Biological Applications Of The Definite Integral

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Annotation
Mathematical models have long been very successfully used in mechanics, physics, and astronomy. In the modern period, the role of mathematical methods in natural science is increasing. They are now widely used in both biology and chemistry. Mathematical models are also successfully applied here. This article contains some of these applications.
Keywords. mathematical model, definite integral, population size, mean span length.

The role of mathematics in various fields of natural science and at different times has varied. It has evolved historically, and two factors have significantly influenced it: the level of development of mathematical apparatus and the maturity of knowledge about the object being studied, as well as the ability to describe its fundamental features and properties in the language of mathematical concepts and relationships – or, as is now commonly said, the ability to construct a "mathematical model" of the object being studied.
Let's give a simple example of a mathematical model. Imagine that we need to determine the area of the floor of a room. To accomplish this, we measure the length and width of the room and then multiply the resulting numbers. This elementary procedure essentially means the following. The real object – the floor of the room – is replaced by an abstract mathematical model – a rectangle. The dimensions obtained from the measurement are assigned to the rectangle, and the area of this rectangle is approximately taken as the desired area.
A mathematical model based on some simplification or idealization is never identical to the object under consideration; it does not convey all of its properties and characteristics, but is merely an approximate reflection. However, by replacing a real object with an appropriate model, it becomes possible to mathematically formulate the problem of studying it and use a mathematical framework independent of the specific nature of the object to analyze its properties. This framework allows for a uniform description of a wide range of facts and observations, their detailed quantitative analysis, and prediction of how an object will behave under various conditions – that is, to forecast the results of future observations.
Mathematical models have long been successfully used in mechanics, physics, and astronomy.
In modern times, the role of mathematical methods in the natural sciences is increasingly growing. They are now widely used in biology and chemistry, where mathematical models are also successfully applied. This article describes some of these applications.
1. Population size. The number of individuals in a population (population size) changes over time. If conditions are favorable, the birth rate exceeds the death rate, and the total number of individuals in the population increases over time. Let's call the increase in the number of individuals per unit time the population growth rate. Let's denote this rate as $v = v(t)$. In "old", established populations that have long inhabited a given area, the growth rate $v = v(t)$ is low and slowly approaches zero. However, if the population is young, its relationships with other local populations have not yet been established, or there are external factors that alter these relationships, such as deliberate human intervention, then $v = v(t)$ can fluctuate significantly, decreasing or increasing.

If the population growth rate $v = v(t)$ is known, we can find the population growth rate over the time interval from t_0 to T. Indeed, from the definition of $v = v(t)$ it follows that this function is a derivative of the population size $N(t)$ at time t, and, therefore, the population size $N(t)$ is the antiderivative of $v = v(t)$.
Therefore,

$$N(t) - N(t_0) = \int_{t_0}^{T} v(t)dt \quad (1).$$

It is known that under conditions of unlimited food resources, the growth rate of many populations is exponential, i.e., $v(t) = ae^{kt}$. In this case, the population "does not age." Such conditions can be created, for example, for microorganisms by periodically transplanting the developing culture into new containers with nutrient medium. Using the formula (1), we obtain in this case:

$$N(t) = N(t_0) + a\int_{t_0}^{T} e^{kt}dt = N(t_0) + ae^{kt}\Big|_{t_0}^{T} = N(t_0) + a\left(e^{kT} - e^{kt_0}\right) \quad (2).$$

Using a formula similar to (2), the number of cultivated mold fungi that produce penicillin is calculated, in particular.
2. Average flight length. Some studies require knowing the average flight length, or the average distance traveled by an animal over a fixed distance.
Let's calculate this for birds. Let's assume the distance is a circle of radius R (Fig. 1). We'll assume that R is not too large, so that most birds of the species under study traverse this circle in a straight line.

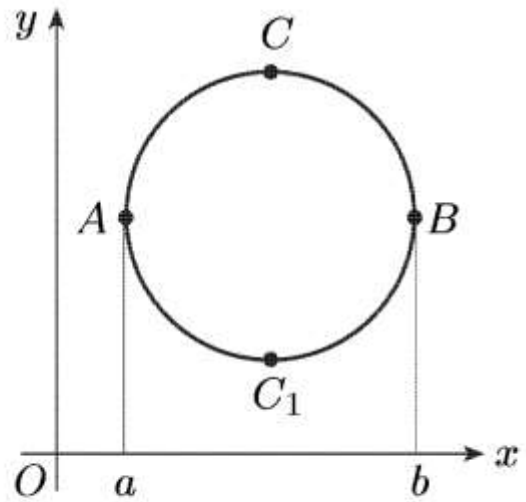

Fig. 1
A bird can cross the circle at any angle and at any point. Depending on this, the length of its flight over the circle can be equal to any value from 0 to 2*R* . We are interested in the average flight length, which we will denote by *l*.
Since a circle is symmetrical with respect to any of its diameters, we only need to consider those birds that fly in a single direction parallel to the Oy axis (see Fig. 1). Then the average flight length is the average distance between the arcs ACB and AC_1B.

In other words, it is the average value of the function $f_1(x)-f_2(x)$, where $y=f_1(x)$ is the equation of the upper arc, and $y=f_2(x)$ is the equation of the lower arc, i.e.,

$$l=\frac{\int_a^b (f_1(x)-f_2(x))dx}{b-a}$$

or

$$l=\frac{\int_a^b f_1(x)dx-\int_a^b f_2(x)dx}{b-a} \qquad (3).$$

Since

$$\int_a^b f_1(x)dx$$

is equal to the area of the curvilinear trapezoid $aACBb$, and

$$\int_a^b f_2(x)dx$$

is equal to the area of the curvilinear trapezoid aAC_1Bb, their difference is equal to the area of the circle, i.e., πR^2. The difference $b-a$ is obviously equal to 2R. Substituting this into (3), we get:

$$l=\frac{\pi R^2}{2R}=\frac{\pi}{2}R.$$

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