Stocking Density and Supplemental Feeding

Work Plan 6, Thailand Study 6

James S. Diana
School of Natural Resources and the Environment
University of Michigan
Ann Arbor, USA

C. Kwei Lin
Agriculture and Aquatic Systems
Asian Institute of Technology
Bangkok, Thailand

Yang Yi
Agriculture and Aquatic Systems
Asian Institute of Technology
Bangkok, Thailand

Introduction

Pond carrying capacity is largely determined by management practices. Earlier work on semi-intensive culture of tilapia using manure or inorganic fertilizers indicated that carrying capacity might reach 2,000 to 3,000 kg/ha (Diana et al., 1991a and 1991b; Knud-Hansen et al., 1991). As stocking density increases in fertilized ponds, carrying capacity remains largely the same and density-dependent growth occurs (Diana et al., 1991b). Thus the ultimate size of fish at harvest is largely related to the density stocked in fertilized ponds, while biomass at harvest is more consistent regardless of stocking density. Maximum size at harvest for these fertilized ponds is approximately 250 g for fish grown five months.

Increasing the carrying capacity or size at harvest of tilapia requires more intensive management, which largely involves supplemental feeding. Experiments with supplemental feeding indicated that tilapia can reach 500 g in 5 months when feed and fertilizers are provided in combination (Diana et al., 1994, in press). Such experiments were done at fish densities of 3 fish/m^2, which would cause density-related declines in growth for fish in fertilized ponds. However, the addition of supplemental feed increased the growth rate of fish stocked at high density, and resulted in a higher carrying capacity for the pond. The limit on such feeding and density increases is reached when conditions in ponds climb to limiting levels due to increased oxygen demand, build up of metabolites, or other factors which produce poor water quality. Such a limit to tilapia production was demonstrated for Honduran ponds stocked at 3 fish/m^2 (Green, 1992) while Diana et al. (1994) found no decline in water quality for tilapia stocked at 3 fish/m^2 in Thai ponds. In the latter study, concomitant fertilization probably helped maintain reasonable water quality.

The purpose of this experiment was to determine the upper limits to tilapia production utilizing supplemental feeds. In order to test this relationship, fish were stocked at three, six, and nine fish/m^2. These fish were supplementally fed to 50% satiation for 191 days. This manuscript represents the third run of this study. Pond poaching biased the first attempt. The second attempt gave reasonable results, except that water quality differences were insignificant among treatments. This attempt used automated monitoring of dissolved oxygen.

Materials and Methods

Data for this study were collected at the Ayutthaya Freshwater Fisheries Station located at Bang Sai (140° 45' N, 100° 32' E), approximately 60 km northwest of Bangkok, Thailand. The nine ponds used in the experiment were 280 m^2 in surface area and normally filled to a depth of 1 m. Sex-reversed

Table 1. The biomass (kg), number, and mean size (g) of tilapia stocked and harvested in each experimental pond.

Pond	Stocking			Harvest		
	Number	*Biomass (kg)*	*Size (g)*	*Number*	*Biomass (kg)*	*Size (g)*
A1	840	12.8	15.2	678	335.2	494
A2	840	12.8	15.2	735	445.1	606
A3	840	12.2	14.5	669	313.9	469
B1	1680	26.3	15.6	1155	502.5	435
B2	1680	26.6	15.8	1357	652.8	481
B3	1680	26.4	15.7	1351	567.6	420
C1	2520	38.1	15.1	1325	417.4	315
C2	2520	40.3	16.0	1382	452.5	327
C3	2520	41.1	16.3	1634	533.5	326

Nile tilapia (*Oreochromis niloticus*) averaging 15 g were stocked on 28 July 1995 (Table 1). The ponds were divided randomly into three treatments, with triplicate ponds for each treatment receiving either three, six, or nine fish per m^2 (840, 1680, and 2520 fish per pond). Fish were fed to satiation from 0800-1000 h and 1500-1700 h every Monday. Maximum consumption was determined using floating feed (30% crude protein) and was estimated individually for each pond. The average consumption for each treatment was used to set the feeding rate at 50% of that level for the remainder of the week.

In addition to feeding, ponds were also fertilized weekly to bring a balance of N and P addition to 4 and 1 kg/ha/d, respectively. Fertilization was done to balance input of N and P generated in fish wastes. The amounts of N and P in fish wastes were estimated weekly from total feed inputs and fish biomass, based on N and P contents of feed and fish carcasses (feed = 10% moisture, 4.2% N, and 1.2% P; fish = 78% moisture, 2.2% N, and 0.6% P). Urea and triple super phosphate (TSP) were used for this balancing, with average daily inputs of 4.1 kg urea/ha and 4.5 kg tsp/ha.

Physical and chemical data were collected in a similar manner to earlier experiments (Diana et al., 1991a and 1994). Meteorological data, including solar radiation, rainfall, and wind speed were collected daily. For most analyses, a combined water sample encompassing the entire water column was taken from three locations of each pond. Pond water analyses, including temperature, dissolved oxygen (both taken at the top, middle, and bottom of the water column), ammonia, nitrate-nitrite, orthophosphate, total phosphorus, alkalinity, pH, Secchi-disk depth, and chlorophyll-*a* content were conducted biweekly using standard methods (see APHA, 1980 and Egna et al., 1987, for detailed descriptions of methods). Finally, dissolved oxygen concentrations were evaluated regularly by data loggers for two ponds in each treatment. Readings were taken near the surface (25 cm below) and bottom (25 cm above) of each pond at hourly intervals most days (121 out of 194 days) of the experimental period.

Ponds were harvested on 7 February 1996, after 194 days. Final biomass and numbers were determined. Overall individual growth (g/d) and net yield (kg) were calculated. During the experiment, fish were sampled biweekly for size. About 40 fish were seined from each pond, measured, and weighed. Biomass in the pond was estimated biweekly by extrapolating the number of fish in the pond linearly from stocking to harvest and multiplying this number by the average size of fish.

Preliminary economic evaluations of each growout were done using POND© 3.0 (Bolte et al., 1996). Facility costs and labor were not included. Local market prices were used for income and expenses. Feed prices were set at $0.50 per kg, fertilizer (urea and TSP) at $0.28 per kg, and sex-reversed fry at $0.009 each. Market value of Nile tilapia varied with size: fish from 300-500 g sold at $0.60 per kg, while fish above 500 kg sold at $0.80 per kg.

Statistical analyses were conducted using SYSTAT (Wilkinson, 1990). Overall growth (g/day), net yield (kg), and percent survival were calculated for each pond. Feeding rate (% BW/d) was estimated

Table 2. Growth (g/fish/d), survival (%), yield (kg), feed applied (kg), feed conversion rate (FCR), and forecasted annual yield (kg/ha/yr) for tilapia from each pond.

Pond	Growth	Survival	Yield	Feed	FCR	Annual Yield
A1	2.47	80.7	322	463	1.44	21663
A2	3.04	87.5	432	505	1.17	29048
A3	2.34	79.6	302	458	1.52	20273
B1	2.16	68.8	476	624	1.31	32001
B2	2.40	80.8	626	783	1.25	42080
B3	2.08	80.4	541	712	1.32	36369
C1	1.55	52.6	379	590	1.55	25490
C2	1.61	54.8	412	660	1.60	27701
C3	1.60	64.8	492	689	1.40	33090

biweekly, while feed conversion rate (FCR) was calculated for overall data and for biweekly data. Average overall values for physical and chemical parameters and total food input were also calculated. Multiple regressions between growth and density were done to test main effects. Because many of the chemical variables were interrelated, residuals of the above regression were correlated to each physical or chemical variable. Variables which were significantly correlated to the residuals were then examined for autocorrelation, and acceptable variables were used as input for multiple regression to evaluate additional determinants of variations in fish growth, survival, or yield. Variables were included in the regression if $p < 0.10$. Treatment effects on fish or chemical variables were tested with the biweekly data set by ANOVA and Tukey's multiple range test. Differences were considered significant at an alpha of 0.05.

Results

Fish growth rate proceeded in a linear fashion throughout the experiment (Figure 1). Overall growth rate differed significantly among treatments (ANOVA, $p < 0.05$) with the low and intermediate density treatments having higher growth than the high density treatment but not being significantly different from one another (Tukey's test, $p < 0.05$; Table 2). Similarly, survival

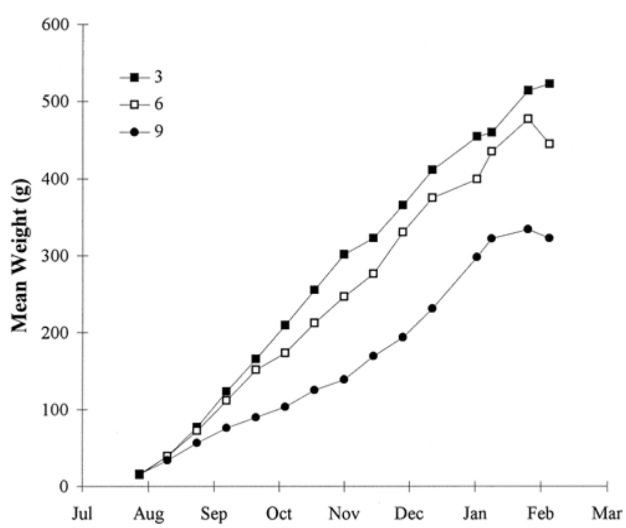

Figure 1. Changes in mean weight of tilapia during culture under three treatments.

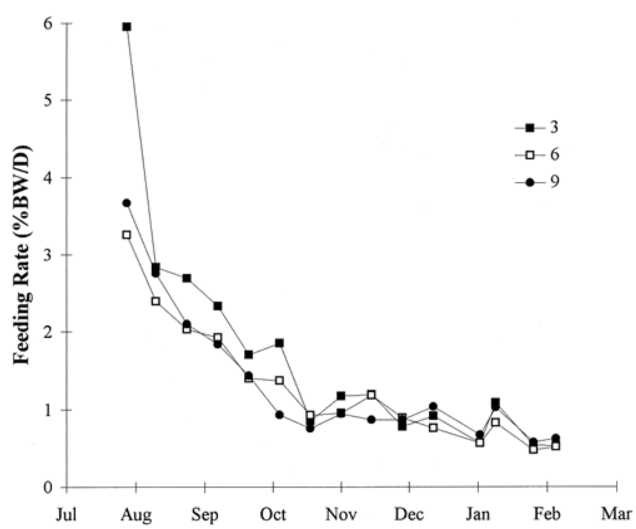

Figure 2. Changes in feeding rate and feed conversion rate during culture for ponds in each treatment.

Table 3. Multiple regression results for main effects (density) related to fish growth (g/d), survival (%), and yield (kg).

Variable	Coefficient	P
GROWTH RATE ($r^2 = 0.789$, $p < 0.001$)		
Constant	3.169	0.001
Density	-0.172	0.001
SURVIVAL ($r^2 = 0.736$, $p < 0.001$)		
Constant	0.978	0.001
Density	-0.042	0.002
YIELD ($r^2 = 0.000$, $p > 0.05$)		
Constant	366.78	0.006
Density	12.61	0.408

was varied among treatments, with lowest survival in the high density treatment but with no significant differences between the two lower density treatments (Tukey's test, $p < 0.05$; Table 2).

Feeding rate was initially high but then declined in all treatments (Figure 2). Feeding rate did not differ significantly among treatments (mean = 1.65% BW/d). Feed conversion rate averaged 1.40 and did not differ significantly among treatments.

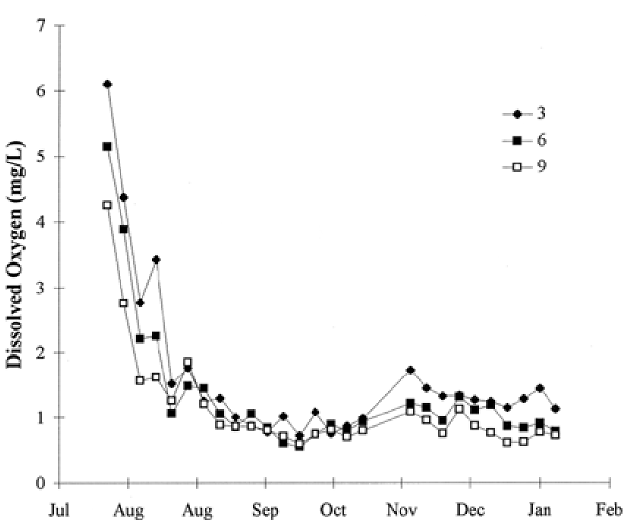

Figure 3. Changes in dissolved oxygen content of pond water during culture in each treatment.

Most physical and chemical variables showed no significant differences among treatments. Exceptions were alkalinity, which was significantly different in all three treatments, as well as NH_3 and dissolved inorganic nitrogen (DIN), which were significantly higher in the high density treatment than in the other two treatments (Tukey's test, $p < 0.05$). Alkalinity was highest in the mid density treatment (224 mg/l), intermediate in the low density treatment (169), and lowest in the high density treatment (141 mg/l).

Dissolved oxygen levels were difficult to analyze due to the large volume of data produced. Mean DO at 0600 h was significantly different among treatments (Tukey's test, $p < 0.05$), with low and mid density treatments having similar levels (1.58 and 1.31 mg/l, respectively), while mid and high density also had similar levels (1.31 and 1.08 mg/l, respectively; Figure 3). There were significant differences in the total number of data-logged hours when DO was less than 1 mg/l; mean values were similar at low and mid densities (167 and 353, respectively) and at mid and high densities (353 and 550, respectively).

Growth rate was significantly correlated to density ($r^2 = 0.789$, $p < 0.001$; Table 3). Residuals of this regression were not significantly correlated to any chemical or physical variables. Survival was also significantly related to density ($r^2 = 0.736$, $p < 0.01$).

Table 4. Calculation of profit for each stocking density.

Treatment Density (fish/m^2)	Fertilizer (kg)	Feed (kg)	Biomass at Harvest (kg)	Fish Size (g)	Profit per Pond
3	46.3	475	352	523	$23.40
6	43.7	520	547	445	$40.67
9	51.3	646	427	322	$-104.05

Residuals of this regression were also not significantly correlated to any physical or chemical variable. Finally, yield was not significantly related to density ($p > 0.05$).

Alkalinity and DIN differed among treatments (Figure 4). Both were also significantly correlated to one another using overall data (Figure 5) but not with biweekly data. This relationship is difficult to understand.

The economic analysis indicated that the growouts at 3 and 6 fish/m^2 were profitable (Table 4). Fish at 6 fish /m^2 did not reach 500 g at harvest, which would produce a higher market price. If price per kg of fish were the same ($.80) for each treatment, then the treatment at 6 fish/m^2 would be even more profitable ($150 per pond).

Discussion

Growth and survival of tilapia differed as expected among treatments, with best growth and survival at lowest density. Trends in growth rate among treatments were clearly differentiated by the first month sample. Growth was rapid in all ponds and reached rates near the maximum measured for tilapia cultured in ponds although growth was slightly lower than in our previous density experiment (Diana et al., 1995). Reductions in growth which occurred at high density appeared to be due to poor water quality because dissolved oxygen concentration at dawn (total hours when DO was less than one) and NH_3 levels all differed significantly among treatments.

Under normal conditions, profit was generated by fish grown at 6 fish/m^2 maximum ($40.67 per pond). However, if fish in the 6 fish/m^2 treatment had reached 500 g in size, they would have generated even more income ($148.00 per pond). Return rates in the current experiment were comparable to our earlier experiments (Diana et al., 1996); however, extrapolated profit for 6 fish/m^2 and 500 g final weight would have been the best for all our treatments to date.

Most rapid growth and highest survival occurred at 3 fish/m^2. The optimal feeding system at present

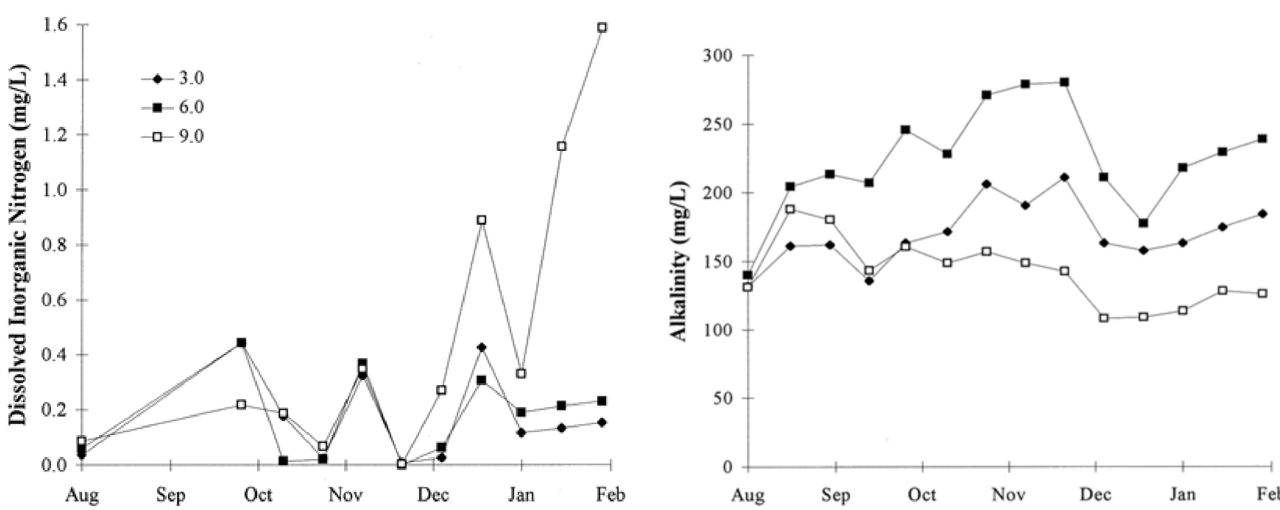

Figure 4. Changes in dissolved inorganic nitrogen and alkalinity during culture in each treatment.

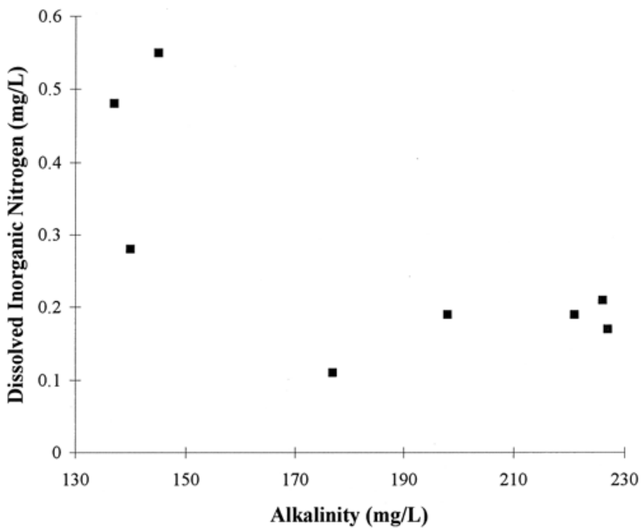

Figure 5. Relationship between alkalinity and dissolved inorganic nitrogen in ponds of all treatments.

appears to be with tilapia stocked at 6 fish/m^2. The combined application of feed and fertilizer remains an important tool because even at 9 fish/m^2 and intensive feeding, water quality remained relatively high. The fertilizer/fish waste balancing of inputs in this experiment appeared to be a successful way to control nutrient addition, as there were no differences in most chemical and biological variables between treatments. In our previous density experiment, chlorophyll-*a* content was higher in high density ponds, apparently in response to increased P levels, which were correlated to feed input rate (Diana et al., 1995). The same relationships occurred in this experiment.

Literature Cited

American Public Health Association (APHA), 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition. American Public Health Association Washington, D.C. 1134 pp.

Bolte, J., S. Nath, and D. Ernst, 1996. POND Version 3.0. Department of Bioresource Engineering, Oregon State Unversity, Corvallis, USA.

Diana, J.S., D.D. Dettweiler, and C.K. Lin, 1991a. Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis. Canadian Journal of Fisheries and Aquatic Sciences, 48:183-190.

Diana, J.S., C.K. Lin, and P.J. Schneeberger, 1991b. Relationships among nutrient inputs, water nutrient concentrations, primary production, and yield of *Oreochromis niloticus* in ponds. Aquaculture, 92:323-341.

Diana, J.S., C.K. Lin, and K. Jaiyen, 1994. Supplemental feeding of tilapia in fertilized ponds. Journal of the World Aquaculture Society, 25:497-506.

Diana, J.S., C. K. Lin, and Y. Yi, 1995. Stocking density and supplemental feeding. In: H. Egna, B. Goetze, D. Burke, M. McNamara, and D. Clair, (Editors), Thirteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, OR, USA, pp. 117-125.

Diana, J.S., C.K. Lin, and Y. Yi, in press. Timing of supplemental feeding for tilapia production. Journal of the World Aquaculture Society.

Egna, H.S., N. Brown, and M. Leslie, 1987. Pond Dynamics/Aquaculture Collaborative Research Data Reports, Volume 1: General Reference: Site Descriptions, Material and Methods for the Global Experiment. Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, OR, USA, 84 pp.

Green, B.W., 1992. Substitution of organic manure for pelleted feed in tilapia production. Aquaculture, 101:213-222.

Knud-Hansen, C.F., C.D. McNabb, and T.R. Batterson, 1991. Application of limnology for efficient nutrient utilization in tropical pond aquaculture. Proceedings of the International Association of Theoretical and Applied Limnologists, 24:2541-2543.

Wilkinson, L., 1990. SYSTAT: The System for Statistics (manual and 5 diskettes). SYSTAT, Inc., Evanston, Illinois, 677 pp.