“FSA”
Fisheries Stock Assessment Package

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What does FSA do?

"A variety of simple fish stock assessment methods" (Ogle 2013).

Covers:

- Age comparisons
- Age-length relationships
- Size structures
- Weight-Length Relationships (wrAdd)
- Abundance from capture-recapture data
- Depletion Methods for Estimating Abundance
- Mortality rates
- Growth rates
- Recruitment (in partnership with other packages)
- Catch Curve Estimates of Mortality (catchCurve)

What conservation problems can the package be used for?

Package

Fisheries management, including:

- health of a fish population and its environment
- finding the population size of closed populations
- estimating mortality rate

Model(s)

- catchCurve = linear regression
- weight-length = linear regression
- depletion = linear regression
- other functions use different models

Unique Insight!

The FSAdata package can be used to get datasets that correspond to packages in FSA

- help.search("Weight-Length",package=c("FSAdata","FSA"))
- help.search("Depletion",package=c("FSAdata","FSA"))
- help.search("Catch curve",package=c("FSAdata","FSA"))
- help.search("Size Structure",package=c("FSAdata","FSA"))

Weight-Length Model Overview

Weight of individual fish

$$Wr = \frac{W}{Ws} * 100$$

Relative weight

Standard weight (for fish of the same length)

Weight-Length Data

	netID	fishID	species	length	weight	year
1	206	501	Bluegill	1.5	0.7	2008
2	205	502	Bluegill	1.7	1.4	2008
3	205	503	Bluegill	2.2	1.5	2008
4	205	504	Bluegill	2.1	1.4	2008
5	205	505	Bluegill	1.5	1.0	2008
6	205	506	Bluegill	1.9	1.8	2008

Data should look something like this: weight and length for individual fish in a species

Weight-Length Example

Fisheries managers want to assess the health of a fish population and its environment for management

OR

They are concerned about how a fish population is doing

	netID	fishID	species	length	weight	year
1	17	199	Bluegill	5.6	59.0	2007
2	20	201	Bluegill	5.5	54.0	2007
3	15	203	Bluegill	5.6	40.0	2007
4	15	206	Bluegill	5.8	30.0	2007
5	15	207	Bluegill	4.7	20.0	2007
6	16	210	Bluegill	9.0	280.0	2007
7	16	211	Bluegill	8.8	260.0	2007
8	16	212	Bluegill	8.8	260.0	2007
9	16	213	Bluegill	8.8	240.0	2007
10	16	214	Bluegill	5.9	60.0	2007
11	16	215	Bluegill	5.4	60.0	2007
12	21	217	Bluegill	3.7	14.0	2007
13	21	219	Bluegill	5.1	38.0	2007
14	26	220	Bluegill	5.2	49.0	2007

Weight-Length Example

```
#wrAdd() calculates the relative weight for each fish based on the standard weight equation for that species
bluegill_2007_weights <- wrAdd(weight~length_mm+species, data=bluegill_2007) #calculates relative weight

#add to the dataframe
bluegill_2007 <- bluegill_2007 %>%
  mutate(relative_weight = bluegill_2007_weights)
```

	netID	fishID	species	length	weight	year	length_mm	relative_weight
1	17	199	Bluegill	5.6	59.0	2007	142	101.82721
2	20	201	Bluegill	5.5	54.0	2007	140	97.68619
3	15	203	Bluegill	5.6	40.0	2007	142	69.03540
4	15	206	Bluegill	5.8	30.0	2007	147	46.16331
5	15	207	Bluegill	4.7	20.0	2007	119	62.01779
6	16	210	Bluegill	9.0	280.0	2007	229	99.07032
7	16	211	Bluegill	8.8	260.0	2007	224	98.98079
8	16	212	Bluegill	8.8	260.0	2007	224	98.98079

Weight-Length Example

#find the average relative weight by size class

````
```{r}
#for bluegill research groups them into the following classes:
## <8 cm
## <15 cm
## <20 cm
## <25 cm
## <30 cm
#approximate length at maturity for bluegill is 15cm, so the first two size classes are juveniles

#categorize each fish into its size class
bluegill_2007 <- bluegill_2007 %>%
  mutate(class = ifelse(length_mm < 80, "young_of_year", ifelse(length_mm < 150, "juvenile", ifelse(length_mm < 200, "adult_1", ifelse(length_mm < 250, "adult_2", "adult_3")))))

#the relative weight function doesn't work for fish in the young of year class for this species (they're too short), so we can compare juveniles to different classes of adults

bluegill_2007_summary <- bluegill_2007 %>%
  group_by(class) %>%
  summarize(mean_relative_weight = mean(relative_weight, na.rm = TRUE))
````
````

Weight-Length Example

class <chr>	mean_relative_weight <dbl>
adult_1	89.82584
adult_2	96.11699
juvenile	79.45157
young_of_year	NaN

Bluegills in different life phases in this particular lake differ in how healthy they are, and by extension how ideal their environment is for them

All Bluegill in this population are skinnier than expected for the species, so management may be necessary

Catch Curve Overview

Linear Regression Basis:

$$C_t = vN_0e^{-Zt}$$

catch of fish at age t

initial population size

time

proportion vulnerable to fishery (constant)

instantaneous total mortality parameter

Catch Curve Inputs

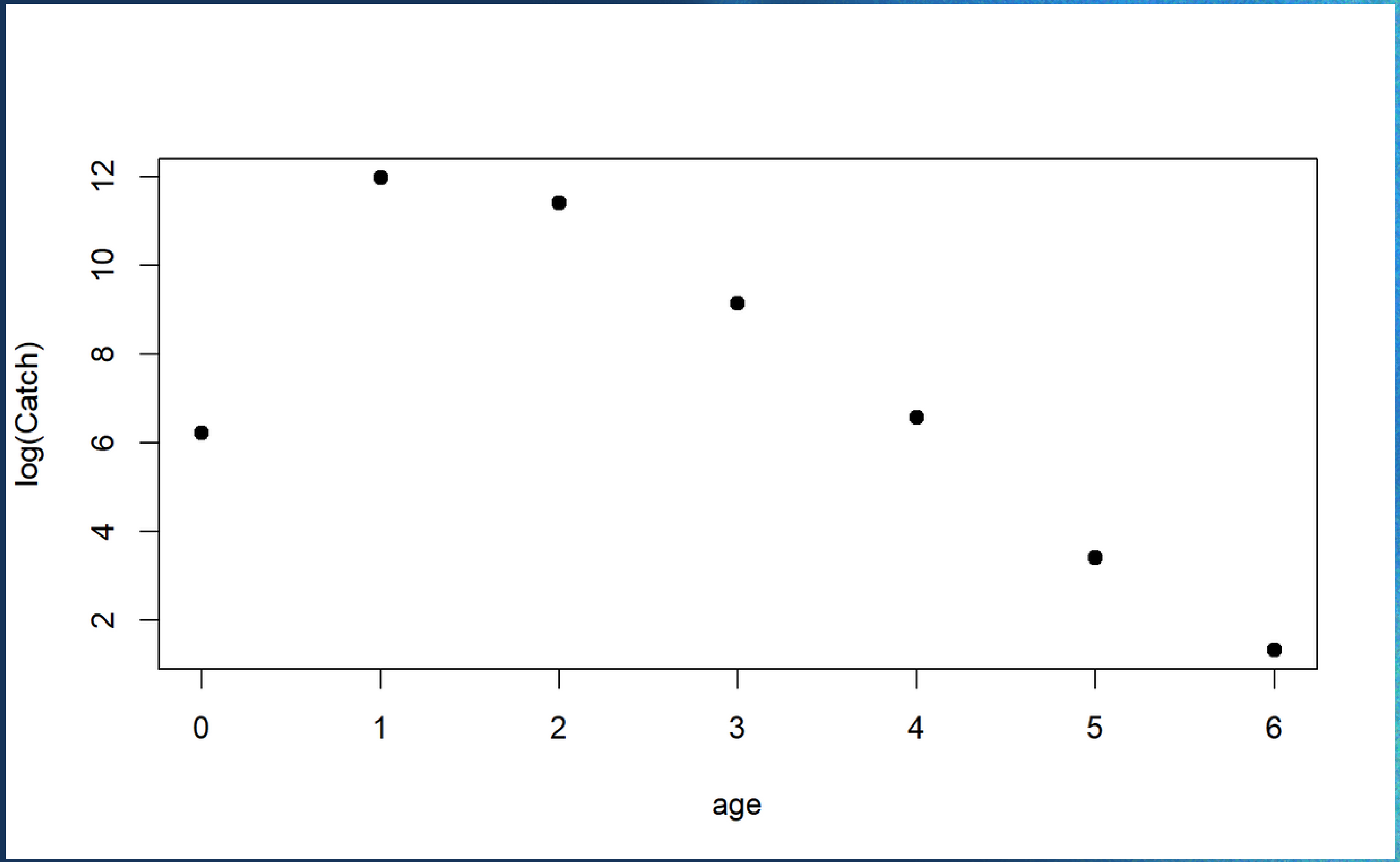
AGE	CATCH	LOG(CATCH)
0	501.9	6.2
1	161219.8	12.0
2	90815.0	11.4
3	9419.4	9.2

The dataframe should consist of two columns: age and catch per age class (both must be numeric), then you calculate log(catch) for plotting

Catch Curve Example

Fisheries managers can use this to determine the annual mortality rate of a population

```
plot(logct~age,data=data,ylab="log(Catch)",pch=19)
```



Catch Curve Example

weighted linear regression will reduce the relative impact of older ages with fewer fish

```
catchCurve(
  x,
  catch,
  ages2use = age,
  weighted = FALSE,
  negWeightReplace = 0,
  ... )
```

x = formula of the form catch~age

ages2use = numeric vector of ages that define the descending limb of the catch curve

use.weights = logical that indicates whether a weighted regression should be used

Example:

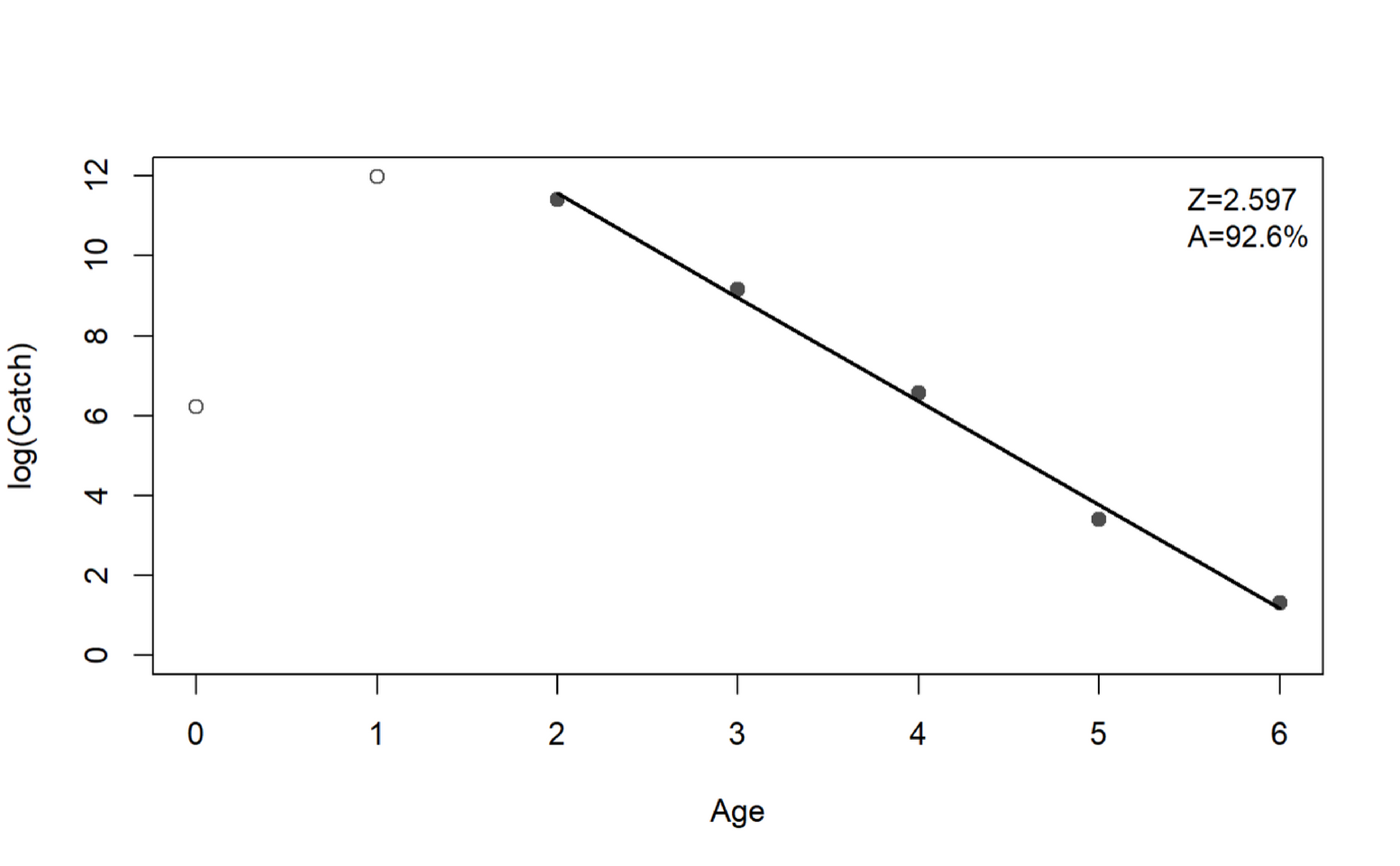
```
weighted_results <- FSA::catchCurve(catch~age, data=data,
    ages2use=2:6, use.weights=TRUE)
```

Catch Curve Example

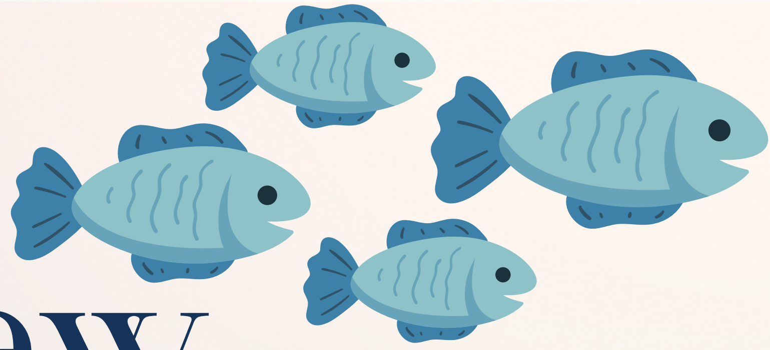
Annual mortality rate for this population is 92.6%

Z = instantaneous mortality rate

A = annual mortality rate



Depletion Model Overview



What does it do?

- Estimates the total population size for a closed population
- The ‘depletion’ refers to the removal of fish from the population

How does it do it?

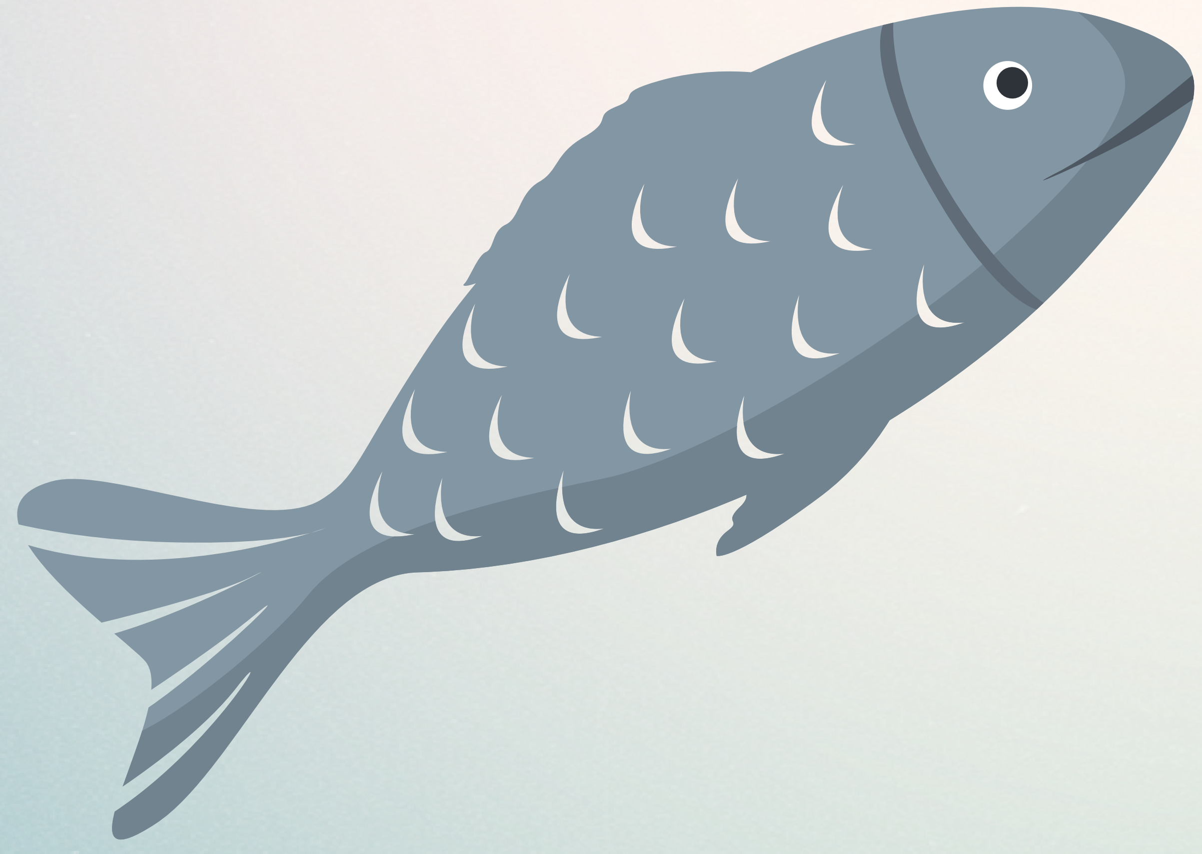
3 Methods for Estimating Abundance

1. Leslie Method
2. DeLury Method
3. K-Pass Method

Why is this useful?

- For management
- Species-habitat relationships
- Measuring recovery status
- How removal of fish affect relative abundance

Leslie Method



initial number of fish in the population

amount of current catch

catch-per-unit-effort (CPUE)

level of effort for the *t*th removal (last removal)

$$\frac{C_t}{f_t} = qN_0 - qK_t$$

catchability coefficient

cumulative catch prior to the *t*th removal

Leslie Method Broken Down

Before actually using the package, it is important to understand how to calculate everything!

Step 1: Enter catch and effort into R as data frames

```
> mac <- data.frame(catch=c(7,7,4,1,2,1),effort=c(10,10,10,10,6,10))
```

Step 2: Calculate CPUE or CPE

- catch/effort

```
> mac$cpe <- mac$catch/mac$effort
> mac

  catch effort    cpe
1     7     10 0.7000
2     7     10 0.7000
3     4     10 0.4000
4     1     10 0.1000
5     2      6 0.3333
6     1     10 0.1000
```

Step 3: Find K

- This is just the cumulative sum of the catch which is the addition of all prior values

```
> mac$K <- cumsum(mac$catch)-mac$catch
> mac

  catch effort    cpe  K
1     7     10 0.7000  0
2     7     10 0.7000  7
3     4     10 0.4000 14
4     1     10 0.1000 18
5     2      6 0.3333 19
6     1     10 0.1000 21
```

Leslie Method Broken Down

Step 4: Set up the regression

```
> lm1 <- lm(cpe~K,data=mac)
```

Step 5: Slope and intercept are extracted from the model

```
> coef(lm1)
(Intercept)           K
    0.78643    -0.03019
```

Step 6: Calculate q (which is K) and N0 (the intercept)

```
> ( q.hat <- -coef(lm1)[2] )
      K
0.03019
> ( N0.hat <- coef(lm1)[1]/q.hat )
(Intercept)
      26.05
```

There are an estimated 26 age-0 largemouth bass in the 0.11 ha enclosure!

Leslie Method with depletion()

Skipped defining the catch and effort data frame here since it was already done previously (this could also be loaded in through an excel file)

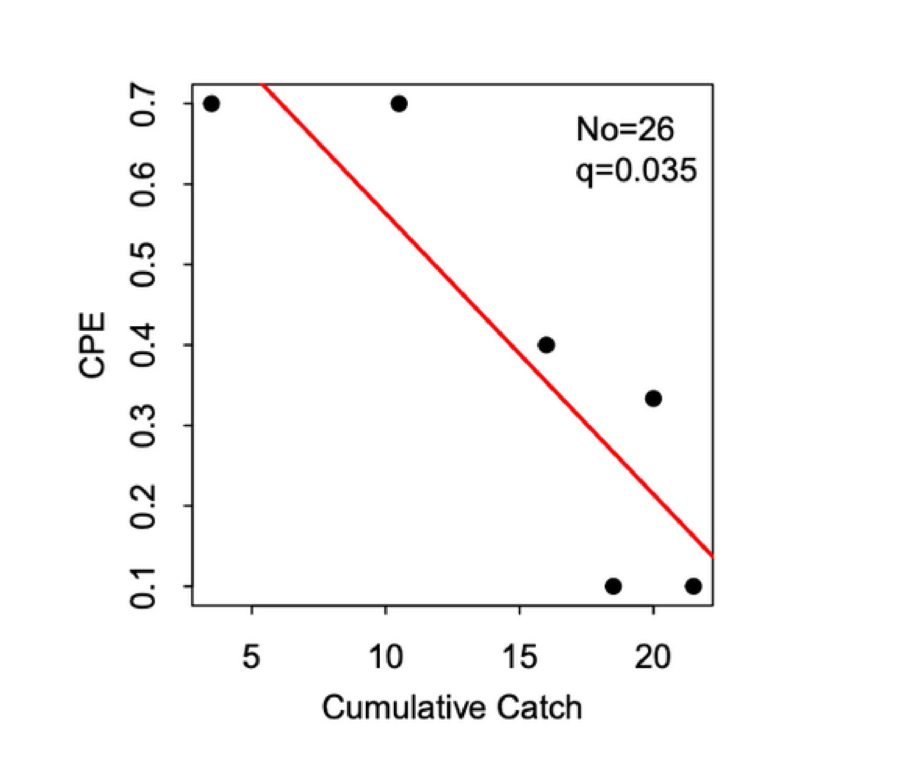
Immediately get N0 and q!

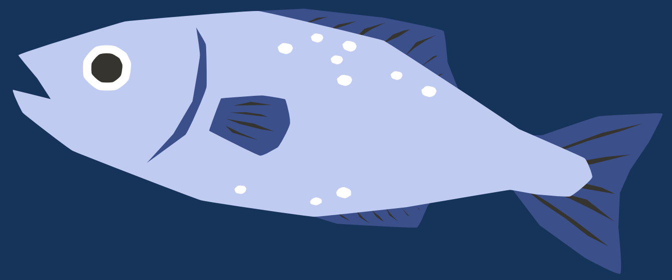
There are between 17 and 36 age-0 largemouth bass in the enclosure and the catchability coefficient is between 0.009 and 0.061.

```
> lm2 <- with(mac,depletion(catch,effort,ricker.mod=TRUE))
> summary(lm2)
The Leslie method was used.
   Estimate Std. Err.
No 26.14071  3.383672
q   0.03491  0.009253
> confint(lm2)
     95% LCI 95% UCI
No 16.746130 35.5353
q   0.009217  0.0606
```

Can then plot it!

```
> plot(lm2)
```





Assumptions and Downfalls of Leslie

ASSUMPTIONS

1. Population is closed
2. Catchability is constant
3. Enough fish are removed to reduce catch-per-unit-effort
4. The catches remove 2% of the population
5. All fish will be caught by method of capture
6. The units of effort are independent

POPULAR VIOLATIONS

1. Closed population
2. Catchability
3. Human error

DeLury Method

Use this method when the fraction of the stock removed by unit of fishing effort is really small (less then 2%)

$$log\left(\frac{C_t}{f_t}\right) = log(qN_0) - qE_t$$

log of CPUE

log of catchability coefficient and initial population size

cumulative effort prior to time t

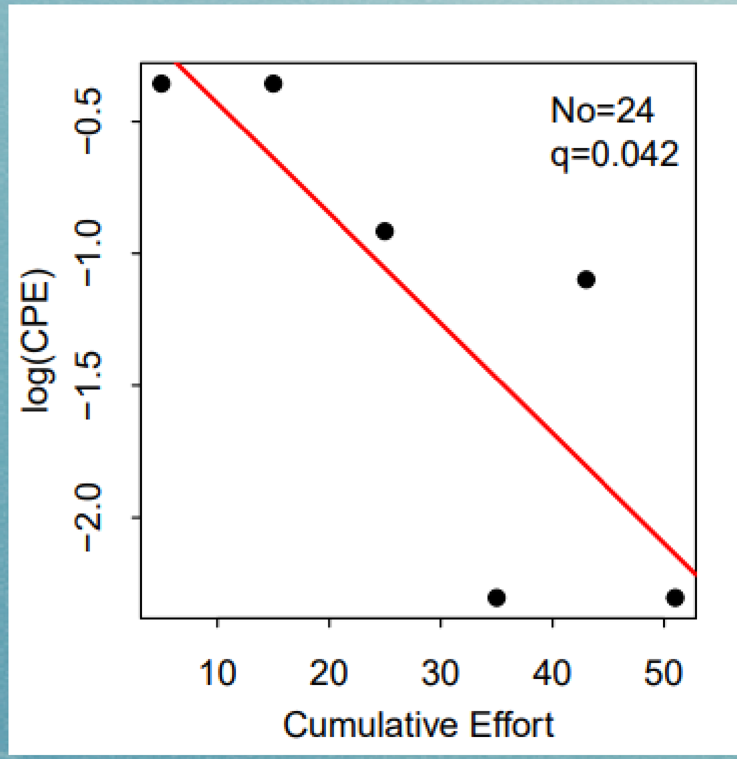
DuLury Method with depletion()

Used catch and effort data frame that was made earlier.

Again, you get N0 and q as well as the confidence intervals.

```
> lm4 <- with(mac,depletion(catch,effort,"Delury",ricker.mod=TRUE))
> summary(lm4)
The Delury method was used.
    Estimate Std. Err.
No 23.66606   5.84805
q   0.04165   0.01489
> confint(lm4)
      95% LCI  95% UCI
No 7.4292678 39.90285
q  0.0003136  0.08298
```

```
> plot(lm4)
```



K-Pass Method

Most accurate depletion method for estimating population size!!

$$X = \sum_{i=1}^{k} (k-i) C_i$$

succssive captures

probability of capture

q = 1-p or the probability of escape

$$L(\vec{C} | N_0, p) = \frac{N_0! \, p^T q^{kN_0 - X - T}}{(N_0 - T)! \prod_{i=1}^{k} C_i!}$$

$$T = \sum_{i=1}^{k} C_i$$

initial population size

total number of removal periods

total number of individuals captured

number of individuals captured in the first removal period

K-Pass Method Broken Down

Before actually using the package, it is important to understand how to calculate everything!

Step 1: Enter the three capture amounts

```
> ( ct <- c(187,77,35) )
[1] 187  77  35
```

Step 2: Can then compute k, T and X

```
> ( k <- length(ct) )          # number of removals
[1] 3
> ( T <- sum(ct) )             # total catch
[1] 299
> i <- seq(1,k)                # needed to compute X below
> ( X <- sum((k-i)*ct) )
[1] 451
```

K-Pass Method Broken Down

Step 3: Can then plug everything into the really scary equation

```
> mle <- function(N0) { (N0+0.5)*((k*N0-X-T)^k) - (N0-T+0.5)*((k*N0-X)^k) }
```

Step 4: You then continue to plug in different variations of N0 into the function until you get an answer that is negative

```
> mle(300) # must start >T
[1] 878409227
> mle(330) # arbitrarily picked this
[1] -363778799
> mle(320) # between 320 and 330
[1] 132897577
> mle(325) # between 320 and 325
[1] -105113899
> mle(322) # between 322 and 325
[1] 40171398
> mle(323) # first negative >T, done
[1] -7430898
```

There are an estimated 323 rainbow trout less than 85 mm in this stretch of stream

K-Pass Method with removal()

Still used data frame from before.

Now get N0 and p.

```
> pr1 <- removal(ct)
> summary(pr1)

The Zippin's K-Pass Removal Method method was used.
   Estimate Std. Error
No 323.0000    8.41582
p    0.5772    0.03557

> confint(pr1)

    95% LCI  95% UCI
No 306.5053 339.4947
p    0.5075   0.6469
```

Advantages & Limitations

Depletion

Advantages: efficient package, has multiple ways of finding the total population size, each method requires slightly different types of data, can be used for more than just fish
Limitations: can be biased, human error is easily achieved, assumptions are often not met

FSA

Advantages: lots of documentation and accessible data; wide array of common fisheries assessment methodologies; coding is relatively straightforward
Limitations: weight-length needs pre-existing standard weight function; so many functions it can be hard to find what you need; doesn't do recruitment on its own; documentation is old

Resources

Package

- Package documentation
- Book with R scripts for various functions
- Weight-length vignette (Ogle 2013)
- Catch Curve Estimates of Mortality Vignette (Ogle 2013)
- Depletion Vignette (Ogle 2013)

Applications

- Brett T. Miller, Ernesto Flores, D. Scott Waters, Ben C. Neely; An Evaluation of Goldeye Life History Characteristics in Two Kansas Reservoirs. *Journal of Fish and Wildlife Management* 1 June 2022; 13 (1): 243–249. doi: https://doi.org/10.3996/JFWM-21-090
- Maceina, M. J., S. J. Rider, and D. R. Lowery. 1993. Use of a catch-depletion method to estimate population density of age-0 largemouth bass in submersed vegetation. North American Journal of Fisheries Management 13:847–851. doi:10.1577/1548-8675(1993)0130847:UOACDM2.3.CO;2

Portfolio Assignment

Depletion:

Grab a new set of data and use the Leslie, DeLury, and K-Pass methods to calculate the initial population size! Answer the following questions:

1. Compare and contrast the initial population sizes between the three methods
2. Why are the Leslie and DeLury methods not valid at estimating N0?
3. What values can you look at to determine the reliability of the data? (Hint: Think back to what we learned about statistics in 206)

Catch Curve:

1. How do the estimates of Z and A change between between the weighted and non-weighted regressions? How does the confidence interval change?