

Optoelectronic device, a useful tool to record surfacing behaviour in air-breathing fishes

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An optoelectronic digital system was designed to record the frequency of surfacing in Indian catfishes, *Clarias batrachus* and *Heteropneustes fossilis*. The system uses a single infrared (IR) beam generated by a transmitter (Tx). The interruption of the beam is recorded by an IR receiver (Rx) that relays signals to a 4-digit electronic counter. Thus, the frequency of surfacing over a specified time scale is expressed in number of interruptions per unit time. The efficiency of the system is tested. This system can be slightly modified to monitor swimming activity, accesses to food, emergence from an artificial burrow, phototactic behaviour and other behavioural activities of various fish species.

MANY fish species exhibit air-breathing behaviour. The habit of air breathing is often referred to as air-gulping activity or surfacing activity or simply surfacing behaviour and is characterized sequentially by a fast upward movement, a quick air gulping at the water-air interface and an equally swift descent. The rate of surfacing has been chosen as an important parameter to analyse the effects of a number of natural and experimentally-simulated factors^{1,2}. A survey of the literature reveals that the frequency of surfacing has been recorded either by visual observation^{3,4} or by using ichthyometer⁵, paddle apparatus⁶⁻⁸, photocell⁹⁻¹², ultrasonic telemetry^{13,14}, electronic channel recorder^{15,16} and radiotelemetry¹⁷. However, each one of the above techniques has some demerits in terms of accuracy or reliability and/or cost effectiveness. We present here a low-cost, reliable, optoelectronic, digital monitoring system that uses IR transmitter (Tx) and receiver (Rx) to enumerate the frequency of surfacing or air-gulping activity.

The principal objective of this device is to get rid of all kinds of shortcomings attributed to the method of visual observation practised in ethological studies. Usually visual observation of surfacing in air-breathing fishes or of any other behavioural events in a given animal species is time-consuming, tedious and subjective.

Secondly, the aim of this device that employs the principle of IR beam interruptions is to effectively monitor swimming activity, accesses to food/food source, emergence from an artificial/natural burrow, phototactic behaviour, eclosion and many other behav-

ioural activities in a number of aquatic and terrestrial species of animals.

Thirdly, this device has been designed with an objective to use it in class room exercise in the domain of ethology, respiratory physiology and fish physiology.

Specific glass aquaria with narrow mouth at the top were designed (Figure 1a). The area available for surfacing was further reduced by putting removable packing materials in two sides of the mouth (Figure 1b).

A single beam was placed at the mouth of the aquarium about 2–3 mm below the level of the water. The IR sensors [Tx and Rx; Electronic Switches (I) Pvt. Ltd., Nashik or any other locally-made compatible type (Pandeyatronics, Raipur)] were fixed by a pair of adjustable holders. The beam alignment was achieved with the help of indicators (LEDs) located at the rear end of the sensors and also in the front panel of the 4-digit counter [Electronic Switches (I) Pvt. Ltd., Nashik or any other locally-made compatible type (Pandeyatronics, Raipur)]. The scheme of the optoelectronic device and the complete assembly are shown in Figure 2a, b. Figures 3–5 depict block diagrams of the circuitry of various components of the device.

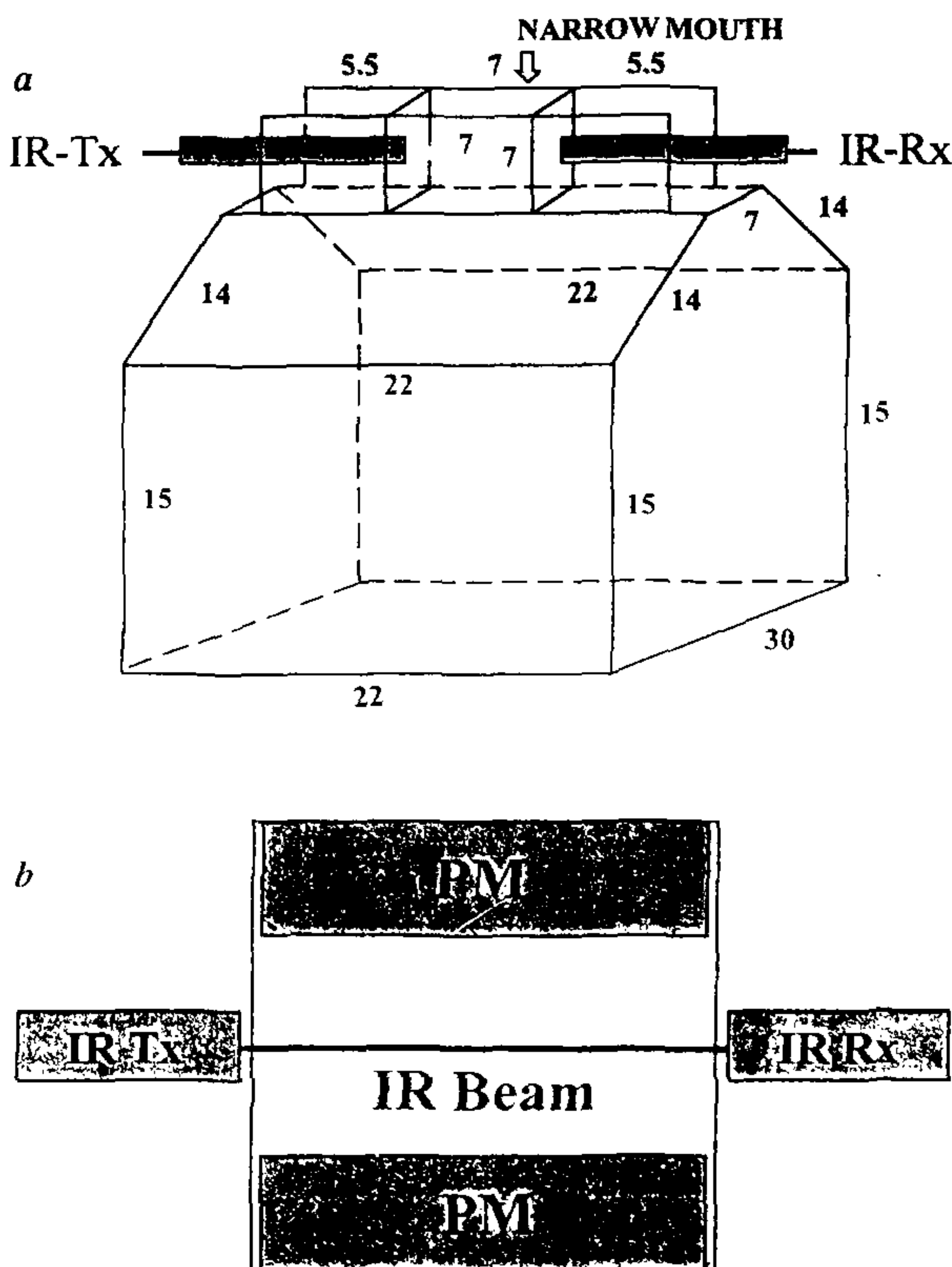


Figure 1. a, The specially-designed aquarium with a narrow mouth (7 × 7 cm). b, Top view of the mouth. IR Tx, IR transmitter or emitter; IR Rx, IR receiver or detector; PM, Packing material. Packing material has been used to reduce the area available for surfacing. This increases the sensitivity of IR sensors for detection.

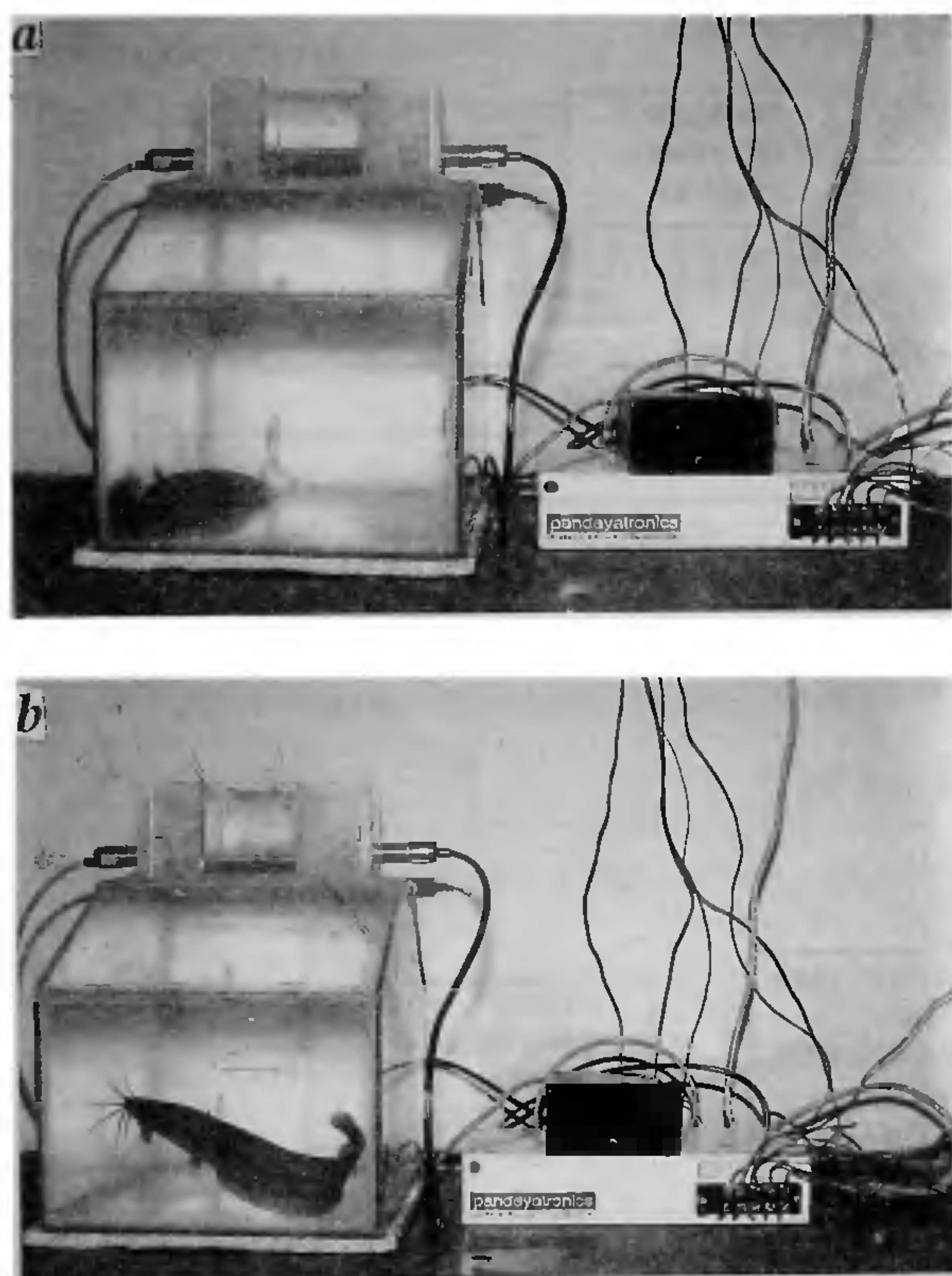


Figure 2. *a*, Complete assembly of the device showing IR transmitter (sensor positioned in the top of the aquarium in the left), IR receiver (sensor positioned in the top of the aquarium in the right), amplifier (white rectangular box in the right side below), 4-digit counter (black box above the amplifier), and a resting fish inside the aquarium; *b*, Same as above showing position of a fish prior to a surfacing bout.

Live specimens of Indian catfishes, *Clarias batrachus* and *Heteropneustes fossilis* in the range of 60–80 g body weight were used separately. The fishes were procured locally and were kept in large stock aquaria for about a week for proper laboratory acclimatization. Each fish was introduced individually in the specially-designed aquarium with stagnant water conditions at least 2–3 days prior to beginning of the study. The surfacing frequency was recorded by counting the number of times the beam was disrupted when fish surfaced for air-gulping. It is advisable to use aerators to ensure 100% oxygen saturation in the water inside the aquarium. It is also important to maintain the fish under fixed photoperiod, temperature and feeding schedules.

The efficiency of the system was determined by counting the number of nondetection and bouncing for each set of 50 counts in the display panel of the digital counter (Table 1). Nondetection is defined as a valid but stealth air-gulping without addition of the event in the counter. A single interruption by a sudden and speedy

Table 1. Cumulative data on number of detection, nondetection and bouncing shown in blocks of 50 detections of surfacing by *Clarias batrachus* and *Heteropneustes fossilis*

| Cumulative detection (CD) | Nondetection (ND) | ND (as % CD) ^a | Bouncing (B) | B (as % CD) ^b | ND + B | ND + B (as % CD) ^c |
|---------------------------|-------------------|---------------------------|--------------|--------------------------|--------|-------------------------------|
| 50 | 3 | 6.0 | 0 | 0 | 3 | 6.0 |
| 100 | 7 | 7.0 | 2 | 2.0 | 9 | 9.2 |
| 150 | 9 | 6.0 | 2 | 1.3 | 11 | 7.4 |
| 200 | 10 | 5.0 | 3 | 1.5 | 13 | 6.6 |
| 250 | 12 | 4.8 | 3 | 1.2 | 15 | 6.1 |
| 300 | 14 | 4.7 | 3 | 1.0 | 17 | 5.7 |
| 350 | 17 | 4.8 | 3 | 0.9 | 20 | 5.8 |
| 400 | 20 | 5.0 | 5 | 1.3 | 25 | 6.3 |
| 450 | 24 | 5.3 | 6 | 1.3 | 30 | 6.7 |
| 500 | 26 | 5.2 | 8 | 1.6 | 34 | 6.9 |
| 550 | 27 | 4.9 | 9 | 1.7 | 36 | 6.6 |
| 600 | 29 | 4.8 | 11 | 1.9 | 40 | 6.8 |
| 650 | 32 | 4.9 | 15 | 2.4 | 47 | 7.4 |
| 700 | 36 | 5.1 | 16 | 2.3 | 52 | 7.6 |
| 750 | 41 | 5.5 | 17 | 2.3 | 58 | 7.9 |
| 800 | 46 | 5.7 | 23 | 3.0 | 69 | 8.9 |
| 850 | 50 | 5.9 | 25 | 3.0 | 75 | 9.1 |
| 900 | 54 | 6.0 | 25 | 2.8 | 79 | 9.0 |
| 950 | 58 | 6.1 | 25 | 2.7 | 83 | 9.0 |
| 1000 | 62 | 6.2 | 25 | 2.6 | 87 | 8.9 |

^aND = ND/CD × 100.

^bB = [B/(CD – B)] × 100.

^cND + B = [(ND + B)/(CD – B)] × 100.

Note: Data obtained for *C. batrachus* and *H. fossilis* was pooled, specially because it does not interfere with the process of evaluation of the efficiency of the proposed optoelectronic device. Furthermore, there was no statistically significant difference in the surfacing frequency of the two species.

air-gulping by the fish with a jerk was noticed to be recorded as two interruptions. This is termed as bouncing. The phenomenon of nondetection and bouncing was recorded for a total of 1000 interruptions (Table 1).

Prior to beginning of this study, on 15 November 1996, surfacing behaviour in *C. batrachus* and *H. fossilis* was examined and compared. There was no statistically significant difference in the surfacing frequency of the two species ($t = 0.584$; $df = 14$; $p = 0.57$). Therefore, data obtained from both species were pooled and subjected to further statistical analyses in blocks of 50 interruptions. The percentages of nondetection, bouncing and both of these together were in the order of 6.2, 2.6 and 8.9, respectively. Macroscopic examination of raw data reveals that while at least up to 350 cumulative detections, the dependent variable, 'bouncing' remained negligible and did not change at all, it becomes almost 5 and 8 times more at the levels of 700 and 1000 cumulative detections, respectively. Therefore, the data were subjected to exponential regression ($Y = ae^{bx}$) analysis and coefficients were obtained (Figure 6 and Table 2) taking into consideration cumulative detection as the

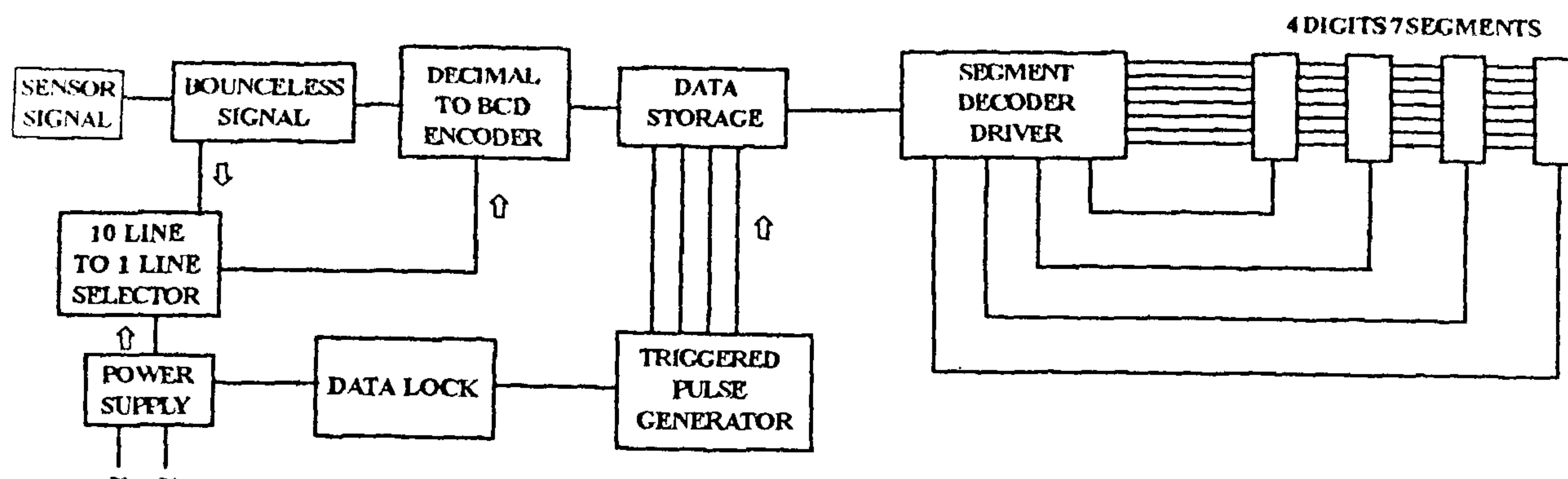


Figure 3. Block diagram of the digital counter.

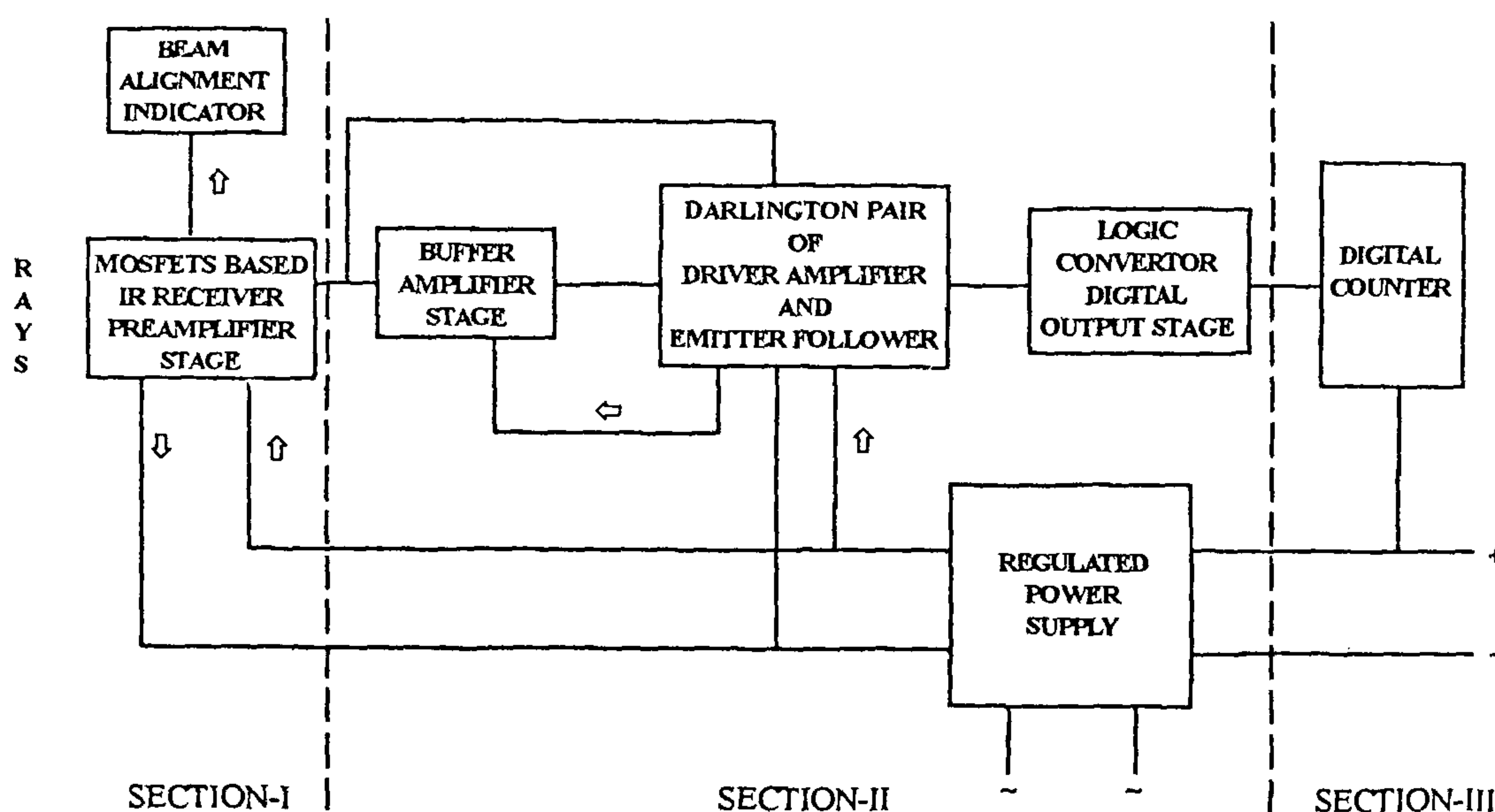


Figure 4. Block diagram of IR receiver (Section I) and amplifier (Section II). In Section III, digital counter has been shown (See Figure 3 for details).

independent variable and frequency of nondetection or bouncing or nondetection + bouncing as dependent variable. A common use of regression is the prediction of a new value (Y) of the dependent variable, given the value for the independent variable (X). In the present case, most of the data followed the predictions (Table 2 and Figure 6). Thus, when this device would be used, the outcome of any future study in terms of nondetection and bouncing would not vary randomly, rather one would have a close approximation of the expected detection both in quantity and quality. With a sensitivity of about 94%, the present optoelectronic device appears to be an excellent research tool for recording surfacing activity in Indian air-breathing fishes. We observed that

both catfishes are nocturnal and the rate of surfacing was 4–5 times higher in the dark phase as compared with the corresponding photophase¹⁸. Furthermore, the rate of surfacing per hour was never more than 50 times in both species. Within this range, the percentages of bouncing and nondetection were nil and 6, respectively. The problems of nondetection and bouncing can be solved by increasing the number of IR beams and improving upon the circuitry of the system, respectively.

The proposed system, with slight modifications, could also be used to monitor swimming activity, accesses to food, emergence from an artificial burrow, phototactic behaviour and many other behavioural activities in a number of fish species. The locomotor activity of cave

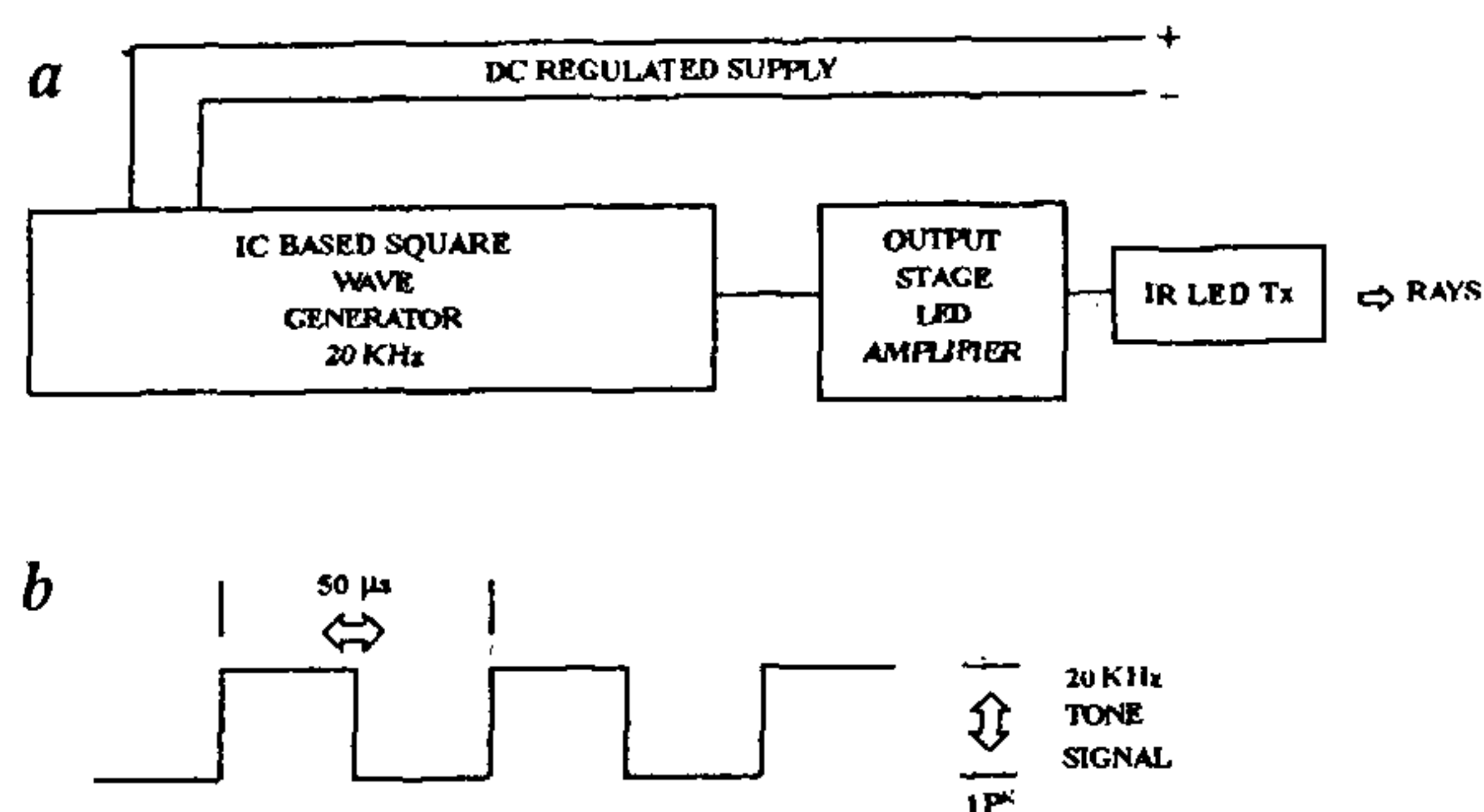


Figure 5. *a*. Block diagram of IR transmitter; *b*. Infrared beam code wave forms.

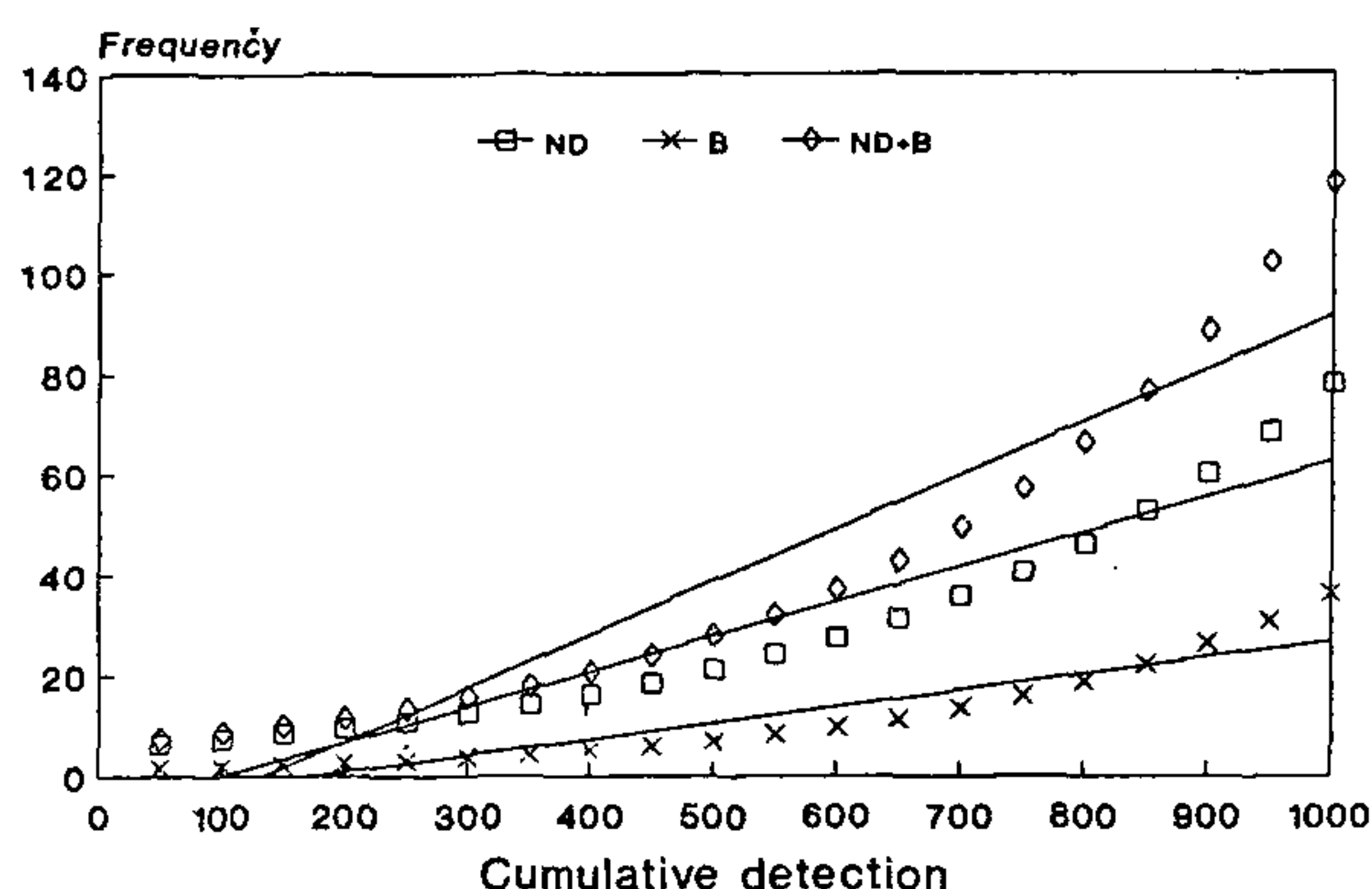


Figure 6. Prediction curves for nondetection (ND), bouncing (B) and nondetection + bouncing (ND + B) based on data shown in Table 2.

Table 2. Regression ($Y = ae^{bx}$) equations for predicting nondetection (ND), bouncing (B) and both (ND + B). Based on cumulative data (Table 1) consisting of 1000 IR beam interruptions

| Variable for prediction | Constant | Regression coefficient | R^2 | Correlation coefficient | $n-2$ |
|-------------------------|----------|------------------------|-------|-------------------------|-------|
| ND | 5.7 | 0.0026 | 0.92 | 0.988*** | 18 |
| B | 1.37 | 0.0033 | 0.96 | 0.964*** | 18 |
| ND + B | 6.51 | 0.0029 | 0.92 | 0.985*** | 18 |

R^2 = Coefficient of determination.

*** $p < 0.001$.

loach, *Nemacheilus evezardi* is also being recorded by the same system successfully. In this case the IR beam interruption signals were fed to an event recorder (Angus Electronics Co., USA). The proposed IR system could also be used for conducting a number of physiological and behavioural experiments in graduate and postgraduate laboratories of biology departments in colleges and universities.

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