Introduction to R
Lecture 4

EEB C119/C219 (Winter 2012)

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Overview

- Packages
  - What are they?
  - Installing packages, **deSolve** in particular
  - What packages are loaded? Where are they located? What packages are installed on your computer?
  - Using packages in scripts
- Ordinary differential equations (ODEs)
  - Define function for use with deSolve
  - How to (numerically) integrate ODE
- Examples
  - Desity-dependent growth
  - Lotka-Volterra predator-prey

Packages

What are they?

- Packages
  - Allow expansion of R's available tools – set of functions coded by someone else and 'packaged' for you to use
  - Developed by many different people (universities, industry, etc.)
  - We will use **deSolve**, a nice ODE tool
- Other packages
  - Browse: `http://cran.r-project.org/`
  - Link to 'Packages' on left

Installing packages

- Can install package using interface
  - **rstudio**
  - Win, Mac – interface with R install
  - ** Might need to run program as **administrator** **
- R command line
  - Use command:

    ```
    > install.packages('packagename', dep = TRUE)
    ```

  - ** Might need to start R as **administrator** **
- Repository
  - Choose repository (where packages are downloaded from) – one is at UCLA
- Only need to install package **once**

Package information

Helpful commands

- What packages are installed on **your computer**?

  > *library()*

  - Note: these are not 'loaded' and ready to use

- What packages are 'loaded' in session?

  > *search()*

- Where does R look for packages (on your computer)?

  > *.libPaths()*

Using packages

Command line and scripts

- To use package at command line use **library** command, ex:

```
> library(deSolve) # load deSolve
```

- Again, to see what packages are loaded, type **search**:

```
> search()

 [1] ".GlobalEnv"        "package:deSolve"   "package:stats"
 [4] "package:graphics"  "package:grDevices" "package:utils"
 [7] "package:datasets"  "package:methods"   "Autoloads"
[10] "package:base"
```

- In script, use (usually at top of file):

```
> library(packageName)
```

or

```
> require(packageName)
```

deSolve

Numerical integration of ODEs

- deSolve uses well established algorithms for numerical integration of ODEs
- You don't have to worry about details (ask if interested)
- Using deSolve requires specific syntax
  - For a given ODE, have to define **function** for right-hand side of ODE
  - We'll do both 1d and 2d today
- Once you know the syntax, it's fairly simple to implement most ODEs

deSolve

Format for lsoda

- `lsoda` syntax:

  > *`lsoda(IC, times, ODEfunction, pars)`*

  - `IC`: intitial condition for state variables
  - `times`: vector of times where we want to know value of state variables
  - `ODEfunction`: function **we** define, describing ODE
  - `pars`: parameters for the ODE

- We'll do examples, so hang on.

deSolve

Format for function describing ODE

- ODE function syntax:

```
ODEfunction <- function(t, y, pars) {

  derivs <- [insert model equations]

  return(list(derivs))
}
```

  - `t`: is a variable used by R to keep track of the time
  - `y`: is the state variable (or vector of state variables)
  - `pars`: is a vector of model parameters
  - `derivs`: describes right hand side (RHS) of ODE

Density-dependent growth

Remember the basics

- Equation is:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

- State variable: N
- Parameters: r, K

Density-dependent growth

Define a function for the ODE

```
> desDepGrowthODE <- function(t, N, pars) {
+   # dN/dt = r * N * ( 1 - N/K )
+   dNdt <- pars['r'] * N * ( 1 - N/pars['K'])
+
+   # return as list
+   return(list(dNdt))
+ }
```

- This defines RHS of ODE, still need a script to call `lsoda` and get output
- This is function, just like last lecture!

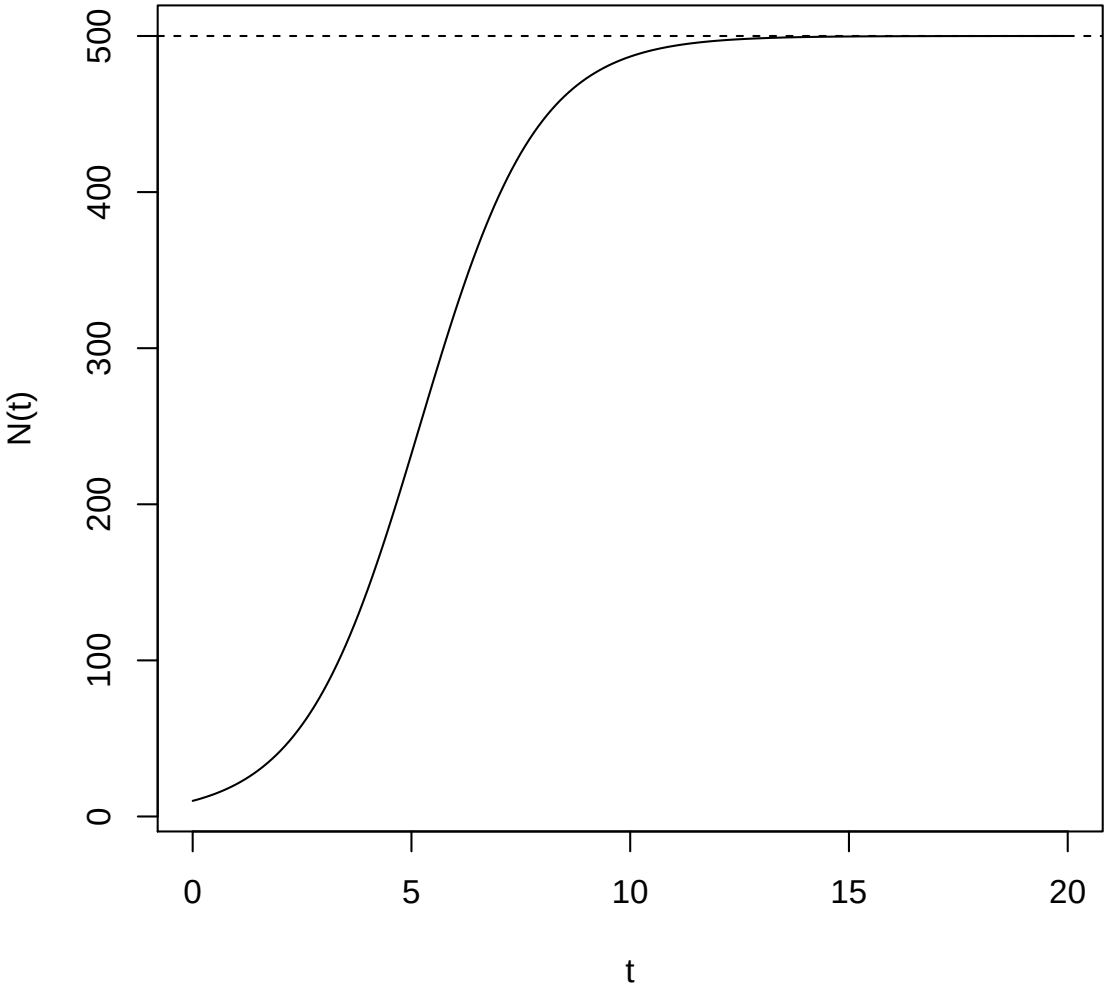
Density-dependent growth

Script to plot output from ODE – use **source**

```
> library(deSolve) # deSolve loaded
> # define ODE
> desDepGrowthODE <- function(t, N, pars) {
+   # dN/dt = r * N * ( 1 - N/K )
+   dNdt <- pars['r'] * N * ( 1 - N/pars['K'])
+   # return as list
+  return(list(dNdt))
+ }
> # setup Init condition, times, parameters
> IC <- c(N=10)
> times <- seq(0, 20, by=0.1)
> pars <- c(r = 0.75, K=500)
> # call lsoda to get output
> output <- lsoda(IC, times, desDepGrowthODE, pars)
> # plot
> plot(output[,1],output[,2],type='l',xlab='t',ylab='N(t)')
> abline(h=pars['K'],lty=2)  # dashed line at y==K
```

Density-dependent growth

Plot resulting output from script



Density-dependent growth

What does the output look like?

```
> # setup Init condition, times, parameters
> IC <- c(N=10)
> times <- seq(0, 20, by=0.1)
> pars <- c(r = 0.75, K=500)
> # call lsoda to get output
> output <- lsoda(IC, times, desDepGrowthODE, pars)
> # get start of output
> head(output)
```

```
     time        N
[1,]  0.0 10.00000
[2,]  0.1 10.76208
[3,]  0.2 11.58086
[4,]  0.3 12.46035
[5,]  0.4 13.40480
[6,]  0.5 14.41871
```

- Using `desDepGrowthODE`, as defined on previous slide.

Demo: `Lecture04_Ex01.R`

Lotka-Volterra predator-prey

PER Section 6.1,pg 162

- Example of predator-prey (system of ODEs)
- Demonstrate deSolve implementation (not math)
- Details:
  - State variables:
    - H: prey (herbivore?)
    - P: predator
  - Parameters:
    - b: per-capita growth rate of prey
    - a: rate of encounter/eating
    - e: efficiency of prey to predator conversion
    - s: per-capita death rate of predator

Lotka-Volterra predator-prey

Equations and meaning (PER Section 6.1,pg 162)

- Exponential growth for prey

$$\frac{dH}{dt} = bH - aPH$$

$$\frac{dP}{dt} = eaPH - sP$$

- Predator eats prey
- Mortality for predator

Lotka-Volterra predator-prey

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Lotka-Volterra predator-prey

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- Mortality for predator

Lotka-Volterra predator-prey

Define function for ODE

```
> predPreyLVODE <- function(t, N, pars) {
+   # get state variables from N
+   H <- N[1]
+   P <- N[2]
+
+   # dH/dt = b*H - a*P*H
+   dHdt <- pars['b'] * H - pars['a']*P*H
+   # dP/dt = e*a*P*H - s*P
+   dPdt <- pars['e']*pars['a']*P*H - pars['s']*P
+
+   # return as list
+   return(list(c(dHdt,dPdt)))
+ }
```

- Note: return of function should have same ordering as `N` vector – H, then P in this case

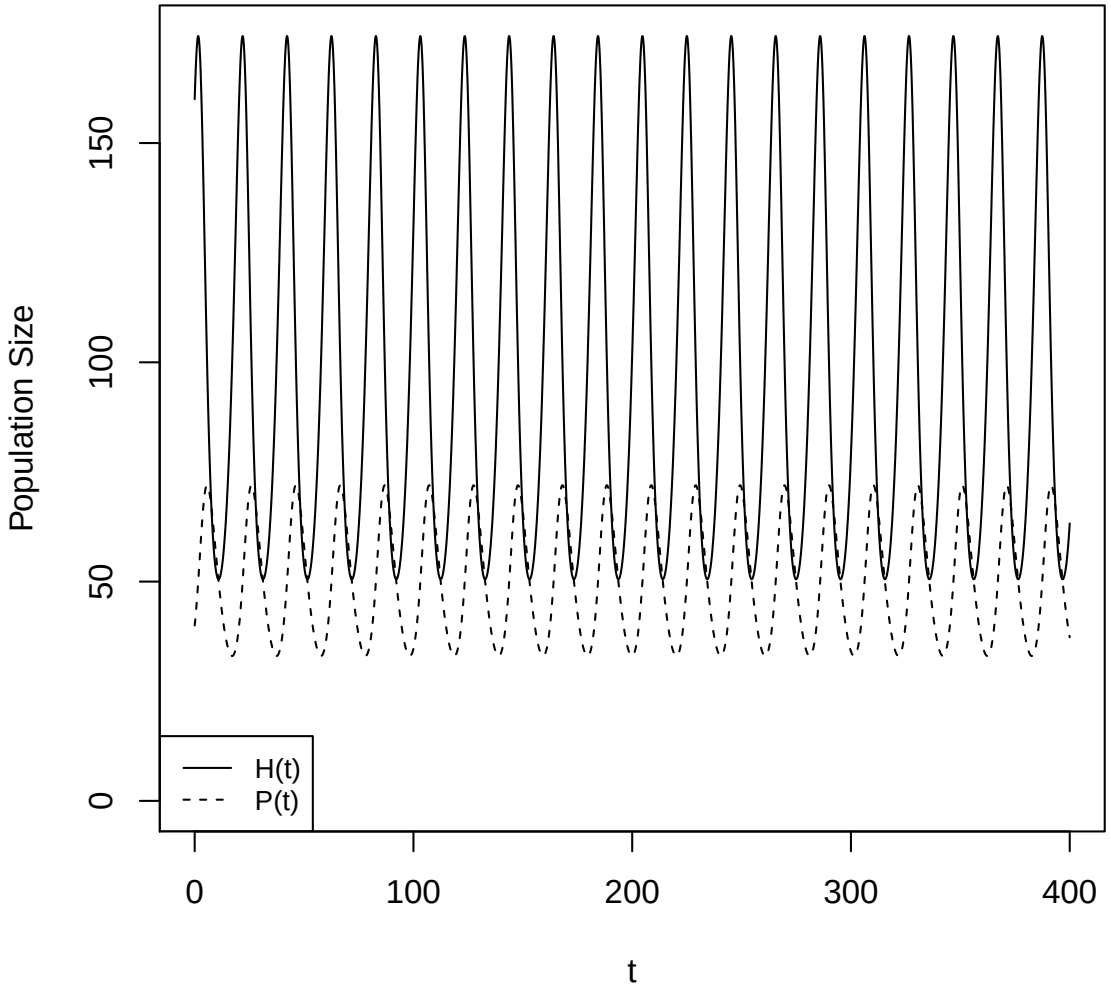
Lotka-Volterra predator-prey

Script to plot output

```
> library(deSolve) # load deSolve
> predPreyLVODE <- function(t, N, pars) {
+   # get state variables from N
+   H <- N[1]; P <- N[2]
+   # dH/dt = b*H - a*P*H
+   dHdt <- pars['b'] * H - pars['a']*P*H
+   # dP/dt = e*a*P*H - s*P
+   dPdt <- pars['e']*pars['a']*P*H - pars['s']*P
+   # return as list
+   return(list(c(dHdt,dPdt)))
+ }
> # IC, time, parameters
> IC <- c(H=160,P=40); pars <- c(b=0.5,a=0.01,e=0.2,s=0.2)
> times <- seq(0,400,by=0.1)
> # run lsoda
> output <- lsoda(IC, times, predPreyLVODE, pars)
> # plot
> plot(output[,1],output[,2],type='l',lty=1, ylim=c(0,max(output[,2])),
+      xlab='t',ylab='Population Size')
> lines(output[,1],output[,3],lty=2)
> # make a legend
> legend("bottomleft", c("H(t)","P(t)"), cex=0.8, lty=c(1,2))
```

Lotka-Volterra predator-prey

Plot resulting from script



Demo: `Lecture04_Ex02.R`