THE HYDROLOGY OF A SMALL FISH POND AT THE UNIVERSITY OF AGRICULTURE, MAKURDI EXPERIMENTAL FISH FARM

BY

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ABSTRACT

The monthly and seasonal water requirements of a small fish pond (0.068ha; maximum capacity of 613.83m³) at the University of Agriculture, Makurdi Fish Farm were determined during the period of February to August 1996. The sources of water for the pond were rainfall, (103.4cm), run-off (6.3cm) and regulated inflow (95.0cm).

The water loss for the period were Evapotranspiration, (106.74cm), Seepage (71.64cm) and regulated discharge (25.00cm). Evapotranspiration was identified as the main source of water loss while rainfall was the major source of water gain. The mean monthly water deficit was 24.56±11.43cm while the mean monthly surplus was 9.84±8.05cm. The quantity of water required to maintain the optimal water level in the pond was 474.00m³.

Preliminary water budget of the study area showed that rainfed aquaculture can be effectively carried out at Makurdi during the months of June to October with supplementary inflows during the dry season months.

INTRODUCTION

Pond hydrology is the science that deals with the process of depletion and replenishment of the water resources of any pond and its catchment area, including their relationship to aquatic organisms. Pond hydrology until recently and particularly in the tropics, had not been a field of intensive research focus (Boyd, 1982; Teichert-Coddington et al 1988). This situation has led to poor tropical water management resulting in the inability to satisfy increasing demands for water mainly for Urbanisation, Agriculture (including aquaculture) and Industry (Salao, 1990). Pionerring studies were those of Parson (1945), Mason et al (1968), Allred et al (1971), Boyd (1982, 1985b) Teichert-Coddington et al (1988).

Major sources of water for aquacultural practice (use) are rainfall, stream, river, pools reserviour and water table wells. There are fluctuations in the availability of water from these sources in time and space. The attendant effect is a state of overstressed water resources that limit Agriculture (aquaculture) and industrial development (Salao 1990). Aquaculture is a much more water intensive practice (Boyd 1982). Consequently, it is bound to suffer drastically from scarce water resources.

This paper presents the results of a study of the pond hydrology of a fish pond at the University of Agriculture, Makurdi, focusing on factors affecting water gains and losses. These information are required for a sustainable water management strategy of the fish pond.

MATERIALS AND METHODS

The Study Site

Makurdi is bounded by latitudes 8°45' and 9°00'N and longitudes 7°45' and 8°00'E with a tropical Savannah climate showing distinct wet (April - October) and dry (November - March) seasons. The annual rainfall ranges from 973mm to 1,324mm. Whereas, the mean monthly temperature ranges from 23°C to 32°C. The relief ranges from 100m above mean sea level to 133m above mean sea level and it lies within the River Benue flood plain. Makurdi is underlaid by the recent alluvium and turonian rocks, Agwu Shale and Makurdi sandstone. The vegetation of the study area is the Southern guinea Savannah type.

The University of Agriculture Experimental Fish Farm is located East of the University's Raw Water booster station on the Northern bank of River Benue. It consists of six small ponds of 0.06ha each with depth ranging from 120cm to 140cm. It has a small catchment area of about 30% - 35%. The ponds were constructed in 1992 on a gentle slope so that their full capacity is achieved both by excavation and by closures with Earth dykes. The ponds are arranged adjacent to each other so that the runoff is limited to the dykes delimiting the ponds. The dykes were grassed to
check soil erosion and mud turbidity.  
The primary water source to the pond is the University of Agriculture raw water booster station. The Eastern outlet carries water in 6" AC pipe used for filling and maintaining the ponds. The fish ponds consist of alluvial and clayish soil. The alluvial soil occurs at the top soil horizon. The alluvium is underlaid by sand clay (about 51% clay, 38% sand and 11% silt) that has shale material.  

*Oreochromis niloticus*, *Clarias gariepinus* and *Heterotis niloticus* were cultured in the ponds at a stocking density of 1.5m² (ratio 2:1:2: respectively). The fish were fed with 19% crude protein feed.

**Hydrological Measurement**

Potential evapotranspiration was determined using the Thomthwaite et al (1939) and Adegoye (1986) formular expressed as $EP = 16(10^T)a$. Where $EP =$ Potential Evapotranspiration; $T =$ annual monthly temperature, $I =$ Annual heat index =$ (The equation need to insert here)x$x$x$x$I =$ monthly heat index =$ (ToC)1.5$ and $a =$ cubic function of$I$, $a = I 6 I + 0.5$. 

Runoff was estimated using the hydrograph separation technique. This involve substracting $E_P$ from rainfall and multiplying the result with the surface water Index for Makurdi (Adegoye 1986).

In the pond for the study, a staff guage used for monitoring and reading water level was mounted and the pond filled to a depth of 90cm from a reserviour. Thereafter, between 0800-0830 hours 5 days a week (from February to August 1996) water level was recorded and then adjusted to the starting depth of 90cm either by water addition from regulated inflow or removal by regulated outflow from the pond. Water volumes were estimated using changes in depth. Water gain was calculated using the formular losses ± changes in storage (Boyd 1982). Data on water level changes in the pond, rainfall, runoff and regulated inflow were used to compute water gain. Seepage, evapotranspiration and regulated outflow were used to assess water loss for the pond.

Daily Seepage = Rainfall + Runoff + Water level at time $T_1$ - Water level at time $T_2$ - Evapotranspiration. Water level at time $T_2$ is the water depth 24 hours after time $T_1$. Temperature and rainfall data were obtained from the Nigerian Airforce Base Meterological Station, Makurdi. The monthly/seasonal water requirements to maintain water levels were calculated from the water balance equation. Water required = (Rainfall + Runoff) - Seepage + Evapotranspiration. 

Preliminary water budget was computed for the pond using temperature and rainfall data and calculated potential evapotranspiration. Rainfall minus potential evapotranspiration gave excess water. Monthly soil moisture condition, ground water and surface reserves were also computed.

**RESULT**

Water budget for the pond showing monthly water loss, gain and balance, regulated inflows (water addition from reserviour), regulated outflow are given in table 1.

Rainfall (Fig. 1) and Runoff (Fig. 2) were the sources of water to the pond other than the regulated inflow to supliment the water level reduction while water loss was through evapotranspiration and seepage. Twenty weeks out of the twenty-eight weeks of the study had measurable rainfall with seven having less than 2.5cm (mean, 1.06±0.85cm) and the rest with range of 2.79-14.13cm (mean, 7.38±3.14cm). Total rainfall for the period was 103.3cm with the highest value in August and the lowest value in March (Fig. 1). Total runoff (Fig. 2) for the period was 6.3cm with a range of 0-2.20cm. Total water gain was 109.70cm with the highest in August (36.10cm) and the lowest in March (0.0cm). 

Rainfall contributed 94.2% of the total water gain.

Total seepage loss was 71.54cm (0.34cm/day) with a maximum loss in March.
(0.52cm/day) and the minimum of 0.15cm/day in August. Total water loss due to evapotranspiration was 106.74cm (0.50cm/day) with the highest value in March (0.65cm/day) and the lowest in August (0.40cm/day). Total water loss was 178.41cm, the highest being in March (35.96cm) and lowest in August (17.05cm). Evapotranspiration accounted for 59.6% of the total water loss and seepage 40.4%. The monthly temperature used for computing evapotranspiration is presented in Table 2. It ranged from 25.9°C in July to 31.3°C in February. Mean for the period was 28.7°C ± 2.41°C.

Table 2: 1996 Mean Weekly Temperature (°C) at Markurdi (°C) February - August, 1996.

<table>
<thead>
<tr>
<th>Month</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Monthly Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>31.43</td>
<td>31.29</td>
<td>30.43</td>
<td>32.07</td>
<td>31.31±0.68</td>
</tr>
<tr>
<td>March</td>
<td>30.86</td>
<td>32.14</td>
<td>30.15</td>
<td>31.40</td>
<td>31.14±0.84</td>
</tr>
<tr>
<td>April</td>
<td>32.29</td>
<td>30.93</td>
<td>30.71</td>
<td>29.89</td>
<td>30.96±1.00</td>
</tr>
<tr>
<td>May</td>
<td>29.08</td>
<td>29.22</td>
<td>28.07</td>
<td>27.80</td>
<td>28.54±0.71</td>
</tr>
<tr>
<td>June</td>
<td>26.22</td>
<td>25.93</td>
<td>24.72</td>
<td>26.70</td>
<td>25.89±0.84</td>
</tr>
<tr>
<td>August</td>
<td>26.00</td>
<td>26.29</td>
<td>25.50</td>
<td>26.45</td>
<td>26.06±0.42</td>
</tr>
</tbody>
</table>

Source: Federal Civil Meteorological Station, Makurdi

The water budget in volumetric term is given in Table 3. Water deficit totalling 668.86m³ occurred from February to May with the highest in March (245.16m³) and the lowest in May (77.10m³). Total water surplus was 194.18m³ with the highest value in August (122.76m³) and the lowest value in June (43.11m³). This translate to a net water requirement of 474.68m³ for the pond area of 682.1m², (6949m³/ha) for the 7 months in addition to the initial filling volume of 613.9m to 90cm depth or 8988.4m³/ha.

Table 3: Water Budget in Volumes (m³) for a fish Pond at U.A.M. From February, - August, 1996

DISCUSSION

The major sources of water for the University of Agriculture, Makurdi earthen fish pond were rainfall, runoff and regulated inflow from a water reservoir. Losses were through seepage and evapotranspiration. The mean monthly rainfall, runoff and temperature were 17.23cm/month, 0.9cm/month and 28.7°C/month respectively while evapotranspiration was 0.65cm/day and daily seepage rate was 0.35cm/day. The total water deficit was 668.86m³ while the surplus was 194.18m³, giving a net water requirement of 474.68m³ for a pond of about 0.0682ha filled to a depth of 0.9m.

Boyd (1982) reported monthly runoff values ranging from 0.20cm/month in September to 1.30cm/month in May (i.e.) 0.33cm/month and a total of 2.3cm for 3 months for pond area of 10.8ha and a water shed of less than 50% of pond area in Auburn while Teichert-Coddington et al (1988) at Gualaca, Panama observed runoff ranging from 0.80cm/month in April to 2.10cm/month.
10.8ha and a water shed of less than 50% of pond area in Auburn while Teichert-Coddington et al (1988) at Gualaca, Panama observed runoff ranging from 0.80cm/month in April to 2.10cm/month in November (average of 1.30cm/month), totalling 15.5cm over a twelve month period for a pond area ranging from 818m$^2$ to 1037m$^2$ and a water-shed ranging from 32.5% to 83.7% (mean = 68.0%) of the pond area. The monthly runoff in the Makurdi pond was higher than for Auburn but lower than Gualacan ponds. This is expected, because of the differences in the geography and locations of these study areas. Factors affecting runoff are rainfall distribution pattern, watershed and soil.

The daily seepage ranges of 0.15cm - 0.52cm/day (mean, 0.34cm/day) at Makurdi was bigger than the 0.1cm/day reported by Eisenlhor (1996) and Allred (1971) for small natural water bodies in North Dakota and small lakes in Mississippi, USA respectively but similar to the result (0.2cm - 0.5cm/day) obtained by Boyd 1985 in catfish pond in USA. Higher seepage rates were reported by Toshida (1981) in rate field in Asia (0.02cm/day - 1.56cm/day) and Boyd (1982) in Auburn fish pond (0.79cm/day). Factor affecting seepage rate are the porosity of the soil and method of pond construction (Boyd 1982). Natural ponds and lakes had less seepage than artificially constructed ponds. The amount and duration of rainfall also had profound effect on seepage rate as infiltrated rainwater through the levees later seepage into the pond and reduced net seepage losses. Furthermore, Boyd (1985b) reported that species of fish cultured could affect the seepage rate and that, increased temperature also increased the seepage rate.

Water loss through evapotranspiration (0.65cm/day) showed considerable variation with respect to temperature differences. This value compared favourably with the report of Yoshida (1981) who observed a range of evaporation rate of 0.10cm/day to 0.62cm/day in rice field in Asia, Boyd (1982)'s record of 0.12cm/day in late October to 0.60cm/day in late June in Alabama and Teichert-Coddington et al (1988)'s range of 0.12cm/day to 1.06cm/day during the dry season in ponds in Gualaca, Panama. Variations in evapotranspiration rates are due to the geographical location and temperature regimes. During cold weathers evapotranspiration is usually low and high during high temperatures. The small variations in Evapotranspiration observed in Makurdi could be as a result of little variations in the Makurdi temperatures. Teicher-Coddington et al (1988) also established a strong correlation between solar radiation and evaporation in Gualaca, Panama. The water requirement of 95050m$^3$/ha or 55445.8 for 7 months (Teichert Coddington et al 1988), 2137m$^3$/year or 12468.7me for 7 months (Boyd 1982) and 33285m$^3$/ha or 19416.25m$^3$/for 7 months Boyd (1985b) were reported for Gualacan fish pond, catfish pond built on heavy clay soil in the Mississippi Delta region of U.S.A. and small pond experimental area of the fisheries Research Unit of Auburn respectively. In a related agricultural practice, Yoshida (1981) observed water requirement of 24,800m$^3$/ha-year or 14466.67m$^3$/ha-for 7 months in intensively irrigated rice farm in Asia and schwab et al (1971) recorded water requirement of 3000m$^3$ ha to 4500m$^3$ha-year-for irrigation in Eastern U.S.A. In all these cases, water requirement were more than the value obtained in this study apart from that of South Eastern U.S.A. The low value recorded could be as a result of the high quantity of rainfall in the study area during the period and the low seepage value. Water demand can be reduced further for Makurdi ponds if seepage can be reduced considerably using leakage proof materials.

In conclusion, this study has shown that water requirement for aquaculture in the Makurdi area is quite low being a mere 6949m$^3$/ha. Rainfed aquaculture during the rainy season with supplementary inflows from rain harvested reserviour during the dry season months is practicable. aquaculture therefore could be a very profitable agricultural venture given the nearest to River Benue and the various favourable hydrological features presented for a small fish pond in the area.
REFERENCES


