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Category III

"MATHEMATICAL APPLICATIONS IN BIOLOGY"

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ABSTRACT

Nowadays experimental techniques used to investigate biological systems are generating more amounts of data. This is the reason for which researchers are turning to mathematical and computational models to understand and make quantitative predictions of data as to how biological systems will behave in different conditions. The advancement of mathematical modeling, computer equipment, and computational methods has made it possible to describe in detail systems consisting of many billion atoms, while the achievements of molecular biology have helped to acquire large amounts of data from experiments. These prerequisites laid the foundation for new scientific disciplines, such as mathematical biology, bioinformatics etc., which study the structure, operation of living systems and proceeding. The main applied tasks of these disciplines are computer-aided design of medications, nanobioelectronics, and analysis of individual genetic information. Heavy metals with its high metallic weight and density are accumulated depending on the period of exposure causing notable changes in physiology and anatomy. Jointly with toxicology, human genome mass sequencing and mathematical biology form the basis for the national development.

KEYWORDS: Mathematical biology, Computational methods, Bioaccumulation, Statistics Toxicology.

INTRODUCTION

What is biomaths or bio-math·e·mat·ics?. The definition biomathematics is the application of math to the field of biology or using mathematical principles and applications to understand biology better. Mathematical biology aims at the mathematical representation and modeling of biological processes, using techniques and tools of applied mathematics. Mathematical and Theoretical biology is a branch f biology which employs theoretical analysis, mathematical models and abstractions of the living organisms to investigate the principles that govern the structure, development and behavior of the systems, as opposed to experimental biology which deals with the facts on experimental basis. Mathematical biology is a broad topic that can cover a large range of length scales, from the submicron lengths of DNA polymers to the kilometer length scales of migration patterns of animal herds. Where Math is used: Biologists use math as they plot graphs to help them understand equations, run small "trial and error" tests with some sample numbers, developing algorithms, and use the R project (Reverse phase analysis) for analyzing protein sequences and structures Yates .A, et al. (2004) Is there math in Biology? One key role of math in biology is the creation of mathematical models. These are equations, formulas, graphs, models, tables, methods that can predict or describe natural occurrences, such as organism behavior, patterns, population changes or bioaccumulation over time. The Malthusian growth model is the grand daddy of all population models where statistics are used to count the number of individuals A.Friedman and F. Reitch (2001). Biofluid mechanics is a new branch applying fundamental ideas from fluid mechanics to understand better the biology of living systems where maths is used to measure the amounts of fluid and for preparation of fluid mixtures Avner Friedman, (2010). Biomathematics has both theoretical and practical applications in biological, biomedical and biotechnology research. Describing any systems in a quantitative manner means their behavior can be better simulated and hence properties can be predicted that might not be evident to the experimentation. This requires precise mathematical models. Mathematical biology employs many components of mathematics and has contributed to the development of new techniques Gyllenberg and M. Lewis (2018). Fast bioanalysis requires the use of short columns packed with high efficiency particles in HPLC, the use of ultra-high performance liquid chromatography (UHPLC) comes at a price of much higher pressure when sub-2 μm particles are employed for separation. In developmental biology genomics groups in ESAM are using tools from statistics, machine learning, and statistical physics to build data-driven mathematical models to address it A. Friedman and F. Reitch (2001). With advances in both chromatography and mass spectrometry, sensitivity and accuracy of a technique called LC-MS has further increased, allowing detection and identification of low-level analysis of analytics in complex sample matrices. This analytical technique has helped in quantization and identification of unknown from a variety of complex samples like human health nutritional requirements, minerals which include light and heavy metals such as copper, chromium, iron and zinc. They are non-toxic unless taken in large amounts. Other heavy metals such as mercury, arsenic, lead are toxic even at low levels. Heavy metals if accumulated in vital organs of human body such as in heart, brain, kidney, intestine and liver may create disturbances in the cell to cell communication occurring between inflammatory mediators, nerve cells or hormones. So it is pertinent to calculate the amount of heavy metals accumulated in the tissue which requires the aid of mathematics. .

CASE STUDY

Organism's growth in size is not a static matter before reproductive phase. It changes with time, food availability, toxicity and environmental resistance. Growth shows a predictable pattern represented in two growth graphs 'J' (Exponential growth) when the resources like food, space is available in plenty and 'S' type growth showing lag phase, acceleration, deceleration and finally asymptote phase which are also seen in experimental fish *Pangasianodon hypophthalamus* fish fry exposed to copper concentration of 0.25, 0.5, 1.0, 2.0, 4.0 for 96 hours shows LC50 value of 33.33, 53.63, 71.76, 80.45, 89.44 Pratima K.S (2014). The control fish showed no death and there was study growth in the fish population hence J shaped growth graph was seen. Never a population of any species in nature has at its disposal unlimited resources due to limit in resources, toxicity, different anthropological activities and competition there by maintaining a particular carrying capacity in a habitat. A sigmoid curve is seen. Using the principles of calculus, statistics and an integral form of the exponential growth an equation derived is

$$N_t = N_o e^{rt} \quad \text{Where}$$

N_t = Species density after time t;

No = Species density at time zero;

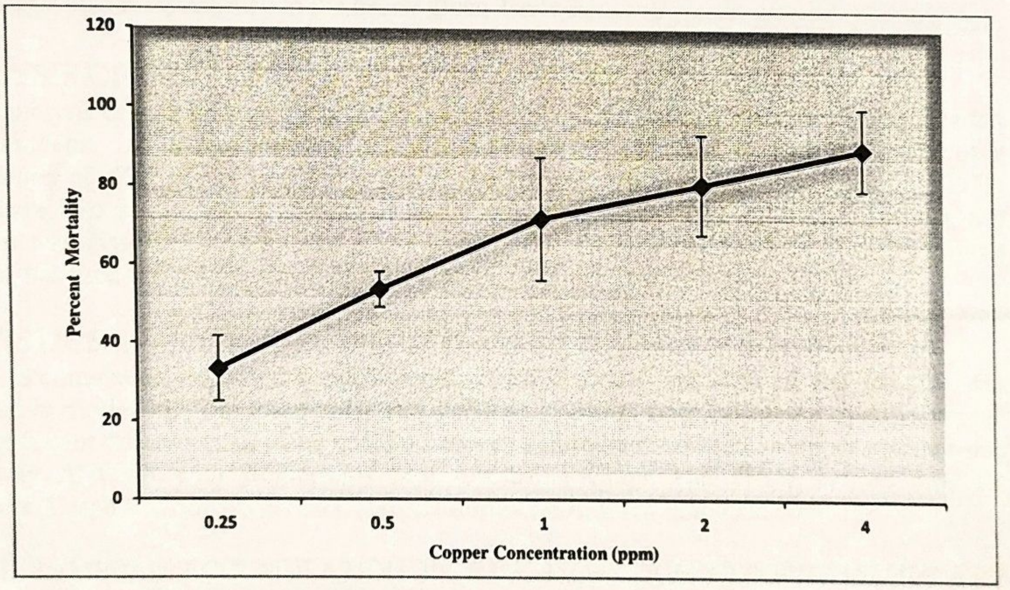
r = Intrinsic rate of natural increase

e = The base of natural logarithms

TABLE 1: TOLERANCE OF *PANGASIANODON HYPOPHTHALMUS* FRY EXPOSED TO DIFFERENT CONCENTRATIONS OF COPPER. EACH VALUE OF PERCENT MORTALITY REPRESENTS THE MEAN ± STANDARD DEVIATION OF FIVE EXPERIMENTS.

Concentration of copper (ppm)	No. of animals exposed in each experiment	Percent mortality ± Standard Deviation
0.25	20	33.33 ± 8.36
0.5	20	53.63 ± 4.52
1.0	20	71.76 ± 15.66
2.0	20	80.45 ± 12.73
4.0	20	89.44 ± 10.44

Graph: 1 THE MEAN PERCENT MORTALITY RATES OF THE FRY AFTER 96 HRS OF EXPOSURE TO DIFFERENT CONCENTRATIONS OF COPPER SHOWING A SIGMOID GROWTH.



The mean percent mortality rates of the fry after 96 hrs of exposure to different concentrations of copper are presented in Table 1. The linear regression equation obtained for log concentration of exposure and probit values of percent mortality was Y = 2.7227 + 1.3712X with correlation coefficient (r) of 0.9947 as seen in Table 2. All these calculations require different applications formulas and procedure to ultimately note the effect of copper on the fish even in minor amounts. This will help ultimately to study its effect on fish ponds and tanks where Malachit Green a copper containing chemical is used as disinfectant by local farmers in a un calculated amounts which are showing its adverse effects on fish growth, physiology and biochemical reactions reflecting on its total productivity.

TABLE 2: LC_{50} VALUE, SAFE CONCENTRATION, REGRESSION EQUATION, CORRELATION CO-EFFICIENT FOR THE FRY OF *PANGASIANODON HYPOPHTHALMUS* FRY EXPOSED TO COPPER.

Parameters	*Pangasianodon hypophthalmus*
LC_{50} (ppm)	0.4578 ± 0.03167
Safe concentration (µg/L)	4.578
Regression equation	Y = 2.7227 + 1.3712X
Correlation co-efficient	0.9947

When the fish fry were exposed to a sublethal concentration (0.0915 ppm) i.e. $1/5^{th}$ of 96 hrs LC_{50} for a period of 30 days and the experiment repeated thrice for a batch of 50 fishes, it was seen that metal accumulation increased with increase in exposure period. Graph Pad Prism combines powerful biostatistics, curve-fitting, and scientific-graphing tools in a comprehensive program. Prism meets practically the majority of the data handling necessities of lab specialists, particularly researcher and scientific experts. It doesn't just reduce project risks but also provides one source of truth throughout the entire project. So ONE WAY ANOVA was done taking the above data which is represented in the below given Table 3.

ANALYSIS OF COPPER

The analysis of metal content was carried out with the dried tissue powder of *Pangasianodon hypophthalmus*. A known quantity of the tissue powder was kept in muffle furnace at a temperature of 600^0 C for about 4-5 hrs to make into ash (George and Kureishy, 1979; Prabhakara Rao *et al.*, 1986; Uma Devi and Prabhakara Rao, 1989b, 1989c). The dry ash obtained was dissolved in a known amount of 0.01N HNO_3. The final clean and colorless solution was used for metal estimati n with ICPMH (Agilent Technologies).

STATISTICS

The accumulation experiments were repeated for 3 times and each of the samples was analyzed in triplicates. The mean value and standard deviation were calculated at each interval. The significant differences in metal content between control and exposed group was made using "One-way ANOVA with Bonferronis post test using Graph Pad Prism version 5.00 for Windows, Graph Pad Software, San Diego California USA, www.graphpad.com".

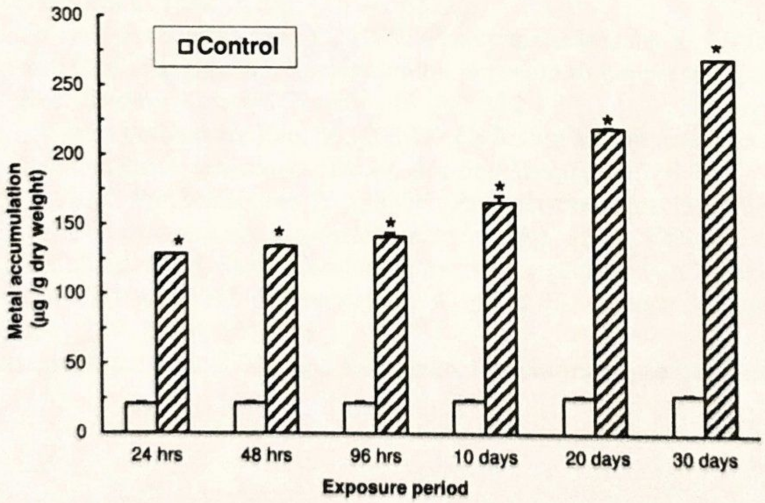
TABLE 3: METAL ACCUMULATION IN *PANGASIANODON HYPOPHTHALMUS* FRY EXPOSED TO 0.0915 PPM OF COPPER. EACH VALUE REPRESENTS THE MEAN ± STANDARD DEVIATION. THE VALUES IN THE PARENTHESES REPRESENT PERCENT DECREASE OVER THEIR RESPECTIVE CONTROLS. *SIGNIFICANTLY DIFFERENT FROM THEIR RESPECTIVE CONTROLS AT $P < 0.05$.

Groups	Exposure period					
	24 hrs	48 hrs	96 hrs	10 days	20 days	30 days
Control (µg/gm dry Wt.)	22.09 ± 2.51	22.79 ± 2.731	17.94 ± 4.19	21.33 ± 1.144	20.01 ± 2.651	20.33 ± 4.73
Exposed (µg/gm dry Wt.)	28.31 ± 2.731 (21.97)	36.56 ± 3.719* (37.66)	40.92 ± 2.316* (56.15)	43.87 ± 2.302* (51.37)	66.59 ± 5.155* (69.96)	111.2 ± 2.267* (86.76)

ONE WAY ANOVA

Source of Variation	Degrees of freedom	Sum of squares	Mean Square	F Value
Treatments (between columns)	11	24360	2215	221.9
Residuals (with in Columns)	24	239.5	9.979	
Total	35	24600		

Metal accumulation in P. hypophthalmus fry exposed to sublethal copper. Vertical lines represent standard deviation. * Signifies different from their respective controls at P< 0.05..



CONCLUSION

Mathematics has evolved by the urge of science and technology. Some of the science branches have developed due to advancements in mathematics. By using mathematics and computational model, biochemical and physiological changes can be understood better in the fish body. Without various tabloid formulations employed in the experiment it would be impossible to precisely explain what was the effect of copper on the fishes. The data obtained by experiments was very well analyzed by ONE WAY ANOVA which fully involves mathematics and graph respectively. The graphic representation helps even a lay man to understand easily the effect of copper. So it is easy to educate our literate and illiterate farmers which will help them to use calculated amounts of disinfectants in the fish ponds which reflect on our countries over all blue revolution output. By seeing the present trend in mathematical biology globally, I believe that the coming decades will demonstrate very clearly that mathematics and biology are frontiers of each other.

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