Bryan Price, Xiaosong Ge, Laura Tiu, and Bill Owens for their help with sampling. A special thanks goes to Burr Settles and Monica Williams for helping process samples. This research was partially funded by a grant from the Distiller's Feed Research Council, Ft. Wright, Kentucky and in part by a USDA/CSRS grant to Kentucky State University under agreement KYX-80-91-04A.

REFERENCES

Boyd, C.E. 1979. Water Quality in Warmwater Fish Ponds. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Brown, P.B., J.E. Wetzel II, and A. Spacie. 1992. Evaluation of naturally-occurring organisms as food for juvenile crayfish *Procambarus clarkii*. Journal of the World Aquaculture Society 23:211-216.

Corbin, J.S., M.M. Fujimoto, and T.Y. Iwai, Jr. 1983. Feeding practices and nutritional considerations for *Macrobrachium rosenbergii* culture in Hawaii. Pages 393-423 *in* J.P. McVey, ed. Handbook of Mariculture, Vol. 1. CRC Press, Inc., Boca Raton, Florida.

Coyle, S., T. Najeeullah, and J. Tidwell. 1995. A preliminary evaluation of naturally occurring organisms, distillery by-products, and prepared diets as food for juvenile freshwater prawn, *Macrobrachium rosenbergii*. Journal of Applied Aquaculture 6(2):57-65.

D'Abramo, L.R., and S.S. Sheen. 1991. Nutritional requirements, feed formulation and feeding practices for intensive culture of the freshwater prawn *Macrobrachium rosenbergii*. Review of Fisheries Science 2:1-21.

D'Abramo, L.R., J.M. Heinen, H.R. Robinette, and J.S. Collins. 1989. Production of freshwater prawn *Macrobrachium rosenbergii* stocked as juveniles at different densities in temperature zone ponds. Journal of the World Aquaculture Society 20:81-89.

Hickman, C.P., Jr., L.S. Roberts, and F.M. Hickman. 1988. Integrated Principles of Zoology. C. V. Mosby Co., St. Louis, Missouri.

Hird, F.J.R., S.C. Ciancios, and R.M. McLean. 1986. Investigations on the origin and metabolism of the carbon skeleton of ornithine, arginine, and proline in selected animals. Comparative Biochemistry and Physiology 83:179-184.

Lehmkuhl, D.M. 1979. How to Know the Aquatic Insects. William C. Brown Co., Dubuque, Iowa.

Lind, O.T. 1979. Handbook of Common Methods in Limnology. C. V. Mosby Co., St. Louis, Missouri.

MacLean, M.H., K.J. Ang, J.H. Brown, and K. Jauncey. 1989. The effect of organic fertilizer and formulated feed in pond culture of the freshwater prawn *Macrobrachium rosenbergii* (de Man): Prawn production. Aquaculture and Fisheries Management 20:399-406.

MacLean, M.H., K.J. Ang, J.H. Brown, K. Jauncey, and J.C. Fry. 1994. Aquatic and benthic bacteria responses to feed and fertilizer application in trials with the freshwater prawn, *Macrobrachium rosenbergii* (de Man). Aquaculture 120:81-93.

Merritt, R.W., and K.W. Cummins. 1984. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Needham, J.G., and P.R. Needham. 1966. A Guide to the Study of Freshwater Biology. Holden-Day, Inc., San Francisco, California.

Pennak, R.W. 1978. Freshwater Invertebrates of the United States. Ronald Press Co., New York, New York.

SAS. (1988) SAS/STAT User's Guide, Release 6.04. SAS Institute, Cary, North Carolina.

Spinelli, J., C. Mahnken, and M. Steinberg. 1979. Alternate sources of proteins for fish meal in salmonid diets. Pages 131-142 *in* J.E. Halver and K. Tiews, eds. Finfish Nutrition and Fishfeed Technology, Vol. II. H. Heenemann GmbH, Berlin, Germany.

Tidwell, J.H., C.D. Webster, J.A. Clark, and L.R. D'Abramo. 1993a. Evaluation of distillers dried grains with solubles as an ingredient in diets for pond culture of the freshwater prawn, *Macrobrachium rosenbergii*. Journal of the World Aquaculture Society 24:66-70.

Tidwell, J.H., C.D. Webster, D.H. Yancey, and L.R. D'Abramo, 1993b. Partial and total replacement of fish meal with soybean meal and distillers by-products in diets for pond culture of the freshwater prawn (*Macrobrachium rosenbergii*). Aquaculture 118:119-130.

Tidwell, J.H., C.D. Webster, J.D. Sedlacek, P.A. Weston, W. L. Knight, S.J. Hill, Jr., L.R. D'Abramo, W.H. Daniels, M.J. Fuller, and J.L. Montanez. 1995. Effects of complete and supplemental diets and organic fertilization on production of *Macrobrachium rosenbergii* and associated benthic macroinvertebrate populations. Aquaculture 138:169-180.

Wahab, M.A., Z.F. Ahmed, M. Aminul Islam, M.S. Haq, and S.M. Rahmatullah. 1995. Effects of introduction of common carp, *Cyprinus carpio* (L.), on the pond ecology and growth of fish in polyculture. Aquaculture Research 26:619-628.

Weidenbach, R.P. 1980. Dietary components of prawns reared in Hawaiian ponds. Proceedings of the Giant Prawn Conference, 1980. Report 9. Bangkok, International Foundation For Science.

Wellborn, T. L., Jr. 1985. Production of Freshwater Shrimp. Mississippi Cooperative Extension Service Bulletin, No. 1511. Mississippi Cooperative Extension Service, Mississippi State, Mississippi.