MATLAB program and functions used for calculating the number of parasites on pasture and in horses

larv.m

```
%larv calculates the density of parasites on a hectare of pasture and the
%mean of the parasites in a given amount of horses. The program
calculates
%two ODE with the functions larvODE and larvregODE
%The inputs are changed directly in the program, and the description of
the
%variables is:
%
%H = Host population density
%lambda = Mean rate at which an adult parasite produces eggs
%D = probability that an ingested larva develops into an adult parasite
%use = Months anthelmintics are used
%ra = rate at which larvae are lost from pasture because of reasons other
%L = starting value of the density of nematode on a pasture
%A = starting mean of the amount of nematodes in the horses
%a1, a2 = month of the year when anthelmintics are used
%time = time interval of the model in months

global Ha lambda D xmod use temp ra a1 a2

%Read temperature-data file
temp = xlsread('weather17.xlsx','D11548:D11912');

%Overall non-changing variables
Ha = 1;
lambda = 54;
D = 0.48;
use = 0.5;
ra = 0.025;
a1 = 2;
a2 = 8;
L = 1000;
A = 0;
y0 = [L; A];
time = [0,60];

%Vector for counting anthelmintic use in larvODE
xmod = [];

%Solve the optimized anthelmintics use
[t, y] = ode45(@larvODE, time, y0);

%Solver of regular anthelmintic use
[tr, yr] = ode45(@larvregODE, time, y0);

%Figure1 - Worm density on a pasture with modified use of anthelmintics
figure(1)
plot(t,y(:,1));
xlabel('Time [months]')
ylabel('Density [parasites/ha]');
title('Density of nematodes on pasture with optimized anthelmintic use');
```

```
%Figure 2 - The amount of worm density on a pasture with regular use of
%anthelmintics
figure(2)
plot(tr, yr(:,1));
xlabel('Time [months]')
ylabel('Amount [parasites/ha]');
title('Density of nematodes on pasture, using anthelmintics February &
August');

%Figure 3 - The mean amount of worms in horses, modified use
figure(3)
plot(t,y(:,2));
xlabel('Time [months]')
ylabel('Amount [parasites/horse]')
title('Mean of parasites per horse, with optimized use of
anthelmintics');

%Figure 4 - The mean amount of worms in horses, regular use
figure(4)
plot(tr, yr(:,2));
xlabel('Time [months]')
ylabel('Amount [prasites/horse]')
title('Mean of parasites per horse, using anthelmintics February &
August');
```

larvODE.m

```
function dydt = larvODE(t, y)
%Variables used in the calculations:
%B = Rate at which larvae are eaten by single host animal
%q = Probability that an egg develops into an infective larva
%my = Mortality rate of adult parasites
%u1 = Binary value of anthelmintics use, 1 if used, 0 if not
%xmod = vector where the time-steps are saved, to calculate how long the
%anthelmintics cure has been.
%use = Months anthelmetics are used

global Ha lambda D use temp xmod ra

%Use anthelmetics only when amount of worms goes over threshold
if (y(2) >= 100000 || isempty(xmod) == 0)
    u1 = 1;
    my = 0.99;
    xmod = [xmod, t];
else
    u1 = 0;
    my = 0.03;
end

%The lenght of anthelmetic-cure
if length(xmod) > use && (xmod(end)-xmod(1)) > use
    my = 0.03;
    u1 = 0;
    xmod = [];
end

%70% decrease in food intake if worms overexceed healthy amounts
```

```
if y(2) >=100000
    B = 6;
else
    B = 20;
end

%Calculate the probabilty of the egg to develop into a larva depending on
%the temperature.
tm = t;
while tm > 12
    tm = tm-12;
end

whichDay = floor((tm/12)*length(temp));

if whichDay == 0
    whichDay = 1;
    whichTemp = temp(whichDay);
else
    whichTemp = temp(whichDay);
end

if whichTemp < 4
    q = 0;
else
    q = probhatch(whichTemp);
end

%ODE
dydt = [-(ra + (B*Ha))*y(1) + q*lambda*Ha*y(2);
    D*B*y(1) - my*y(2) - u1*y(2)];


end
```

larvregODE.m

```
function dydt = larvregODE(tr, yr)
%Variables used in the calculations:
%B = Rate at which larvae are eaten by single host animal
%q = Probability that an egg develops into an infective larva
%my = Mortality rate of adult parasites
%u1 = Binary value of anthelmintics use, 1 if used, 0 if not
%xmod = vector where the time-steps are saved, to calculate how long the
%anthelmintics cure has been.
%use = Months anthelmetics are used

global Ha lambda D use temp ra a1 a2

tm = tr;

while tm > 12
    tm = tm-12;
end

if  a1 < tm && tm<(a1+use) || a2 < tm && tm< (a2+use)
    u1 = 1;
```

```
    my = 0.99;
else
    u1 = 0;
    my = 0.03;
end

%70% decrease in food intake if worms overexceed healthy amounts
if yr(2) >= 100000
    B = 6;
else
    B = 20;
end

whichDay = floor((tm/12)*length(temp));
if whichDay == 0
    whichDay = 1;
    whichTemp = temp(whichDay,1);
else
    whichTemp = temp(whichDay,1);
end

if whichTemp < 4
    q = 0;
else
    q = probhatch(whichTemp);
end

%ODE
dydt = [-(ra + B*Ha)*yr(1) + q*lambda*Ha*yr(2);
    D*B*yr(1) - my*yr(2) - u1*yr(2)];

end
```

probhatch.m

```
function y = probhatch(x)
%Calculates the probability of an egg to develop into a larva depending
on
%the given temperature.

y = (0.0342*x - 0.2411)*0.05;

end
```