Behaviour of Fishes in Relation to Moving Nets.—II*

Influence of the Colour of Webbing on the Avoidance Responses of the Fish

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Preliminary towing experiments described in the part I¹⁾ of this report have shown the significance of the colour of light falling on the visual sense of the fish while being driven by the net. For further evaluation of this fact, more details of the avoidance responses of fish such as swimming speed, swimming patterns, in relation to differently coloured nets as well as the effect of environmental factors, were needed. As it has been shown by other workers²⁾, for obtaining these details the behaviour of individual fish in the vicinity of the net has to be studied minutely. For this purpose a modified device has been used for studying the effect of differently coloured nets on individual fish in a specially designed circular channel.

Materials and Methods

Fish used. 'Rengyo' (*Hypothalamichthys molitrix*) was used for these experiments. The fish were of 0-age group with a mean total length of 9.8 cm and mean weight of 8.5 grm, and were obtained from an experimental culturing pond of the Saitama Prefectural Fisheries Experimental Station. They were fed twice a day—in the morning and in the evening—using 'Vita Shrimp' a commercial fish food.

Experimental setup. The experiments were conducted in a doughnut shaped tank of 120 cm diameter having a square cross section of 40 cm width and 40 cm height, keeping water 20 cm deep. The total length of the channel measured as the circumference in the middle, was 251 cm and the outer circumference was 377 cm. The water in the channel was circulated at a rate of 5 liter per minute, without causing any apparent change in the behaviour of the experimental specimens.

The tank was kept in a double walled light proof chamber made of an outer wall of black cloth and an inner one of white vinyl sheets. The interior of the experimental tank was painted white with lacquer paint, leaving the inside of the chamber completely white. The tank was illuminated by diffused light from four 20 watt daylight fluorescent

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Fig. 1. Spectral distribution of light reflected by coloured nets.

tribution of the light reflected by the nets as recorded by a recording Spectrophotometer is shown in Fig. 1. The opening of the net was rectangular, 15 cm high and 20 cm wide. The size of the net opening was sustained by adjusting the length of the warps on either side of the net that were connected to the radial bar fitted to the motor.

Lowering and raising of the net inside the tank during the trials were done from outside the chamber by means of a fine monofilament nylon thread tied to the hinder tip of the net and taken out through the upper walls of the chamber. Similarly, the switch of the motor used for towing the net was also taken out of the experimental chamber, so as to carry out the entire operation from outside the enclosed chamber without causing any disturbance to the fish used for the trials.

In these studies, direct observation has been avoided by using a Sony Videocorder 'PV 120' model and a television camera. The camera was mounted on the roof of the inner white wall, the lens projecting into the tank through a circular hole, 120 cm above the water level of the tank. Thus the interior of the tank as well as the fish and the net could be viewed on the monitor T.V. screen and at the same time it could be recorded on the videotape. Data were obtained from the T.V. screen after the trials, by playing back at slow speeds and also from stills.

Experimental procedure. In each test, firstly the individual fish from a shoal kept

tubes from the top through the inner white wall to a level of 220 lux.

In the central dry portion of the tank, a 1/12 Hp electric motor fitted with gears was set encased in latex rubber and cellophane sheets to eliminate sound and vibration on towing the net by the motor. An underwater microphone was also used for checking the presence of underwater noises. A radial bar attached to the motor was used to hold the net in the circular channel of the tank. Wingless model nets of blue, red, white and black nylon webbing, with 0.75 cm mesh opening were used for towing experiments. Spectral dis-

in an 'Aquamaster' aquarium with temperature control facilities, was gently transferred to the experimental tank and 10 minutes later, when the fish was about 100 degrees away in front of the radial bar, the net was lowered into the water and simultaneously the motor was switched on. A constant speed of 1 round per 8 seconds was found to be the most suitable, as a result of some preliminary trials at different speeds.

For analysing the responses of individual fish driven by different nets, four parameters viz., 1) swimming speed ahead of the net, 2) angular distance between the fish and net at every second for a total period of 40 seconds, 3) frequency of fright responses for 16 seconds and 4) driving effect of the net or the frequency to be continuously driven by the net for 60 seconds, were recorded from the T. V. screen. For calculating the swimming speed and angular distance, in each test, cellophane spread on the T. V. Screen, on which the actual course of the fish was traced in relation to space and time, was used. As for the swimming speed, the swimming course was traced for two rounds of 16 seconds and from this trace the actual distance covered by the fish inside the tank was calculated by means of a 'Kent' Curve Meter. This distance was divided by the total length of the respective individual for obtaining the speed in total body lengths swam in 16 seconds. The distance between the fish and net was taken in angular degrees due to the circular course of the movement of the net. Frequency of sudden muscular flexion, often resulting in a change of orientation as exhibited by the fish on avoiding the net, was taken as the fright responses.

These experiments were repeated under two temperature levels of 22 to 23°C and 32 to 33°C. But the black net was used only under the latter temperature. The fish were acclimatized for about 40 days in the same temperature. For avoiding the learning effect, one fish was used only for a single trial.

Results

Data on the swimming speed were taken only for those fish that swam continuously ahead of the net for a minimum period of 16 seconds, whereas angular distance was recorded only for those fish that swam ahead of the net continuously for 40 seconds at least. White net was found to induce the least swimming responses and hence in this case, data on swimming speed and angular distance were not sufficient for any comparison. Table 1 shows the calculated swimming speed ahead of different nets. Red net was found to induce the highest swimming speed at both the temperature levels tested, while fish driven by the black net showed the lowest swimming speed. Swimming speed ahead of the blue net was less than that for the red net under both temperatures.

The frequency of angular distance between the fish and the net shows distinct variation with regard to the colour of the net, (Figs. 2a & 2b). It was noted that under both

Table 1. Effect of colour of net on fish driven by different model nets.

Ser. No.	Number of fish used	Water temperature	Colour of net	Swimming speed		Mean fright responses	Driving effect
				Mean	Std. deviation		
1	27	22—23°C	Blue	70.83	2.8	25.78	67%
2	22	"	Red	80.70	4.8	30.75	54.5%
3	11	"	White	...	...	...	18.2%
4	15	32—33°C	Blue	62.54	6.4	24.43	46.7%
5	10	"	Red	71.98	3.9	26.25	27.3%
6	10	"	White	...	...	...	0%
7	16	"	Black	60.69	4.7	23.00	50%

Fig. 2. (a) Frequency of angular distance between fish and net:

I- 50 to 69 degrees; II- 70 to 89 degrees; III- 90 to 109 degrees; IV- 110 to 129 degrees; V- 130 to 149 degrees; VI- 150 to 169 degrees; VII- 170 to 189 degrees; VIII- 190 to 209 degrees; IX- 210 to 229 degrees; X- 230 to 249 degrees.

the temperature levels, fish swimming ahead of the red net was occupying an angular distance of more than 129.4 degrees from the net for the highest frequency, whereas with the blue net, the highest frequency of this distance was less than 129.5 degrees in all the cases. As for the black net, the fish did not show much dispersal in its swimming position, mostly keeping a distance between 110 and 129 degrees.

The frequency of fright responses as exhibited by the fish ahead of different nets is given in Table 1. The frequency of fright responses was clearly higher with the red net. The black net showed the lowest frequency of fright responses under the higher temperature level, when this net was used. Fig. 3 shows the driving effect with different nets plotted as the percentage of fish that swam ahead of the net in relation to time during 60 seconds.

Fig. 2. (b) Distance between net and fish plotted for two individuals of equal total length; One driven by the red net and the other by the blue. (Total length of each fish 97 mm)

Fig. 3. Driving effect of different nets.

The results were agreeing under both the temperature levels, the blue net being more efficient than the red one and white net the least. The driving effect of the blue net and that of the black net were rather identical as it can be made out from Figure 2. In all the cases the occurrence of 'falling back' or ceasing to continue swimming ahead of the net, was observed mainly during the first 20 seconds of towing. Where a fish did not fall back within this time, it was found to continue swimming throughout the trial with rare exceptions.

Discussion

From the studies on the colour

sensitivity of the gold fish, Muntz and Cronby-dillon³⁾ have shown that this fish has a preference for blue. Other workers also have reported similar preferences, especially for blue and green in various species of fishes⁴⁻⁷⁾. In the present studies, a lesser intensity of responses has been noted in the fish swimming ahead of the blue net compared with the red net. These responses include a higher rate of swimming speed, more fright responses and keeping a longer distance from the net with a wider range in swimming positions. On analysing the angular distance from the net, it was found that at 22–23°C temperature level, more than 56% of the recorded locations occupied by the fish ahead of the blue net was within the range of 50 to 130 angular degrees, from where the front part of the net was visible to the fish due to the doughnut shape of the experimental tank. With the red net, the fish was swimming within this range for only 39.9% of the recorded locations, at the temperature level of 22–23°C. As for the higher temperature tested, the percentage frequency of locations in the part of the tank from where the front of the net was visible to the fish was 72, 53, and 76 for blue, red and black nets respectively. This, as well as a tendency shown by the fish to swim faster ahead of the red net suggests that the fish were more scarred by the red net. It is said that fear responses include locomotion away from a stimulus for avoidance⁸⁾. Based on the results from the present studies, it can be said that the fear responses elicited by the net in the fish have been more in the case of the red net than either the blue or the black nets. This also shows that out of the two colours used, the fish had a lesser dislike for the blue than for the red. The minimum effect of the white net on the fish can be attributed to the white background in the tank where the white net was not very conspicuous. However, the black net was also less effective in eliciting higher rate of avoidance responses in comparison with the coloured nets. Thus it can be concluded that there is a distinct effect for the colour of the net on the fish and that the effect of the red net is not one of attracting or soothing nature, but of a repelling or scarring nature.

Summary

A series of experiments were carried out to record and analyse the swimming and avoidance patterns of small fresh water fish driven by differently coloured net models in a specially designed circular channel, using Sony Videocorder and Television camera. Four parameters viz. swimming speed, angular distance between the fish and the net, fright responses and driving effect were recorded and analysed. The avoidance responses of fish were found to be greatly influenced by the colour of the net material as the red net was eliciting a higher rate of swimming speed and avoidance responses compared with blue, black and white nets.

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