Overwintering Tilapia In A Recirculating System

Introduction

Once the New Alchemists described their system for raising fish in greenhouses (McLarney and Todd 1974), considerable interest was aroused by their concept of combining aquaculture with horticulture. Theoretically, aquaculture, or fish farming, complements hydroponic horticulture in an elegant way.

For example, the wastes excreted by the fish can serve as nutrients for plants. Similarly, the carbon dioxide (CO_2) excreted by fish stimulates plant growth. Conversely, plants produce free oxygen (O_2) which is necessary for the respjration of animals, including fish. This union between aquaculture and greenhouse horticulture can be physical as well as biological. The presence of a fish tank or pond in a greenhouse provides a heat reservoir that stores heat in the day and releases it at night, thus reducing the energy needed to maintain the temperature in the greenhouse. Therefore, the idea of combining fish culture with greenhouse horticulture is advantageous for the following reasons: (1) to conserve energy through the presence of a water reservoir in the greenhouse; (2) to conserve nutrients by recycling fish wastes as plant fertilizer; and (3) to conserve water by using the same water to irrigate vegetable troughs as well as to raise fish. This union between horticulture and aquaculture can be productive both on a large scale (LeMare 1952) as well as on a small scale (Deryckx 1976), where it would be useful in home food production.

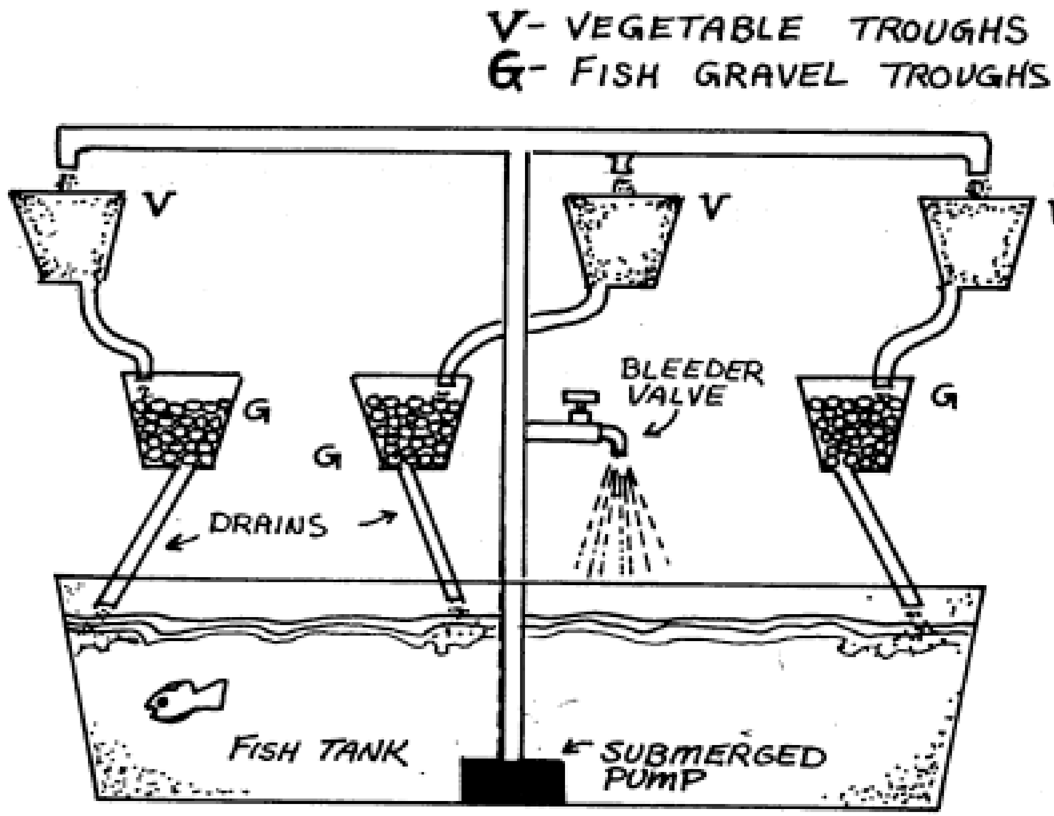
The purpose of my experiment was to construct a recirculating system for raising fish and vegetables on a combined basis and to describe how well this system works. The results of this experiment and of others like it will help develop the idea of integrating agriculture and fish culture so as to maximize food production from a limited piece of land (Eusebio et al. 1976).

Importance of Tilapia

Various species of the genus Tilapia are of great value throughout the world for subsistence fish farming. This is due to their rapid growth, herbivorous food habits, and ability to tolerate poor water quality. Tilapia sp. are widely raised in polyculture, or in combination with other species of fish. For example, when Tilapia are raised together with carp in Israel up to twice the total weight of fish can be produced using the same amount of feed (Yashouv and Halevy 1972). Tilapia, however, cannot tolerate temperatures below 12°C (55°F) for any length of time. This is beneficial from one point of view, because it prevents the spread of this fish in temperate waters. From another point of view, this is unfortunate because these fish must be overwintered until pond water temperatures rise high enough for them to grow well out-of-doors (above 21°C or 70°F).

Description of System

A system for overwintering <u>Tilapia aurea</u> in a closed recirculating arrangement was constructed in the fall of 1976. Gravel trickling filters and hydroponic vegetable troughs were incorporated into the system to purify the water and utilize some of the fish wastes for vegetable production. Theoretically, the vegetables could recover part of the cost of building and operating such a system. This



particular system was constructed in a gas-heated greenhouse to maintain the high water temperature necessary to sustain this fish. The experiment lasted from November 16, 1976 to March 10, 1977.

The system originally consisted of a galvanized steel tank 1.22 meters (m, 4 feet) in diameter and 53.34 centimeters (cm, 21 inches) high in which 155 *Tilapia aurea* weighing 16.4 kilograms (kg, 36.16 lbs) were fed 1 percent of their total body weight daily with Purina trout chow. A 1/2-horsepower submerged pump automatically pumped the 570, ±30 liters (150 gallons) of the system's water from the bottom of the fish tank to the top of three gravel-filled steel troughs, 2.44 m (8 feet) in length in which 34 tropic tomato seedlings were planted. After fertilizing the hydroponic troughs, the fish tank water drained into three gravel biofilters. These biofilters are made up of 5.1-cm (2-inch) PVC pipes perforated with holes which allow the fish tank water to drain onto a layer of pea-sized gravel suspended above the bottom of the steel trough. After being filtered, this water drained back to the fish tank. The gravel biofilters were necessary to oxidize any ammonia (NH_3) or nitrite (NO_2) ions remaining in solution for both these excretion products are toxic to fish. To balance the water's pH, 1.36 to 1.81 kg (3 to 4 lbs) of crushed oyster shells were placed in the fish tank. The entire system was kept in a greenhouse heated to 21°C (70°F).

About 1 month after starting the experiment, an excessively high zinc (Zn) concentration, 34 mg/liter, developed in the fish tank water, presumably due to the solution of Zn from the galvanized steel tank into the system's water. Consequently, the steel tank was replaced with a fiberglass tank having a total volume of about 530 liters (140 gallons).

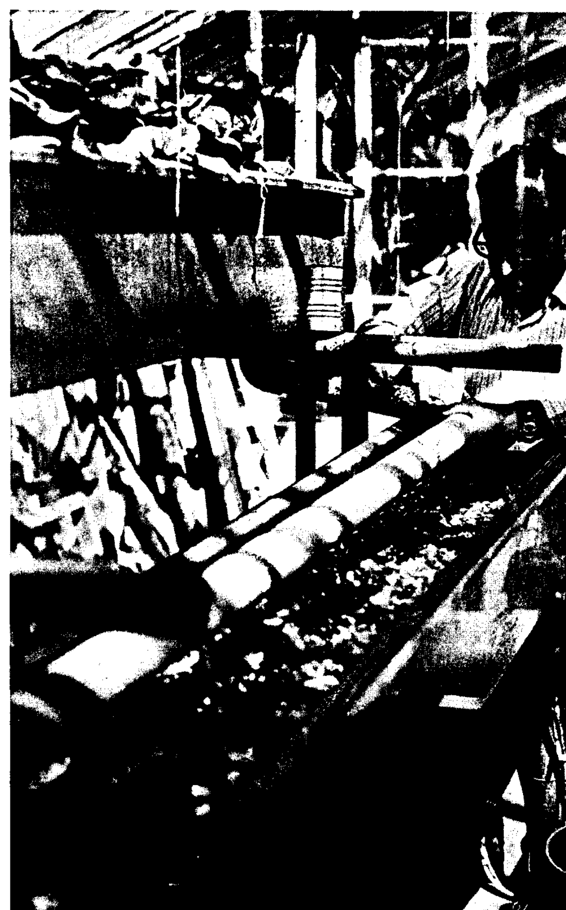
The 570 liters of the original system were recirculated about 21 times per day with a replacement time of about 20 minutes while the pump was on. When the fiberglass tank was installed, the 540 liters of the system's water were fully recirculated about 25.7 times per day with a replacement time of about 18.7 minutes. The pump was turned on 15 minutes out of every 45 minutes by a timer to allow the roots of the vegetables to be exposed to the air.

The water for the system was supplied from a tap in the greenhouse that delivered chlorinated water from the city of Auburn, Alabama. At first this water was dechlorinated by filtering it through charcoal. Three weeks after starting the experiment all the fish in the tank were in distress and over half of them died. After the kill occurred, a high level of free chlorine was discovered in the water of the system (more than 1 part per million). The addition of a few grams of sodium thiosulfate to the fish tank stopped the fish from dying. From this point on, sodium thiosulfate was mixed into all the water added to replace the system's evaporation losses (about 11.36 to 18.93 liters or 3 to 5 gallons per day).

Aeration for the fish was provided by a lawn sprinkler head attached to a bleeder valve that sprayed a stream of water onto the tank's water surface whenever the pump was on. The circulation of water through the perforated filter pipes and coarse gravel provided additional dissolved oxygen to the water.

Results

For the first 30 days of the experiment, the tilapia did fairly well in spite of the high initial stocking rate - 28.8 grams/liter or 4.6 lb/gallon. But the accumulation of free chlorine from the tap water killed 58.7 percent of the fish on day 21. After the first major fishkill, the mortality declined to 7 out of 64 fish (10.9 percent mortality) for the remaining 3 months of the experiment. This decline in mortality demonstrated that the tilapia could survive in the system. The later fish mortality was probably due to environmental stress caused by excessive cold (after a heater breakdown), excessive heat (after a warm sunny day) or excessively high ammonium ion (NH_4^+) concentration (up to 6 mg/liter when no plants were growing in the system). Examination of the fish that died during the experiment revealed no case of any parasites and only one instance of a possible bacterial infection. Samples of living fish taken during the course of the experiment and after its conclusion were also free of infection. The healthy condition of the surviving fish may be attributed in part to the prophylactic treatments of acriflavin, formalin, and malachite green these fish received before stocking.

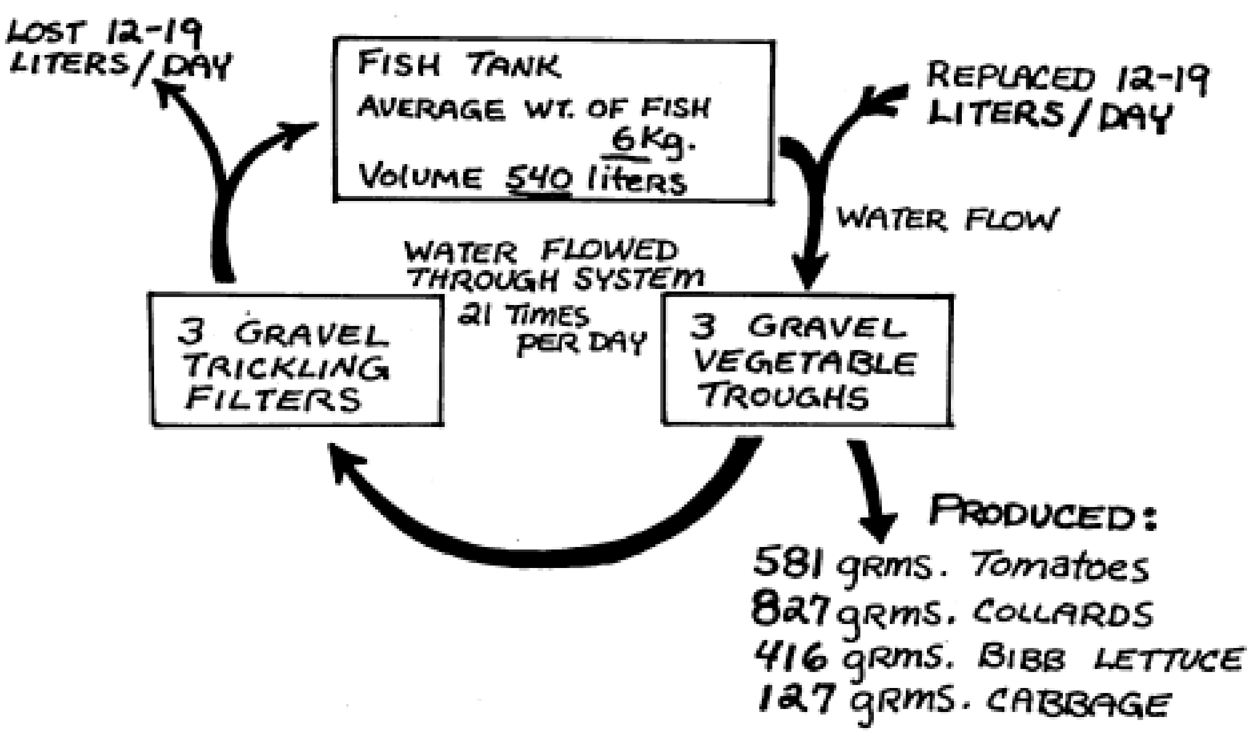


Each day the pH, dissolved oxygen, and the temperature of the system's water were measured. For most of the experimental period, the dissolved oxygen in the water varied from 5.0 to 7.5 mg/liter, while the water temperature usually varied from 20° to 23°C (68° to 73°F). At one point during the experiment, water temperature dropped to 14.5°C (58°F) after a heater failure. Occasionally during warm sunny days, the system's water temperature would reach 29°C (85°F), but the temperature would drop again at night. At first, the pH in the water was about 6.5, and it rose to 7.0 before the major fishkill. After the kill it dropped to 6.0 or even 5.5. Generally, the pH remained around 6.0. Small amounts of KOH solution and dolomitic limestone were added regularly to keep the pH of the system's water near 6.0. Why the pH of the system's water tended to decrease is unknown.

The fish were fed 1 percent of their body weight each day with Purina trout chow in which 3 ml of cod liver oil were added. If the first month's growth and mortality is ignored because of the chlorine problem, then the survivors of the first major fishkill (12/03/76) can be considered as the initial stocking rate. This would mean that the 64 surviving tilapia had an average weight of 75.75 grams, while the 57 fish that survived until the end of the experiment (03/10/77) had an average weight of 94.5 grams. This leaves an average weight gain of 18.84 grams per fish over a period of 88 days. Taking mortality into consideration, this leaves an average growth rate of 0.2 gram per fish per day over the 88 days of the latter part of the experiment.

Vegetable Results

The first vegetables to be planted were tropic tomatoes. November 22, 1976, 34 tropic tomato seedlings planted in peat pots were transplanted into three gravel troughs. These seedlings grew well for the first few weeks, but by the middle of December, they began showing signs of nutrient deficiency. To counteract this 10 grams of osmacote, a slow release fertilizer (18-6-12) was added to each plant. But the tomatoes



still had curled leaf tips, even after adding 1 gram of Le Chatelier's hydroponic fertilizer mix to each plant. A mixture of iron, molybdenum, copper, boron, manganese, and magnesium improved the plants somewhat but did not harm the fish. But, by the beginning of January, the tomato leaves began to wilt and die off. The cause of this leaf curling and yellowing was diagnosed to be the result of red spider mites which infested all of the plants. In spite of this infestation, 22 tomatoes were harvested January 22, 1977, 62 days after planting. These tomatoes were small and green with a total weight of 580.9 grams for an average weight of 26.4 grams (1 oz) per fruit. Small as they were, the tomatoes turned red on exposure to sunlight and were quite tasty. The tomato plants were then removed; watercress was grown in one of the troughs. However, the watercress failed to grow, even after flooding the trough.

On January 29, 1977, 8 Savoy cabbages, 16 Georgia collards, and 8 Bibb lettuce seedlings in peat pots were transplanted into two of the three troughs, 16 plants to the trough. Once these vegetables were planted, the NH_4^+ content of the system's water declined after having risen to 6 mg/liter during the period when no plants were in the system. The collard greens and lettuce both grew well, with a few of the collards flowering in the hot dry air of the greenhouse. On March 10, at the time of harvest, the collard greens were of good quality (except for the ones planted right next to the drain outlet). The collard greens reached the height of about 30 cm (12 in). The Bibb lettuce was also of good quality, and all of these plants were growing straight and tall in preparation for flowering. In contrast to this, the Savoy cabbage was immature, and the leaves of several of these plants were yellow or colorless. After a growth period of 40 days, 827.1 grams of Georgia collards, 415.8 grams of Bibb lettuce, and 127.3 grams of Savoy cabbage were harvested.

Summary

A recirculating system for maintaining large numbers of *Tilapia aurea* in a greenhouse has been described. Included in the system are gravel trickling filters and gravel vegetable troughs for growing tomatoes, lettuce, cabbage, and collard greens hydroponically. An account of tilapia growth and mortality is given along with vegetable production in this system.

Tilapia aurea grew 0.2 grams per day in a closed system in which vegetables were rooted. They can tolerate concentrations of 75 mg/liter of $SO_4^{=}$, 2.6 mg/liter of $PO_4^{\equiv}$, 60 mg/liter of NO_3^-, 2.2 mg/liter NH_4^+, 33 mg/liter of K^+, and 444 mg/liter of $CaCO_3$ as total hardness at a pH of 6.0 without apparent difficulty.

These nutrient concentrations are sufficient for the growth of collard greens and Bibb lettuce but are not sufficient for the growth of tomatoes.

Conclusion

Energy conservation was not a factor taken into consideration in this experiment, the reason being that the greenhouse and heating system were provided and were not subject to modification. Thus, considerable energy was wasted because the greenhouse was not insulated. However, if the greenhouse were designed from the ground up with energy conservation in mind, the fish tank water in such a structure would help conserve heat due to the water's thermal inertia, possibly reducing the need for insulation of the greenhouse (Jensen 1977).

Nutrient conservation was the primary objective in designing this system. The presence of vegetables in the system helped prevent the build-up of toxic NH_3 and CO_2 in the system's water (Naegel 1977). These two compounds are the most toxic compounds excreted by fish and the ones most likely to accumulate in the water of a closed, recirculating system. However, the nutrient concentrations recommended by hydroponic texts for growing vegetables are 5 to 10 times that which the tilapia tolerated in this experiment (Schwarz 1968). Although some species of tilapia (a notoriously hardy fish) may be bred to tolerate the high nutrient concentrations (200 ppm N and 50 ppm K) recommended for plant growth, it may be preferable not to try to raise fish under stressed environment. Instead, it is more practical to raise plants separately in concentrated nutrient solutions and dump the exhausted solution into a fish pond rather than throw this solution away as is normally done. The spent solution lacks sufficient nutrients for plant growth but contains more than enough nutrients for the algae upon which many species of tilapia feed. Otherwise, algae and aquatic plants could make better use of the dilute nutrients present in fish pond water (Le Mare 1952).

Because the gas heater blew heated air directly onto the fish tank and over the plants, water was not conserved in this greenhouse system. In a properly designed system, water loss could be kept to a minimum (Houston, Jr. 1975).

The concept of integrating fish culture and hydroponic plant culture has an excellent potential for increasing food production, for reducing pollution from excess fertilizer use, and for conserving land and energy. This field of research is still in the embryonic stage.

- Louis Landesman

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Water Quality Parameters of
Recirculating Fish Tank Water

	Initial Water Quality			Results					
Date	T.H.	Ca^{+2} as mg/l $CaCO_3$	T.A.	SO_4^{-2} mg/l	PO_4^{-3}-P mg/l P	NO_3^--N mg/l N	NO_2^--N mg/l N	NH_4^+-N mg/l N	K^+ mg/l
11/16/76	52.2	37.2	23	28	0	0.19	---	0.01	3
11/22/76	53	47	91	30	0.21	2.0	---	3.0	8.9
11/29/76	66	41	135	27	0.94	5.5	---	3.0	17.4
12/06/76	93	63	34	47	0.8	23	3	1.4	7.9
Changed tanks and replaced water									
12/13/76	52.2	37.4	18	28	0.257	3.8	6	0.03	2.7
12/20/76	115.4	77	6	39	1.34	20	0.068	0.73	11.0
12/27/76	142.8	58.4	4	45	0.7	25	0.06	1.15	12
01/03/77	233.8	129.6	4.8	135	0.7	35	0.08	1.3	12
01/10/77	251.4	---	2.4	150	1.2	35	0.12	2.2	16.7
01/17/77	249	---	0.4	100	1.65	37	0.043	1.31	25.9
01/24/77	280	180	2.2	63	2.12	40	0.084	4.0	35
02/01/77	355	170	1.2	115	3.32	65	0.057	6.0	43.7
Half of water replaced to reduce NH_4^+ concentration									
02/07/77	356	236	1	112.5	2.64	55	0.024	2.2	40.5
Major water leak - 95 percent of water replaced 02/09/77									
02/14/77	242	193	0.5	70	2.2	40	0.074	0.2	20.2
02/21/77	298	192	3.8	60	1.85	51	0.05	0.35	25
02/28/77	384	210	3.6	60	1.89	60	0.035	0.2	27.8
03/07/77	444	244	4.2	75	2.6	58.5	0.07	0.2	32.7

Fish Production

	Initial 11/16/76	11/29/76	12/12/76	12/26/76	01/11/77	02/05/77	02/20/77	Final 03/10/77
Wt. (g)	16,398	16,398	4,848	4,717	4,616	4,698	5,358	5,391.25
Number	155	155	64	61	61	58	57	57
Average wt. (g)	109.8	109.8	75.75	77.33	75.67	81.0	94.5	94.59
Mortality (%)	---	---	57.8	0.05	---	0.05	---	---

free chlorine fishkill

Weight gain from 12/12/76 to 03/10/77 (from after major fishkill until harvesting). Total weight taken both times. Average weight gain 94.59 - 75.75 = 18.84 g per fish over a period of 88 days, or for an average weight gain of 0.2 g per day.