The schooling of sumatra barbs (barbus tetrazona tetrazona) and minnows (phoxinus phoxinus)

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THE SCHOOLING OF SUMATRA BARBS (BARBUS TETRAZONA TETRAZONA) AND MINNOWS (PHOXINUS PHOXINUS)

by

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Thesis

IN THE NAME OF GOD, MOST GRACIOUS, MOST MERCIFUL

It is He who has made the sea subject, that ye may eat thereof flesh that is fresh and tender, and that ye may extract therefrom ornaments to wear; And thou seest the ships therein that plough the waves, that ye may seek (thus) of the bounty of God And that ye may be grateful.

The Holy Quran - Sura Al-Nahl, 14.

TO

My Father, Mother,

Mona, Sami and Bassem

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr. J. C. Coulson for his guidance, and advice at all stages. And also to all the lecturers of the M.Sc. Ecology Course.

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TABLE OF CONTENTS PAGE

LIST OF TABLES

LIST OF FIGURES

Page

adhere to stones, rarely to plants, and hatch in 5 - 10 days. Sexually mature at the end of 1 - 2 years (Terofal 1979).

Breeding in captivity not very difficult. When morning sunshine is expected, serveral breeding pairs can be placed in the breeding tank the previous evening. This should contain crystal-clear fresh water and have large stones on the bottom on which the animals will spawn; the water level should not exceed 15 cm and vigorous aeration must be provided. The young hatch after 6 days and should be fed with sifted small crustacea. They grow very slowly and are first sexually ripe at 3 - 4 years old (Sterba 1963).

INTRODUCTION

1.1 Preface

A lot of work has been done on schooling fishes (Breder 1951, 1954, 1959, 1965, 1967; Shaw 1962, 1978; Pitcher 1973, 1979; Radakov 1974; Kennedy and Pitcher 1977; Helfman 1978; Stott and Buckley 1979; Partridge 1980, 1982; Takashi 1985).

A school of fish is something more than a crowd of fish; it is a social organisation to which the fish are bound by rigorously stereotyped behaviour and even by anatomical specialisation. Schooling fishes do not merely live in close proximity to their kind, as many other fishes do; they maintain, during most of their activities, a remarkably constant geometric orientation to their fellows, heading in the same direction, their bodies parallel and with virtually equal spacing from fish to fish. Swimming together, approaching, turning and fleeing together, all doing the same thing at the same time; they create the illusion of a huge single animal moving in a sinuous path through the water (Shaw 1962, Khalaf 1986 b).

Although the schooling of fish is one of the most familiar forms of animal social behaviour, until recently it was little understood, partly because of the difficulty of observing minute changes of position and velocity in a shoal under natural conditions. The fact that a great many species of fish congregate in schools suggests that the behaviour offers a considerable evolutionary advantage. How the school is formed and maintained, however, is only beginning to be understood in detail. It had been thought that each fish maintains its position in the school chiefly by means of vision. Research has shown that the lateral line, an organ sensitive to transitory changes in water displacement, is as important as vision (Partridge 1982 b). Recent work has also shown that the fish school is not a regular geometric structure like a crystal lattice. In each species a fish has a "preferred" distance and angle from its nearest neighbour. The ideal separation and bearing, however, are not maintained rigidly. The actual distance and direction vary greatly, approximating the ideal only over a long period. The result is a probabilistic arrangement that appears more like a random aggregation than a lattice. The tendency of the fish to remain at the preferred distance and angle, however, serves to maintain the structure. Each fish, having established its position, uses its eyes and its lateral lines simultaneously to measure the speed of all the other fish in the school. It then adjusts its own speed to match a weighted average that emphasises the contribution of nearby fish. The combination and comparison of information from the two sensory systems provides the basis of all the intricate manoeuvers of the school.

Although most people have an intuitive sense of what a fish shoal is, students of animal behaviour have spent much time trying to define the notion precisely. Do two fish constitute a school? Do three? Is a school that has a million members made up of half a million pairs? Does a school have a leader?

There seems to be an important qualitative difference between a pair of fish and a larger group. Brian Partridge of University of Miami, analysis of video tapes of European minnows (<u>Phoxinus phoxinus</u>) swimming in a tank shows that when there are two fish, one leads and the other follows. The follower adjusts its speed and direction to match those of the leader; the speed and direction of the leader, however, are not influenced by the movements of the follower. When a third minnow is added to the tank, the pattern changes: in a group of three or more fish there is no leader. Each minnow adjusts its speed and heading to agree with those of all the other fish, with the neighbours nearest to a given fish having the greatest influence on it. Thus in a sense, the entire school is the leader and each individual is a follower (Partridge 1982 b).

One of the most striking qualities of a school of fish is its polarization: the parallel arrangement of the members. Polarization has been cited repeatedly in efforts to define the concept of a school. When fish feed, they often form a loose group, with the members facing in many directions. when the school is in motion however, the polarized arrangement tends to prevail. Moreover, when the school is threatened, its members often move closer to one another and align themselves more uniformly with their neighbours. That the polarization of the school is more pronounced under a threat suggests it may be connected in some way with the adaptive advantage conferred by schooling behaviour.

The role the school plays in the life of the individual fish varies greatly from one species to another. In some species fish join schools only occasionally, spending most of their time as isolated individuals. Fish that spend all or most of their time in schools are often called obligate schoolers; those that form schools part of the time are called facultative schoolers. In much of the work done on fish schools it has been assumed that there is an important difference between obligate and facultative schools. Partridge's work on minnows and cod, which are facultative schoolers, and with herring, which are obligate schoolers, suggests on the contrary that in all three species the school is formed and maintained on the same principles. The only difference seems to lie in the amount of time the fish spend in a school. From these observations it is possible to formulate a useful working definition of a school. It is a group of three or more fish in which each member constantly adjusts its speed and direction to match those of the other members of the school.

Evelyn Shaw of Stanford University has estimated that out of about 20,000 species of fish more than 10,000 species collect in schools during some part of their lives. The species that school, however, are not a representative sample. Most of the fish that form schools are small; it has generally been thought that the main evolutionary advantage of schooling lies in protecting such small fish from predators.

It might seem that a school made up of thousands or even millions of fish, however small the individuals are, would be highly visible; actually a school is not much more likely to be found by an ocean predator than an isolated fish is. The reason has to do with the optical character of the medium in which both the prey and the predator live. Contrast is extremely important for distinguishing an object from its background. In a large body of water the scattering of light by suspended particles and the absorption of light by the water itself greatly reduce the contrast. As a result, even in water of exceptional clarity the greatest distance at which an object can be seen is about 200 meters, and the distance does not depend on the size of the object. In practice the maximum is usually much less. (Scuba divers consider a visibility of from 30 to 50 meters to be exceptionally good).

It seems that in many species schooling can offer a substantial evolutionary advantage only if it reduces the chance than an individual will be eaten once the school has been found. There are several ways it might do so. Albert Eide Parr, one of the first workers to study schools in a quantitative way, observed that a school is more densely packed and more highly polarized when it is under attack. Parr hypothesized that open-water fish respond to the lack of cover in the ocean by hiding behind one another; the school is the result. It has also been suggested that a predator might perceive a dense group of small prey as a large, frightening object, but one would expect natural selection to favour predators that are not fooled in this way.

A more plausible explanation of the adaptive value of the tightly packed school is that it reduces the predator's chance of making a successful kill. A predator facing a large number of prey often has difficulty choosing a single fish to attack. The phenomenon has been designated the confusion effect, but it may result from two quite different processes. One process takes place in the central nervous system: the predator simply cannot make a choice among the members of the school. Many predators prefer to strike prey that are distinct from the rest of the school in appearance or behaviour. Even very small differences are enough to overcome the predator's inability to make a decision, and the predator may have difficulty selecting one.

The second process may have its origin in the peripheral nervous system. It is the sensory confusion caused by a large number of prey moving around the predator. Even if the predator makes the decision to attack a particular fish, the movement of other prey in the vicinity can be distracting (Partridge 1982 b, Khalaf 1986 b).

The function of the lateral line in determining the structure of the school is also important. Most species of fish have a prominent lateral line on each side of the body. The displacement sensitive receptors that make up the line are known as hair cells. The hair cells are placed in canals laid out in a complicated way on the head of the fish and in a roughly linear arrangement between the head and the tail.

Although it has been suggested that the lateral line plays role in the formation of the school, most workers thought vision was much more important.

A test whether the lateral line might not also have some influence, schools of saithe were observed, that included fish that had been temporarily blinded or had had their lateral lines cut behind the operculum, the bony flap covering the gills. The saithe were blinded by placing opaque contact lenses over their eyes. When the blinded fish were placed in a school of unimpaired fish, they responded to changes in speed and direction by the school and maintained their position among the other fish. Behavioural changes were observed, however: the blinded fish tended to swim somewhat farther from their nearest neighbour than saithe ordinarily do.

Fish whose lateral lines had been cut were also able to school. In contrast to the blinded fish, however, those whose lateral lines had been cut swam closer to their nearest neighbour than saithe generally do. Only if the fish were both blinded and had had their lateral lines cut did they fail to maintain position. The results suggest that information from both the eye and the lateral line is utilised when fish school. The distance maintained by the eyes alone is smaller than the distance maintained by the lateral line alone; the preferred distance in the unimpaired fish lies between these values. Vision does seem to provide the attractive force between members of the school; the repulsive force, however, appears to be provided by the lateral line.

Other results suggest that vision is the more important sense for maintaining distance from the angle to the nearest neighbour. The lateral line appears to be most important for determining the neighbours speed and direction. Strong evidence that both senses are being utilised at once comes from measurements of the correlation between the speed and direction of a particular fish and those of other fish in the school a short time before; such correlations can indicate what standard of reference each fish employs in adjusting its velocity. For neither speed nor heading is the correlation between a fish and its nearest neighbour very strong.

The strongest correlations are observed between the speed and direction of the individual and the average speed and direction of the entire school. The average that is most strongly correlated is not the simple arithmetic mean of the speeds and headings of the members of the school. A fish is much more strongly influenced by its near neighbours than it is by the distant members of the school.

In investigating particular forms of animal behaviour biologists have tended to look for a single sensory explanation. It is now known that schooling is accomplished by comparing information from more than one sensory source. This might have been expected for evolutionary reasons alone: selection would tend to favour the animal capable of exploiting the most information (Partridge 1982 b, Khalaf 1986 b).

1.2 The aim of the study

The aim of this work is to study the schooling of two species of fish. One is the Sumatra barb (*Barbus tetrazona tetrazona*), an aquarium type, and the other is the minnow (*Phoxinus phoxinus*), a river type. Both are studied under laboratory conditions. And to investigate how the difference in size can affect their activities. Then to compare between the activites of the two species.

1.3 The importance of the study

The study is important as it studies the formation of schools in schoaling fish, and its importance in the fishes life. It is also important because it studies the schooling in two freshwater fish species living originally in two different environments.

1.4 A biological note on the Sumatra Barbs and the minnows

Barbus tetrazona tetrazona (Bleeker 1855)

Family:	Cyprinidae.
Genus:	Barbus.
English Name:	Sumatra Barb or Tiger Barb.
Origin:	Indonesia, Sumatra and Borneo.
Size:	Approximately 7 cm.
Habitat:	Found in nearly all still and running waters as well as in mountain streams (Van Ramshorst 1985).
Fin Formula:	Dorsal 4/8-9; Anal 3/5-6; Pectoral 1/12; Ventral 2/8.
Scale Formula:	Longitudinal series: 21.
Shape, colouring and markings:	The body is deep and laterally very compressed. The basic colouration is silvery-white: the upper half of the body is brownish with a green tinge: the flanks have a reddish-brown iridescence. There are four bluish-black transverse bands running across the body. The first band runs across the head, past the eye and covers the greater part of the cheek below: the second band is more or less cone-shaped and runs from the back down to the lower half of the body to the level of the pectoral fin: the third band starts immediately behind the dorsal fin and continues into the first anal fin rays: the fourth band crosses the base of the caudal fin. The scales which lie within the bands have beautiful shiny golden-green edges. The dorsal fin has a black base and is otherwise the same blood red as the anal fin. The other fins are reddish and more or less transparent. Some specimens have a very dark or completely black central fin (Van Ramshorst 1985).

Females when spawning have more rounded bellies: the pigmentation of the dorsal and anal fin rays is less vivid.

Males are slightly more slender.

It has no barbels; and its lateral line is incomplete.

Care and Breeding: After vigorous driving, which is often initiated by the female which goes pale while driving, the fishes press against one another in the tufts of plants and, with violent quivering, emit the eggs and milt. They are very prolific, the female produce 600 - 1,000 eggs. The breeding pairs should not be kept isolated beforehand, since isolated individuals often become quarrelsome and snappish; they are best kept in community tanks with other fishes. Bredding temperature 27°C. It is further recommended that the fishes be fed with Enchytraeids while spawning. The young hatch after 24 - 30 hours and swim freely after six days at the latest. (Sterba 1963). Fed with fine-grade food; and rearing is easy.

<u>Phoxinus phoxinus (Linnaeus 1758)</u>

Family: Cyprinidae.

Genus: Phoxinus.

English Name: Minnow.

Distribution: The whole of Europe, with the exception of southern Spain, southern Italy and Iceland (Sterba 1963, Terofal 1979, Khalaf 1986 a).

Size: Average length 7 - 10 cm, maximum up to 14 cm, the females somewhat larger than the males.

Habitat: An adaptable shoaling fish, often living in large numbers close to the surface of clear waters.

Fin formula: Dorsal 3/7; Anal 3/7; Pectoral 1/15; Ventral 2/8.

Scale formula:	Longitudinal series 80 - 90 .
Shape, colouring and markings:	The body is elongated, almost cylindrical, with only the caudal peduncle laterally compressed. The mouth is small and forwardly directed. Scales are small, and the lateral line often incomplete. The colouration is very changeable. Back olive to grey-green, often with dark blotches; the flanks are yellow-green with metallic glints. Corners of mouth carmine-red. Throat is black. Breast often scarlet. Belly is white-yellowish. A gleaming gold longitudinal stripe extends from behind the eye to the root of the tail. The dorsal, anal and caudal fins are more or less dirty yellow; anal occasionally crimson. Pectoral and ventral fins are grey to crimson. The colouration depends very much upon the condition of the fish; now and then vague transverse bars appear. At spawning time pointed whitish tubercles appear from the nape backwards. The sexes can hardly be distinguished, but at spawning time the bellies of the females are rounder (Sterba 1963, Khalaf 1986 a)
Diet:	Invertebrates on the bottom and in open water, and also flying insects.
Care and Breeding:	Very well suited to the unheated aquarium. Tanks with coarse, sandy bottom soil and fresh water provide the best imitation of its preferred natural habitat. Aeration essential. It prefers to eat red midge-larvae, Enchytraeids and other worms, also beetles and other insects.

Breeding season is from April to July. It gathers in great shoals to spawn in the shallows, mainly on stones, when both sexes develop nuptial tubercles. The female lays 200 - 1,000 eggs (diameter 1 - 1.3 mm) where adhere to stones, rarely to plants, and hatch in 5 - 10 days. Sexually mature at the end of 1 - 2 years (Terofal 1979).

Breeding in captivity not very difficult. When morning sunshine is expected, serveral breeding pairs can be placed in the breeding tank the previous evening. This should contain crystal-clear fresh water and have large stones on the bottom on which the animals will spawn; the water level should not exceed 15 cm and vigorous aeration must be provided. The young hatch after 6 days and should be fed with sifted small crustacea. They grow very slowly and are first sexually ripe at 3 - 4 years old (Sterba 1963).

2 Methods

2.1 Study Area

The Sumatra Barbs were bought from a pet shop in Sunderland, England, and from another pet shop in Saarbrücken, Germany.

The minnows were caught from the River Wear, North East England from the following locations: Shincliffe, Croxdale and near Durham Cathedral.

All the English fish were transferred to a cold room belonging to the Zoology Department, Durham University, where the work was carried out.

While the studies on the German Sumatra barbs were carried out in our home in Rilchingen-Hanweiler, Germany.

2.2 Procedures

The fish were kept in two storage tanks in the cold room. The Sumatra barbs (size 4.5 - 4.8 cm.) and minnows (sizes 2.3 - 2.9 cm.) were kept in the big storage tank, with its measurements: length 59.5 cm, width 30 cm and height 29.5 cm. The smaller minnows (sizes 1.00 - 1.2 cm) were kept in the smaller storage tank, with its measurements: length 32 cm, width 22.5 cm and height 20.5 cm. During the experiments the fish were transferred to the experiment aquarium, with its measurements: length 181.5 cm, width 23.5 cm and height 38.5 cm.

The temperature in the cold room was constantly 20°C for the Sumatra barbs, and constantly 15°C for the minnows. Lights were kept on for 24 hours, and the fish were fed daily, 7 days a week, on normal fish food (Tetra Min - stable food for all tropical fish).

The experiment aquarium was divided into 12 sections, by drawing vertical bars on the outside glass ; the length of each section was 15 cm.

The activity of the fish was measured by counting how many bars does one fish cross in 30 seconds; and then choosing another fish for the next reading. And for each number of fish a minimum of 21 recordings and maximum of 55 recordings for Sumatra Barbs were taken, and 25 recordings for the two sizes of minnows. So, for example, if a school of fish of 6 were in the experiment aquarium, its activities were recorded in intervals of 30 seconds for at least 21 times for barbs and 25 times for minnows.

Minimum of 2 and maximum of 6 sets of experiments was carried out for each number of minnows, and 3 sets of experiments on Sumatra Barbs.

3 Results

3.1 The relationship between food and activity in Sumatra Barbs.

20 Sumatra Barbs were obtained from Sunderland on 4.6.1986. They were kept in 20°C. In this experiment we want to find out if the food contribute to the fishes activity and to observe their daily pattern. 10 Sumatra Barbs were transferred to the experiment aquarium on 5.6.1986. Till now they are not fed, and will remain so till the end of the day. Their activities were recorded from 9.00 am - 9.00 pm. (Except from 1.00 pm - 2.00 pm) (See table 1 and figure 1).

On the next day (6.6.1986) 10 Sumatra Barbs were transferred to the experiment aquarium, and their activities were recorded; all the conditions were the same, the only difference that they were fed at 12.00 midday. (See table 2 and figure 2).

From table 1 and figure 1 we can notice that the activity was very high (8.4 bars crossed) when we first placed the barbs in the experiment aquarium. That is normal, as the barbs were exploring the new environment and also due to external disturbances. The activity then slowed down, and then rose slightly at midday (5.5 bars), then it went down again, and afterwards rose considerably after 5.00 pm. The first rise at midday is due possibly to its daily pattern, while the second rise at 5.00 pm is may be because it was fed at that time previously in the pet shop, but anyway it was without significance .

From table 2 and figure 2, we can notice that the swimming activity at 9.00 am was not as high as the first day, as they are now familiarised to its new surrounding, and have less energy than the day before. Activity then goes down to a minimum record (1.9 bars) at 11.00 am. It was observed from the period 10.00 am - 12.00 pm that the fish were more aggressive: chasing and nipping each other more often than normal. And also they were not schooling as before. That is a direct affect of starving. After they have been fed at 12.00 midday activity is risen enormously (8 bars crossed), and then it slows down steadily throughout the day, and normal behaviour of schooling is observed again. From this experiment we can see a clear relationship between food and swimming activity by Sumatra Barbs. As the feeding time comes, the fish are more active and swim more actively, and as food is given it becomes more active as they feed and search for food debris fallen to the bottom of the aquarium.

But by comparing the two experiments by the student's t test, it was calculated that the difference between the two experiments on the starving and the fed day was not significant. So that means that there is no real difference in the activity if the fish were starved and fed in two successive days. While the activity was significant within the experiment day, which meas that activity is variable and not constant during the day.

We can notice from the standard deviation in table I that it was slightly high in the first two readings , and that is because the activity of the fish was not consistent in the begining of the experiment .

Table I :Activity of Sumatra barbs on a starving day (5th June I986)

no. of recordings \ time	9.00	I0.00	II.00	I2.00	I3.00	I4.00	I5.00	I6.00	I7.00	I8.00	I9.00	20.00
I	I0	II	4	5		I	3	3	3	2	3	2
2	I5	7	2	6		3	4	3	6	3	2	I
3	I	II	6	4		4	3	3	5	5	I	3
4	8	2	5	7		4	3	3	3	5	2	5
5	5	I3	4	4		2	I	3	5	4	2	3
6	4	I5	4	5		4	I	3	2	3	9	6
7	I6	5	4	8		I	4	4	II	3	3	4
8	2	7	2	4		4	5	4	I	6	I	3
9	I0	I2	5	4		I	5	4	3	7	2	I
I0	7	I5	I	II		4	2	4	8	4	4	5
II	I7	I4	6	3		2	2	6	I3	2	8	3
I2	7	2	3	4		2	I	4	I0	7	5	I
I3	I2	8	3	4		3	4	6	6	8	2	2
I4	I2	9	I	7		I	I	7	3	4	7	6
I5	6	7	8	6		7	3	5	6	6	9	3
I6	II	8	7	I0		2	I	3	5	5	2	2
I7	I4	4	3	6		2	3	6	4	4	2	I
I8	4	I	8	I3		6	2	3	5	7	5	5
I9	3	8	II	3		4	7	9	4	6	3	3
20	5	2	5	3		2	I	I	4	7	I	4
2I	I0	6	3	2		4	5	I	7	II	4	5
22	2	6	4	4		I	8	I0	6	2	I	3
23	8	3	3	9		3	I	2	5	5	I	I0
24	I0	I	3	4		4	4	3	9	3	2	3
25	I0	3	5	I		7	6	7	9	6	5	I
mean	8.4	7.2	4.4	5.5		3.I	3.2	4.3	5.7	5.0	3.4	3.4
var.	20.4	I9.6	5.4	8.3		3.I	4.0	5.0	8.5	4.7	6.3	4.3
S. D.	4.5	4.4	2.3	2.9		I.8	2.0	2.2	2.9	2.2	2.5	2.I
S. E.	0.9	0.9	0.5	0.6		0.4	0.4	0.4	0.6	0.4	0.5	0.4

Figure I : Histogram showing the activity of Sumatra barbs on a starving day .

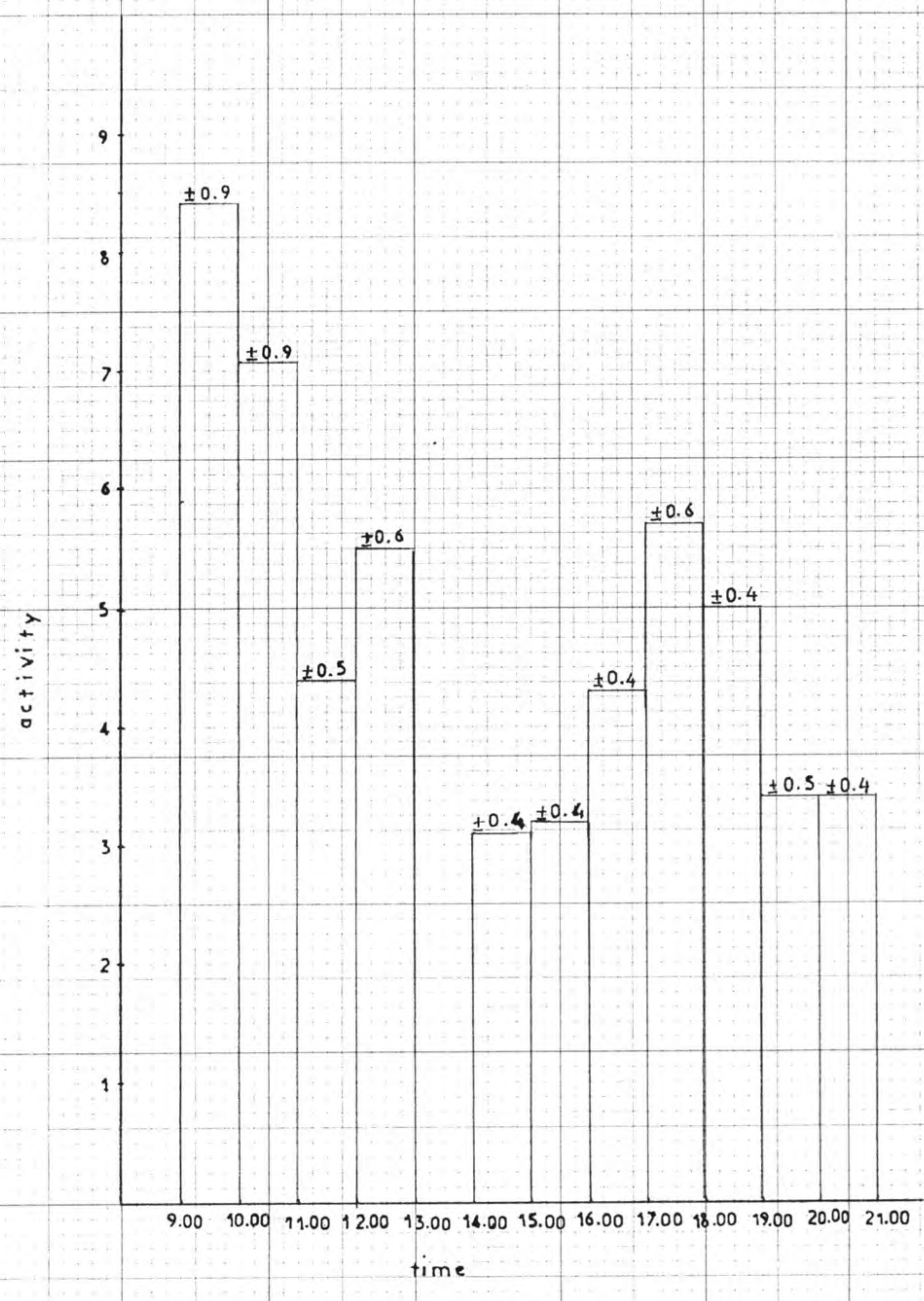
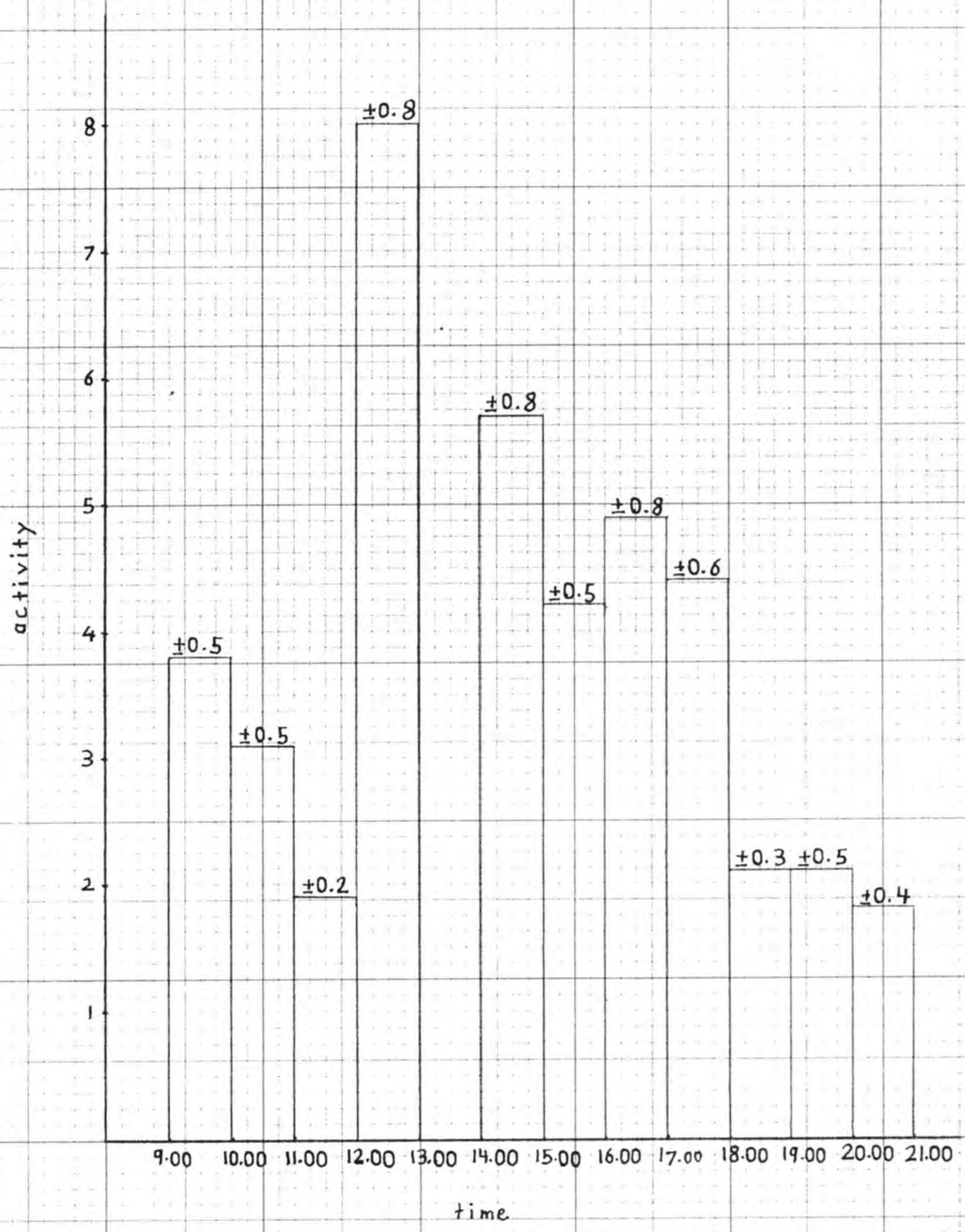


Table 2 : Activity of [illegible] birds on a normal day ([illegible]th June [illegible]) .

time / no. of recordings	9.00	I0.00	II.00	I2.00	I3.00	I4.00	I5.00	I6.00	I7.00	I8.00	I9.00	20.00
I	4	9	I	9		I	4	2	3	I	I	I
2	3	5	I	5		I2	5	I	5	I	2	I
3	2	2	I	6		8	3	I	5	I	2	I
4	I	3	3	9		7	4	3	4	2	I	I
5	3	2	3	5		I	4	4	8	I	2	2
6	9	I	4	7		2	I0	3	I0	2	I	I
7	2	I	2	5		2	4	I2	2	I	4	I
8	2	I	2	I0		8	6	5	3	I	I	1
9	6	2	3	I0		2	I0	I	4	I	I	2
I0	I	2	2	I7		3	3	I	II	I	4	I
II	6	3	I	I5		I4	2	2	7	5	2	2
I2	I	2	I	3		4	2	9	3	3	2	3
I3	4	I	I	I0		2	I	9	I	4	2	I
I4	2	2	I	2		9	6	4	8	1	2	I
I5	2	3	I	9		3	2	9	I	2	2	I
I6	I	9	I	7		I0	2	5	3	2	I	9
I7	6	2	I	II		8	4	4	2	5	I	I
I8	2	I0	I	6		I4	6	6	5	4	I	6
I9	2	4	I	I3		I0	3	I6	2	4	I	2
20	7	3	3	7		2	3	5	4	I	I	I
2I	6	2	2	I0		7	2	4	I	I	I	I
22	4	2	5	3		I	5	8	7	I	I4	2
23	2	2	3	8		2	5	I	2	4	I	I
24	I0	3	3	I0		5	7	4	6	I	I	I
25	6	I	I	2		6	I	3	4	3	2	I
mean	3.8	3.I	I.9	8.0		5.7	4.2	4.9	4.4	2.I	2.I	I.8
var.	6.6	6.5	I.3	I4.5		I7.I	5.7	I4.3	7.7	2.0	6.9	3.4
S. D.	2.6	2.5	I.2	3.8		4.I	2.4	3.8	2.8	I.4	2.6	I.8
S. E.	0.5	0.5	0.2	0.8		0.8	0.5	0.3	0.6	0.3	0.5	0.4

Figure 2 : Histogram showing the activity of Sumatra barbs on a normal day .



3.2 Experiment on settling down time of Sumatra Barbs after disturbance of water.

We are doing this experiment as to know how long it takes after the fish are transferred from the storage tank to the experiment aquarium to settle down and show normal behaviour. As this information will be used in the further experiements, because it will give us the precise time needed for the barbs to settle down, before starting to observe and record the swimming activities, because we do not want to record abnormal activity data.

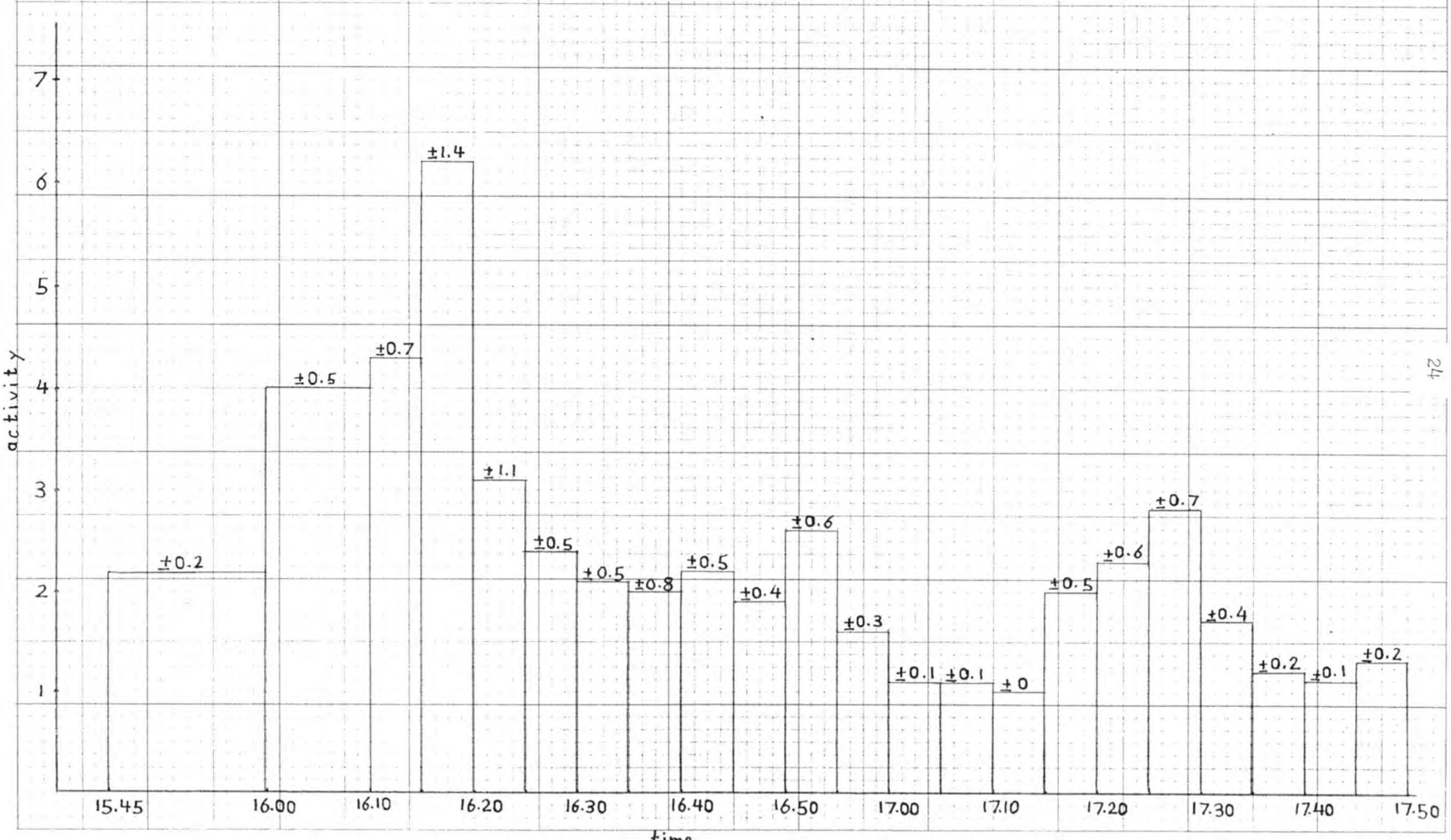
The experiment was performed on 9.6.1986 on five Sumatra Barbs. At 3.45 pm activity of the normal Sumatra Barbs were recorded in the aquarium till 4.00 pm when the water was disturbed by stirring the net in the water, as trying to catch a barb, to disturb the fish. Observations were taken at 4.00 pm and 4.10 pm and for every five minutes till 5.50 pm.

From analysing table 3 and figure 3 we can notice that the settling down time is 20 - 25 minutes. The rhythm of activity displayed between 3.45 pm and 4.00 pm is repeated at 4.20 pm - 4.25 pm. This settling down time will be used for the next experiments on Sumatra Barbs.

Table 2 : Activity of Sumatra barbs before and after the disturbance of the water **on** 9th June 1986 .

recording no.'s / time	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	I8	I9	20	mean	variance	s.d.	s.e.
I5.45	4	2	I	I	4	2	3	2	2	2	I	I	2	4	3	2	2	2	3	I	2.2	I.0	I.0	0.2
I6.00	5	5	7	I	4	2	2	6	4	2	2	5	6	6	3						4.0	3.6	I.9	0.5
I6.I0	2	3	4	5	8	7	4	2	4												4.3	4.3	2.I	0.7
I6.I5	2	4	2	3	3	I0	I2	I2	8												6.2	I8.2	4.3	I.4
I6.20	I	6	2	I0	I	2	I	2													3.I	I0.4	3.2	I.I
I6.25	3	6	2	I	2	I	3	I	3												2.4	2.5	I.6	0.5
I6.30	I	3	I	6	2	I	I	2	2												2.I	2.6	I.6	0.5
I6.35	I	7	I	I	I	I	2														2.0	5.0	2.2	0.8
I6.40	2	4	I	4	I	I	4	2	I												2.2	I.9	I.4	0.5
I6.45	I	2	2	I	5	2	I	2	I												I.9	I.6	I.3	0.4
I6.50	2	3	I	4	I	5	2														2.6	2.3	I 5	0.6
I6.55	2	4	I	2	I	I	I	I	I												I.6	I.0	I.0	0.3
I7.00	I	I	I	I	I	I	2														I.I	0.I	0.4	0.I
I7.05	2	I	I	I	I	I	I														I.I	0.I	0.4	0.I
I7.I0	I	I	I	I	I	I	I														I.0	0	0	0
I7.I5	[illegible]	I	I	3	3	5	I	I													2.0	2.3	I.5	0.5
I7.20	3	5	I	2	2	I															2.3	2.3	I.5	0.6
I7.25	4	I	7	3	4	2	I	I	2												2.8	3.9	2.0	0.7
I7.30	4	I	I	4	I	I	I	I	I												I.7	I.8	I.3	0.4
I7.35	I	I	2	I	I	I															I.2	0.2	0.4	0.2
I7.40	I	I	I	I	I	I	I	I	2												I.I	0.I	0.3	0.I
I7.45	I	2	I	I	I	2	I	2	I												I.3	0.3	0.5	0.2

Figure 3 : Histogram showing the activity of Sumatra barbs before and after the disturbance of the water.



3.3 The Relationship between school number and activity in Sumatra Barbs (Size 4.5 - 4.8 cm).

Experiments on Sumatra Barbs were carried out in Durham, England, between the period 12.6 - 27.6.1986, and some integral behavioural studies were carried out in Rilchingen - Hanweiler, Germany, between the period 20.8 - 4.9.1986

From table 4 and table 5 and figure 4 and figure 5, we can notice very clearly a considerable increase in activity whenever there was an increase in fish number. The Sumatra Barbs are a schooling type. When number is increased the activity increases by crossing more bars in the aquarium. For example, one fish cross an average 3.7 ± 0.5 bars, while 4 fish cross 9.3 ± 1.1 bars, and 16 fish cross 15.1 ± 0.8 bars. So its a steady increase and its highly significant at P = 0.001.

There was also a significant difference inside each number of fish. The measurements of fish number 1 for example, is variable and also significant. The case is similar in fish numbers 3, 4, 6, 9 and 10.

The difference inside the single group is attributed to the difference in activity of the individuals; if one fish is more active than the others, it will lead to active schooling inside the group, this was observed in Durham, and confirmed in Rilchingen - Hanweiler. There was no obvious relation between the dates and time of the day and activity, as the Barbs were active on different occasions, with no definite pattern.

We can notice from table 5 that the standard deviation is slightly smaller in fish groups of I6 if we compare it with group sizes 4 , 6 , 8 and IO . And that means that the swimming schooling activity of the fish becomes consistent if the number of fish is bigger .

Table 4 : Activity of the Sumatra barbs .

no. of recordings \ fish no.	I	I	I	2	2	2	3	3	3	4	4	4	6	6	6	8	8	8	I0	I0	I0	I6	I6	I6
I	I	7	I	4	I	I	2	I7	I	I	6	II	I3	9	20	22	I7	I3	I8	7	2I	I4	I5	2I
2	I	5	I	I0	II	I2	3	I5	I	I	6	I3	7	6	I3	6	8	I2	I4	8	24	5	I9	I2
3	3	I	I	I0	I4	7	7	I	I	I0	I	22	I	2	7	I	7	22	I2	9	23	9	I8	I9
4	I	9	I	I2	6	I2	I0	I	I	I2	3	I7	II	2	I3	I	I5	I3	3	I0	23	9	I0	8
5	I	I	3	I5	3	9	II	I	I	8	2I	I3	I3	2	20	2	8	I4	5	7	25	II	I6	I8
6	I	3	I	II	I	7	3	8	I	3	I	23	2	I	I4	5	2	I0	I8	I3	2I	I7	I8	I6
7	I	8	I	9	I	2	4	I3	I	I	4	I9	2	3	I8	I4	4	2I	6	I5	I7	I7	8	I9
8	I	6	I	I	3	I2	3	6	I	I	5	I7	24	4	I7	I0	6	7	I3	I9	I8	I3	I5	I5
9	I	4	3	4	I	I3	3	II	I	I	I5	I8	23	I2	I6	I3	6	9	I2	I4	I4	5	I7	I9
I0	I	I	I	9	3	5	2	I4	I	7	4	20	20	2	8	II	6	I3	I4	I4	I	II	I8	I4
II	I	5	2	9	I	5	4	I2	I	I5	8	I2	24	8	4	4	3	I	I5	I2	23	9	2I	I0
I2	I	7	I	9	I	I	3	3	I	I7	I8	I	9	I0	I5	2	I2	22	8	5	3	20	I6	I5
I3	I	5	2	4	2	I	4	3	I	9	6	I0	I3	3	I3	I0	2	3	3	3	I6	I0	I7	I5
I4	I	2	2	I	3	I	5	9	I	II	I6	I6	I	8	4	I	I	3	I4	2I	2I	9	20	I8
I5	I	2	2	I	7	I	3	I5	I	3	I4	I6	23	2	6	8	3	20	7	I0	I7	I0	I6	I0
I6	I	3	7	I	I	I3	2	3	I0	I3	I	I7	4	3	6	I6	6	I4	I	I5	I6	6	I7	20
I7	I	4	4	I	3	7	9	I7	I	I3	I	I8	I3	9	I0	7	3	I2	3	6	I8	I0	23	I6
I8	I	9	4	I	3	II	I2	2	6	4	I	I7	2	I	I0	I3	5	I3	I4	I	20	3	I7	I0
I9	I	8	6	6	I	2	I	I6	I	I	I	I	24	I4	5	22	I	8	I7	I6	26	I0	20	I9
20	I	5	3	7	I	I	I	I8	3	I	I	I4	I4	7	4	I2	9	23	I2	I8	23	II	2I	20
2I	I	5	4	I	I	I	2	24	I	II	7	I2	2	4	2	3	6	20	I8	I7	I7	2	2I	I0
22	I	6	I		I	I	I	I2	I	2	I0	23	I2	2	I0	I7	3	I6	II	6	6	20	2I	4
23	6	II	I		I	2	I	I4	I	I	7	I8	I2	4	II	I	8	I8	I0	I4	3	9	I2	22
24	II	8	I		I	I3	2	2I	I	I	I7	I3	I	3	4	9	4	I8	I	I0	I3	II	20	22
25	I	II	I		I	I	3	I5	I	I	I3	7	I	7	6	4	5	I6	7	I6	2I	I6	2I	20
26	4	7			I		7	I9		I						22	2		I5	I8		I4		
27	I4	6			3		9	22								9	4		2	4		I3		
28	I2	3			4		3	I								I4	4		I2	I7		2I		
29	I	8			I2		5	I2								6	5		I2	2I		I5		
30	I5	8			7		6	I6								I9	3		3	I2		I8		

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cont. table 4 :

fish no. / no. of recordings	I	I	I	2	2	2	3	3	3	4	4	4	6	6	6	8	8	8	I0	I0	I0	I6	I6	I6
31	9	II			4		3									II			20			I6		
32	I4	I0			4		I2									I3			I5			I5		
33	I	5			8		2									9			2			I		
34	I	3			7		4									I2			6			II		
35	I	4			8		4									I9			4			7		
36	I															I						I4		
37	I															2						9		
38	I															I						I7		
39	I															4						I2		
40	I															4						I7		
41	I																							
42	3																							
43	II																							
44	I																							
45	I																							
46	I																							
47	I																							
48	I																							
49	I																							
50	2																							
51	9																							
52	2																							
53	I																							
54	I																							
55	I																							

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Cont. table 4 :

fish no. / variables	I	I	I	2	2	2	3	3	3	4	4	4
mean	2.9	6.0	2.2	6.0	3.7	5.7	4.5	II.4	I.6	5.7	7.5	I4.7
var.	I5.3	9.3	2.7	I8.6	II.9	22.5	I0.0	47.0	4.0	28.0	37.8	3I.6
S.D.	3.9	3.0	I.6	4.3	3.4	4.7	3.2	6.9	2.0	5.3	6.I	5.6
S.E.	0.5	0.5	0.3	0.9	0.6	0.9	0.5	I.3	0.4	[illegible]	I.2	I.I
Date	I3.6	I7.6	24.6	I3.6	I6.6	23.6	I6.6	I9.6	27.6	II.6	I9.6	26.6
Time	I0.45	I2.30	I2.35	I7.25	I6.I0	I2.05	II.42	I0.30	I7.I7	I6.35	I5.06	II.25

fish no. / variables	6	6	6	8	8	8	I0	I0	I0	I6	I6	I6
mean	II.0	5.3	I0.2	9.0	5.6	I3.6	I0.I	I2.2	I7.6	II.7	I7.5	I6.I
var.	69.6	I2.9	28.4	4I.3	I3.9	36.6	30.6	30.5	48.9	29.6	I2.4	2I.8
S.D.	8.3	3.6	5.3	6.4	3.7	6.I	5.5	5.5	7.0	5.4	3.5	4.7
S.E.	I.7	0.7	I.I	I.0	0.7	I.2	0.9	I.0	I.4	0.9	0.7	0.9
Date	I2.6	I3.6	24.6	I2.6	I6.6	26.6	I2.6	I9.6	25.6	I8.6	20.6	24.6
Time	I0.I4	I2.45	I5.30	II.46	I4.I8	I0.35	I5.45	I2.00	II.20	I0.50	I0.35	II.40

Table 5 : Calculations of the activity of Sumatra barbs.

variables / fish no.	no. of replicates	mean	var.	S.D.	S.E.	n.
I	3	3.7	9.I	[illegible].9	0.45	38
2	3	5.2	I7.7	4.2	0.82	27
3	3	5.8	20.3	4.0	0.72	30
4	3	9.3	32.4	5.7	I.I2	25
6	3	8.7	37.00	5.8	I.I4	25
8	3	9.4	30.6	5.4	0.96	32
I0	3	I3.3	36.6	6.0	I.I0	30
I6	3	I5.I	21.5	4.5	0.832	30

Figure 4 : Histogram showing the activity of the Sumatra ba[illegible]

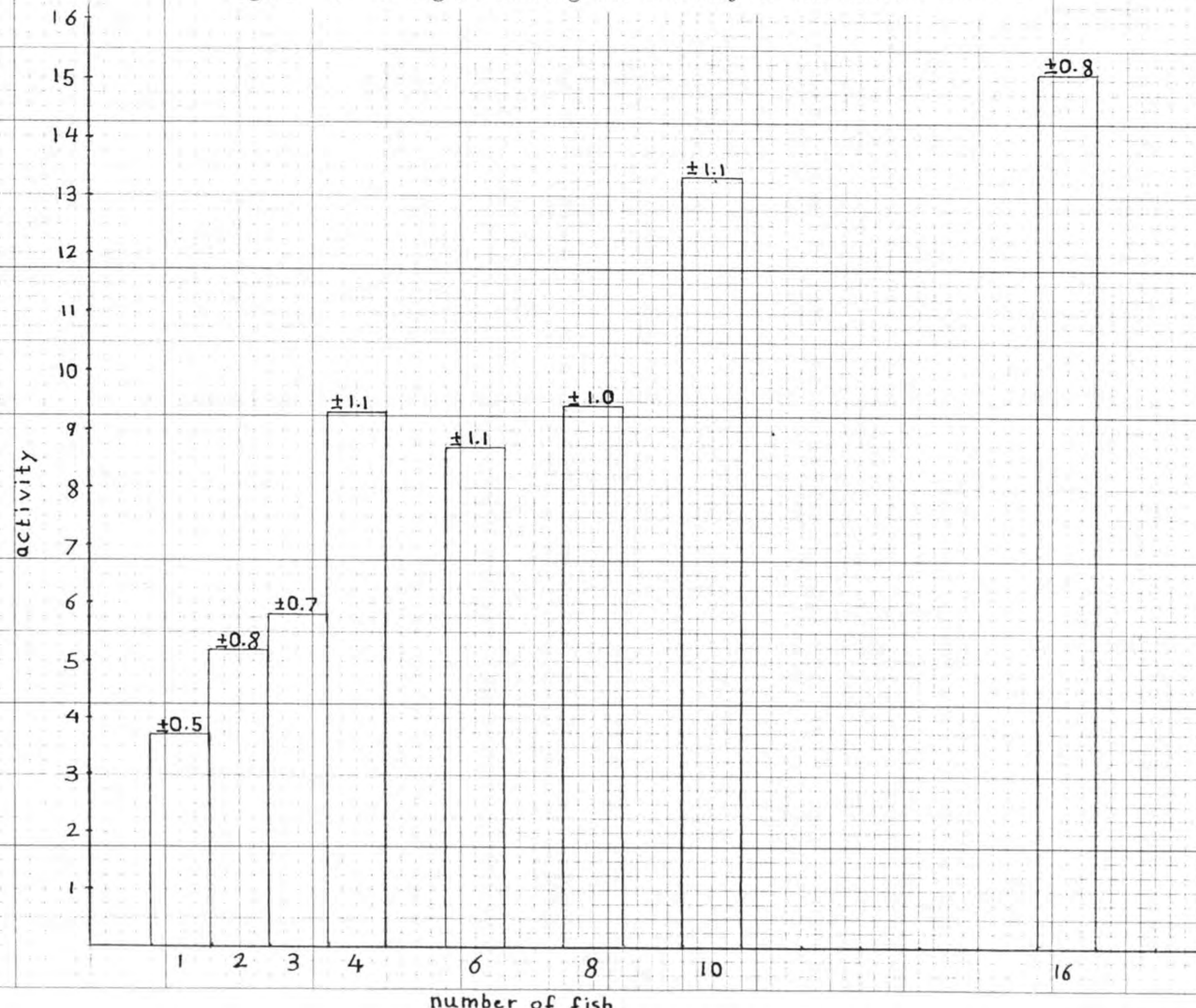
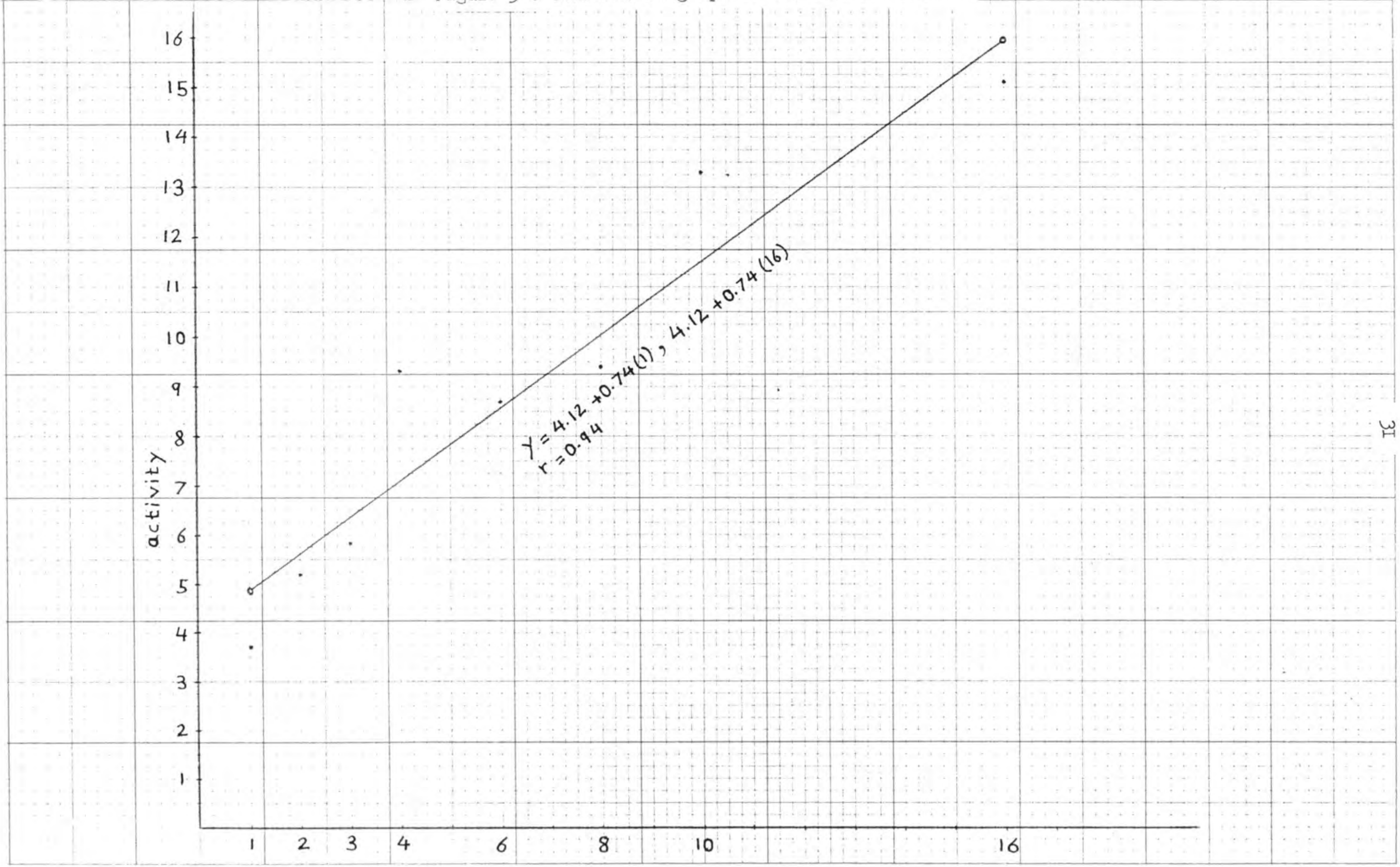


Figure 5 : Correlation graph of the Sumatra barks .



3.4 The Relationship between school number and activity in 2nd yearling minnows.

Experiments on minnows (size 2.3 - 2.9 cm) were carried out in Durham, England between the period 17.7 - 28.7.1986.

From table 6 and table 7 and figure 6 and 7, we can notice a slight increase in activity whenever there was an increase in fish number. The minnows are a schooling fish . When number is increased the activity increases by crossing more bars in the aquarium. For example, one fish cross an average 1.4 ± 0.1 bars, while 4 fish cross 2.6 ± 0.3 bars, and 16 fish cross 3.7 ± 0.3 bars. Its a small, but a steady, increase and its highly significant at $P = 0.001$.

There was no significant difference inside each number of fish. The activity in the minnows was not as high as in the Sumatra Barbs. There was a tendency of less activity on the later days, because it was observed that they were more active on the first days, and schooling was more often. It was observed also that some individuals were more active than others.

Table 6 : activity of second yearling minnows .

fish no. \ no. of recording	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	I8	I9	20	2I	22	23	24	25
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	[illegible]	[illegible]
	I	I	I	I	3	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	2	2	I	2	2	I	I	I	I	I	I	I	I	I	2	I	I	I	I	2	I		I	2	I
[illegible]	I	I	I	3	3	I	2	3	2	I	2	2	I	I	I	2	2	2	I	I	I	[illegible]	[illegible]	I	I
I	2	2	2	2	2	2	3	2	3	I	2	3	I	I	2	2	4	3	3	2	3	2	I	2	3
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
2	I	I	2	I	I	2	I	I	I	I	I	2	I	I	I	I	I	I	I	I	I	[illegible]	[illegible]	2	I
2	2	[illegible]	[illegible]	2	3	4	2	4	5	7	4	3	4	5	3	2	I	I	I	2	2	2	2	2	2
2	I	I	5	2	I	I	3	5	I	I	I	4	2	2	I	3	I	I	I	I	I	I	2	2	3
2	3	2	3	3	I	2	3	3	3	I	6	3	I	4	2	I	I	2	I	3	3	5	2	2	2
2	3	3	2	3	4	I	3	2	2	3	2	2	2	3	2	3	3	3	4	2	3	3	3	2	3
3	2	I	I	I	I	I	2	I	I	2	I	3	3	5	I	3	3	2	I	I	I	5	6	I	3
3	I	2	I	2	2	2	3	I	4	2	3	I	I	I	2	I	2	2	I	I	I	2	I	I	I
3	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
3	I	5	3	I	3	2	3	I	4	2	3	2	5	2	3	3	4	I	I	5	I	5	I	I	6
4	I	4	4	4	5	3	3	I	5	6	6	5	6	3	3	5	7	6	2	6	5	2	5	2	2
4	I	I	3	3	2	I	4	I	2	I	I	2	I	I	I	I	2	I	I	2	I	I	I	I	2
4	2	5	I	I	2	3	I	3	I	7	I	3	I	3	I	I	3	3	I	3	4	3	2	2	I
[illegible]	[illegible]	[illegible]	I	2	3	2	4	3	2	2	4	2	2	3	3	2	I	2	2	I	3	2	2	I	I
6	I	4	I	6	2	I	I	I	4	8	3	6	I0	6	I	4	6	6	5	2	3	5	I	I3	2
[illegible]	2	I	I	I	I	I	5	I	I	2	I	I	I	I	I	I	I	2	I	2	I	2	I	I	I
[illegible]	[illegible]	4	4	I	5	4	5	4	5	6	4	4	4	3	6	5	6	6	7	3	2	[illegible]	4	[illegible]	2
[illegible]	[illegible]	[illegible]	I	[illegible]		4	I	4	I	I	3	2	2	I	[illegible]		2	I	I	I	2	3	[illegible]	[illegible]	[illegible]
	2	4	I	2	I	I	2	3	[illegible]		I	I	I	2	I	3	I		I	I	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
I0	3	3	II	6	6	8	6	9	I0	5	5	I	I2	4	I3	6	I3	9	7	4	I	2	9	[illegible]	3
I0	[illegible]	[illegible]	[illegible]	2	I	I	2	I	2	3	I	2	2	I	I	2	I	3	2	I	I	2	I	3	I
I0	3	I	2	2	2	2	4	2	3	2	I	I	3	4	[illegible]	2	2	2	2	3	2	3	4	I	3
I6	8	3	5	5	5	2	8	4	8	4	4	4	3	2	2	3	3	3	4	3	2	2	4	2	4
I6	3	5	4	5	5	4	3	4	3	2	3	2	2	4	2	4	6	2	2	3	2	3	3	3	4

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Cont. table 6 :

variables / fish no.	mean	var.	S.D.	S.E.	Date	Time
I	I	0	0	0	I7.7.86	I5.20
I	I.I	0.2	0.4	0.I	2I.7.86	I8.00
I	I.3	0.2	0.5	0.I	22.7.86	II.56
I	I.8	0.7	0.8	0.2	22.7.86	I7.3I
1	2.2	0.6	0.7	0.I	23.7.86	I2.20
I	I.0	0	0	0	23.7.86	I5.45
2	I.2	[illegible]	0.4	0.I	I7.7.86	16.I0
2	2.8	2.0	1.4	0.3	I9.7.86	10.I5
2	[illegible]	I.4	1.2	0.2	23.7.86	10.20
2	2.5	I.5	I.2	0.2	23.7.86	14.49
2	2.6	0.5	0.7	0.I	23.7.86	16.25
3	2.1	2.1	1.4	0.3	I8.7.86	II.60
3	1.8	2.I	I.5	0.3	2I.7.86	I6.43
3	I.0	0	0	0	22.7.86	I6.56
3	2.7	2.5	I.6	0.3	28.7.86	9.05
4	4.0	2.9	I.7	0.3	I7.7.86	I0.45
4	I.6	0.7	0.9	0.2	23.7.86	II.I0
4	2.3	2.I	I.5	0.3	28.7.86	9.35
6	2.2	0.7	0.8	0.2	I8.7.86	I5.33
6	4.I	9.2	3.0	0.6	22.7.86	I0.20
6	I.4	0.8	0.9	0.2	23.7.86	9.25
8	4.8	[illegible]	I.5	0.3	17.7.86	II.40
8	[illegible]	I.I	I.I	0.2	2I.7.86	I7.20
8	I.7	0.9	0.9	0.2	22.7.86	16.17
I0	6.7	I2.6	3.6	0.7	I7.7.86	I2.20
I0	1.5	0.6	0.8	[illegible]	I9.7.86	II.00
10	2.4	0.7	0.8	[illegible]	20.7.86	II.20
I6	4.0	3.0	I.7	0.3	I8.7.86	II.45
16	3.3	I.3	I.1	0.2	I8.7.86	I2.30

Table 7 : Calculations of the activity of 2nd yearling minnows .

variables / fish no.	no. of replicates	mean	variance	Standard deviation	Standard error	number
I	6	I.4	0.2	0.4	0.08	25
2	5	2.2	I.I	1.0	0.I9	25
3	4	I.9	I.7	I.I	0.22	25
4	3	2.6	2.5	I.3	0.26	25
6	3	2.6	3.6	I.6	0.3I	25
8	3	2.8	I.4	I.2	0.23	25
I0	3	3.6	4.7	I.7	0.35	25
I6	2	3.7	2.I	I.4	0.28	25

Figure 6 : Histogram showing the activity of 2nd yearling minnows .

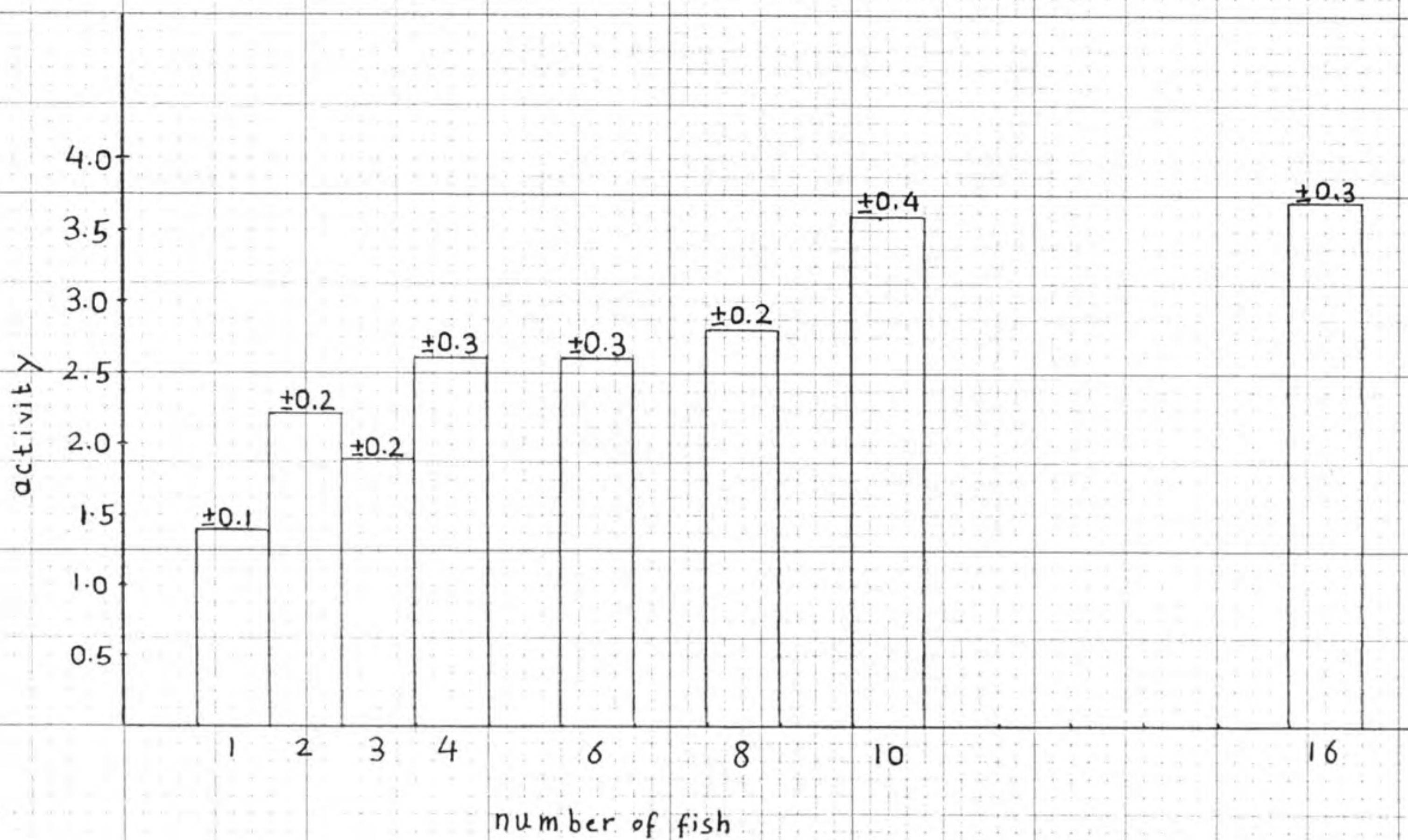
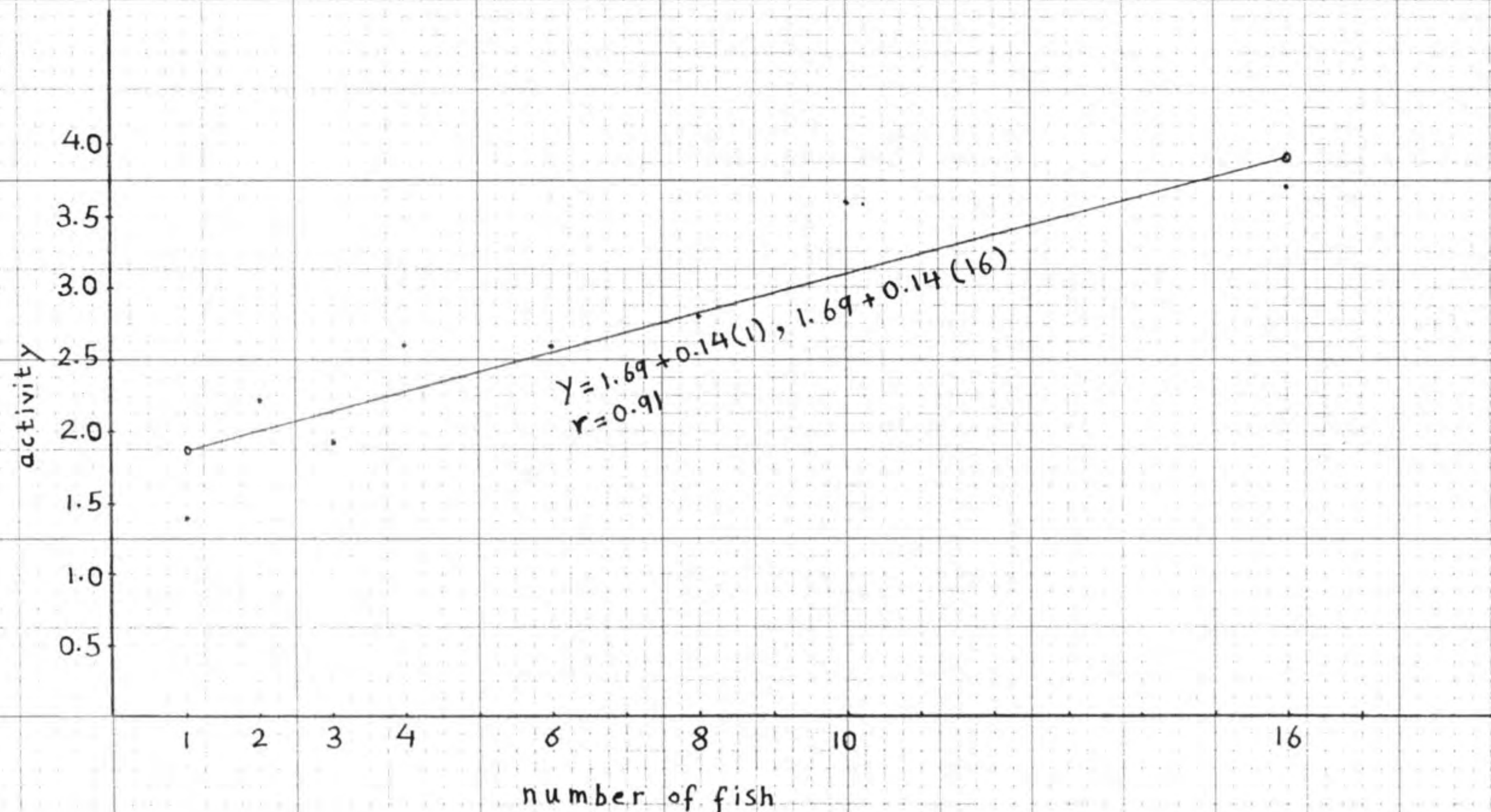


Figure 7 : Correlation graph of 2nd yearling [illegible]llows .



3.5 The Relationship between school number and activity in 1st yearling minnows.

Experiments on minnows (size 1.0 - 1.2 cm) were carried out in Durham, England, between the period 20.7 - 30.7.1986.

From table 8 and 9 and figure 8 and 9 we can notice there is a slighter increase in activity whenever there was an increase in fish number. But when calculated it was not significant. The minnows school when they are small in size, but as this experiment shows, there is no significant relationship between school number and activity.

And there was also no significant difference inside each number of fish, and also on different dates and times and activity .

Table 8 : Activity of [illegible] yearling minnows .

no.'s of recording / fish no.	I	2	3	4	5	6	7	8	9	IO	II	I2	I3	I4	15	16	17	18	19	20	2I	22	23	24	25
1	I	I	2	2	2	I	2	3	2	3	I	I	4	I	I	[illegible]	I	I	6	4	2	I	2	2	2
[illegible]	2	I	I	2	3	2	3	2	2	2	2	[illegible]	[illegible]	3	2	I	2	2	2	3	2	2	3	I	2
1	I	I	1	I	I	2	I	2	I	4	2	I	2	2	I	1	1	I	2	2	2	2	2	2	2
1	2	I	1	1	1	I	I	I	I	2	2	I	2	1	1	I	2	2	I	2	3	3	2	1	1
1	3	2	I	2	I	I	2	I	I	1	1	2	1	1	I	2	2	2	I	3	3	2	3	2	2
2	I	I	I	2	I	1	1	1	2	2	2	1	1	2	2	2	1	2	I	2	I	I	I	I	I
2	2	3	3	3	2	2	3	2	I	I	1	1	1	I	2	I	I	I	2	1	1	2	3	I	2
2	I	2	2	2	3	2	2	2	I	2	I	2	2	3	3	2	I	2	2	2	2	2	2	3	3
2	1	3	I	I	I	2	I	I	2	2	4	2	3	2	I	2	2	I	2	I	I	2	2	2	2
2	I	2	I	2	2	1	1	I	2	I	I	I	1	2	I	I	3	3	2	3	I	I	I	I	I
3	2	2	I	I	I	I	2	2	I	2	3	I	3	2	2	2	2	2	5	7	2	3	2	3	I
3	2	4	3	2	3	5	4	5	2	3	6	3	3	4	5	5	2	2	I	I	2	2	2	2	2
3	I	I	3	I	2	I	2	2	2	1	2	2	2	3	3	I	2	4	4	5	2	3	I	2	2
4	I	I	I	2	2	I	I	2	2	I	4	3	2	2	I	I	2	3	2	2	I	I	I	I	1
4	1	2	I	I	4	2	I	2	4	I	2	2	3	2	2	2	3	I	I	I	I	2	2	3	I
4	2	2	3	5	I	5	3	5	I	4	3	2	4	3	I	4	3	2	I	3	3	3	I	I	I
6	5	4	5	5	4	2	2	2	2	2	4	4	4	4	I	I	2	2	I	2	2	3	I	2	2
6	I	2	I	4	I	2	3	4	3	2	2	I	2	I	2	I	I	I	I	2	I	2	2	2	3
6	3	3	2	3	2	I	I	I	I	3	I	3	2	2	3	3	2	I	I	3	I	4	2	I	I
3	2	3	2	I	I	2	4	3	I	I	2	3	I	I	I	3	2	2	2	I	[illegible]	2	I	1	1
3	3	6	2	2	I	2	2	5	2	3	I	3	I	2	I	6	3	6	2	2	I	2	I	1	I
8	4	4	3	4	I	3	I	3	2	4	4	5	5	I	3	2	2	3	2	4	I	2	I	I	I
IO	4	3	4	6	3	4	4	3	2	I	2	3	4	3	3	5	5	1	4	1	7	3	2	2	4
10	2	I	2	3	2	1	3	5	3	6	I	2	2	3	2	1	I	4	2	2	4	3	2	4	I
IO	8	3	3	4	4	I	3	3	1	2	2	7	3	4	3	I	3	2	3	2	1	I	2	3	2
I6	4	3	2	6	1	2	4	4	2	2	3	2	I	3	2	I	2	2	2	3	2	I	3	3	8
I6	2	2	2	1	2	3	2	1	I	3	4	I	6	3	3	I	2	2	3	2	3	3	2	2	I
16	3	3	5	3	3	5	5	5	6	3	3	3	5	3	[illegible]	7	3	6	4	3	4	3	5	5	6
32	2	2	2	3	2	4	I	3	3	2	4	2	3	3	2	2	3	2	I	4	3	3	2	2	1
32	2	3	3	I	1	1	2	6	2	3	6	6	I	5	2	3	5	2	2	5	5	2	3	2	3
32	I	2	2	3	2	3	2	I	I	I	2	2	3	I	I	I	3	2	2	3	3	5	6	2	2

continued on next page

Cont. table 8 :

Variables / fish no.	mean	var.	S.D.	S.E.	Date	Time
1	2.1	1.6	1.3	0.3	24.7.86	15.26
I	2.0	0.4	0.6	0.I	28.7.86	15.08
1	1.6	0.5	0.7	0.I	29.7.86	9.28
1	1.5	0.4	0.6	0.I	30.7.86	9.2I
1	1.7	0.5	0.7	0.1	30.7.86	11.07
2	I.4	0.3	0.6	0.1	20.7.86	10.00
2	1.7	0.6	0.8	0.2	20.7.86	10.20
2	2.0	0.4	0.6	0.I	20.7.86	10.35
2	I.8	0.6	0.8	0.2	30.7.86	9.47
2	I.5	0.5	0.7	0.I	30.7.86	II.36
3	2.2	I.8	1.3	0.3	24.7.86	I2.10
3	3.0	I.8	I.4	0.3	28.7.86	I6.25
3	2.2	I.I	I.0	0.2	29.7.86	I2.I0
4	I.6	0.6	0.8	0.2	24.7.86	16.48
4	I.9	0.8	0.9	0.2	25.7.86	I5.27
4	2.6	1.8	I.3	0.3	29.7.86	11.15
6	2.7	I.7	1.3	0.3	24.7.86	16.15
6	I.9	0.9	0.9	0.2	28.7.86	I5.30
6	2.0	0.9	0.9	0.2	30.7.86	10.25
8	I.8	0.7	0.9	0.2	24.7.86	I4.40
8	2.4	2.6	I.6	0.3	25.7.86	I6.27
8	2.6	I.8	I.3	0.3	29.7.86	I0.08
10	3.4	2.I	I.4	0.3	24.7.86	11.10
10	2.5	I.7	I.3	0.3	25.7.86	I2.27
10	2.8	2.8	1.7	0.3	28.7.86	I2.I2
I6	2.7	2.5	I.6	0.3	24.7.86	9.24
I6	2.3	I.2	I.I	0.2	25.7.86	I0.30
I6	4.I	I.8	I.4	0.3	28.7.86	II.28
32	2.4	0.8	0.9	0.2	24.7.86	I0.0I
32	3.0	2.7	I.6	0.3	25.7.86	9.26
32	2.2	I.5	I.2	0.2	25.7.86	II.I9

Table 9 : Calculations of the activity of Ist yearling minnows .

Variables / fish number	no. of replicates	mean	variance	Standard deviation.	Standard error	number
I	5	I.8	0.7	0.8	0.I0	25
2	5	I.7	0.5	0.7	0.I3	25
3	3	2.5	I.6	I.2	0.24	25
4	3	2.I	2.0	I.0	0.20	25
6	3	2.2	I.2	I.I	0.2I	25
8	3	2.3	I.7	I.3	0.25	25
I0	3	2.9	2.2	I.5	0.29	25
I6	3	3.0	I.8	I.3	0.26	25
32	3	2.6	I.6	I.2	0.25	25

Figure 2 : Histogram showing the activity of 1st yearling minnows .

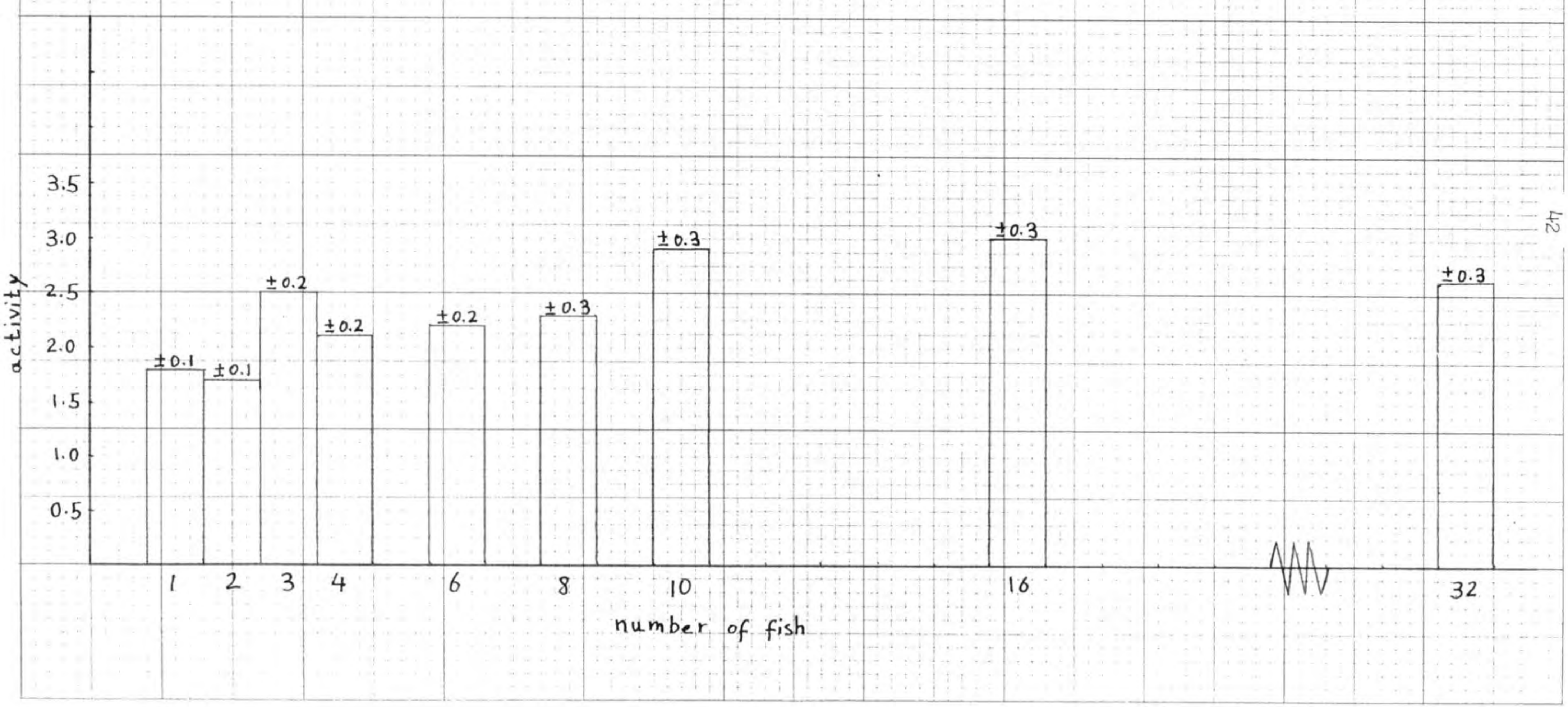
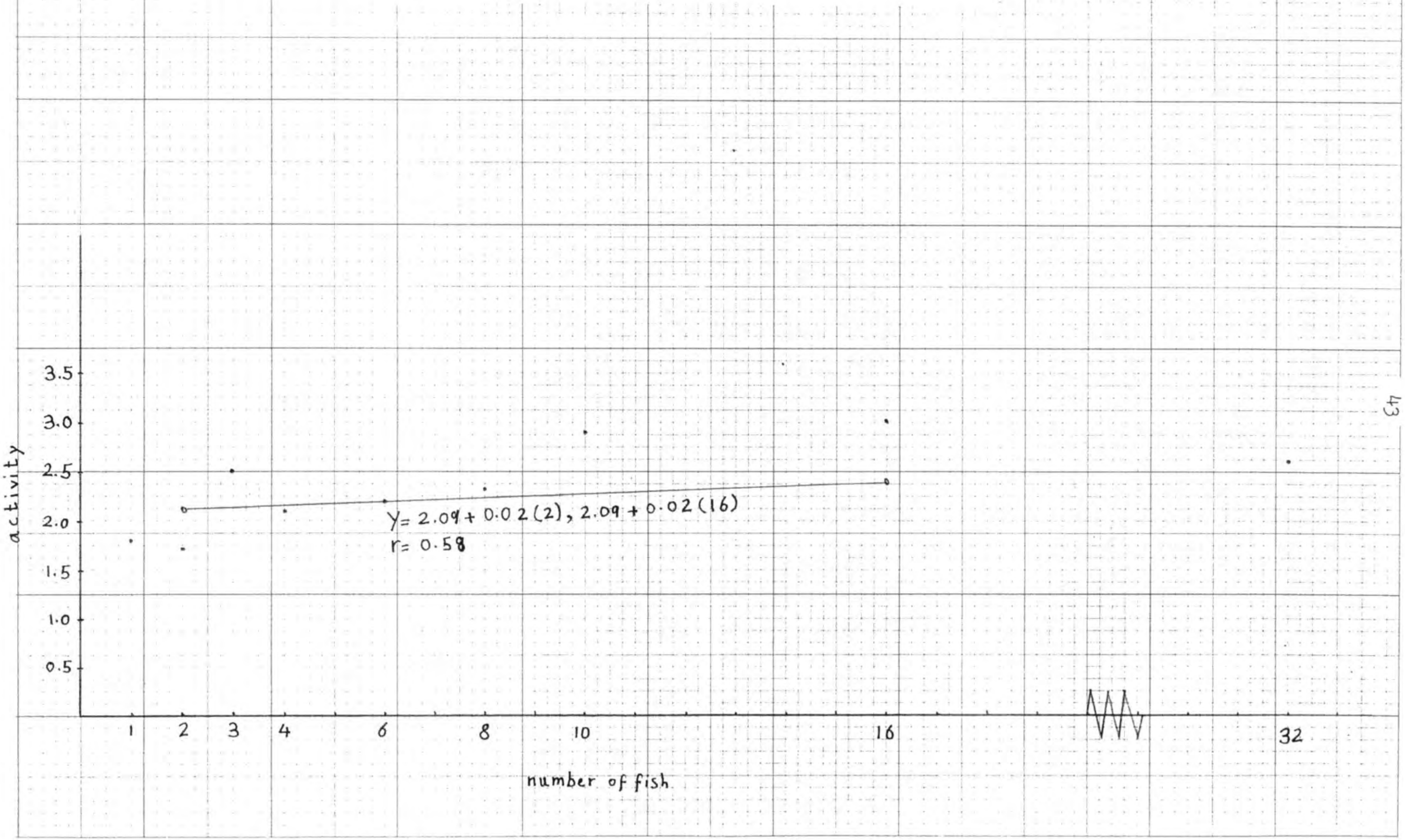


Figure 9 : Correlation graph of 1st yearling minnows .



3.6 The difference in schooling activity between Sumatra Barbs and minnows.

From the results obtained in sections 3.3, 3.4 and 3.5 it is very obvious that Sumatra Barbs are much more active than minnows. And they are more organised schoolers than the two sizes of minnows, which are not as regular and active schoolers.

By using the student's t test it was noticed that the difference in activity between Sumatra Barbs and minnows (size 2.3 - 2.9 cm) was significant at P = 0.01, and between Sumatra Barbs and minnows (size 1.0 - 1.2 cm) was also significant at P = 0.01. So the calculations confirms the very obvious andclear difference in schooling activity in both species.

In table IO and figure IO we can see a comparison between Sumatra barbs and 2nd year minnows , as they are the comparable sizes for the study .

Table IO : Calculations for the difference in activity between Sumatra barbs and 2nd year minnows .

Variables / fish no.	$m_1 \pm$ s.e.	$m_2 \pm$ s.e.	Dif.	S.E. of dif.	t	P
I	3.7 ± 0.45	I.4 ± 0.08	2.3	0.45	5.04	s.
2	5.2 ± 0.82	2.2 ± 0.I9	3.0	0.82	3.65	s.
3	5.8 ± 0.72	I.9 ± 0.22	3.9	0.75	5.20	s.
4	9.3 ± I.I2	2.6 ± 0.26	6.7	I.I4	5.87	s.
6	8.7 ± I.I4	2.6 ± 0.3I	6.I	I.I8	5.I6	s.
8	9.4 ± 0.96	2.8 ± 0.23	6.6	0.97	6.79	s.
IO	I3.3 ± I.IO	3.6 ± 0.35	9.7	I.I6	8.36	s.
I6	I5.I ± 0.33	3.7 ± 0.28	II.4	0.87	I3.0I	s.

S.: significant.

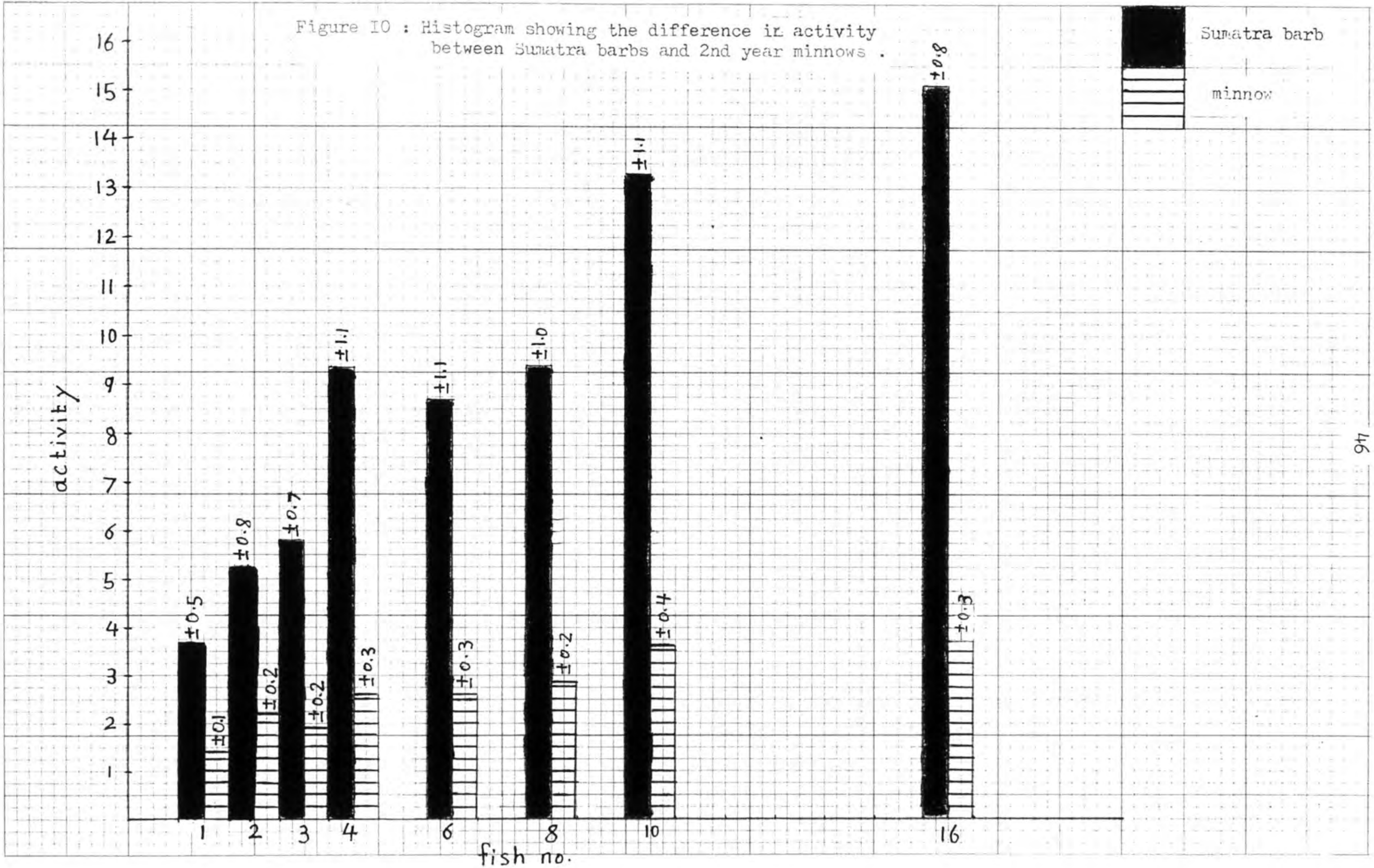


Figure 10 : Histogram showing the difference in activity between Sumatra barbs and 2nd year minnows .

3.7 The difference in schooling activity between the two sizes of minnows.

Both size of minnows, the 2nd yearling (2.3 - 2.9 cm) and the 1st yearling (1.0 - 1.2 cm) were schooling, but as mentioned in sections 3.4 and 3.5, the schooling of the first size was significant, while the second size was not.

By using the student's t test, it was calculated that there was no significant difference between the two sizes in schooling activity by comparing the different fish number. So different sizes did not play a significant role in the same species.

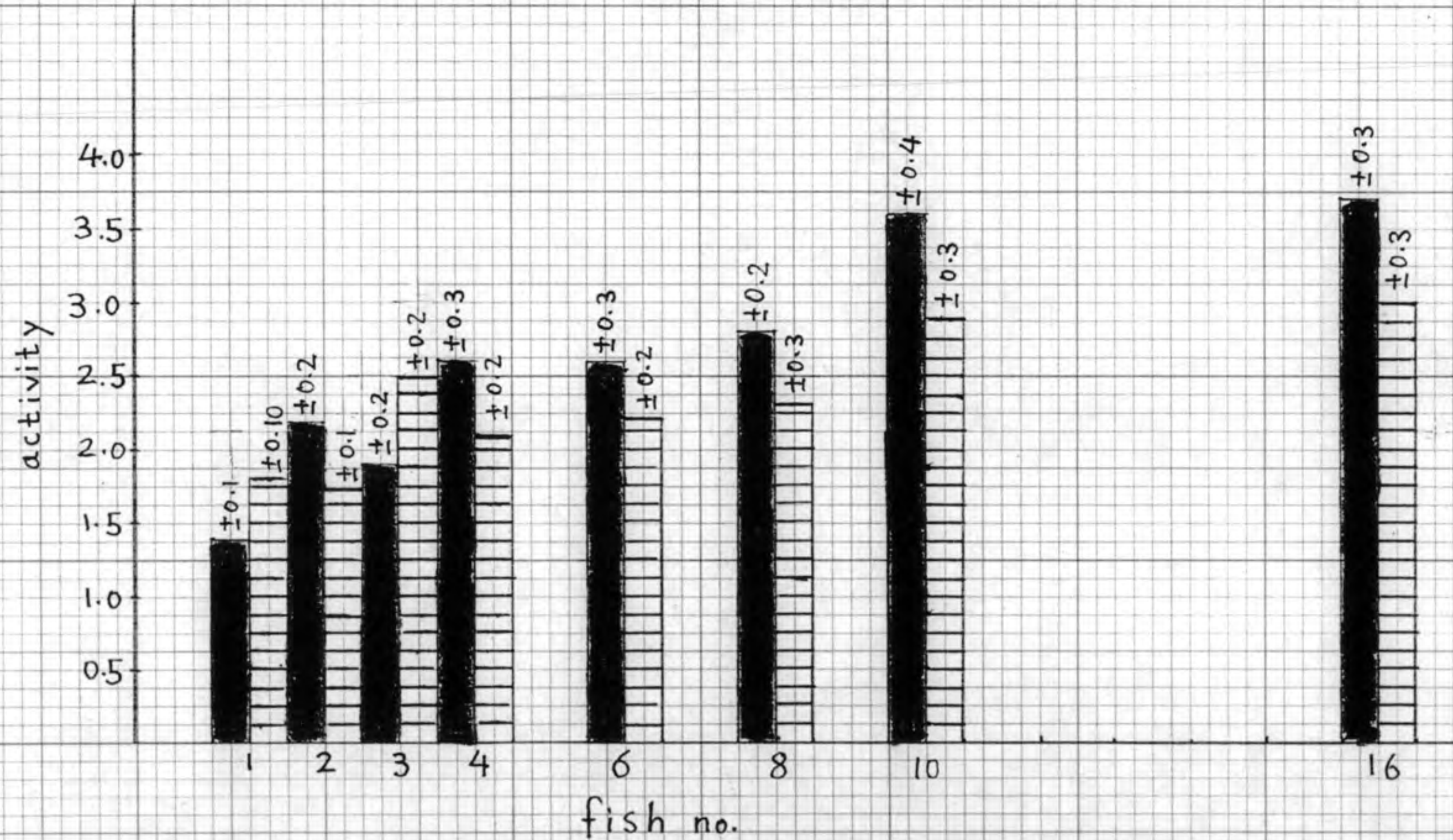
From table II and figure II we can see that the significance between the two sizes was only significant in fish number I and 2 . And as we know these numbers are not a school ; as a school begins with 3 individuals , as mentioned in the Preface (section I.I) .

Table II : Calculations for the difference in activity between the two sizes of minnows .

variables / fish no.	$m_1 \pm$ s.e.	$m_2 \pm$ s.e.	Dif.	S.E. of dif.	t	P
I	I.4 ± 0.08	I.8 ± 0.I0	0.4	0.I2	3.I2	s.
2	2.2 ± 0.I9	I.7 ± 0.I3	0.5	0.23	2.I7	s.
3	I.9 ± 0.22	2.5 ± 0.24	0.6	0.32	I.87	n.s.
4	2.6 ± 0.26	2.I ± 0.20	0.5	0.32	I.52	n.s.
6	2.6 ± 0.3I	2.2 ± 0.2I	0.4	0.37	I.08	n.s.
8	2.8 ± 0.23	2.3 ± 0.25	0.5	0.33	I.47	n.s.
I0	3.6 ± 0.35	2.9 ± 0.29	0.7	0.45	I.55	n.s.
I6	3.7 ± 0.28	3.0 ± 0.26	0.7	0.38	I.84	n.s.

S. : Significant
n.S. : not Significant.

Figure II : Histogram showing the difference in activity between the two sizes of minnows .



4 DISCUSSION

4.1 Schooling activity in Sumatra Barbs.

The study has shown that Sumatra Barbs are freshwater schooling fishes. They are an aquarium type, which are very active when they form in schools. It was observed very clearly that activity has increased when fish school number increases. The difference between the different numbers are highly significant. This was a behavioural matter in the species. There was a significant difference inside each group number of fish; this was attributed to the individualistic difference in the species, simply some fish are more active than others. There was no obvious relation between dates and time of the day and activity, as the Barbs were active on difference occasions, with no definite pattern.

4.2 Schooling activity in Minnows.

The study has shown that minnows are freshwater schooling fishes, living in the rivers, which are active by forming schools. There was two sizes of minnows in the study: 2nd yearling (size 2.3 - 2.9 cm) and 1st yearling (1.0 - 1.2 cm). Both of them were schooling. There was a significant relationship between school number and activity in 2nd yearling as fish number increased activity increased. While in the 1st yearling this relationship was not significant, so increased number of fry minnows did not increase its activity significantly. It was observed in minnows especially in the 2nd yearling that their activity had dropped in the later days of the experiment, they schooled less frequently, swimming more slowly and being solitary most of the time. This was attributed probably to the change of the environment from an open river to a closed aquarium, which led to a change in temperature, light periods, water quality and the change of food, all these are dealt with detail in part 4.4. Time of the day did not play a significant role in increased activity. And it was observed that some individuals were more active than others, and they initiated more movement. There was no significant difference between the two sizes in their activity if compared.

4.3 The difference in schooling activity between Sumatra Barbs and Minnows.

This study showed that there was a very obvious and signifigant difference in schooling activity between the two species. The Sumatra Barbs are much more active and organised than the minnows. And this is attributed because of the species differences as a whole.

4.4 Problems related to the study.

One of the serious problems faced in this study was catching the minnows in the first place. I was delayed for a long time simply because we could not find a lot of minnows on the banks of the River Wear. Fishermen told us that this was probably because of the cold summer this year, and so the fish tend to hide inside the river. 2nd yearling were difficult to find, the first one was caught on 19.5.1986, while 1st yearling were easier to find afterwards and more abundant. We caught the first fry minnows on 1.7.1986.

Keeping the fish was another problem. First when minnows were transported, extra care was taken. Small cooled transporters were used as not to give them a temperature shock. But even though many died when they reached the cold room in the Zoology Department. Sumatra Barbs had also this problem as they were transported from one aquarium to another, nearly the same temperature.

The two species suffered a lot of death. Sumatra Barbs were bought from Sunderland in two occasions, 4th June and 12th June, 1986, and the total fish was 30 individuals. At the end date of the experiment on 27.6.86 only 10 of them survived, this is a ratio of 1:3.

The case was not different in the minnows. From 19 minnows (2nd yearling) caught on two occasions (19.5 and 16.7.1986), six only survived till 24.7.1986. And in the 1st yearling also big losses have occurred.

It was noticed that if the fish were left in the experiment aquarium for long periods (several days), death occurred very rapidly. Possible explanation were suggested as follows:

1 Temperature difference: in the pet shops the temperature was 24°C for the Sumatra Barbs, while in the cold room in Durham University it was 20°C, two died in the first four days. In the case of the minnows the river temperature was about 12°C while in the cold room it was constant 15°C.

2 Light stress: light was on for 24 hours a day throughout the experiment days. This was may be an extra stress on them as both species experience day and night conditions.

3 Water quality: there is a big possibility that there was an infection of some kind in the experiment tank, as fish were dying there more often than in the two storage tanks. Methylene Blue was added to the water for sterilization, but without any success.

4 Environmental stress: the change of the environment especially for the minnows from a river to an aquarium, may be was responsible for their reduced activity in the later days of the experiment. While the Sumatra Barbs were changing one aquarium to another, like changing one home to a similar one.

5 Change of food: especially to the minnows, because naturally they feed on invertebrates and flying insects, and during the experiment they were fed on tropical fish food. But anyway most of them survived by eating it. Reduction in activity by minnow could be attributed to this factor. While for Sumatra Barbs the situation was better, as this food was their speciality.

SUMMARY

1 The aim of this work is to study the schooling behaviour of two species of freshwater fish. The Sumatra Barbs and the Minnow. And to investigate how the difference in size can affect their activity.

2 The study is important as it studies the formation of schools in schooling fish, and its importance in the fishes life.

3 The Sumatra Barbs were bought from a pet shop in Sunderland, England and Saarbrücken, Germany.

4 The minnows were caught from the River Wear, North East England from different localities: Shincliffe, Croxdale, and near Durham Cathedral.

5 The experiments were carried out in a cold room in the Zoology Department, Durham University, where the fish were kept.

6 The temperature was constant 20°C for the Sumatra Barbs and 15°C for minnows, and light was kept on for 24 hours a day, and fish were fed daily.

7 The long experiment tank (length 181.5 cm) was divided into 12 sections, 15 cm each.

8 Activity of the fish was recorded by counting how many bars does one fish cross in 30 seconds. Then another fish was chosen for the next 30 seconds.

9 Fish numbers of 1, 2, 3, 4, 6, 8, 10, and 16 were studied in Sumatra Barbs (size 4.5 - 4.8 cm) and 2nd yearling minnows (2.3 - 2.9 cm) and 1st yearling minnows (1.0 - 1.2 cm); for the last one number 32 was also studied.

10 For each number of fish a minimum of 21 and maximum of 55 recordings was recorded for each sample of Sumatra Barbs. And 25 recordings were taken for minnows.

11 For each number of fish, the sample was repeated three times for Sumatra Barbs and minimum of two and maximum of six for minnows.

12 There is a relationship between food and activity in Sumatra Barbs. As the feeding time comes, the fish are more active and swim more actively, and as the food is given a considerable increase in activity is recorded. Starved fish showed reduced activity. By calculation the difference between the two situations was not significant .

13 The settling down time for Sumatra Barbs after the disturbance of water is 20 - 25 minutes. This time is important in our study as to know when to begin to observe the fish after placing them in the aquarium.

14 There is a relationship between school number and activity in Sumatra Barbs. If we increase the number of fish, activity increased significantly. As more fish are in the aquarium, swimming activity increases.

15 There is a significant difference in some recordings within each group, and is due to individual differences.

16 As number of fish increases in 2nd yearling minnows activity increases significantly.

17 Less activity was observed in the later days of the experiment on minnows, possibly due to change of environment and change of food.

18 There was no significant relationship between school number and activity in 1st yearling minnows.

19 There was no significant difference within each number of fish in the two sizes of minnows.

20 There is a significant difference in schooling activity between Sumatra Barbs and minnows (both sizes); it was much greater in the Sumatra Barbs.

21 There is no significant difference in schooling activity between the two sizes of minnows.

22 Minnows were not caught easily in the River Wear, and 1st yearlings were most abundant.

23 A lot of fish died, possible reasons:

(1) temperature difference

(2) light stress

(3) infection in the water

(4) environmental stress

(5) food change.

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