Analysis of Irrigation Pond Ecosystems. V. 
Ecological Characteristics of Large Reservoirs 
Located in Mountaneous Regions of Hyogo.

Osamu YAMAGUCHI*, Mariko TOMOKAWA*, and Tohru OGOSHI**

Abstract

Three large water reservoirs were examined over a one-year period. They are located in the mountaneous regions of Hyogo. The measured items were transparency, temperature, pH, dissolved oxygen, chlorophyll a and gross production. The vertical distributions of these characters were analyzed and compared with the standards described from the other ponds. The distribution curves were quite similar to those of the other oligotrophic ponds. The mean values of the characters were also in the ranges of oligotrophism. There was a sharp contrast to that of eutrophic irrigation ponds in Yashiro town. The large stable planktonic populations can be used for the standards of early stages of planktonic succession and evolution in pond ecosystems.

Introduction

A lacustrine ecosystem is closed and is thus easy to be analyzed ecologically. So far, we have examined some ecological characteristics in irrigation ponds located in the southern part of Hyogo Prefecture. Most of them were constructed artificially for irrigation use, and thus, the water level is higher than that of the surrounding rice fields. Each pond forms its own ecosystem independently of others even though the physical distance between the bodies is short. They would be expected to proceed in its own microevolution independently. However, some of them are eutrophic and show the identical water bloom caused by blue-green algae, *Microcystis aeruginosa*, in warm seasons (Yamaguchi et al., 1987). This is not restricted in Hyogo but widely distributed around big cities (Watanabe et al., 1991). There is a possibility that *Microcystis* sp. is colonizing rapidly. We have to find out the standard not contaminated by this sort of colonies and inflow through drainage from kitchens to speculate evolution of pond ecosystems. Large water-reservoirs were chosen among mountaneous regions in the middle part of Hyogo. Their ecological characteristics are described and compared with those of irrigation ponds which show some evidence of eutrophism.

*Department of Biology, Hyogo University of Teacher Education, Yashiro, Hyogo 673-14
**Present address: Masuda Elementary School, Masuda, Shimane 698.
Table 1. Description of the reservoirs and its capacity for irrigation

<table>
<thead>
<tr>
<th></th>
<th>Onzui reservoir</th>
<th>Ginzan reservoir</th>
<th>Tsubaichi reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Haga Town</td>
<td>Ikuno Town</td>
<td>Sasayama Town</td>
</tr>
<tr>
<td>Dam height</td>
<td>66.0 m</td>
<td>56.5 m</td>
<td>34.5 m</td>
</tr>
<tr>
<td>Completion</td>
<td>March 31, 1958</td>
<td>March 31, 1973</td>
<td>January, 1969</td>
</tr>
<tr>
<td>Reservoir area</td>
<td>0.88 km²</td>
<td>0.90 km²</td>
<td>0.09 km²</td>
</tr>
<tr>
<td>Attitude of maximum</td>
<td>EL472.0 m</td>
<td>EL389.1 m</td>
<td>EL294.8 m</td>
</tr>
<tr>
<td>storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pondage</td>
<td>21,950,000 m³</td>
<td>18,000,000 m³</td>
<td>1,070,000 m³</td>
</tr>
<tr>
<td>Depth</td>
<td>27.0 m</td>
<td>31.5 m</td>
<td>18.5 m</td>
</tr>
</tbody>
</table>

Materials and Methods

Description of water reservoirs examined

In 1990, a total of nine comparatively large ponds or reservoirs in Hyogo were preexamined for transparency, pH, or existence of water bloom as candidates for the present analysis. All of them are located among the Chugoku mountain range. The following three were finally chosen in terms of natural environment surrounding them and easiness of sampling. They were constructed for multipurposes of irrigation, generation of electric power and water supply by damming of natural valleys. No human habituation is adjacent to them. Onzui reservoir is located at an altitude of 472 meters above sea level and is surrounded by a deciduous oak forest and ceder afforestation. Ginzan reservoir is located at 389 meters above sea level and is surrounded by ceder afforestation. Tsubaichi reservoir is at 295 meters above sea level and is surrounded by a red pine forest. The capacities of water storage and the other description of these reservoirs are shown in Table 1.

Sampling of the water and scoring of ecological characters

Periodic sampling of the water was done once a month for one year from August of 1990. Sampling was not done in mid-winter since snowing. Transparency was measured by Secchi’s white plastic disc. The water was sampled at the constant point which has the maximum of depth of the reservoirs. The samples were collected at each of 1 meter-layer from the surface to the depth of 20 meters by a Meyer’s bottle. The measured items were temperature (Temp.), amount of desolved oxygen (DO), concentration of hydrogen ion (pH), concentrations of photosynthetic pigments (Chl. a, Chl. b, Chl. c, and carotenoid), flora and concentration of plankton, and concentration of bacteria. The experimental results of last three items will be reported in a separate paper (Tomokawa, Ogoshi and
Yamaguchi, in preparation). Gross primary production was estimated by the method using light-dark bottles in four seasons.

Experimental Results

Vertical distribution of the ecological characters

Vertical distribution of water temperatures is shown in Figure 1. In all the three reservoirs, typical alternation of stagnation and circulation is seen clearly. The former is in summer seasons and the latter in spring and autumn seasons. The thermocline lies between the layers from 8 to 13 meters in depth. That of Onzui reservoir is at around 13 meters. This corresponds to the depth of product of the transparency, 5.0 m, times 2.5 (Hogetsu, 1974). Those of Ginzan and Tsubaichi reservoirs were 8 and 11 meters, respectively. The maximum of actual depth lies sufficiently beyond the thermocline for each reservoir. Thus, the pond ecosystems are able to develop the stable functional layers of production, consumption, and decomposition.

Vertical distribution of pH is shown in Figure 2. The maximum pH values lie in the surface or near surface layers especially in the summer. This simply means that high photosynthesis consumes much amount of dissolved carbon dioxide and carbonic acids, and causes high pH value. In Onzui reservoir, the maximum value of July lay in the surface layer, while that of August did in the 5 meter layer. The difference seems to be caused by check of strong light and high temperature in August. The same tendency was seen in both Ginzan and Tsubaichi reservoirs.

Amount of dissolved oxygen is determined by product of photosynthesis or disolvement of oxygen from the air. The former is biotic event, and the latter is abiotic. High temperature affects it positively, while it works negatively to disolvement of oxygen into water. Vertical distribution of DO is shown in Figure 3. There were weak peaks around at the 5 meter-layer in warm seasons. However, the distribution as a whole is rather linear from the surface to the pond bottom for each reservoir. Nonoxygen bottom layer was not observed. Abiotic force seems to be dominant over photosynthesis. This is indicative of oligotrophism or at least no eutrophism in all the reservoirs.

Amount of photosynthetic pigments is expected to be an indicator of amount of photosynthesis. Especially, chlorophyll a is in the active center of photosynthesis. Its amount is directly proportional to that of production. Vertical distribution of chlorophyll a is shown in Figure 4. The maximum value lay in around the 5 meter-layer of the summer in all the reservoirs. The distribution curves depicted the similar patterns to that of pH (Figure 2) or of the amount of dissolved oxygen (Figure 3). The overlay of these curves seems to be the best indicator of actual amount of photosynthesis.

Blooming of specific plankton or so-called water bloom is seen at the end of summer or the bigining of autumn. The most popular plankton in the surface
Figure 1. Monthly changes of vertical distribution of water temperature. 
a: Onzui reservoir, b: Ginzan reservoir, and c: Tsubaichi reservoir.
Figure 2. Monthly changes of vertical distribution of pH. a: Onzui reservoir, b: Ginzan reservoir, and c: Tsubaichi reservoir.
Figure 3. Monthly changes of the amount of dissolved oxygen.  
a: Onzui reservoir, b: Ginzan reservoir, and c: Tsubaichi reservoir
Figure 4. Seasonal changes of the concentration of chlorophyll a. 
a: Onzui reservoir, b: Ginzan reservoir, and c: Tsubaichi reservoir.
Figure 5. Some of phytoplankton popularly found in reservoir ecosystems especially in summer. A: A colony of *Uroglenopsis americana* seen in Onzui reservoir. B: Individuals of *Uroglenopsis americana*. They have two flagella, long and short ones. C: *Peridinium volzii* seen in Ginzan reservoir. D: *Glenodinium sanguineum* seen in Tsubaichi reservoir.
Figure 6. The score ranges of ecological parameters of transparency, the concentration of hydrogen ions (pH), the amount of dissolved oxygen (DO), the concentration of chlorophyll a, and gross production commonly found in ponds of Japan. Data from some reviews (see the text). The scores of the ponds in Hyogo were superimposed on them. Thin lines are of the reservoirs. Black triangles are of Sara pond, and white ones are of Haibaraguchi pond. Both the irrigation ponds are located in Yashiro town. Arrows mean rough barriers between eutrophic and oligotrophic ponds.
water in the summer seasons of 1990 and 1991 are shown in Figure 5. They are *Uroglenopsis americana* in Onzui reservoir, *Peridinium volzii* in Ginzan reservoir, and *Glenodinium sanguineum* in Tsubaichi reservoir, respectively.

**Discussion**

From the above experimental results, the large water reservoirs in Hyogo are summerized for their ecological characteristics as follows. The average transparency is in the range from 3 to 6 meters. The thermocline is thus estimated to be from 8 to 15 meters in depth. This line means the expected barrier between epilimnion or production layer and hypolimnion or consumption layer (Welch 1952). Approximately linear clines of the amount of dissolved oxygen and also complete absence of nonoxygen bottom layer indicate to be oligotrophic pond ecosystem (Yoshimura 1936). They were constructed at least more than 20 years ago. Therefore, they seem to be in an equilibrium or nearly equilibrium state.

The present ecological scores were plotted on the distribution of other ponds already reported in Japan. The results are shown in Figure 6. The most of the standards come from the reviews of Ariga (1973), Hogetsu (1974), Kurasawa and Aoyama (1984), and Okino (1990). Eutrophic barriers are indicated by arrows there. Some of eutrophic ponds in Hyogo are also superimposed on it (Yamaguchi *et al.* 1987 and 1988). The present reservoirs are classified into a group of oligotrophic ponds in the chracters of transparency, pH, the concentration of chlorophyll a, and production capacity. Even in the character of the amount of dissolved oxygen, the distribution patterns seen in Figure 3 are typical of oligotrophic ponds.

**Acknowledgements**

We express our cordial thanks to the members of Control Office of Hikihara Dam and of Control Office of Ikuno Dam for their kind helps to the present works. Thanks are also to Mr. Kichiji Inoue for the permission to undertake the present works in Tsubaichi reservoir.

**References**


