

## S1 File. Mathematical codes for Model 1 and Model 2.

### Model 1

% This function defines the differential equations for an epidemic model of Newcastle Disease transmission in a homogeneous population of white-winged parakeets.

```
function dx=Newcastle3(t,x)
```

```
% Parameters
```

```
N=200;
```

```
d=1/(5.0*365); % Natural mortality rate; tested at 2, 5 and 9 years
```

```
h=0.01/365; % Total harvest rate
```

```
h1=0; % Additional harvest rate; tested at 0, 2, 5, 10%
```

```
betaA=3/(14*N); % Transmission rate (Acute-to-Susceptible)
```

```
Ir=0.1; % Infectiousness reduction coefficient for chronically-infected parakeets
```

```
betaC=Ir*betaA; % Transmission rate (Chronic-to-Susceptible)
```

```
Dalph=5.5; % Duration of latency
```

```
alpha=1/Dalph; % Rate of becoming infectious
```

```
Ddelt=30; % Duration of acute infection
```

```
delta=1/Ddelt; % Rate of leaving acutely infectious stage
```

```
Dgam=39; % Duration of chronic infection
```

```
gamma=1/Dgam; % Recovery rate for chronic infection
```

```
muA=0.25*delta; % Disease-related mortality rate (acute)
```

```
muC=0.075*gamma; % Disease-related mortality rate (chronic)
```

```
p1=0.625; % Probability of acute infection
```

```
p2=0.5; % Probability of recovery from acute infection
```

```
Dnu=243; % Duration of immunity
```

```
nu=1/Dnu; % Loss of immunity rate
```

```
% ODEs
```

```
dx=zeros(5,1);
```

```
dx(1)=(d+h)*sum(x)-(d+h+h1)*x(1)-betaA*x(1)*x(3)-betaC*x(1)*x(4)+nu*x(5);
```

```
dx(2)=betaA*x(1)*x(3)+betaC*x(1)*x(4)-(d+h+h1+alpha)*x(2);
```

```
dx(3)=alpha*p1*x(2)-(d+h+h1+muA+delta)*x(3);
```

```
dx(4)=alpha*(1-p1)*x(2)+delta*(1-p2)*x(3)-(d+h+h1+muC+gamma)*x(4);
```

```
dx(5)=delta*p2*x(3)+gamma*x(4)-(d+h+h1+nu)*x(5);
```

## Model 2

% This function defines the differential equations for an epidemic model of Newcastle Disease transmission in an age-structured population of white-winged parakeets.

```
function dx=NewcastleAge4(t,x)
```

```
% Parameters
```

```
N=200;
```

```
h=0.01/365; % Total harvest rate
```

```
h1=0; % Additional harvest rate; tested at 0, 2, 5, and 10%
```

```
DOmeg=135; % Duration of juvenile stage
```

```
Omega=1/DOmeg;
```

```
Ddj=-DOmeg/log(0.6); % Juvenile life expectancy; tested at 0.5, 0.6, and 0.7%
```

```
dj=1/Ddj; % Natural juvenile mortality rate
```

```
Dd=5.0*365; % Life expectancy; tested at 2, 5, and 9 years
```

```
Dda=Dd-Ddj; % Adult life expectancy
```

```
da=1/Dda; % Adult death rate
```

```
hj=0.4*(h+h1); % Total juvenile harvest rate
```

```
ha=0.6*(h+h1); % Total adult harvest rate
```

```
hjl=0.4*h; % Juvenile harvest rate for lambda
```

```
hal=0.6*h; % Adult harvesting rate for lambda
```

```
betaA=3/(14*N); % Transmission rate (Acute-to-Susceptible)
```

```
lr=0.1; % Infectiousness reduction coefficient for chronically-infected parakeets
```

```
cbetaa=0.25; % Age-dependent acute transmission factor
```

```
beta1=(1+cbetaa)*betaA; % Transmission rate (Acute-Juvenile-to-Susceptible)
```

```
beta2=lr*betaA; % Transmission rate (Chronic-Juvenile-to-Susceptible)
```

```
beta3=(1-cbetaa)*betaA; % Transmission rate (Acute-Adult-to-Susceptible)
```

```
beta4=lr*betaA; % Transmission rate (Chronic-Adult-to-Susceptible)
```

```
beta5=beta3;
```

```
beta6=beta4;
```

```
beta7=beta1;
```

```
beta8=beta2;
```

```
Dalph=5.5; % Duration of latency
```

```
alpha=1/Dalph;
```

```
Ddelt=30; % Duration of acute infection
```

```
delta=1/Ddelt;
```

```
Dgam=39; % Duration of chronic infection
```

```
gamma=1/Dgam;
```

```
Dnu=243; % Duration of immunity
```

```
nu=1/Dnu;
```

```
muA=0.25*delta; % Disease-related mortality rate (acute)
```

```
muC=0.075*gamma; % Disease-related mortality rate (chronic)
```

$cm=0.25$ ; % Age-dependent acute mortality factor  
 $\mu_{Aj}=(1+cm)*\mu_A$ ; % Disease-related mortality rate for acutely-infected juvenile parakeet  
 $\mu_{Cj}=\mu_C$ ; % Disease-related mortality rate for chronically-infected juvenile parakeet  
 $\mu_{Aa}=(1-cm)*\mu_A$ ; % Disease-related mortality rate for acutely-infected adult parakeet  
 $\mu_{Ca}=\mu_C$ ; % Disease-related mortality rate for chronically-infected adult parakeet  
 $p1j=0.75$ ; % Probability of acute juvenile infection  
 $p1a=0.5$ ; % Probability of acute adult infection  
 $p2=0.5$ ; % Probability of recovery from acute infection

% ODEs

$dx=zeros(10,1)$ ;

% Juveniles

$dx(1)=(dj+hj+\Omega)*(da+hal)*sum(x)/(da+hal+\Omega)-(dj+hj+\Omega)*x(1)-\beta_1*x(1)*x(3)-$   
 $\beta_2*x(1)*x(4)-\beta_3*x(1)*x(8)-\beta_4*x(1)*x(9)+\nu*x(5)$ ;  
 $dx(2)=\beta_1*x(1)*x(3)+\beta_2*x(1)*x(4)+\beta_3*x(1)*x(8)+\beta_4*x(1)*x(9)-(dj+hj+\Omega+\alpha)*x(2)$ ;  
 $dx(3)=\alpha*p1j*x(2)-(dj+hj+\Omega+\mu_{Aj}+\delta)*x(3)$ ;  
 $dx(4)=\alpha*(1-p1j)*x(2)+\delta*(1-p2)*x(3)-(dj+hj+\Omega+\mu_{Cj}+\gamma)*x(4)$ ;  
 $dx(5)=\delta*p2*x(3)+\gamma*x(4)-(dj+hj+\Omega+\nu)*x(5)$ ;

% Adults

$dx(6)=\Omega*x(1)-(da+ha)*x(6)-\beta_5*x(6)*x(8)-\beta_6*x(6)*x(9)-\beta_7*x(6)*x(3)-$   
 $\beta_8*x(6)*x(4)+\nu*x(10)$ ;  
 $dx(7)=\Omega*x(2)+\beta_5*x(6)*x(8)+\beta_6*x(6)*x(9)+\beta_7*x(6)*x(3)+\beta_8*x(6)*x(4)-$   
 $(da+ha+\alpha)*x(7)$ ;  
 $dx(8)=\Omega*x(3)+\alpha*p1a*x(7)-(da+ha+\mu_{Aa}+\delta)*x(8)$ ;  
 $dx(9)=\Omega*x(4)+\alpha*(1-p1a)*x(7)+\delta*(1-p2)*x(8)-(da+ha+\mu_{Ca}+\gamma)*x(9)$ ;  
 $dx(10)=\Omega*x(5)+\delta*p2*x(8)+\gamma*x(9)-(da+ha+\nu)*x(10)$ ;