Animal Behaviour: Biology 3401
Laboratory 4: Schooling behaviour in fish

Introduction:

Animals show a variety of dispersion patterns in their natural environment. Some species tend to be solitary and individuals are dispersed more or less at random in their habitat. Other species may form cohesive groups such as fish schools, bird flocks, ungulate herds, insect swarms, primate troops, and so forth.

Animal groups can be divided into two general categories:

(a) groups formed by the tendency of animals to be attracted to the same external stimuli (e.g. the attraction of certain animals to light, food, water, heat, etc.). These groups are called aggregations and are not, strictly speaking, true social groups.

(b) groups formed by the positive social responses (mutual attraction) of animals to each other. These are social groups.

In this laboratory exercise we will be concerned mainly with social groups, and we will use as an example the schooling behaviour of fishes. Although there is no single definition of a school that is acceptable to all students of fish behaviour, most would agree that a school is a group of fish showing mutual social attraction. Fish swimming together in a school exhibit a conspicuous form of social organization. Typically, all individuals in a school are of the same species and of relatively uniform size, there is no one "leader", and all of the fish are usually engaged in the same activity at the same time.

The structure and cohesiveness of fish school varies among species. We can distinguish species that swim together in close parallel orientation to each other as polarized schoolers and those not showing parallel orientation as nonpolarized schoolers. Of course, there are gradations in the degree of polarization, and some species may switch from one mode of orientation to the other with changes in light intensity, time of day, hunger, or the sudden appearance of a potential predator (see Figure 1). We can also distinguish species that can be forced to stop schooling only with great difficulty (obligate schoolers) from those in which schooling is not so clearly defined and appears as a result of some environmental change; e.g. presence of a predator (facultative schoolers). Obligate schoolers usually show polarized orientation.

Schooling behaviour occurs in freshwater fishes as well as marine ones, and in predators as well as in omnivorous and herbivorous fishes. In general, it is more common in bony fishes (teleosts) than in cartilaginous fishes (elasmobranchs), such as sharks and rays. Schools may contain only a few (3-10) individuals or range up into the millions (e.g. herring, anchovy).

This laboratory exercise concerns the study of fish schooling behaviour and it is divided into two parts:

(1) determine if a test fish will school more strongly with its own species (conspecifics) than with another species of similar body size (heterospecifics).

(2) determine if a test fish will school more strongly with a large group of conspecifics than with a few conspecifics.

The laboratory exercise:

Materials
Per pair of students
- dipnet
- stopwatch of some sort
- aquarium with two 500 ml jars
- appropriate numbers of neon tetras (*Cheirodon innesi*) and of glow light tetras (*Hemigrammus erythrozonus*) from separate stock tanks.

PART A: Species affinity

Purpose:

(1). Determine the tendency of a test fish to school with conspecifics and with another species (heterospecifics) when given a choice.

Methods:

(1). The aquarium has been divided by vertical lines into three equal sections (A,B,C) as shown in the figure below. Fill each 500 ml jar with aged water from your own aquarium and aerate the water with an air stone. Take the jars to the holding tanks and gently net 4 neon tetras for one of the jars and 4 glow light tetras for the other jar. Place the two jars at opposite ends of the aquarium (sections A and C). The fish may be "disturbed" from the transfer, so allow a few minutes for recovery.

(2). Now net 1 neon tetra (the "test fish") from the holding tank and release it in the centre of the aquarium (section B) and again allow a few minutes for the fish to begin swimming normally.

(3). After the above recovery period, record the position of the test fish in the aquarium (section A, B or C) at 30 second intervals for 15 minutes. This will yield 2 x 15 = 30 observations. This method of recording is called Instantaneous or Scan Sampling and it provides a measure of behavioural tendencies or states (in this case, schooling tendency). To do this, check off the position of the test fish on Table 1 (in the "Fish 1" column) and add up each column after 15 minutes.

(4). During the test period, take notes on apparent interactions between the test fish and the fish in the two jars. For example, does the test fish swim close to a jar, closely following the movements of a fish inside? Does it turn and quickly swim back to a jar after moving a short distance away? Does sudden activity by the fish in a jar appear to stimulate the test fish to swim towards them?

(5). At the end of the 15 min observation period, return the test fish to its holding tank. Be careful not to mix the species in the holding tanks.

(6). Now reverse the positions of the jars and net a second individual of the same species as the test fish. Place this fish in the centre of the aquarium. Allow it to recover and repeat steps #3 to 5. Record your data in Table 1 again ("Fish 2" column). Calculate the mean number of observations for the two test fish at the bottom of Table 1 for each of the 3 aquarium sections. Express these mean numbers as the percentage (%) of time (out of 15 min.) spent by the test fish in each of the 3 aquarium sections.

(7). Repeat steps #2 to 6 with a test fish of the second species (glow light tetra). Record in a similar manner your data in Table 2.

(8). Enter mean percentage values from Tables 1 and 2 into another table for class data which will be provided. Prepare a histogram, showing means and standard error, of the results **using the class data**. Using the X^2 test, determine (i) for each fish species separately whether the time spent by the fish in the three tank compartments deviate significantly from a random distribution, and (ii) whether the time distribution pattern for each species deviate significantly from one another. Convert your mean percentages of time into minutes for calculations of your X^2 values. **See the end of this handout for more information on statistics.**

PART B: Effect of group size on affinity for conspecifics

Purpose:

(1). Determine the tendency of a test fish to school with two separate groups of conspecifics, which differ in numbers, when given a choice.

Methods:

(1). Place 2 neon tetras in one jar and 6 neon tetras in the other at opposite ends of the aquarium (see diagram below). Obtain 1 neon tetra test fish from the holding tank and gently place it in the centre of the aquarium. Allow it time to recover from the transfer.

(2). Record the position of this test fish every 30 seconds for 15 minutes as in the PART A tests. Record your data in Table 3 (in "Fish 1" column).

(3). At the end of this first 15 min. observation period, reverse the position of the jars. Return the first test fish to the neon tetra holding tank.

(4). Repeat steps #1 and 2 with a second neon tetra test fish netted from the holding tank.

(5). Return all fish to their holding tank at the end of the second test period.

(6). Calculate the mean numbers of observations per aquarium section for the two test fish as done previously. Express these mean numbers as the percentage of time (out of 15 min.) spent by the test fish in each of the 3 aquarium sections.

(7). Enter your mean percentage values from Table 3 into another table for class data which will be provided. Prepare a histogram, showing means and standard error, of the results **using the class data**. Using a X^2 test, determine whether the time spent by the fish in the three tank compartments deviate significantly from a random distribution.

Questions for consideration:

(a) Why is it good experimental procedure to reverse the position of the jars before repeating a test?

(b) What possible sensory modalities might be involved in maintaining school structure in nature? Which ones have been eliminated in this study?

(c) What are some benefits to individual fish from schooling with others? Can you think of any potential disadvantages (costs)?

(d) Discuss the ecological advantages of schooling with conspecifics (species affinity) and in large groups.

References:

Godin, J.-G.J. 1986. Antipredator function of shoaling in teleost fishes: a selective review. Naturaliste can. (Rev. Ecol. syst.), 113: 241-250.

Keenleyside, M.H.A. 1955. Some aspects of the schooling behaviour of fish. Behaviour, 8: 182-248. Partridge, B.L. 1982. The structure and function of fish schools. Sci. Amer., 246(6): 114-123.

THE TABLES ON THE FOLLOWING PAGES ARE TO RECORD YOUR DATA.

TABLE 1 - USE FOR THE FIRST SPECIES (Neon Tetras)

TABLE 2 - USE FOR THE SECOND SPECIES (Glowlight Tetras)

TABLE 3 - USE FOR AN ISOLATED FISH

TABLE 1 – Species choice with the Neon Tetras

Time Interval (Min.)	AQUARIUM SECTION WITH:					
	CONSPECIFICS		NO FISH		HETEROSPECIFICS	
	FISH 1	FISH 2	FISH 1	FISH 2	FISH 1	FISH 2
0.5						
1.5						
2.0						
2.5						
3.0						
3.5						
4.0						
4.5						
5.0						
5.5						
6.0						
6.5						
7.0						
7.5						
8.0						
8.5						
9.0						
9.5						
10.0						
10.5						
11.0						
11.5						
12.0						
12.5						
13.0						
13.5						
14.0						
14.5						
15.0						
Total obs						
Mean of Fish 1 & 2						

TABLE 2: Species choice with the Glowlight Tetras

Time Interval (Min.)	AQUARIUM SECTION WITH:					
	CONSPECIFICS		NO FISH		HETEROSPECIFICS	
	FISH 1	FISH 2	FISH 1	FISH 2	FISH 1	FISH 2
0.5						
1.5						
2.0						
2.5						
3.0						
3.5						
4.0						
4.5						
5.0						
5.5						
6.0						
6.5						
7.0						
7.5						
8.0						
8.5						
9.0						
9.5						
10.0						
10.5						
11.0						
11.5						
12.0						
12.5						
13.0						
13.5						
14.0						
14.5						
15.0						
Total obs						
Mean of Fish 1 & 2						

TABLE 3: Effect of school size with Neon Tetras

Time Interval (Min.)	AQUARIUM SECTION WITH:					
	2 FISH		NO FISH		6 FISH	
	FISH 1	FISH 2	FISH 1	FISH 2	FISH 1	FISH 2
0.5						
1.5						
2.0						
2.5						
3.0						
3.5						
4.0						
4.5						
5.0						
5.5						
6.0						
6.5						
7.0						
7.5						
8.0						
8.5						
9.0						
9.5						
10.0						
10.5						
11.0						
11.5						
12.0						
12.5						
13.0						
13.5						
14.0						
14.5						
15.0						
Total obs						
Mean of Fish 1 & 2						

Assignment:

Write a formal results section and answer the 'Questions for Consideration' in a question and answer format. Please back up the answers to your questions with some references.

In the results section you should have analyzed your data using the X^2 statistical test. Present your data in text as well as visually using graphs.

Stats.

You will be using X^2 to test for significance. Do this by assuming that your expected values are 10, 10 and 10 as 30 minutes is your max time. You are working with 2 degrees of freedom and anything equal to or less than 0.05 is significant.

$X^2 = \Sigma \text{ (observed-expected)}^2/\text{expected}$

Further instructions and/or questions about the stats will be addressed during lab.