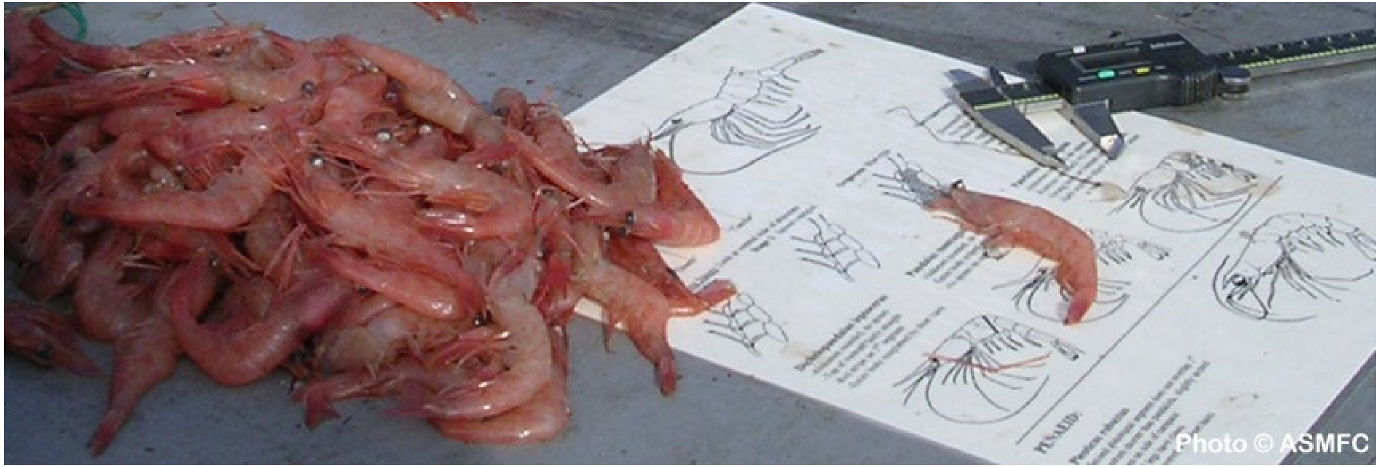


Length -Based Stock Assessment Techniques

1.

Stage-based models

Catch-Survey Analysis (CSA)

Stage-based modeling

- Stage = some identifiable transition point inthe life of animal
- Any transition that can be reliably measured, often…
  - <u>Length</u> at recruitment to the fishery
  - Market category/grade (often based on <u>size</u> of animal)
- Stages may be artificial (not meaningful biologically) but can still be useful for monitoring and tracking animals over time

Catch-Survey Analysis (CSA)

- aka Collie-Sissenwine Analysis (see Collie & Sissenwine 1984, Collie et al. 2005)
- Suggests that if :
  - we can divide the stock into discrete stages
  - we can monitor relative numbers in each stage (usually based on survey catch at length)
  - we know natural mortality and how many animals are caught by the fishery
  - …then we can estimate abundance in each stage and use that along with catch to calculate exploitation rate

Catch-Survey Analysis (CSA)

- Assumes:
  - There is at least one clean breakpoint at which you can divide the stock into pre- and post-recruits to the fishery (knife-edged selectivity)
  - Indices are directly proportional to abundance
  - Catchability (q) of the survey for each stage is constant over time
  - Natural mortality (M) is known
- Watch out for the terminology used!
  - "pre-recruit vs recruits"
  - "recruit vs. post-recruit"
  - "recruit vs adult"

Parameter estimation – MLE framework

- Two models:
  - **Population model:** uses catch, indices, and starting values (guestimates) for abundance in first year, mean recruitment, and annual deviations from mean recruitment to calculate abundance, exploitation rate, and catchability
  - **Observation model**: uses catchability and abundance from population model to estimate indices
  - Find best set of estimates for N, R, and Rdevs parameter that generate best fits to indices (IOW, smallest differences between observed indices and predicted indices from observation model)

Population model

- Assuming a pulse fishery mid-year…
  - Recruits are added to the population (N+R)
  - ½ of the natural mortality is applied
  - Catch is removed
  - ½ of the natural mortality is applied to the remaining population

$$N_{t+1} = \left((N_t + R_t)e^{-\frac{M}{2}} - C_t \right) e^{-\frac{M}{2}}$$

$$U_{t+1} = \frac{C_t}{(N_t+R_t)e^{-\frac{M}{2}}}$$

N = abundance
t = time
R = recruit abundance
C = catch
M = natural mortality
U = fishery exploitation rate

Observation model

- Calculates indices based on N from population model
- And using q which is generated from the difference between estimated N and the observed indices
- In the case of one index with 2 stages (pre-rec and rec)…

$$n_t = q_n N_t e^{n_t}$$

$$r_t = q_r R_t e^{\delta_t}$$

$$q_n = e^{\sum \frac{(\log(n_t) - \log(N_t))}{k}}$$

$$q_r = e^{\sum \frac{(\log(r_t) - \log(N_t))}{k}}$$

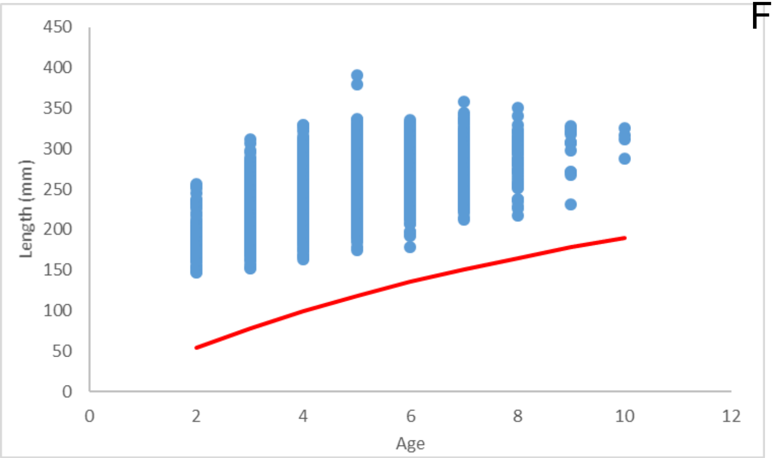
n = estimated survey recruits
t = time
q = catchability
N = abundance
r = estimated survey pre-recruits
R = recruit abundance
k = number of survey years

Parameter estimation – MLE framework

- Use starting values (guestimates) for $N_0, \bar{R}$, and annual R deviations…
  - Population model generates initial N and R time series
  - Observation model generates estimated indices of abundance (n_t and r_t)
- Model searches across different combinations of parameter values to find the parameters that maximize the probability of generating the observed data

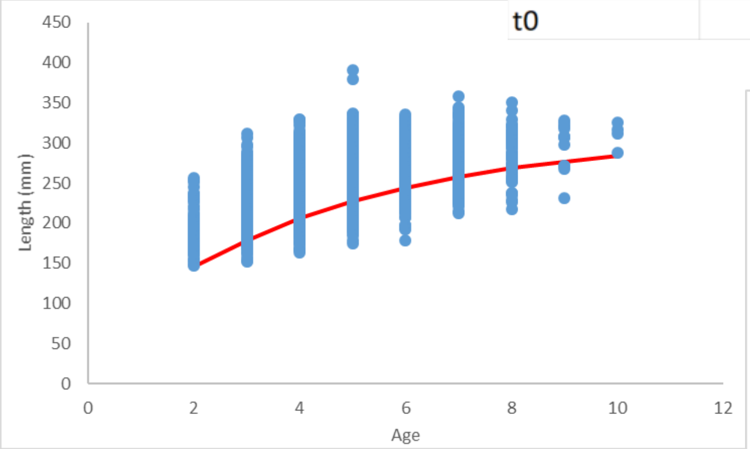
First guess = starting values

von B parameter estimates	
Linf	300
K	0.10
t0	0.00



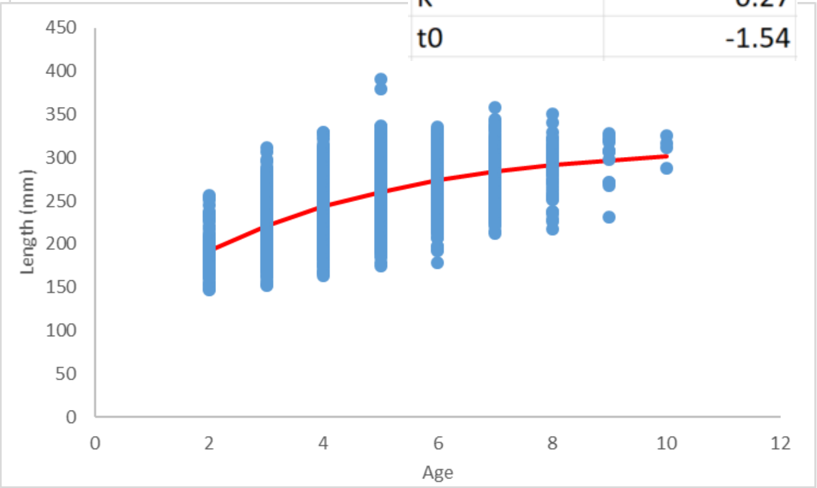
Second guess – getting closer!

von B parameter estimates	
Linf	310
K	0.23
t0	-0.75



Solver's best estimates

von B parameter estimates	
Linf	316
K	0.27
t0	-1.54



Likelihood

$$L_n = k \log(\sigma_s) + \frac{1}{2\sigma^2} \sum \left(\log\left(n_{t,s,obs}\right) - \log\left(n_{t,s,est}\right)\right)^2$$

$$L_r = k \log(\sigma_s) + \frac{1}{2\sigma^2} \sum \left(\log\left(n_{t,s,obs}\right) - \log\left(n_{t,s,est}\right)\right)^2$$

$$\text{LL} = L_n + L_r$$

s = survey
k = number of survey years
σ = standard deviation of survey
n = recruit survey abundance
t = time
obs = observed (input data)
est = estimated
r = estimated survey pre-recruits

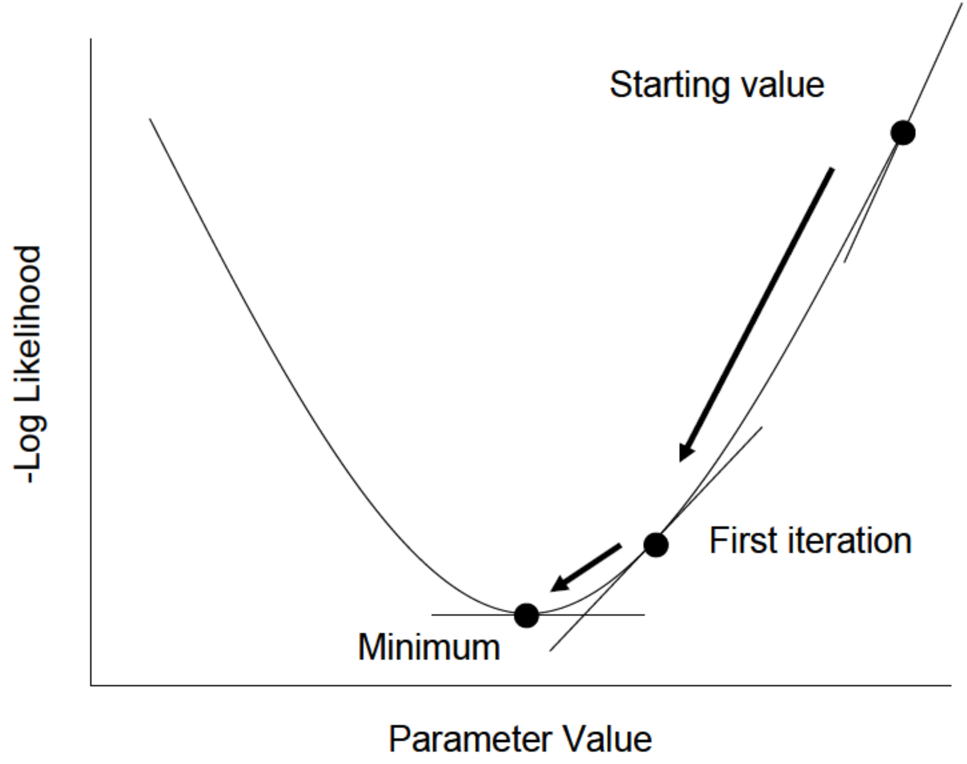
Likelihood Nomenclature

- Terms used to identify likelihood methods can be confusing

Likelihood	L(p|data)
Log likelihood	log(L(p|data))
Negative log likelihood	**-log(L(p|data))**

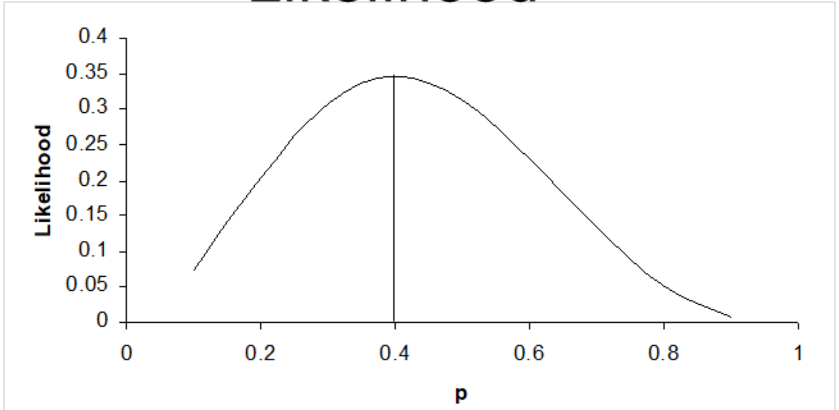
- We often use the log likelihood instead of the likelihood because it is easier to evaluate (given magnitude of parameter values is usually quite different)

Parameter Estimation

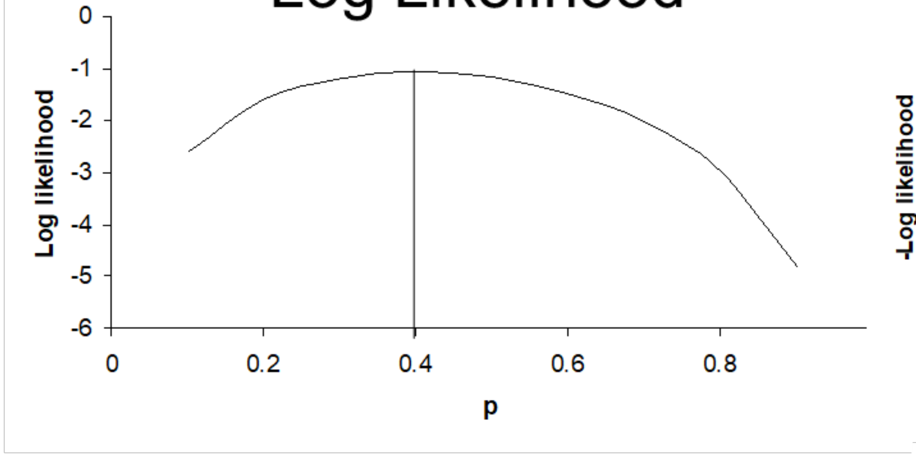


n = 5

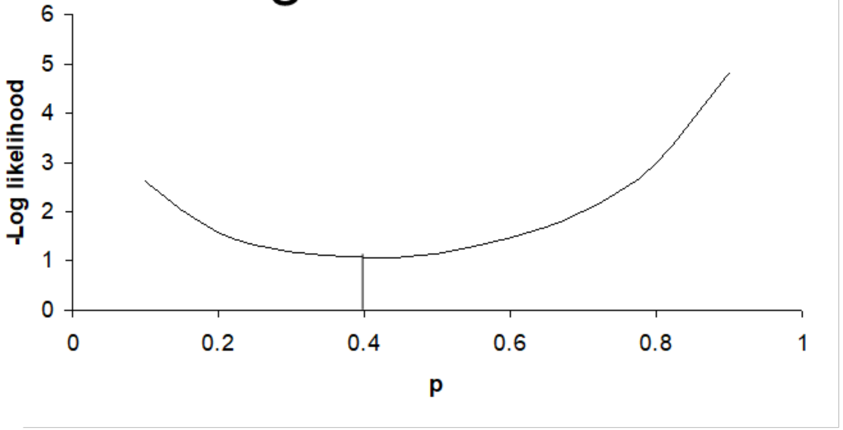
Likelihood



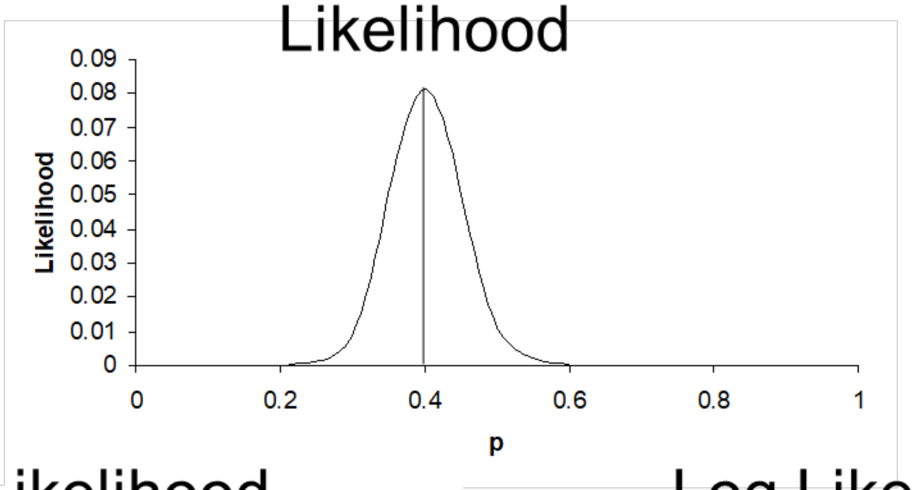
Log Likelihood

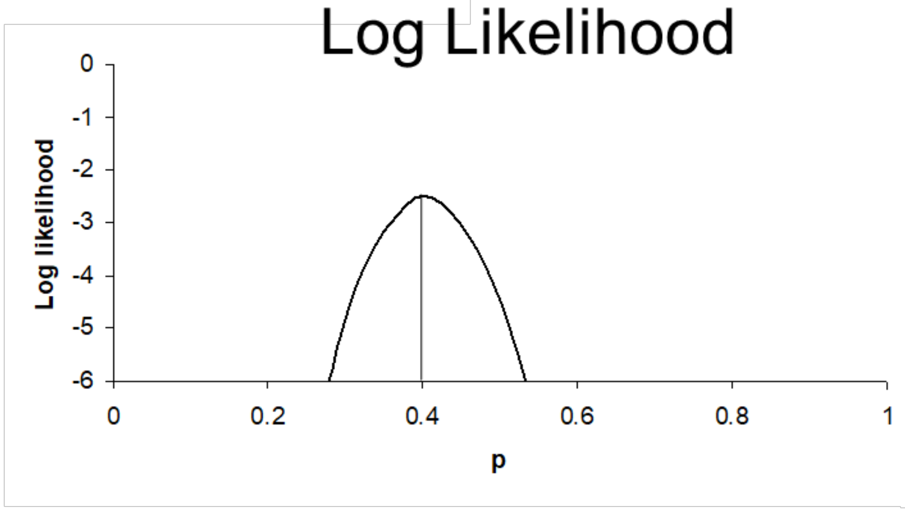


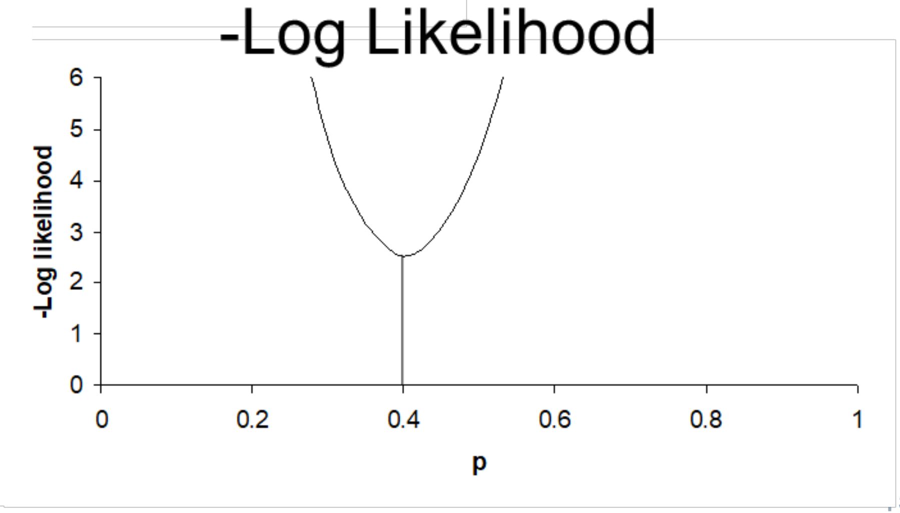
-Log Likelihood



n = 100


Likelihood
Likelihood
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1
p


Log Likelihood
Log likelihood
0
-1
-2
-3
-4
-5
-6
0
0.2
0.4
0.6
0.8
1
p


-Log Likelihood
-Log likelihood
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
p

MICHIGAN STATE UNIVERSITY

Department of Fisheries and Wildlife
Quantitative Fisheries Center

Online course:
Software Tools for Maximum Likelihood Estimation using ADMB/TMB at the Quantitative Fisheries Center at Michigan State**:**

https://www.canr.msu.edu/qfc/education/software_tools_mle

CSA

- Can incorporate multiple stages (see Collie et al. 2005 for 3-stage example)
- Flexible - can fit to multiple surveys (e.g., different programs and/or split surveys into male/female)
- Alterative estimation frameworks (e.g., hierarchical Bayesian approach in Lee et al. 2018 and Yan's guest lecture Oct 6)
- Reasonably robust (accurate) across wide range of scenarios, but often relatively low precision (Batts et al. 2022)

2.

Break

5 minutes

Meet back here at X:XX.

3.
Breakout Room Exercise

Meet back here at X:XX.
2 minute warning

3.
Discussion

Questions?

- Supplemental readings
- Next week: Intro to SCAL