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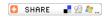
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Lotka-Volterra equation

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Lotka-Volterra equation - The equations

The usual form of the equations is:

where

- y is the number of some predator (for example, dingoes);
- x is the number of its prey (for example, wallabies);
- t represents the growth of the two populations against time; and
- a, β, γ and δ are parameters representing the interaction of the two species.

Lotka-Volterra inter-specific competition equations, Population

Lotka-Volterra equation - Physical meanings of the equations

When multiplied out, the equations take a form useful for physical interpretation.

Lotka-Volterra equation - Prey

The prey equation becomes:

The prey are assumed to have an unlimited food supply, and to reproduce exponentially unless subject to predation; this exponential growth is represented in equation above by the term ax. The rate of predation upon the prey is assumed to be proportional to the rate at which the predators and the prey meet; this is represented above by βxy . If either x or y is zero then there can be no predation.

With these two terms the equation above can be interpreted as: the change in the prey's numbers is given by its own growth minus the rate at which it is preved upon.

Lotka-Volterra equation - Predators

The predator equation becomes:

In this equation, δxy represents the growth of the predator population.

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Yoga Symbols

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Hence the equation represents the change in the predator population as the growth of the predator population, minus natural death.

Lotka-Volterra equation - Solutions to the equations

The equations have periodic solutions which do not have a simple expression in terms of the usual trigonometric functions. However, an approximate linearised solution yields a simple harmonic motion with the population of predators leading that of prey by 90°.

Lotka-Volterra equation - Dynamics of the system

In the model system, the predators thrive when there are plentiful prey but, ultimately, outstrip their food supply and decline. As the predator population is low the prey population will increase again. These dynamics continue in a cycle of growth and decline.

Lotka-Volterra equation - Population equilibrium

Population equilibrium occurs in the model when neither of the population levels are changing, i.e. when both of the differential equations are equal to 0.

$$x(\alpha - \beta y) = 0 - y(\gamma - \delta x) = 0$$

When solved for x and y the above system of equations yields $\{y = 0, x = 0\}$

hence there are two equilibria.

and

The first solution effectively represents the <u>extinction</u> of both species. If both populations are at 0, then they will continue to be so indefinitely. The second solution represents a fixed point at which both populations sustain their current, non-zero numbers, and, in the simplified model, do so indefinitely. The levels of population at which this equilibrium is achieved depends on the chosen values of the parameters, $\alpha,\beta,\gamma,$ and $\delta.$

Lotka-Volterra equation - Stability of the fixed points

The stability of the fixed points can be determined by performing a linearization using partial <u>derivatives</u>.

The Jacobian matrix of the predator-prey model is

When evaluated at the steady state of (0,0) the Jacobian matrix ${\bf J}$ becomes

The eigenvalues of this matrix are

$$\lambda_1 = \alpha_1 \lambda_2 = -\gamma$$

In the model a and γ are always greater than zero, and as such the sign of the eigenvalues above will always differ. Hence the fixed point at the origin is a saddle point.

The stability of this fixed point is of importance. If it was stable, non-zero populations might be attracted towards it, and as such the dynamics of the system might lead towards the extinction of both species for many cases of initial population levels. However, as the fixed point at the origin is a saddle point, and hence unstable, we find that the extinction of both species is difficult in the model.

Evaluating J at the second fixed point we get

The eigenvalues of this matrix are

As the eigenvalues are both complex, this fixed point is a focus. The real part is zero in both cases so more specifically it is a centre. This means that the levels of the predator and prey populations cycle, and oscillate around this fixed point.

See also

- Lotka-Volterra inter-specific competition equations
- Population dynamics

Lotka-Volterra equation - Bibliography

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