Silver Springs . . . And the Balanced Aquarium Controversy

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Balanced aquaria are common in school laboratories. Are they really balanced? What systematic studies have been made on such aquaria?

Dr. Odum and Mr. Johnson's article on Silver Springs, a kind of balanced aquarium in nature, and their laboratory study of the balanced aquarium is highly informative.

Perhaps you and your students can undertake a similar project.

Last semester Mr. Johnson was a graduating senior at Duke University.

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When J. Leconte was traveling in the south in 1860, his path like that of his famous earlier predecessor, Ponce De Leon, led to some of Florida's giant outflows of clear spring water. He was fascinated with Silver Springs, one of the largest, and wrote a paper in one of the few scientific journals of that day on the peculiar properties of this water in bending light (1861). He also briefly described the lush underwater communities of plants and animals as thick beds of waving grass coated with moss-like plants.

Nearly a century later the water grass *(Sagittaria)* with the mossy encrustrations of algae is still waving in clear gushing waters near Ocala, Florida (Fig. 1). Thousands of people see this entirely natural underwater community each year from glass bottom boats.

FIGURE 1. Underwater view of the waving grass community in Silver Springs, Florida. Miss Ginger Stanley is shown in a record underwater swim down Silver River.
Florida's Silver Springs

Thus it is easy to affirm that the plants, insects, snails, shrimps, and fish in this ecological community eat, grow, are eaten, and die continually in place year after year so that the overall community hardly changes at all. It is a system of nature that has been called a steady state.

The spring with its communities has been called a giant aquarium. What is especially pertinent is that it is a kind of balanced aquarium. Light and the raw materials dissolved in the ground water enter this flowing aquarium whereas heat (from absorbed light), waste products, and excess organic matter flow out as diagrammed in Figure 2. The temperature does not vary more than a degree from year to year or from day to day. The chemical properties of the water even of the natural fertilizer elements like nitrate and phosphate are constant and continually renewed. Thus the spring possesses its own natural chemostat and thermostat. The only main factor that does change daily and seasonally is the sunlight, which of course is greatest in the long days of summer.

It will be recalled that in photosynthesis a group of reactions occur that may be summarized as follows:

$$\text{Light} + \text{Nutrients} + CO_2 + H_2O \longrightarrow \underset{\text{matter}}{\text{organic}} + O_2 + \underset{\text{energy}}{\text{dispersed heat}}$$

The respiration of the animals, many of the bacteria, and plants at night may be summarized as the reverse process:

$$\underset{\text{matter}}{\text{organic}} + O_2 \longrightarrow CO_2 + H_2O + \underset{\text{nutrients}}{\text{wastes and regenerated}} + \underset{\text{energy}}{\text{dispersed heat}}$$

The photosynthetic and respiration processes in the natural flowing aquarium, Silver Springs, are readily measured by determining the changes in dissolved oxygen in the water between the springhead and a place ¾ mile downstream (Fig. 2). The water emerging from the ground in the boil (spring head) contains 2.8 parts per million (ppm) dissolved oxygen. This water is not saturated with oxygen since at this temperature (73 degrees Fahrenheit) the water can hold about 8 ppm dissolved oxygen when it is in equilibrium with air. At night by the time the water reaches the downstream station an hour later, the dissolved oxygen content has risen to 3.3 ppm. This rise is due to the diffusion of oxygen into the water from the air which more than counterbalances the nighttime respirations of the plants and animals. In the daytime in addition to diffusion and respiration there is a heavy photosynthesis by the algae and grass which produces organic matter and oxygen as a by product

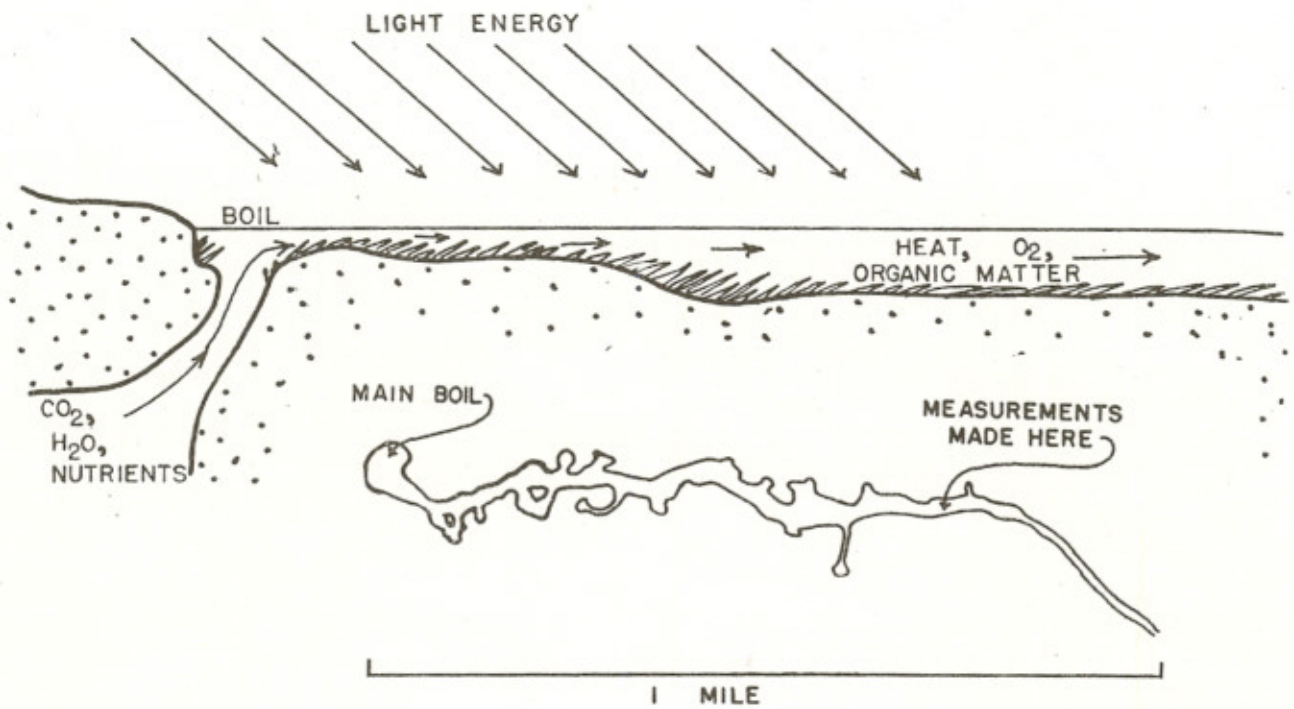

FIGURE 2. Schematic longitudinal section of the headwater area of Silver Springs showing the photosynthetic process which more than balances the respiration of the plants and animals. A map of Silver Springs is included showing the place where measurements of changes downstream were made as illustrated by Figure 3.

as indicated in the equation above. Downstream the oxygen on clear summer days rises to 6.0 ppm. The difference between the downstream oxygen increase at night and that in the daytime is a measure of the amount of photosynthesis. The brighter the sunlight, the greater is the photosynthesis, and the higher is the oxygen downstream. The summer photosynthesis per day is 3 times that in winter. A graph of daily change of oxygen and carbon dioxide at the station downstream during a day and night is given in Figure 3.

The energy of sunlight which is partly stored in the form of organic matter (glucose, proteins, fats, etc.) during photosynthesis as measured by the oxygen production has been roughly accounted for by measuring the organic matter in the water going downstream. About half of the energy is used each night and day by the respiration of the plants and animals. The rest goes downstream as dissolved organic matter, particulate matter, and fragments, which serve to feed communities further downstream. Thus there is a kind of balance although photosynthesis always exceeds respiration within the headwater area. Under these conditions it is found that the ratio of plants to animals is about 15 to 1 (dry weights).

If it is possible for natural ecological communities to become self adjusted into a fairly constant association of organisms is it not possible for the somewhat more closed system, the aquarium, to become self-adjusted? This brings us immediately into the balanced aquarium controversy. In spite of the thousands of aquaria that are kept in schools and homes throughout the world, it is surprising how little in the way of systematic scientific experimentation has been done to see under what if any conditions a balanced aquarium exists. One continually hears of incidental experiments where a community is sealed in a jug and placed in the light with the inhabitants remaining healthy for months, but these interesting projects are rarely published anywhere for others to study and think about. Here is a wonderful opportunity for classrooms at all grade levels. Dr. J. C. Dickinson, Univ. of Florida, Gainesville, for example, describes a closed bottle initially with lake water, which sat in a window and maintained about the same algal population for over ten years. Dr. Larry Whitford, N. C. State College, Raleigh, N. C., tells of a class experiment in which a carboy was sealed, with an aquatic community inside, and kept for a semester.

The status of published knowledge on balancing aquaria has been summarized by James W. Atz (1949). Although his title, "The Balanced Aquarium Myth" and some of his judgments are far too premature, Mr. Atz's main thesis is apparently correct when he indicates that most aquaria as ordinarily set up in homes and classrooms are not balanced. Where he is hasty is in the implication that aquaria cannot be balanced or that if left to themselves will not reach a balance.

For our purposes here we may define a balanced aquarium as being a constant ecological association of plants, animals, and bacteria entirely enclosed in a small container with only the light energy entering through glass and the excess heat being exchanged away through the sides. By this definition the balanced

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the precipitation of calcium carbonate. The oxygen was still high. In spite of extremely alkaline conditions, characteristic of pools in the desert, 4 of the aquaria still had healthy biota. An examination of plant/animal ratios showed surprising changes. The wet ratios were all about the same, (32/1, 32/1, 23/1, 29/1). Thus the readjustments due to births and deaths of snails and the growth and death of plants had modified the initially different ratios so that they were now similar. It is possible that mechanisms exist by which aquaria left to themselves can, under some conditions, readjust their own plant to animal ratios so that the amounts of plants are adequate to support the population of animals.

Whereas Atz emphasized the usual case where aquaria were not balanced because they had an excess of respiration over photosynthesis, these last experiments are an example of imbalance with an excess of photosynthesis over respiration. There was more than enough light to support the community with respect to oxygen and food supply but a developing shortage of carbon dioxide. It is not inconceivable that some intermediate conditions can be found where a balance can be obtained.

More such aquarium experiments are needed to learn how such ecological systems work. Teachers and students should write up their experiments and get them published in various magazines and bulletins.

Under some constant conditions, therefore, steady state communities may develop in nature as in the giant flowing aquarium in natural Silver Springs, Florida. The Silver Springs case and the experiments with aquaria suggest that the idea of the balanced aquarium has not been disproved. Although it is true that most aquaria are not set up with adequate light and allowed to develop a balance, there is no evidence that it can't be done. The minimum sized ecological system that can be balanced has not yet been determined.

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