RESEARCH REPORTS
TITLE XII POND DYNAMICS/AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGR

# Effect of Chicken Manure Additions on Fish Production in Ponds in West Java, Indonesia

Ted R. Batterson, Cal D. McNabb, and Chris F. Knud-Hansen
Department of Fisheries and Wildlife, Michigan State University
East Lansing, Michigan 48824 USA

H. Muhammed Eidman and Komar Sumatadinata
Faculty of Fisheries, Institut Pertanian Bogor,
Jl. Raya Pajajaran Bogor, Bogor, Indonesia

## ABSTRACT

Results of experiments in Cycle III of the Pond Dynamics/Aquaculture CRSP are reported here. Two experiments were conducted: one lasted 156 days and the other lasted 149 days. During both experiments four levels of dried chicken manure (12.5, 25, 50 and 100 g/m²/wk) were added to 0.02 ha ponds. There were three ponds in each treatment. Results of the two experiments were similar. Yield of Nile tilapia (*Oreochromis niloticus*) at final harvest increased linearly with increasing fertilizer application from about 900 kg/ha in the lowest treatment to approximately 2300 kg/ha in the highest. Increased algal productivity and an apparent increase in detritus accompanied increasing fish yield. Analyses of nitrogen and phosphorus suggested that higher algal productivity and fish yields could be obtained by improving the fertilizer regime so that N and P are available in these ponds in proportions required by pond microflora.

## INTRODUCTION

During 1986-87, the third experimental cycle of the CRSP was completed at the Babakan Fisheries Station of Institut Pertanian Bogor in Indonesia.

The Bogor region of West Java is hot and hyperhumid with annual rainfall in the range of 3-6 m per year, increasing with elevation on the surrounding mountain peaks. High rainfall combined with low evaporation rates causes severe leaching of ions from porous volcanic soils in the region. Since these soils have been in place for a long time, they yield few mineral nutrients to the surface waters that drain them. This has important implications for freshwater pond culture in the Bogor region and other wet-tropical regions like it. Nutrients necessary for pond production tend to be in short supply in water used to fill ponds. In practice, this condition is overcome by adding fertilizers or feed to ponds. For economic and biological efficiency, fertilizer applications should be based on the balance of mineral nutrients required by fish-food organisms whose growth they are intended to promote, namely algae, bacteria, and associated microfauna.

Phosphorus, nitrogen, and carbon are elements that most frequently limit production of pond organisms used as food by fish. For normal growth, algae require phosphorus, nitrogen and carbon in the atom ratio of 1:16:100. This converts to a weight ratio of 1:7:40. In fish ponds where this ratio is not approximated in the process of fertilizer application, the element(s) in shortest supply should be exhausted by uptake and growth of algae, leaving a surplus of the other essential elements unused in the water. Inorganic carbon is in short supply in surface waters of the Babakan region; carbonate-bicarbonate alkalinity is approximately 20 mg/l.

Data from Cycle II showed that low levels of inorganic carbon limited productivity of algae and fish in ponds fertilized with 50 g dry wt/m²/wk of chicken manure or triple superphosphate + urea at P and N loading rates equivalent to chicken manure. Cycle III experiments were designed to assess the performance of chicken manure across a range of loadings from 12.5 to 100 g dry wt/m²/wk. The relationship between fish yield and efficient use of fertilizer nutrients was evaluated.

## MATERIALS AND METHODS

In this experimental cycle, four levels of dried chicken manure (12.5, 25, 50, and 100 g/$m^2$/wk) were added to 0.02 ha ponds at the Babakan Fisheries Research Station. There were three ponds in each of these four treatments. After liming, the ponds were filled and maintained at a depth of approximately 0.9 m by adding water diverted from an irrigation canal at the perimeter of the site. Two experiments were conducted, each with the same protocol. One experiment ran from April 9 to September 12, 1986, the other from October 14, 1986, to March 12, 1987. After ponds were filled with water, male *Oreochromis niloticus* (*Tilapia nilotica*) fingerlings were planted at a density of one fish per square meter of pond surface. Methods described by Egna et al. (1987) for water sampling and chemical analyses were used except in regard to primary productivity. Daily net primary productivity was obtained from inorganic carbon losses that occur between dawn and dusk from the carbonate-bicarbonate system in ponds (after Harvey 1955 and Park 1969).

## RESULTS

*O. niloticus* stocking density for all ponds in Experiments 1 and 2 was 1 fish/$m^2$ (200 fingerlings/pond). Mean total weight stocked in the four treatments of Experiment 1 ranged from 9.6 kg to 10.3 kg. The mean weight of individual fingerlings varied among treatments from 49.2 g to 55.0 g. For Experiment 2, mean total weight stocked in treatments ranged from 8.6 to 9.1 kg. Mean weight for individual fingerlings stocked varied among treatments from 43.2 g to 45.3 g.

Yields obtained by harvest at the end of grow-out periods are shown in Figure 1 in relation to chicken manure loading rates used. Yields tended to increase linearly with increased loading, reaching a maximum of 2300 kg/ha at 100 g dry wt chicken manure/$m^2$/wk. The data show that ponds at Babakan could be loaded each week with greater quantities of chicken manure before yield approached an asymptote. Maximum yield obtained in the experiments was high compared to that reported in the literature. Pownall (1975) reported average yields for farm ponds in West Java on the order of 1500 kg/ha/yr, with some reaching 3000 kg/ha/yr. *Cyprinus carpio* accounted for most of this production. DeMaeseneer (1984) cites production of 2000 kg/ha/yr for tilapia in tropical subsistence ponds that are earnestly managed. With grow-out periods of the length used in these experiments, two crops per year could be obtained at Babakan, yielding nearly 4600 kg/ha. This rate of production approaches that expected by Balarin (1984) as a maximum with tilapia in well-managed ponds using feeds and fertilizers: namely, 5000 kg/ha/yr.

Water chemistry data collected from ponds in Experiments 1 and 2 showed similar trends. Data from Experiment 2 are used to describe results. Table 1 shows algal productivity associated with application rates of chicken manure used in the experiment. Net photosynthesis ranged from 0.82 to 1.86 g C/$m^2$/day. Gross photosynthesis (net carbon fixed by algae per day + carbon fixed to supply $O_2$ for community respiration per day) ranged from 1.72 to 3.06 g C/$m^2$/day. Hepher (1962) reported mean net productivity in fertilized fish ponds in Israel at 2.89 g C/$m^2$/day, and gross productivity from 4 to 6 g C/$m^2$/day. Steeman Nielsen (1958) considered a rate near 8 g C/$m^2$/day the maximum for algal productivity. By comparison, algal productivity in ponds at Babakan was low; the maximum

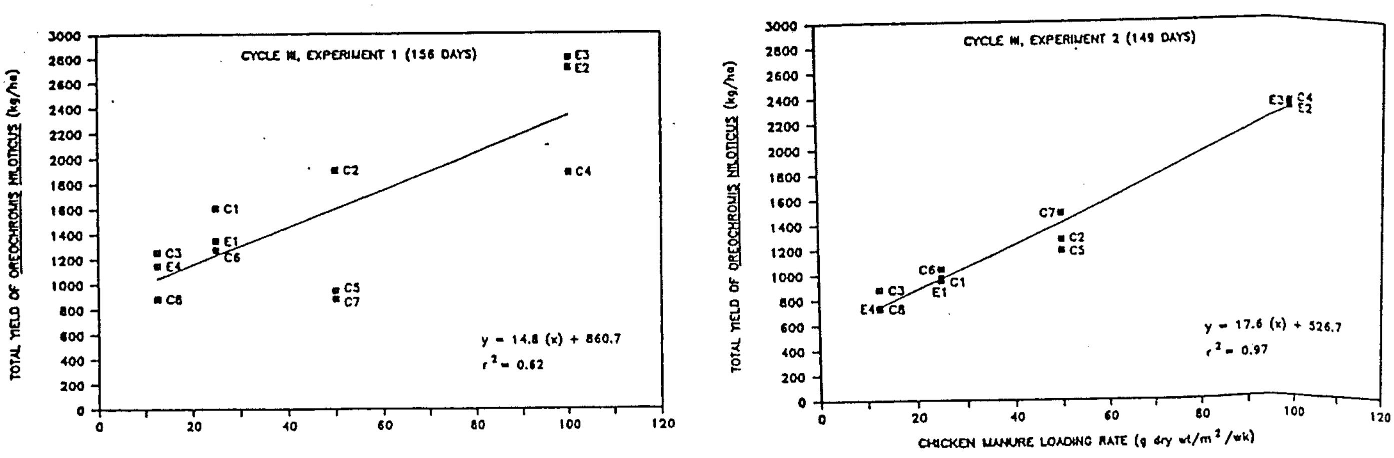


Figure 1. Yield of Nile tilapia (*O. niloticus*) at chicken manure loading rates used in Cycle III. Numbers are shown for individual ponds used for each loading rate.

Table 1. A comparison of nitrogen and phosphorus required by algae to complement observed rates of carbon fixed in photosynthesis and amounts present in ponds on the average during Cycle III, Experiment 2.

| Chicken Manure Loading Rate (g dry wt/m²/wk) | Net Photosynthesis (g C/m²/day) | Total Inorganic Nitrogen (g N/m²) | | Dissolved Reactive Phosphorus (g P/m²) | |
|---|---|---|---|---|---|
| | | Required[1] | Present | Required[1] | Present |
| 12.5 | 0.82 | 0.14 | 0.19 | 0.02 | 0.07 |
| 25 | 0.86 | 0.15 | 0.21 | 0.02 | 0.11 |
| 50 | 1.29 | 0.23 | 0.15 | 0.03 | 0.33 |
| 100 | 1.86 | 0.33 | 0.14 | 0.05 | 0.65 |

[1] Based on a P:N:C requirement of 1:7:40 by weight for normal algal growth (Round 1973; Vallentyne 1974; Wetzel 1983)

productivity was obtained with the highest rate of fertilizer loading, namely 100 g dry wt/m²/wk.

Table 1 also includes an analysis of nitrogen and phosphorus abundance in ponds relative to amounts of nitrogen and phosphorus normally required by algae to complement carbon fixed in net photosynthesis. The forms of nitrogen and phosphorus presented in the table are those preferred by algae over other chemical species of these elements that might be present in ponds (Goldman and Horne 1983). Quantities of nitrogen and phosphorus required for growth are compared with average quantities present during the experiment. The closer the requirements to amounts present, the shorter the immediate supply of the nutrient.

Table 1 shows that inorganic nitrogen tended to be in short supply, particularly at high rates of chicken manure loading. Phosphorus, on the other hand, was present in ponds in amounts in excess of daily algal requirements, and the excess phosphorus increased with increased chicken manure loading. This result was promoted by a 1:2 ratio of N:P by weight in chicken manure added to ponds. With smaller amounts of nitrogen than phosphorus available for uptake and growth relative to algal requirements (N:P=7:1), phosphorus added in fertilizer was unused by algae for growth and tended to accumulate in ponds as the loading rate increased.

Md.Yusoff (1987) used algal bioassays in conjunction with a similar analysis of nutrient shortages. She showed that algal productivity was not limited in ponds in Malaysia when required amounts of these nutrients were greater than or approximately equal to amounts present, but was limited when concentrations were 4 to 6 times less than daily requirements. It is likely from her work and data in Table 1 that ponds at Babakan fertilized at rates of 50 and 100 g dry wt chicken manure/m²/wk were approaching nitrogen limitation for algae. Also, some factor other than nitrogen or phosphorus appears to have limited primary productivity at low chicken manure loading rates (12.5 and 25 g dry wt/m²/wk). Earlier CRSP work at Babakan reported by McNabb et al. suggests that inorganic carbon limited algal productivity at these low manure loading rates.

Nile tilapia is opportunistic and feeds mainly on planktonic algae, periphytic algae, rotifers, copepods, insect larvae, and detritus in fertilized ponds (DeMaeseneer 1984). Figure 2 shows the relationship between yield of Nile tilapia at harvest and mean net photosynthesis during Experiment 2. Rates of fertilizer application also are presented. As fertilizer application increased, so did net photosynthesis and fish yield. Various investigators, among them Melack (1976) and Almazan and Boyd (1978), have observed a similar relationship for fish species that feed at the base of food webs in ponds.

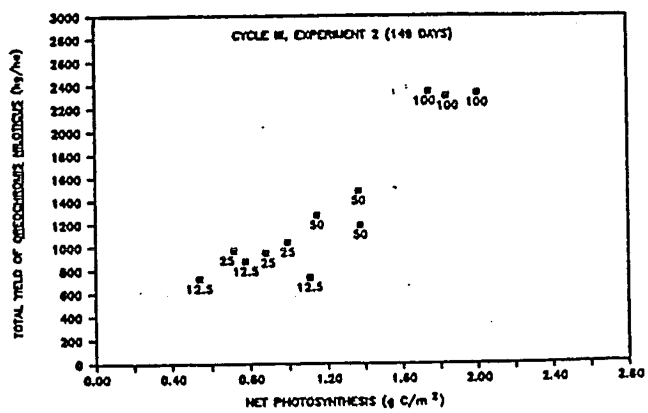


Figure 2. Relationship between Nile tilapia yield at harvest and mean net photosynthesis in ponds. Numbers in figure are chicken manure loading rates in g dry wt/m²/wk.

It is difficult to assess the role of detritus and its associated microfauna as food sources for fish in this experiment. However, respiratory rates of pond communities increased with increased chicken manure loading. The decreases in twelve-hour nighttime dissolved oxygen, corrected for losses to the atmosphere from supersaturated surface water in ponds (Boyd 1979), were 2.9, 2.7, 3.6 and 4.0 g $O_2$/m² with loading rates of 12.5, 25, 50 and 100 g dry wt chicken manure/m²/wk, respectively. Some portion of these decreases was associated with increased pond metabolism due to progressively higher algal productivity in treatments. An unknown portion was also due to heterotrophic metabolism of chicken manure detritus. It is clear from nighttime oxygen losses that metabolism of pond organisms increased with fertilizer loading rates of 25 g dry wt/m$^2$/wk or greater, and that food resources for fish production increased as well, leading to progressively higher fish yields in treatments. Relatively low primary productivity with high fish yields at 100 g dry wt/m$^2$/wk suggest that detritus played a role in fish nutrition.

Manures added to ponds promote 24-hour excursions in surface-to-bottom dissolved oxygen curves such that low concentrations, particularly in the hours before dawn, can be detrimental to fish. Mean concentrations at 0600 h are presented in Table 2 for pond water columns. Concentrations measured at 0600 h were the lowest observed in the 24-hour sampling period. It can be seen from the table that 0600 h concentrations tended to decrease with an increase in loading rates. However, even at the highest loading rates, adequate oxygen for Nile tilapia was present at dawn. Minimum concentrations observed in water columns at 0600 h during both experiments were 2.6, 2.0, 1.0 and 0.4 mg/l for loading rates of 12.5, 25, 50 and 100 g dry wt/m$^2$/wk, respectively. Table 2 also shows dissolved oxygen excursions for days and nights during experiments. These ranged from 2.2 mg/l per 12-hour light/dark cycle at low chicken manure loading rates to 4.5 mg/l at the highest rate. Hepher (1962), Boyd et al. (1978), and Boyd (1979) report mean water column oxygen excursions on the order of 5 to 6 mg/l for days and nights in fertilized, high production ponds with water temperatures comparable to those at Babakan. In these experiments, ponds loaded at the highest rate had lower excursions than noted by these workers.

Ammonia is the common form of inorganic nitrogen in chicken manure, with $NH_3$-N comprising approximately 30% by weight of the total nitrogen present (Sims 1986). It leaches rapidly after chicken manure is added to pond water (Knud-Hansen unpublished data). Emerson et al. (1975) present techniques for determining the fraction of total ammonia that is present as un-ionized ammonia using temperature and pH of pond water. Figure 3 shows mean concentrations of un-ionized ammonia for 24-hour sampling cycles at Babakan. Maxima on curves are associated with 24-hour highs for pH and water temperature, while minima occurred near dawn with lower pH and temperature. Abdalla (in preparation) obtained rapid growth of *O. niloticus* fingerlings at 0.06 mg/l un-ionized ammonia in a temperature range of 28-32°C. Growth was depressed linearly at concentrations above 0.06 mg/l to 1.40 mg/l. Colt and Tchobanoglous (1976) found that growth of juvenile channel catfish was reduced in a linear fashion over a range of 0.06 to 0.99 mg/l un-ionized ammonia, with no growth at 0.97 mg/l. These results and data in Figure 3 suggest that un-ionized ammonia in ponds had no important effect on fish growth during these experiments.

Table 2. Mean dissolved oxygen relationships in ponds during Cycle III, Experiment 2 taken from measurements made over 24-hour periods. 0600 hour dissolved oxygen concentrations were daily minima.

| Chicken Manure Loading Rate (g dry wt/m$^2$/wk) | Depth of Water[1] | 0600 hour D.O. (mg/L) | Daytime Increase[2] (mg/L) | Nighttime Loss[2] (mg/L) |
|---|---|---|---|---|
| 12.5 | top | 4.3 | | |
| | mid | 4.1 | 2.3 | 2.8 |
| | bot | 4.0 | | |
| 25.0 | top | 4.0 | | |
| | mid | 3.7 | 2.2 | 2.5 |
| | bot | 3.6 | | |
| 50.0 | top | 3.3 | | |
| | mid | 3.0 | 3.8 | 4.0 |
| | bot | 2.8 | | |
| 100.0 | top | 2.3 | | |
| | mid | 2.0 | 4.0 | 4.5 |
| | bot | 1.8 | | |

[1]"top" is for measurements 0.25 cm below the surface and "bot" for measurements 0.25 above sediments.
[2]Daytime increase and nighttime losses are for the water columns of ponds obtained from differences between means of "top," "mid," and "bot" concentrations measured at successive times of 0600, 1800, and 0600 hours.

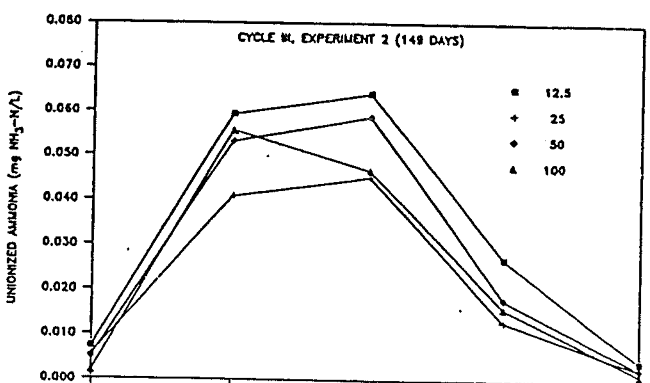


Figure 3. Mean concentrations of un-ionized ammonia during 24-hour periods in ponds fertilized with 12.5, 25, 50, and 100 g dry wt/m$^2$/wk chicken manure.

## DISCUSSION

This report summarizes work from the third and last cycle of standardized experiments in the Pond Dynamics/Aquaculture Collaborative Research Support Program (CRSP) at the

Babakan Fisheries Station. In Cycle I, baseline data were obtained on climatic and hydrological conditions, and on physical and chemical conditions that influenced pond productivity. Relatively consistent warm, wet, and cloudy year-round features of the Station's environment were described. It was shown from the daily record of photosynthetic radiation and algal productivity in ponds that the relatively low quantity of incoming light associated with frequent cloud cover was not limiting pond photosynthesis.

Ponds built of permeable volcanic soils in Java have a high rate of water loss. High rainfall on the island makes water for pond culture plentiful, and farmers indifferent to seepage losses. Seepage and replacement water additions, as well as high rainfall directly on the surface of ponds, causes high variability in measurements of pond parameters made over 24-hour periods, or at longer intervals during experiments. Nevertheless, baseline data in Cycle I revealed trends in variables that influence pond productivity. In particular, low alkalinity and low inorganic carbon ($CO_2$) concentrations limited algal productivity and fish production in ponds. This has great implications for Java as well as for other tropical settings.

Volcanic peaks in Java form the backbone of the island. Uplifted limestone reefs form low elevation ridges among the peaks. Streams and irrigation canals discharge low alkalinity water (20 mg $CaCO_3$/l) from drainage basins with leached volcanic soils, while those discharging from regions of uplifted limestone have high alkalinity (180 mg $CaCO_3$/l). Such drainage basins, often relatively small in area, lie side by side. If inorganic carbon determines the upper limit of autotrophic and heterotrophic production in low alkalinity ponds, such as those at Babakan, the widespread application of fertilizer to ponds to supply phosphorus or nitrogen will have widely different results and ensure inconsistent fish yields from place to place.

With primary productivity limited by nutrients, yield of Nile tilapia at the Station during Cycle I of the CRSP was low: 600 kg/ha in grow-out periods of 145 days. In Cycle II, the performance of inorganic fertilizers (triple superphosphate [TSP] + urea) was compared with an organic fertilizer (chicken manure). Ponds in each treatment received equivalent quantities of phosphorus and nitrogen. The organic fertilizer treatment was applied to ponds in which alkalinity had been doubled from the baseline of approximately 25 mg $CaCO_3$/l. As predicted from results of Cycle I, carbon limitation that occurred in both TSP + urea and chicken manure treatments was alleviated in the chicken manure + alkalinity treatment, and higher algae and fish productivity were obtained. Fish yields were twice those of Cycle I with the same grow-out period. Yields of Nile tilapia in Cycle II were 965, 1040 and 1455 kg/ha in TSP + urea, chicken manure, and chicken manure + alkalinity treatments, respectively. Data indicate that nitrogen, an element in short supply in chicken manure relative to phosphorus, approached limiting concentrations in the treatment with highest yield.

Chicken manure produced better yields in Cycle II than did inorganic fertilizers. Thus, chicken manure loading rates became the topic of Cycle III research. Outstanding fish yields were obtained without stressing the dissolved oxygen dynamics of ponds or exposing fish to harmful concentrations of un-ionized ammonia. Nile tilapia yield was pushed to 4600 kg/ha/yr, approaching the maximum yield of 5000 kg/ha expected for well-managed ponds in which feeds as well as fertilizer are used. However, optimum use of fertilizer, particularly phosphorus, and maximum attainable fish production for the site were not obtained. Research in Cycle IV of the CRSP is aimed at achieving these goals. At Babakan, important contributions were made during the tenure of the CRSP in fine tuning the technology used in tropical pond aquaculture. An understanding has developed regarding key determinants of yield in Indonesia.

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**April 18, 1988** **CRSP RESEARCH REPORTS 88-8**

Editor and Assistant Director ............................ Hillary S. Egna
Director ................................................ Howard F. Horton

**RESEARCH REPORTS**
TITLE XII POND DYNAMICS/AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM

Published by the Program Management Office, Pond Dynamics/Aquaculture Collaborative Research Support Program, Office of International Research and Development, Oregon State University, Corvallis, Oregon, 97331.

Office of International Research and Development
Snell Hall
Oregon State University
Corvallis, OR 97331 USA
(503) 754-2228

The Pond Dynamics/Aquaculture Collaborative Research Support Program is supported by the U.S. Agency for International Development under CRSP Grant No.: DAN-4023-G-SS-2074-00.