MUTUAL ATTRACTION BETWEEN SMALL FISHES

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ABSTRACT

There is an attraction between a group of fishes kept in a small section of water tank. But due to their movements some fishes may escape through the door in the tank. So the escaping rate can measure the balance between their mutual attraction and their agitation. By the experiment in different temperature, we get the relationship of temperature and escaping rate. We found that in a certain scope of temperature, the movement of fish is similar to the movement of molecules. And the different kinds of fish have different escaping rate.

Key Words: Molecules, Fish, Escaping Rate, Average Kinetic Energy, The Sensitive Temperature

1 Introduction

There is an agitation force between water molecules. Some molecules which are near the surface will be able to escape and they will form a cloud of water molecules in the air above the surface of the water. But there is also mutual attraction among molecules, so the percentage of molecules which escape can reveal the balance between their mutual attraction and agitation.

A similar phenomenon for a group of small fishes kept in a section of a water tank from which they can escape through a little door is also found. Although there is an attractive force between fish, due to their movements some fishes may escape through the door. Our experiment is to explore this phenomenon in fish group. It's easy to know that the escaping rate will increase when the temperature is higher to the molecules. Hence, we get the relationship between the temperature and the escaping rate of fish to see if they obey the same rule. We choose two kinds of fish to see if the species could affect the escaping rate.

2 Experiment Conditions

2.1.1The time we choose

After we put the fish to the tank and they have got used to the new environment, we can open the door in the tank. Some fish will escape form the door to another part of the tank. So the number of fish escape from the door will be increasing with time going on. But with the observation of experiments, the number of fish escaping from the door will be stable in about 6 minutes. Finally, we choose the number of fish at another part of the tank to calculate the escaping rate of fish after 6 minutes.

2.1.2 The possible change of temperature while doing the experiment

Six minutes is a short time. By the observation of temperature in the experiment, we found that the change of temperature wouldn't over 1℃ in 6 minutes. Hence, we can assume the temperature is stable during the whole experiment.

2.1.3 The equipment we design

***fig*1. The equipment of this experiment**

2.1.3 The fish we choose

***tab*1. The two kinds of fish**

Name	**Zebra Fish**	**The Red Cross Fish**
Picture		
Scientific Name	Danio rerio	Hemigrammus anisitsi
Character	A kind of tropical fish, silver or golden color. Male fish is thinner than the female fish. The length of the fish is about 3.8cm.	The body of fish is thin. In the breeding season, the male is more bright-colored than the female. The body of adult length can reach 6cm.
Temperature	The range of 25℃~26℃ is most suitable for the fish. They can still live in 11℃~15℃.	The best temperature is 25℃. The low temperature they can bear is 10℃.

3 The experiment Steps

3.1 The position of experiment

In order to simulate the real environment of fish, we choose the garden in our school to be our experiment site. There is no person walking around the tank but some voice from nature, like the sound of wind, the birdcall. The more similar to the real environment of fish, the more accurate result we can get.

3.2 The initial space of the fish in the tank

What's the best initial space of fish? We put forty fish into the tank, but if the initial space is too large, the fish can hardly find the small door on the wall, if the original space is too small, most of the fish will ran out because of the crowded space. Both of them will affect the result we get, so we use the model of water molecules to set the initial space of fish.

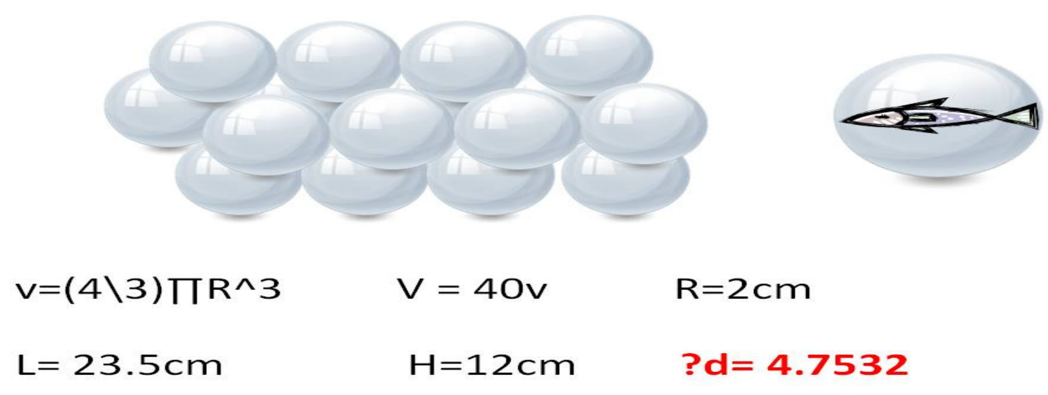
We can assume the fish as one water molecule and the space which the round molecules need when they stay together is the original space of fish.

(1) We assume the fish to be a round molecule, and the length of fish is about 4cm. So the radius is 4cm;

(2) Then, we calculate the total space of the 40 round molecules as the total space which the fish stay in. According to the width of tank (L=23.5cm) and the height of the water (H=12cm), we can get the position which we put the wall to divide the tank into two parts.

(3) We get that we should put the wall at 4.7532cm, but considering the fish have larger volume than the molecule and they move around everywhere in the water. In the end, we choose the position at 7cm to put the wall.

***fig*2. The initial space of the fish**



3.3 Measure the data

- Put the fish into the tank, set the wall at 7cm .After the fish get used to the new environment, we open the door on the wall and begin to count.
- Record the number of fish escaping from the door every minute until 6 minutes.

■ Repeat the experiment for six times and get six groups of data .Using the average result to stand for the escaping rate.

■ Use the hot water and ice to change the temperature of water, and repeat 1~3 again to get the new escaping rate at different temperature.

4 Analysis

4.1 The original data

We choose two kinds of fish to do this experiment and get the escaping rate at five different temperature, 10℃, 15℃,20℃,25℃,30℃. We do 6 groups to get the average result at each temperature.

Here is the result:

The Red cross fish (40 fish)

The number of escaping fish at 10℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***1***	***2***	***1***	***3***	***6***	***8***
NO.2	***3***	***4***	***7***	***11***	***10***	***12***
NO.3	***0***	***1***	***2***	***2***	***8***	***9***
NO.4	***1***	***4***	***6***	***10***	***13***	***12***
NO.5	***0***	***4***	***7***	***8***	***7***	***8***
NO.6	***0***	***3***	***6***	***13***	***11***	***9***
Average Result	0.83	3.00	4.83	7.83	9.16	9.66
Standard Deviation	1.06	1.15	2.40	4.05	2.40	1.69

The number of escaping fish at 15℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***1***	***3***	***3***	***2***	***5***	***8***
NO.2	***0***	***1***	***2***	***3***	***5***	***6***
NO.3	***2***	***3***	***7***	***9***	***8***	***9***
NO.4	***0***	***1***	***5***	***5***	***7***	***10***
NO.5	***1***	***4***	***6***	***10***	***10***	***13***
NO.6	***2***	***5***	***8***	***12***	***12***	***14***
Average Result	1.00	2.83	5.16	6.83	7.83	10.00
Standard Deviation	0.81	1.46	2.11	3.71	2.54	2.76

The number of escaping fish at 20℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***4***	***10***	***15***	***14***	***16***	***20***

NO.2	***8***	***12***	***16***	***17***	***17***	***18***
NO.3	***4***	***10***	***12***	***14***	***15***	***16***
NO.4	***4***	***11***	***14***	***14***	***16***	***17***
NO.5	***2***	***10***	***12***	***15***	***15***	***15***
NO.6	***4***	***6***	***11***	***16***	***18***	***23***
Average Result	4.33	9.83	13.33	15.00	16.16	18.16
Standard Deviation	1.79	1.86	1.79	1.15	1.06	2.67

The number of escaping fish at 25℃

Time(Minute) / **Group Number**	1	2	3	4	5	6
NO.1	***3***	***6***	***18***	***22***	***23***	***27***
NO.2	***8***	***7***	***14***	***17***	***20***	***21***
NO.3	***6***	***8***	***15***	***18***	***19***	***20***
NO.4	***9***	***14***	***18***	***20***	***21***	***25***
NO.5	***4***	***15***	***17***	***24***	***24***	***26***
NO.6	***9***	***11***	***13***	***15***	***18***	***22***
Average Result	6.50	10.16	15.83	19.33	20.83	23.50
Standard Deviation	2.36	3.43	1.95	3.03	2.11	2.63

The number of escaping fish at 30℃

Time(Minute) / **Group Number**	1	2	3	4	5	6
NO.1	***5***	***6***	***8***	***11***	***14***	***15***
NO.2	***3***	***9***	***10***	***10***	***13***	***14***
NO.3	***3***	***7***	***8***	***11***	***14***	***18***
NO.4	***5***	***10***	***11***	***13***	***15***	***16***
NO.5	***6***	***10***	***13***	***17***	***19***	***18***
NO.6	***4***	***3***	***5***	***11***	***12***	***14***
Average Result	4.33	7.50	9.16	12.16	14.50	15.83
Standard Deviation	1.10	2.50	2.54	2.33	2.21	1.67

The Zebra fish (40 fish)

The number of escaping fish at 10℃

Time(Minute) / **Group Number**	1	2	3	4	5	6
NO.1	***1***	***6***	***4***	***10***	***14***	***13***
NO.2	***3***	***5***	***8***	***17***	***20***	***17***
NO.3	***6***	***10***	***12***	***12***	***13***	***14***
NO.4	***1***	***6***	***10***	***14***	***19***	***14***

NO.5	***8***	***15***	***10***	***5***	***12***	***13***
NO.6	***7***	***14***	***13***	***14***	***19***	***18***
Average Result	4.33	9.33	9.50	12.00	16.16	14.83
Standard Deviation	2.80	3.98	2.92	3.78	3.23	1.95

The number of escaping fish at 15℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***13***	***19***	***30***	***29***	***22***	***22***
NO.2	***9***	***18***	***23***	***16***	***23***	***20***
NO.3	***5***	***11***	***13***	***18***	***19***	***21***
NO.4	***6***	***14***	***19***	***23***	***15***	***24***
NO.5	***4***	***6***	***7***	***11***	***20***	***21***
NO.6	***6***	***10***	***19***	***23***	***26***	***20***
Average Result	7.16	13.00	18.50	20.00	20.83	21.33
Standard Deviation	3.02	4.54	7.25	5.77	3.43	1.37

The number of escaping fish at 25℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***9***	***14***	***30***	***17***	***23***	***26***
NO.2	***10***	***15***	***23***	***28***	***31***	***30***
NO.3	***8***	***21***	***28***	***30***	***29***	***26***
NO.4	***11***	***16***	***24***	***34***	***24***	***31***
NO.5	***8***	***18***	***33***	***32***	***30***	***31***
NO.6	***6***	***15***	***28***	***26***	***28***	***30***
Average Result	8.66	16.50	27.66	27.83	27.50	29.00
Standard Deviation	1.59	2.36	3.39	5.48	2.98	2.16

The number of escaping fish at 30℃

Time(Minute) / Group Number	1	2	3	4	5	6
NO.1	***12***	***15***	***14***	***18***	***20***	***25***
NO.2	***11***	***20***	***14***	***10***	***20***	***24***
NO.3	***9***	***18***	***19***	***18***	***16***	***17***
NO.4	***16***	***20***	***24***	***26***	***25***	***25***
NO.5	***4***	***12***	***17***	***21***	***21***	***27***
NO.6	***4***	***9***	***18***	***18***	***21***	***24***
Average Result	9.33	15.66	17.66	18.50	20.50	23.66
Standard Deviation	4.30	4.10	3.39	4.75	2.63	3.14

4.2 The escaping rate at temperature

According to the standard deviation, we can find that the number of escaping fish begin to be stable from 5 minute. We take the escaping number as the final escaping rate of fish at 6 minute. After the statistics of data, we get the escaping rate at different temperature.

***fig*3. The escaping rate of Red Cross Fish at different temperature**

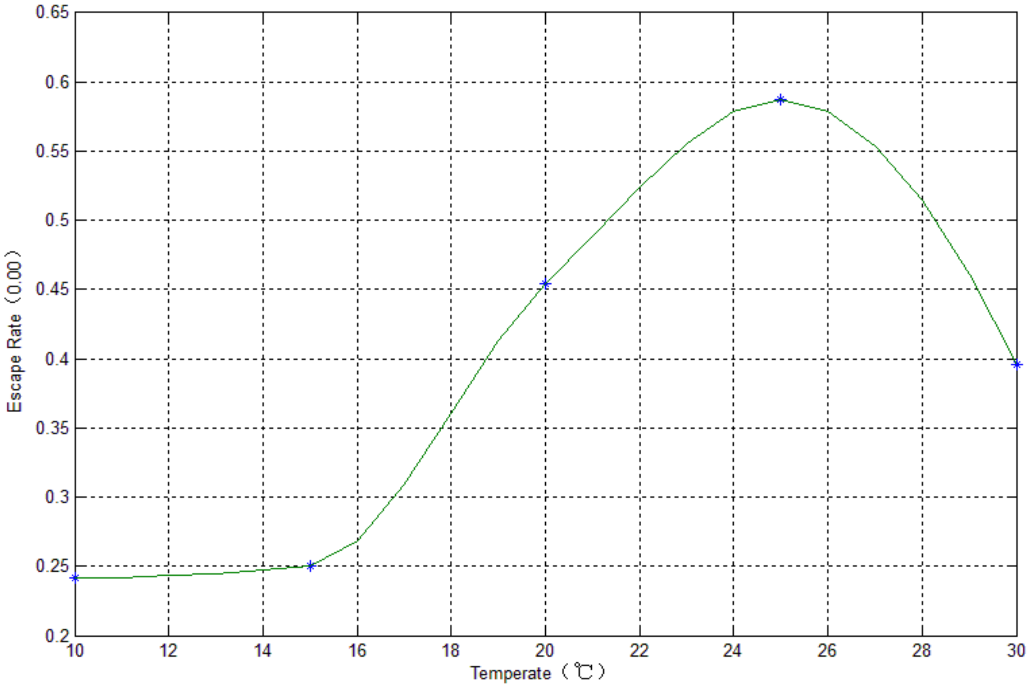


***fig*4. The escaping rate of Zebra Fish at different temperature**

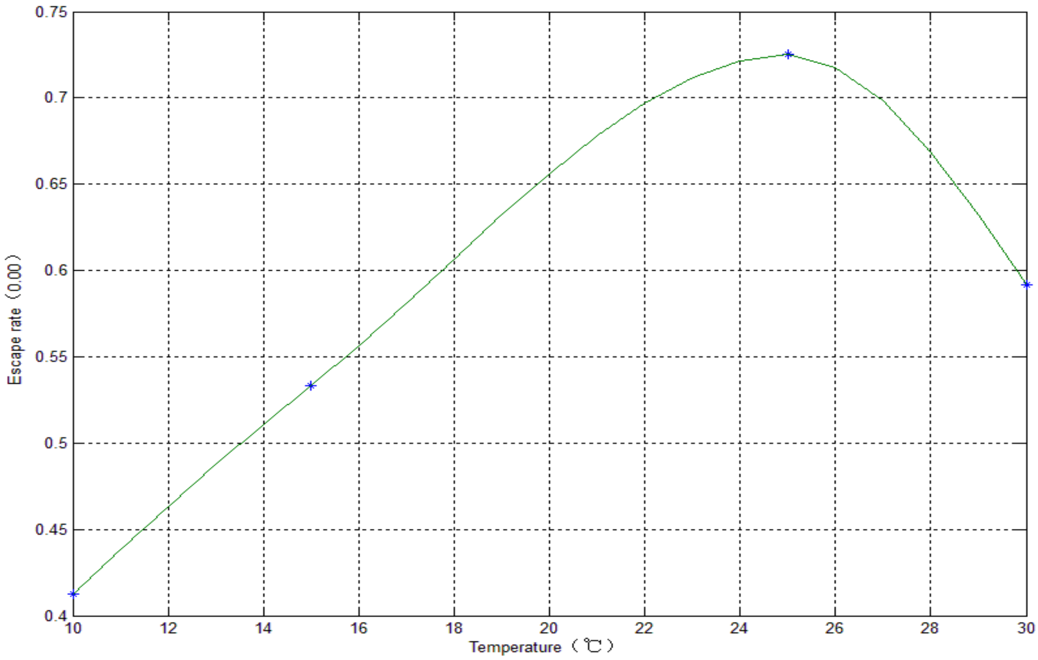
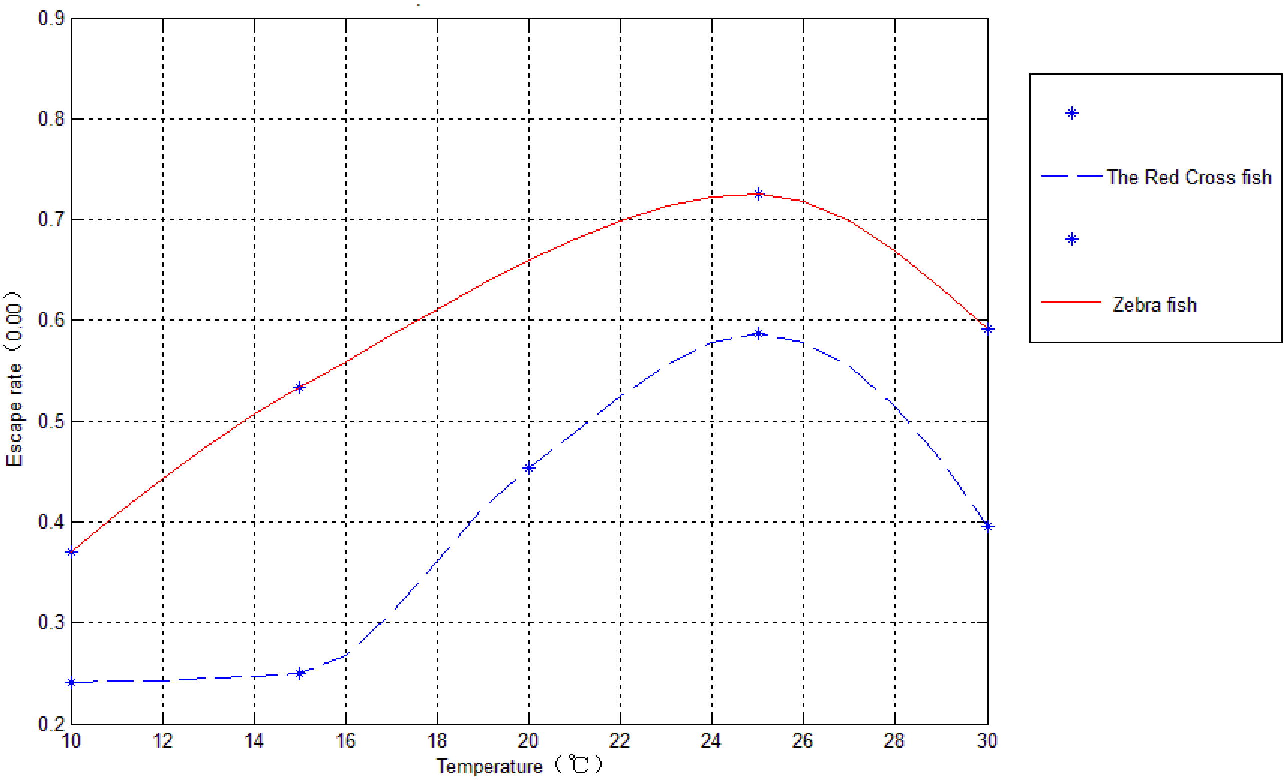


***fig*5. The escaping rate of two kinds of fish at different temperature**



Analysis:

➢ These two kinds of fish's escaping rates are different from each other in the same temperature .And this means that the type of fish must have a big influence on the escaping rate.

➢ The two different curves have the similar trend.

In a certain temperature range （10℃—25℃）, the escape rate increases with the rise of temperature. But when the temperature of water is over a certain range, the escaping rate decreases with the rise of temperature.

Point :

The escaping rate of the red cross fish does not change significantly when the temperature is between 10℃and 15℃.Maybe the reason is that it is not as sensitive as zebra fish to the change of temperature.

4.3 Escape Rate-- Time function

*fig*6. **The escaping rate of Red Cross Fish changes over time in different temperature**

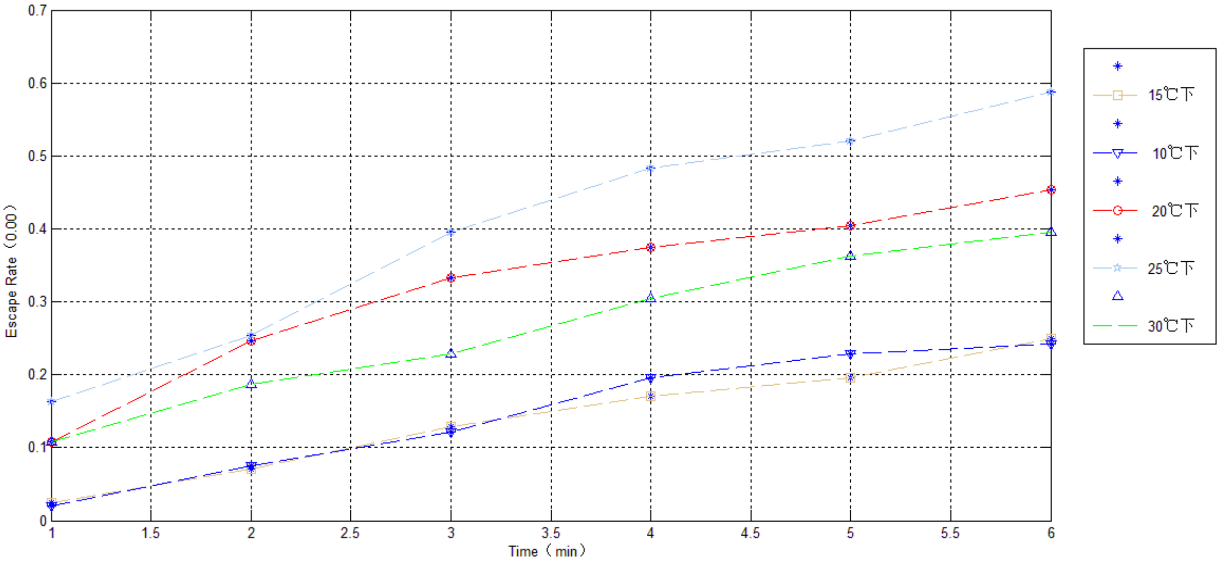
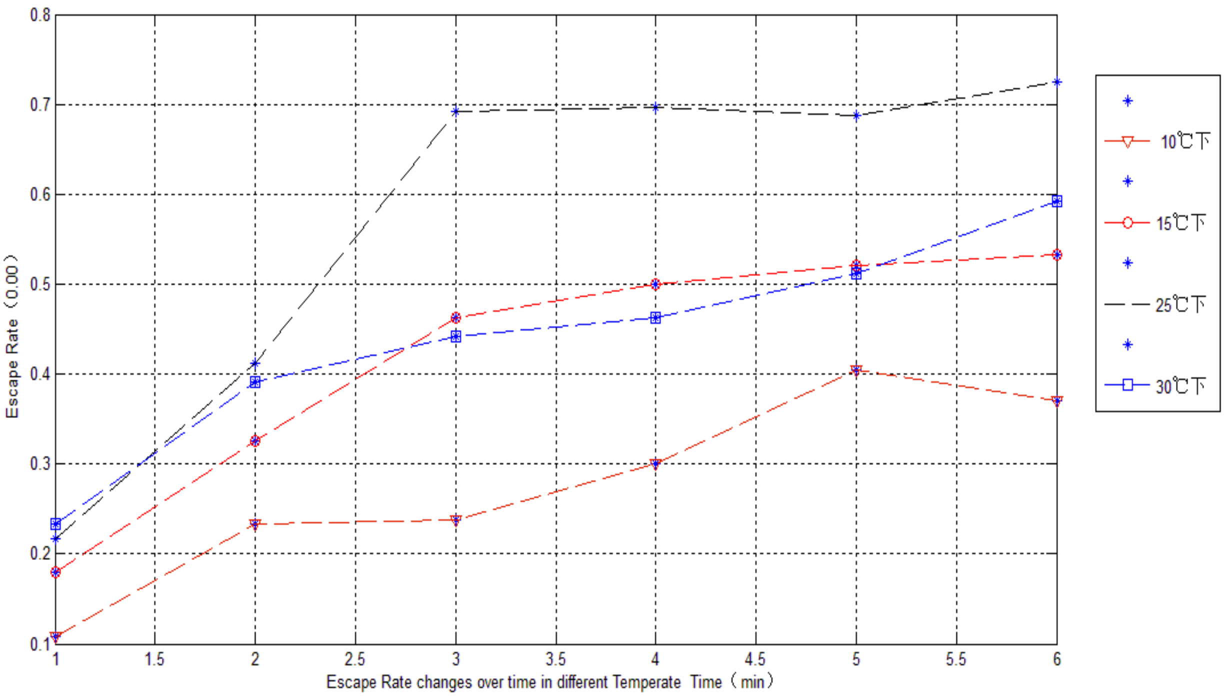


fig7. **The escaping rate of Zebra Fish changes over time in different temperature**



Analysis:

Under different temperatures, we calculate the average number of the data which is measured by six times and get the picture of Escape Rate -----Time function. The slope of it can be called as a Marginal Escape Rate. Then we can compare the time of reaching a certain escape rate under different temperatures by putting the picture of Escape Rate --Time function together.

➢ Escape Rate --Time function is not a linear relation.

This seems to be more obvious in the Red Cross fish curves under 25 ℃, 15 ℃ and 10 ℃ .What's more, Zebra fish's four curves almost obey the rule. In The Red Cross fish's map, the slope of the first four minutes is bigger, indicating that the Marginal escape rate is higher than the Marginal escape rate two minutes later. And in the Zebra fish's map, the slope of the first three minutes is bigger , indicating that the Marginal Escape Rate is higher than the Marginal escape rate three minutes later .This phenomenon says that the fish moves faster when put into the water of different temperatures at first time, and the escape rate remains stable after a few minutes. So we speculate that the fish doesn't adapt to the temperature when first put into the water, and the fish will move here and there.

- The Escape Rate is different from each other under different temperatures ,but both of them reach their max point at 25℃.

In The red cross fish's picture , the Escape Rate at 15℃ is close to Escape Rate at 10℃,which is the lowest. And in zebra fish's picture , the escape rate in 30℃ is close to escape rate in 15℃.And the escape rate at 10℃ is the lowest.

We know that there is a catastrophe point existing in some physical properties of material. As an analogy, we can find a catastrophe temperature. In this temperature, fish's movement will suddenly become lively, and we call this point the sensitive temperature. We can infer that the sensitive temperature of The red cross fish is between 15℃ and 20 ℃ and the sensitive temperature of Zebra fish is between 10℃and 15℃.

4.4 Average kinetic energy-- Escape rate function

In statistical physics, $E = \frac{1}{2}mv^2$ is defined as the agitation of molecules. So the larger the *E*, the more escaping molecules. We take $E = \frac{1}{2}mv^2$ as the average kinetic energy of fish. So if the fish have larger kinetic energy, the larger escaping rate will be.

***fig*8. Average kinetic energy in different temperature (Guppy)**

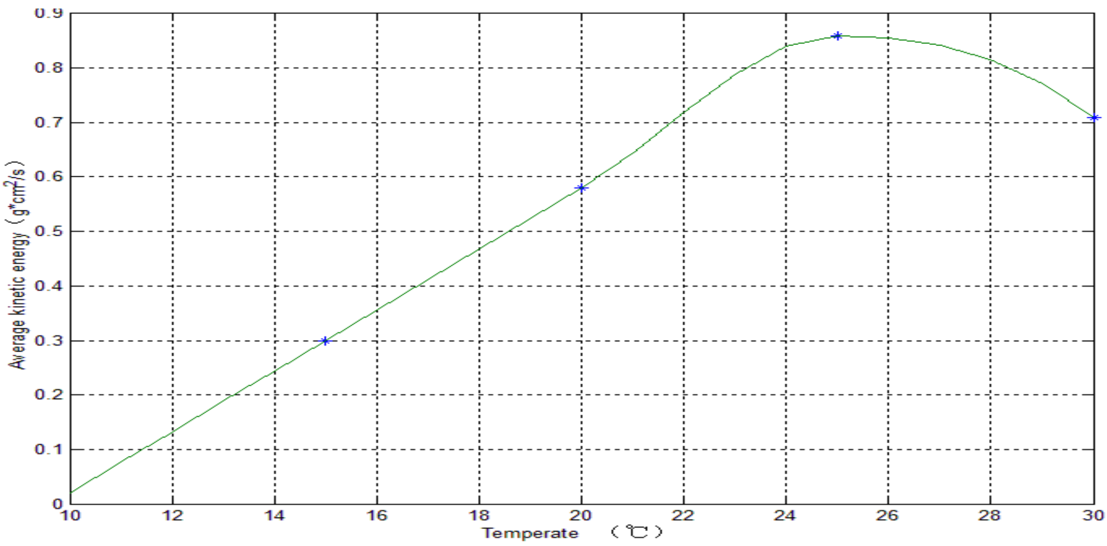
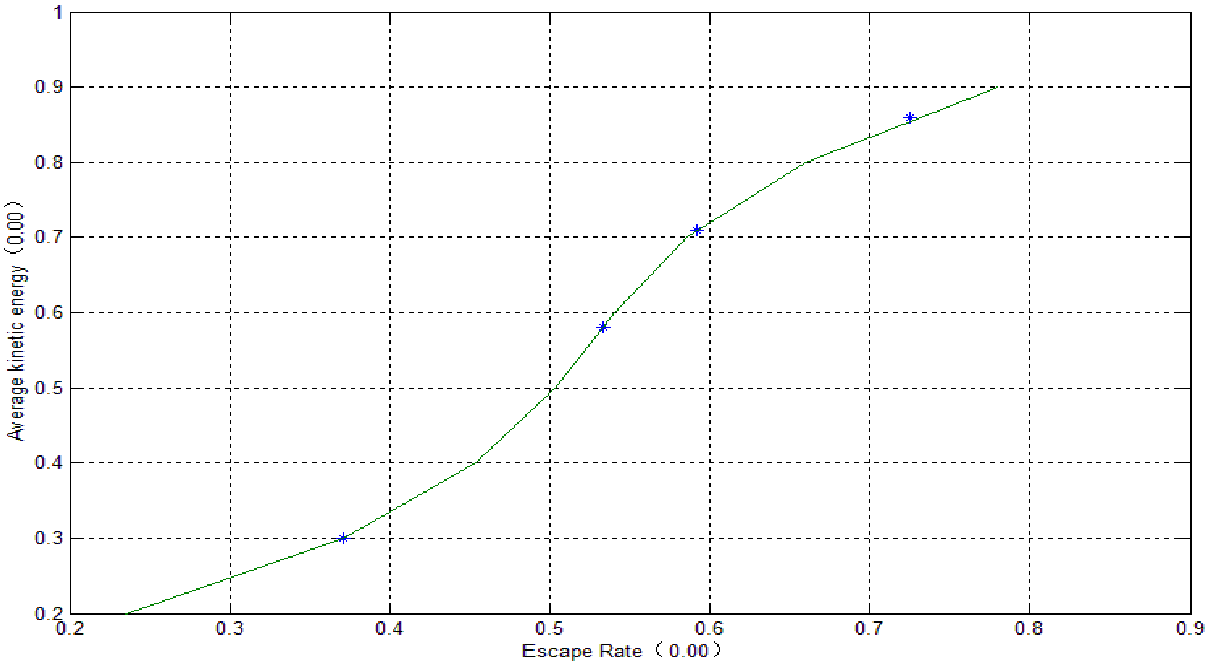


***fig*9. Average kinetic energy in different escape rate**



The point we must know:

Because of the velocity of fish is hard to measure and need a great deal of work. We use the data measured by another group who do the experiment of Fish's Temperature (temperature is the Average kinetic energy of fish). But they use the different kind of fish——Guppy.

From 4.2, we have known that the escaping rate –temperature curve of different fish have the same trend. What's more, both guppy and zebra fish belong to tropical fish, and the lowest temperature they could live in is 10,and the highest temperature they could live in is 35. In other words, guppy's escape rate must be very similar with zebra fish.

So ,we take the zebra fish's escape rate and the guppy's average kinetic energy in the same temperature as a point In this way ,we get the picture about fish's average kinetic energy--- escape rate approximately.

Analysis:

- The bigger the fish's average kinetic energy is, the higher the fish's escape rate is. As we have said in 4.2, when the temperature is around the optimum temperature, materials such as protein and enzyme reach a very high level and metabolism of fish becomes faster. So, the movement of fish becomes faster. As a result, the fish's average kinetic energy is bigger, the fish's escape rate is higher.
- The fish's average kinetic energy-- escape rate function is more like a linear --relation.

5 Conclusion

- The relationship of temperature and the escaping rate of fish

In a certain range of temperature (10℃—25℃), the escaping rate increases with the temperature. But when the temperature id over 25℃, the escaping rate will decrease with temperature. And in the range of temperature suitable for fish, the higher the escaping rate, the more animate the fish.

- The relationship of species and the escaping rate

Through the two kinds of fish, we can find that the escaping rate of Zebra Fish is higher than Red Cross Fish. So we can see that the natural structure of fish is important to the escaping rate.

- The movement of fish and molecules

In the movement of molecules, the higher the temperature, the larger the kinetic energy of molecules. But to the fish, they have the max degree of temperature they can bear. So in the certain range, the movement of fish is similar to the molecules.

During the whole project, we simulate the environment of fish living in, and use the molecules model to calculate the original space of fish. It' more accurate and reasonable to compare the movement of fish and molecules.

Also we do many repeating groups of experiment to get the accurate result. It maybe not rigorous to use two different kinds of fish when we get the escaping rate and the average kinetic energy curve. So we hope the other group can fix this point in the future.

6 Reference

[1] Average kinetic energy in different temperature (guppy)