ECOLOGICAL STUDIES ON THE PISCICULTURE IN TAIWAN

臺灣養魚之生態學的研究

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I

Studies on *Tilapia mossambica Peters*

Tilapia mossambica, the mouth breeder, was originally found in Africa and introduced to Taiwan in 1946. Being freshy tender, delicious and less spiny, it is considered as an excellent food fish. Moreover, the mouth breeders are so adaptive and productive that they become the most important cultured fishes which are widely distributed in Taiwan. In view of its high economic value, the author has initiated the research in details.

On Reproduction

In spawning season, the male and female fishes usually dig a hole on the bottom of the pond before their courtship. The female fish lays eggs in it, and the male spreads its semen over them. Upon conclusion of fertilization, the female holds fertilized eggs in its mouth as long as the eggs hatch.

In this article, the germ cells and mouth breeding, that the author has studied is described.

1. Germ Cells

a. Spermatozoans

The spermatozoan of the fish has a round head equipped with undistinguishable neck and a tail which measures 5 times longer than the head. The average length of a sperm measures 15.35 *u*; the head, 2.69 *u*; and the tail, 12.66 *u*.

The activity of a sperm will quite be effected by water temperature and pH value. It was demonstrated that it can survive in the temperature ranging

from 3°C–42°C and pH value, from 4.2–6.8. The optimum pH is 5.4 in which the sperm may retain activity for 2 days; while in pH 8.2, only for one hour.

Effect of Higher Temperature on Sperm

Water Temperature °C	Activity
36	Very active
38	Active
40	Inactive
42	Inactive
44	Died within 15 minutes

Effect of Lower Temperature on Sperm

Water Temperature °C	Activity
8	Active
6	Active
4	Active
3	Inactive
1	Inactive, died
0	Died within 5 minutes

Effect of pH on Sperm

pH	Duration of Life
1.0,	5 min
3.0, 3.4, 3.6	18 min
4.0	43 min
4.2, 4.4, 4.6, 4.8, 5.0	968 min
5.4	48 hr.
6.2, 6.4, 6.8	310 min
7.2, 7.4	110 min
8.0, 8.2	55 min
8.6, 9.2	40 min
10	5 min

b. Eggs

The egg before maturity is yellowish and round. A matured egg is dark yellow; oval with anterior end more pointed than the posterior. In average, it

is 2.75 mm long and 1.99 wide in diameter. Every 1000 eggs weigh 2.587 g. the flotage of a egg, as changed with its specific gravity, is a factor that effects its fertilization and hatching. The egg will be sedimental if its specific gravity be 1.080–1.095.

The egg contains amylase, lipase and 19.5%–30.1% of lipid.

Female fish	Body length (cm)	Body weight (g)	Length of ovary (cm)	Specific gravity of egg
A	11.0	12.5	2.5	1,090-1,095
B	9.5	13.0	2.0	1,080-1,085
C	10.1	14.1	2.4	1,085-1,090
D	11.2	14.0	2.2	1,080-1,085
E	11.0	22.0	2.8	1,090-1,095

2. Facts about Mouth Breeding

After eggs are fertilized, the female fish holds them in its mouth for breeding. Its mouth with eggs is slightly open. On the lower jaw is a thin and transparent membrane through which eggs are visible. It may be observed that eggs rotate incessantly in its mouth. The operculums of the fish move faster than usual. The frequency of the movement alters from 80–90 into 100–125 per second. In breeding period, the breeder take less food and its body becomes skinny.

Fertilized eggs in the mouth are hatched into fries in 3 days. The breeder may not release fries until it is frightened. In early stage, the dorsal, pectorial and caudal fins of the fly are well developed, but it can still not swim freely because its belly contains a plenty of yolk that draws it down to the bottom. And then the adult fish collects the fries into its mouth again for the purpose of protection. As the fly develops further, the yolk is absorbed by digestion and pelvic fins appear. At that time, the young fishes are getting active when they are released by the breeder, which usually repeats releasing and collecting 2 or 3 times a day for 2 successive days. Subsequently, fries will be entirely set free and lead their independant life.

3. Principle of Mouth Breeding

The mouth breeding appears to be effected by several ecological factors:

1. Through the transparent membrane of lower jaw, eggs are observable to rolate unceasingly in the mouth. It was demonstrated that

hatching rate of other fish eggs, if turned around, will be decreased. The rotation of Tilapia eggs appears to be one of the factors for its hatching.

2. Tilapia egg is sedimental in nature. Egg sinking on the bottom seems to be unfavorable to hatching. This suggests that the egg can be incubated in mouth.
3. There would be enzymes secreted in the mouth cavity to promote egg hatching.

In order to validate the concepts, the author has conducted experiments on artificial fertilization and artificial incubation of the Tilapia eggs.

For artificial fertilization, dry method was applied. Fertilized eggs were categorized into 3 groups. Group A was treated with running water by which eggs were turned around as provided with sufficient oxygen. Group B was provided with sufficient oxygen by changing water at intervals, but left still. Group C was treated with water unchanged and left still. The results are shown as follows:

Temperature 25°–28°

Group A Fertilized on May, 28, hatched on June, 2.
Group B No hatch, died afterwards.
Group C No hatch, died within one day.

The results indicate that egg rotation may supply the egg adequate oxygen and prevent it from molding. In the buccal cavity, the eggs spin in the water current as caused by buccal and opercular movements. Acceleration of opercular movement accommodates the speed of water current as well as egg rotation. Buccal secretion appears to have no close relation with egg hatching.

4. On the Mechanism of the Reproductive Habit

The female fish holds her eggs in the mouth for breeding, while the male fish does not.

The chemical which causes the female fish to hold eggs is estradiol, but it is not the hormone of corpus luteum. The female fish cannot hold eggs in its young period, although an adequate dose of estradiol is injected. After the injection of testosterone propionate or cutting off the cerebrum the mother fish does not hold her eggs in the mouth.

On Brain

The morphism of the brain of mouth breeder is of about the same form and structure as other teleosts. Though there will be an irregular movement of operculum when the part, in front of cerebellum, is transversely cut, the movement of operculum, however, will be in order at last. On finishing a transverse cutting at the middle part of cerebellum, the opercular movement ceases immediately, and another irregular cleaning movement apears continuously. Both the opercular movement and the irregular cleaning movement cease when the transverse cutting is done at the end of cerebellum.

There is no important influence upon the life of fish when its cerebrum is picked out. If we pick out the optic lobes, its visual sense is lost. If we pick out the cerebellum of fish, it loses the equilibration of body and adjustment of muscle.

The frequency of opercular movement increases when a drop of solution of chloride salt is added to the brain. But when the concentration of the salt is over the suitable dose, an opposite result is obtained, even the movement ceased.

The metal ions of chloride salts have an effect on the brain, and the amplitude of vibration of the opercular movement, therefore, is changed as the solution is added.

The frequency of opercular movement is increased, and the amplitude of vibration decreased, when saturated solution of carbon dioxide is added to the brain of fish. The saturated solution of hydrogen sulfide decreases or ceases the movement of operculum, and the amplitude of vibration of the opercular movement decreases too.

On Blood

The erythrocytes of the fish are rice shaped, with nucleus having mean long diameter of 22.5 micra, and mean short diameter of 20.5 micra. The leucocytes of the fish are disc-shaped having a mean long diameter of 19.5 micra and mean short diameter of 17.5 micra. The average number of erythrocyte is 2,000,800 per cubic millimeter and that of leucocyte is 1,600.

The number of erythrocyte of the fish decrease in proportion to the

duration of starvation. During the period of starvation the number of new cells will be less 0.6% compare with the number of destroyed cells daily.

Duration of starvation (day)	Number of R. B. C, (per cmm.)	Body weight (g)
control	2,000,800	18
4	2,000,300	18
8	2,000,400	17.8
12	2,000,100	17.7
16	1,900,076	17.5
20	1,870,680	—
24	1,850.460	17.2
28	1,670,084	16.8

The change of the number of leucocyte is somewhat irregular although the number is also decreased in proportion to the duration of starvation.

Duration of starvation (day)	Number of W. B. C. (per cmm.)	Body weight (g)
cont	1,600	18
4	1,612	18
8	1,937	17.8
12	1,975	17.7
16	2,772	17.5
20	1,337	—
24	1,080	17.2
28	1,280	16.8

The blood of the fish has a good adjustment to the variation of pH value. It's adjustment has a definite limit when it was injected with 0.052% HCl or 0.048% NaOH no harm had been done. The frequency of heart beat was decreased after the injection of HCl or NaOH in varied concentration.

Concentration of HCl (%)	volume of HCl (cc)	Frequency of heart beat (per Min.)
—	—	80
0.1	0.5	76
0.3	0.5	66
0.5	0.5	60
0.7	0.5	56
0.9	0.5	55
1	0.5	54
3	0.5	40
5	0.5	24

Concentration of NaOH (%)	Volume of NaOH (cc)	Frequency of Heart Beat (per Min.)
—	—	80
0.1	0.5	66
0.3	0.5	63
0.5	0.5	58
0.7	0.5	56
0.9	0.5	54
1	0.5	53
3	0.5	36
5	0.5	30

The adjustment of the fish's blood to the foreign proteins had been tested by the injection of albumin, frog's blood and the mixture of albumin, examing in the amplitude of heart beat. The adjustment of fish's blood to the albumin is comparablly weak while that to the frog's blood is strong. Its adjustment is stronger to the mixture of albumin and frog's blood.

On Digestion

The stomach of the mouth breeder is with a form just like the Chinese character "卜". The internal wall of the stomach show many longitudinal stripes, apparent and snake like. The length of its intestine is five times of its body length.

Many fragments and pieces of aquatic plants, algae and moss were found in its stomach at autopsy. The total weight of the dry feces which a fish excreted during seven days was forty mg.

The fish starved to die in 38 to 40 days, during this period, the weight of the fish decreased 5.57 to 5.85 per cent.

Starvation (day)	Body weight (g)	Feces	Activity
1	10.420	+++	++++
10	10.400	++	+++
15	10.200	++	+++
20	10.150	++	++
23	10.150	++	++
28	9.900	+	+
31	9.850	+	+
35	9.850	—	—
37	9.820	—	—
38	9.810	—	Died

The peristalsis of its intestine was rather obvious, the interval lasted 37 and a half seconds and its curve was recorded by a kymograph showed on the Chinese paper.

There are many kinds of enzymes in its digestive tract, such as amylase, invertase, proteinase and lipase. The hydrochloric acid is tested in its gastric juice.

If 0.5 cc of the 1/1000 solution of Folidol E-605 is injected into the digestive tract of a fish 10-13 cm in length through the throat, the fish would die after six hours. But the fish was rescued when the Folidol E-605 solution was 1/2000.

If 0,5 cc of 1/1000 solution of Folidol E-605 is dropped on the gill of the fish. No harm occurs to the fish. If 0.5 cc of the same solution is applied into fish's digestive tract through anus, it does not harm to the fish.

Effect of Urea on the Respiration

The quantity of oxygen dissolved in the urea solution is less than that of tap water while the quantity of carbon dioxide dissolved in the urea solution is more than that of tap water. The pH value of the urea solution is ranged from 6.3 to 6.6.

Concentration of urea solution %	Temperature °C	Content of O_2 in urea sol. cc/L	Content of O_2 in tap water cc/L
10.0	17.2	7.68944	8.48100
5.0	17.2	6.84134	8.48100
1.0	17.0	7.06750	7.91560
0.5	17.0	7.35020	7.91560
0.1	17.0	7.63290	7.91560

Concentration of urea solution %	Temperature °C	Content of CO_2 in urea sol. mg	Content of CO_2 in tap water mg
10.0	28	0.0258564	0.0098076
5.0	28	0.0205068	0.0098076
1.0	28	0.0115908	0.0098076
0.5	28	0.0106992	0.0098076
0.1	28	0.0098076	0.0098076

Concentration of urea solution %	Temperature °C	pH value
10.0	13.5	6.6
5.0	13.5	6.5
1·0	13.5	6.3
0.5	13.5	6.4
0.1	13.5	6.6

As regard to the fish's respiration, urea solution has the effect that can stimulate it and cause it lively and brisk. The urea solution if in high concentration will be harmful to the fish's function, and the fish will be killed if the solution is denser than 5 per cent. The suitable concentration which can help the respiration in fish brisk is from 0.001%–1%, under such a condition the frequency of opercular movement per minute is increased gradually.

Fishes have been poisoned by carbon dioxide cannot be saved by urea solution in any concentration, this is to say this sort of sudden mortality can not be rescued by urea solution.

Effect of Indole on the Respiration

The pH value of indole solution under the concentration of 0.0002% was same as compared with that of tap water. If indole solution diluted by the water which had fishes lived in, the pH value would be same with that sort of water.

Concentration %	pH
Tap water	6.8
0.1000	6.4
0.0200	6.5
0.0100	6.5
0.0010	6.6
0.0002	6.8
0.0001	6.8

The qunatity of carbon dioxide dissolved in the indole solution with a concentration from 0.0002% to 0.0001% loss slightly less than that of tap water.

Indole solution has the effect that enable the respiration of mouth breeder becoming more brisk. The solution with concentration more than 0.001% would be harmful to the respiration of the mouth breeder and even causing the fish died. The more dense of the solution, the faster the fish would die.

Indole solution with a concentration from 0.0002% to 0.0001% had merely the effect to stimulate the respiration more lively, no any harmful result has done to the fish.

The sudden mortality of fishes causing by more carbon dioxide dissolved in the water in which fishes lived would not be rescued by adding indole solution in any concentration. Adding indole solution into the water could only decrease slightly the amount of carbon dioxide and stimulated the mouth breeder briskly so that they could exsist a little longer.

When we put those fishes already showed sudden mortality into indole solution with a concentration from 0.0002% to 0.0001%, they live again.

Effects of Temperature on the Tilapia

The range of optimum temperature is 20–32°C. The higher fatal temperature is 42.8°C, but abnormalities such as giddy, loss of equilibration and convulsion etc., occurs at 39–40°C. Convulsion and trembling are the symptoms of death. Tetanus of muscle occurs after a while of the mortality of high temperature. The mortality of high temperature is caused by the coagulation of protein in the body. The numbness of nerve and sense occurs when the frequency of respiration in fish is urged by the increasing of carbon dioxide and the decreasing of oxygen in the water and reaches a certain limitation. In the meantime the fatal period is shortened and the higher fatal temperature descends.

The lower fatal temperature is 6.8–8°C but the loss of equilibration, sensation and vitality occur during 12.5–9.8°C. The fish can not bear such a change as the sudden ascending or descending of water temperature or a sudden transfer from an environment of ordinary temperature to that of a higher or lower temperature. The cool and warm resistances correspond on the preliminary temperature. The fatal temperature is in proportion to preliminary temperature at both higher or lower condition when the fish is put in higher temperature and so as in the lower temperature.

Preliminary temperature °C	Higher fatal temperature °C			
	1	2	3	4
21.2-21.4	40.8	40.6	40.8	41.0
26.8	42.6	42.8	42.2	42.8

Preliminary temperature °C	Temperature of loss of equilibration °C							
21.8	9.6	9.8	9.8	9.8	10.0	9.8	9.7	9.8
26.8	12.0	11.3	11.4	12.2	10.5	11.2	10.5	12.5

The influence of low temperature to the recovering period of the fish differs with individuals, especially on the recovering ratios. The fish is comparablly weak to the cold weather, so it ceases to move and sinks to the bottom of the aquarium when treated with low temperature. Tetanus of muscle does not occur after the death of low temperature.

On Coloration

Most of chromotaphores of Tilapia are melanophore and xanthophore. The expansoin and the contraction of melanophore is due to the conditions, and the rate of the expansion of melanophore, the melanophore index, can be divided into five degrees. Melanophores do not uniformly distribute in the body, always assemble at certain regions to form coloration.

1. Change of melanophore

According to the melanophore index, its control organs may be determined. If it is controlled by nerve system, the outside stimulate would quickly conducted to melanophore and made a response rapidly. If it is controlled by hormone, the response to outside stimulate would be slower than that controlled by nerve system. The change of melanophore is very fast at the beginning and then gradually slow down. By this we know that the change of melanophore is controlled by nerve system at the beginning and then controlled by hormone.

2. The change of melanophore by water temperature

Author found that the speed of change of melanophore is closely related with water temperature. Within 15°C to 33°C, the speed of change is proportional to water temperature.

3. The change of melanophore by fatigue

Before the test, measure the time required by Tilapia for changing its color. Then, put the sample into the fatigue equipment. After Tilapia has been tired, measure the time required for changing color again. Author found that fatigue would delay the expansion of melanophore. The average time needed by Tilapia is 18.9 sec. in normal condition, and 24.0 sec. in utterly condition. The water temperature is 21°C for both experiment.

4. The change of melanophore by light intensity

The expansion of melanophore is varied with the light intensity. During low intensity, melanophore is in full expansion, while the expansion of melanophore becomes slowly during high intensity. The expansion of melanophore is reversely proportional to light intensity.

5. The change of melanophore by hunger

Before the test, measure the time required by Tilapia for changing color. Then put the sample into distilled water and prevent any organic food from coming into the container. After one week, measure the time required again. Author found that the stravation can greatly slow down the expansion of melanophore. The average time needed by Tilapia is 26.25 sec. in normal condition and 43.25 sec. in hungry condition. The water temperature is 15°C for both experiment.

II

Studies on the Sudden Mortality of Fishes

1. Causes of Sudden Mortality of Fishes:

The sudden mortality of fishes usually occurs when water temperature rises and much decomposable organic substance exists. The causes of the sudden mortality are demonstrated and are summarized as follows:

(1) When water temperature rises, the rot on the bottom of pond accelerates its decomposition into CH_4 and CO_2 of equal amount. The CO_2 content of water is then increased. The reaction is:

$$C_6H_{10}O_5+H_2O\longrightarrow 3CH_4+3CO_2$$

(2) CH_4 produced from this reaction releases mostly into the air and is combined partly with O_2 in water to produce CO_2. Therefore, O_2 in

water is decreased and CO_2 increased. The reaction is:

$$CH_4+2O_2 \longrightarrow CO_2+2H_2O$$

	O_2 of Tap water (cc/L)	O_2 of Sat. CH_4 (cc/L)	O_2 combined with CH_4 (cc/L)
No. 1	7.406	7.293	
No. 2	7.293	7.293	
No. 3	7.349		
Mean	7.349	7.293	0.056

(3) When water temperature rises, the body temperature and metabolic rate of the fish are getting higher. Consequently, the more O_2 the fish consumes, the more CO_2 it excretes.

Effect of temperature on Respiration in the Fish (Wt. 160g)

	Water tem. °C	O_2 inspired (cc)	CO_2 expired (cc)	O_2 inspired (cc/hr)
51 hr. 10 min.	10	329.6	308.70	6.4
22 hr. 50 min.	30	576.0	432.00	25.0

(4) As water temperature rises, the solubility of O_2 in water is reduced. The shortage of O_2 supply may kill fishes in hasty.

Above 4 cases usually happen simultaneously. The shortage of O_2 and excess of CO_2 in water eventually induce the sudden death of the fish.

Effect of Temperature on the Volume of O_2 in Water

Water Temperature (°C)	Total volume of air (cc/L)	Oxygen (cc/L)
2	27.382	9.706
10	22.644	7.965
20	18.690	6.501
30	16.073	5.480

It was found that sudden death among fishes happened in the Lung-chuan pond of Taiwan Normal University in 31, Mar. 1949. A great deal of fishes were killed incidentally. The pond water has been tested and anlyzed by the author and the data are shown below:

In the very day that the incident happened, O_2 content in water was

reduced more than twice than several days ago, while CO_2 increased almost threefold.

Date	O_2 cc/L	CO_2 cc/L	Remarks
Mar. 26	8.2	1.96	
Mar. 31	4.5	4.86	Sudden mortality
April 3	7.9	3.06	

2. Control of Sudden Mortality of Fishes

Control of sudden mortality among fishes depends chiefly upon how to cover the shortage of O_2 and to remove excessive CO_2. There are three ways of control as described below:

(1) To lower water temperature: prevent decaying substances from decomposition and keep O_2 and CO_2 constant.

(2) To add additional O_2 into water so that partial pressure of O_2 can be raised and diffusion of O_2 in water will be accelerated.

(3) To minimize CO_2 content in water to reduce the partial pressure of CO_2 so as help fishes to release CO_2 in the water.

As to first method, the local pisciculturists conventionally plant trees or build shelters along the bank so as to lessen the heat into water from sunshine. This method is not eligible because it may not only take considerable length of time or man power to accomplish, but also be less affective.

In the second method, the O_2 is provided by H_2O_2 as added into the pond. The reaction is: $H_2O_2 \longrightarrow H_2O+(O)$ This method is not desirable for two reasons: In higher temperature, the (O) is less soluble in water, and H_2O_2, as a strong oxidizing agent, may injure fish's skin.

In the third method, it is suggested to remove CO_2 in excess. The local pisciculturists usually dig channels to connect the fish pond with a stream from which the water leading to the pond may dilute concentrated CO_2. However, this method sometimes is not suitable, because it is costly to dig the channel, or it is unfeasible, if there is no stream in the vicinity of the pond.

The author desires to design a new method which should be economical, effective and easy to be handled, but unharmful to fishes. So far he found ammonia water can serve the purpose by reacting with CO_2, but it is more or less poisonous. Caution should be paid in case it is applied.

III

Effects of H_2S on Aquatic Animals

Hydrogen sulfide is a deadly poisonous gas, of which a concentration of 0.3% is strong enough to kill human beings. The gas of such concentration exists quite infrequently in the atmosphere and only occurs occationally in laboratories or in caves where dead animals are decaying. As a matter of fact, this gas is commonly soluble and found in water. Especially, it is copious in hot spring. Water in Taipei area contains more or less H_2S, with which aquatic animals contact at all times. The H_2S content in water appears to be a factor that effects aquatic animals.

The research by the author in this field is divided into 3 parts: (1) H_2S content of water in Taipei area, (2) Relations between H_2S and water qualities, (3) Effect of H_2S on aquatic animals.

1. H_2S content of Water in Taipei Area

All fresh water in Taipei area contains H_2S. It also appears in tap water, if the tap water has been kept in a container to stand for a whole day. In drains and ponds, the H_2S in water tends to be increased. In hot spring, it is in higher concentration.

a. H_2S in tap water

In tap water, there contains considerable amount of H_2S which has been determined for 10 times by the author in May 7, 1957. The yeild was 1.264 cc/L in average. Again, it has been determined for 7 times in 12, June. The yield was averaged 1.173 cc/L. The yield of H_2S in this water, in which if fishes live, may change into 1.408 cc/L., in average. The increase as indicated is due to the fact that this substance is produced from decompodition of nitrogenous compounds which exist in fishes' wastes and the mucus of its integument. The fact shows physiologically significant that the increase of H_2S suggests the acceleration of metabolism. The rate of metabolism, however, can be understood by the determination of H_2S.

H_2S in fish cultured water, 28°C (July 3)

No.	1	2	3	4	5	6	7	8	9	10
H_2S cc/L	1.443	1.443	1.386	1.346	1.476	1.455	1.409	1.467	1.270	1.409
Mean										1.408

b. H_2S in the pond

H_2S content in the pond is so changable. It has been determined for a total of 44 times under the water temperature of 23°C, 27°C, 29°C and 29.1°C respectively.

The yield from the determination under 23°C for 12 times is averaged 1.462 cc/L; under 27°C for 9 times, averaged 1.286 cc/L; under 29°C for 9 times, averaged 1.907 cc/L; and under 29.1°C for 14 times, averaged 1.778 cc/L. The results indicate that H_2S in the water of 29.1°C is less than that of 29°C. The former was determined on 18 May, while the latter, on 10 July. As a matter of fact, the rate of mortality of aquatic animals in July is higher than that of May. For example, the fish plague usually begins in April in May and prevails in July. The more the dead animals remain, the more will H_2S be. If the water temperature be higher is proportional to that of H_2S.

H_2S in Pond Water 29° C (May 18)

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H_2S cc/L	1.801	1.571	1.663	1,848	1,617	1,674	1.732	1.824	1.906	1.848	1.831	1.848	1.939	1.801
Mean														1.778

H_2S in Pond Water 29°C (July 10)

No.	1	2	3	4	5	6	7	8	9
H_2S cc/L	1.893	1.939	1.951	1,939	1.939	1.848	2.078	1.828	1.732
Mean									1.907

c. H_2S in the Drain

By the sides of many streets in counties or cities in Taiwan are open drains, in which sewages are putrefied and decomposed to produce much H_2S that gives rise to bad smell on the street. The H_2S content in drain water of

26°C is averaged 1.628 cc/L; of 28°C, averaged 1.893 cc/L; of 29°C, averaged 2.103 cc/L. In drains, there are constantly sufficient sewages which may be putrefied and decomposed at any time. The water temperature is, therefore, a important factor for the change. The H_2S content in water is proportional to the rise of water termperature.

d. H_2S in the Hot Spring in Sin Pei-tao

The hot spring in Sin Pei-tao is rich in H_2S. In the spring a varity of water in properties were found in different sections. Each section has its specific ecological factors which facilitate the investigators to study animals in relation to their environments. The hot spring region in Sin Pei-tao was demarcated into sections by the author in terms of water temperature; the 26°C-section, the 39°C-section and 69°C-section.

In 69°C-section, H_2S content in water is 6.465 cc/L. The temperature of 69°C does accommodate animals. The temperature in 39°C-section is not for many animals. On the other hand, the H_2S content in this section is 3.992 cc/L, that is also off limits to many animals. Not many kinds of animals inhabit in this section where only the larvae of Chironomus thrive. The temperature in 26°C-section is of ordinary temperature, which is favorable to many animal inhabitats. On the contrary, the H_2S content, 3.703 cc/L, is high than that of pond water and may inhibits many animals.

e. H_2S Content in the Hot Spring of Chao-shan (Grass Mountain)

The hot spring of Chao-shan is famous in Taiwan. In the middle of May the author determined H_2S, water temperature and O_2 content in the source of the spring on the mountain. Its water temperature is lower; while H_2S is higher than that of Pei-tao. The maximum H_2S content in Pei-tao is 6.613 cc/L, while in Chao-shan is 62.000 cc/L as almost ten times higher than Pei-tao. In the hot spring, no 0_2 exists.

2. Sources of H_2S in the Water of Taipei Area

There are two sources of H_2S in the water of Taipei area, e.g. the mineral and animal sources., The sulfur spring in Sin Pei-tao and Chao-shan, for example, is one of the mineral sources which contain H_2S in high and constant concentration all the year round. The colonies of aquatic animals are less changeable in these regions. On the other hand, the animal sources are dead bodies, cast-off skins, and excretions of animals.

The dead animals are chiefly dead fishes, crustaceans and aquatic insects,

The author once conducted experimentation of H_2S from decaying loach, shrimps and Spherodema. 1 gm. of ground meat of loach was submerged in tap water in a tightly sealed container under a temperature of 28°C. After three days, it was determined that the concentration of H_2S was 13.718 cc/L. In same way, the shrimp meat and spherodema meat were treated. The concentration of H_2S was 8.2484 cc/L and 3.052 cc/L respectively.

3. H_2S and Watr Quality

a. H_2S and Water Transparency

Water may change its color and transparency, when H_2S dissolves in it. H_2S in excess may cause water milky and semitransparent. In this case, less light will pass through, while illuminating. The transparency of water is effected by its H_2S content. The more H_2S as water contains, the less transparent will water be.

Concentration of H_2S	Transmission of light (LV)
Saturated	3.8
80%	4.5
60%	5.0
40%	5.5
H_2O	6.3

b. H_2S and O_2 Content

H_2S in water reacts easily with O_2 to produce H_2O and sulfur. Therefore, the change of amount in O_2 in water depends upon the change of amount in H_2S. It was demonstrated that saturated H_2S in different quantity was added into every 1000 cc. of O_2 content was determined and the result as show as follows:

Volume of Sat. H_2S in 1 L. of Pond Water	O_2cc/L	O_2decreased cc/L
0	8.2779	—
10	7.9016	0.3763
20	7.2969	0.9810
30	6.3686	1.9093
40	6.2996	1.9783
50	6.1144	2.1635
60	6.0203	2.2576
70	5.6439	2.6350
80	5.5483	2.7296

c. H_2S and CO_2 Content

CO_2 in water can be slightly increased by H_2S to a extent that aquatic animals may not be directly effected.

Volume of Sat. H_2S in 1L. of Pond Water	CO_2 mg/L	CO_2 varied mg/L
0	3.310	—
10	3.316	0.055(−)
20	3.299	0.089(+)
30	3.121	0.789(−)
40	3.165	0.045(−)
50	3.299	0.089(+)
60	3.343	0.133(+)
70	3.121	0.089(−)
80	3.254	0.044(+)

4. Chemotropism of Aquatic Animals Toward H_2S

That experiment on chemtropism of aquatic animals in water is pratically difficult. An unsatisfactory method as conventionally used is to absorb chemical reagent with blotting paper which is then thrown into water for this purpose. It was improved by the author that a feasible osmotic tube is used in place of paper. The newly designed tube is used for the experiments on the chemotropsim of following aquatic animals toward H_2S. The results showed that Gambusia affinis toward H_2S is negative; Such insects as Sphaerodema rustica, Hydrophilus affins, Cybister tripunctat, Coengrion quadrigeram, and Culex larva, are positive; and Sigara, is negative.

5. H_2S and Life of Aquatic Animals

H_2S 5.365 cc/L may cause a carp to cease its opercular movement. Loaches are quite tolerant against H_2S. In a higher concentration of H_2S as 15.862 cc/L, the loach will be killed in 39 minutes. In H_2S 12.2184 cc/L. Sphaerodema rustica will be killed in 115 minutes; in 35.1135 cc/L. Hydrophilus affinis, killed in 34 hours; in 32. 1907 cc/L, Cybister tripunctatus, killed in 18 hours; and in 24.3750 cc/L, Culex (larva), killed in 8 hours.

References

1. T. S. Miu The Physiology and Ecology of Tilapia. Annals of Nat. Hist. Soc. No. 7
2. T. S. Miu On the Mechanism of the Reproductive Habit of Tilapia. Bulletin

of Taiwan Fishery Institute No. 7

3. T. S. Miu Studies on the Sudden Mortality of Fishes. Annals of Nat.Hist. Soc. No. 1, No. 3

4. T. S. Miu The Ecological effects of Hydrogen sulfide on the Fresh-water Animals in Taipei. Bulletin of Taiwan Normal University Vol. III.

中 文 摘 要

作者在臺灣研究水產生態凡十八載，其中最重要之問題有三：第一爲吳郭魚之生理生態，對於吳郭魚之生殖生理及生殖習性尤多闡明。第二爲魚類之泛池問題，泛池爲魚池之普徧病態，每年在臺灣延續頗久，死魚甚多，作者已發現其原因，並略涉防治方法。第三爲硫化氫對於臺灣淡水動物之影響，硫化氫在臺灣水域中含量很多，分布很廣，對於水棲昆蟲及魚類，有顯著之影響。