Investigating spatial variation in growth of bigeye in the Pacific based on annual ageing data

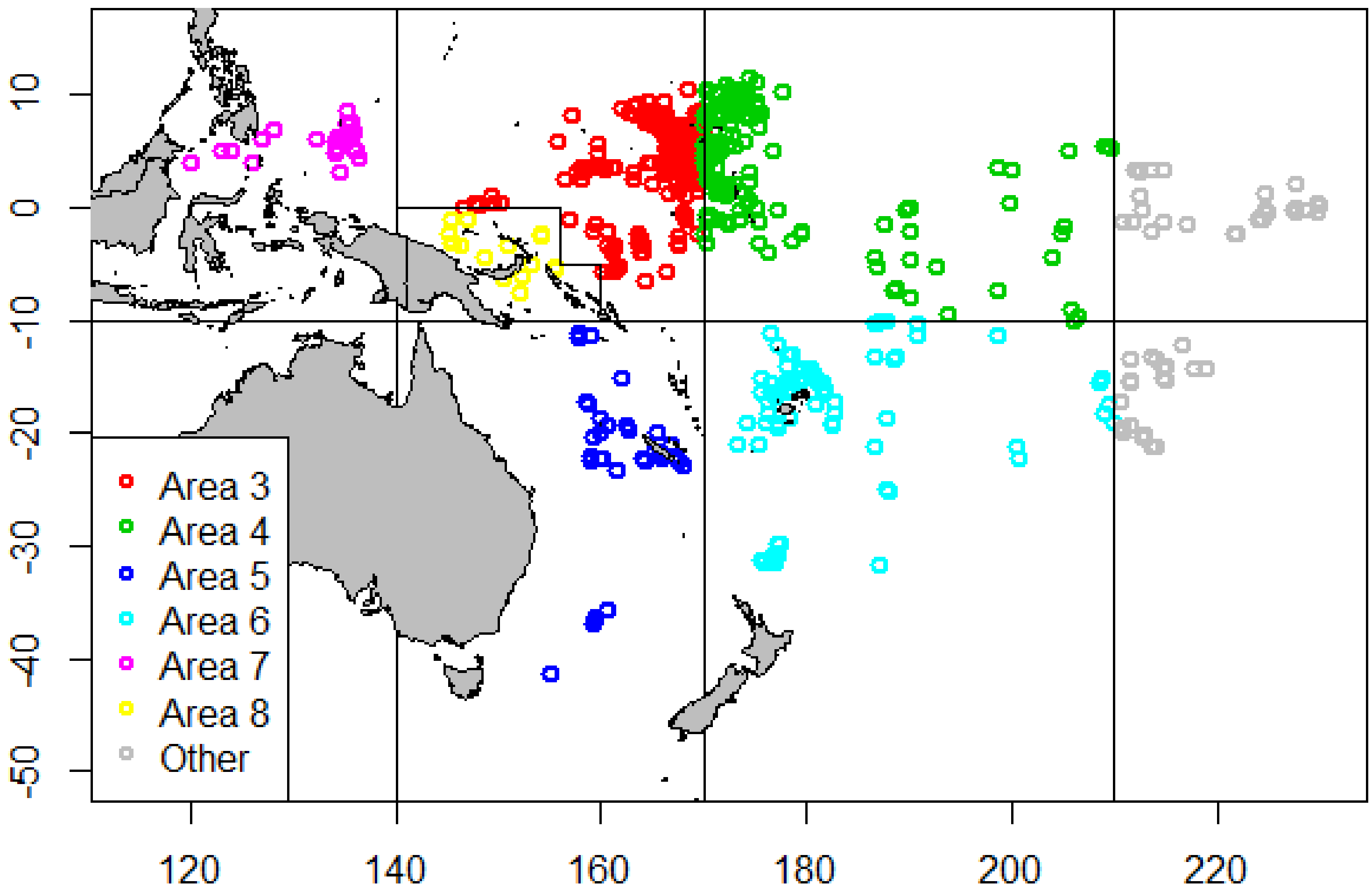
Presenter: Paige Eveson

WORKSHOP ON AGE AND GROWTH OF BIGEYE AND YELLOWFIN TUNAS IN THE PACIFIC OCEAN, JANUARY 23-25, 2019, LA JOLLA, CALIFORNIA, USA

Investigate spatial variation in growth

- Differences in growth observed between EPO and WPO
- Could be due to:
  - differences in otolith age estimates
  - true spatial differences in growth
- Can investigate spatial differences using all the annual ageing data we have for the Pacific from otoliths read using the same technique and reader

Spatial management areas



Investigate spatial variation in growth

- Fit GAM to length data with age and (lat,lon) as smooth terms:

  Length ~ s(Age) + s(Lat,Lon)

- Output from R:

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• Approximate significance of smooth terms:
•                      edf Ref.df       F p-value
• s(Decimal_age)   7.528  8.468 786.925  <2e-16 ***
• s(Lon,Lat)      25.814 28.312   6.895  <2e-16 ***

• R-sq.(adj) =  0.909   Deviance explained = 91.2%
• GCV = 83.008  Scale est. = 80.789    n = 1285
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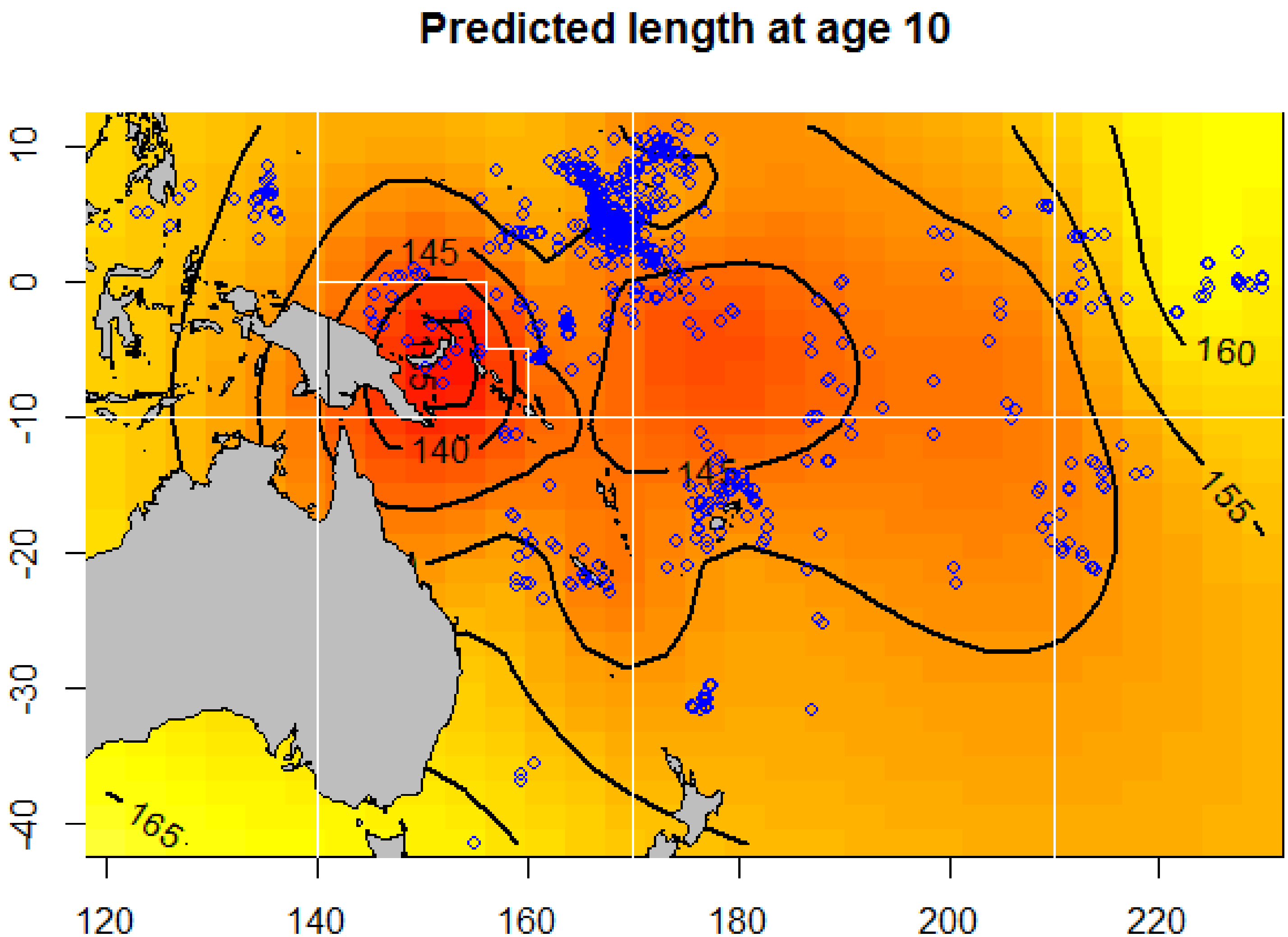
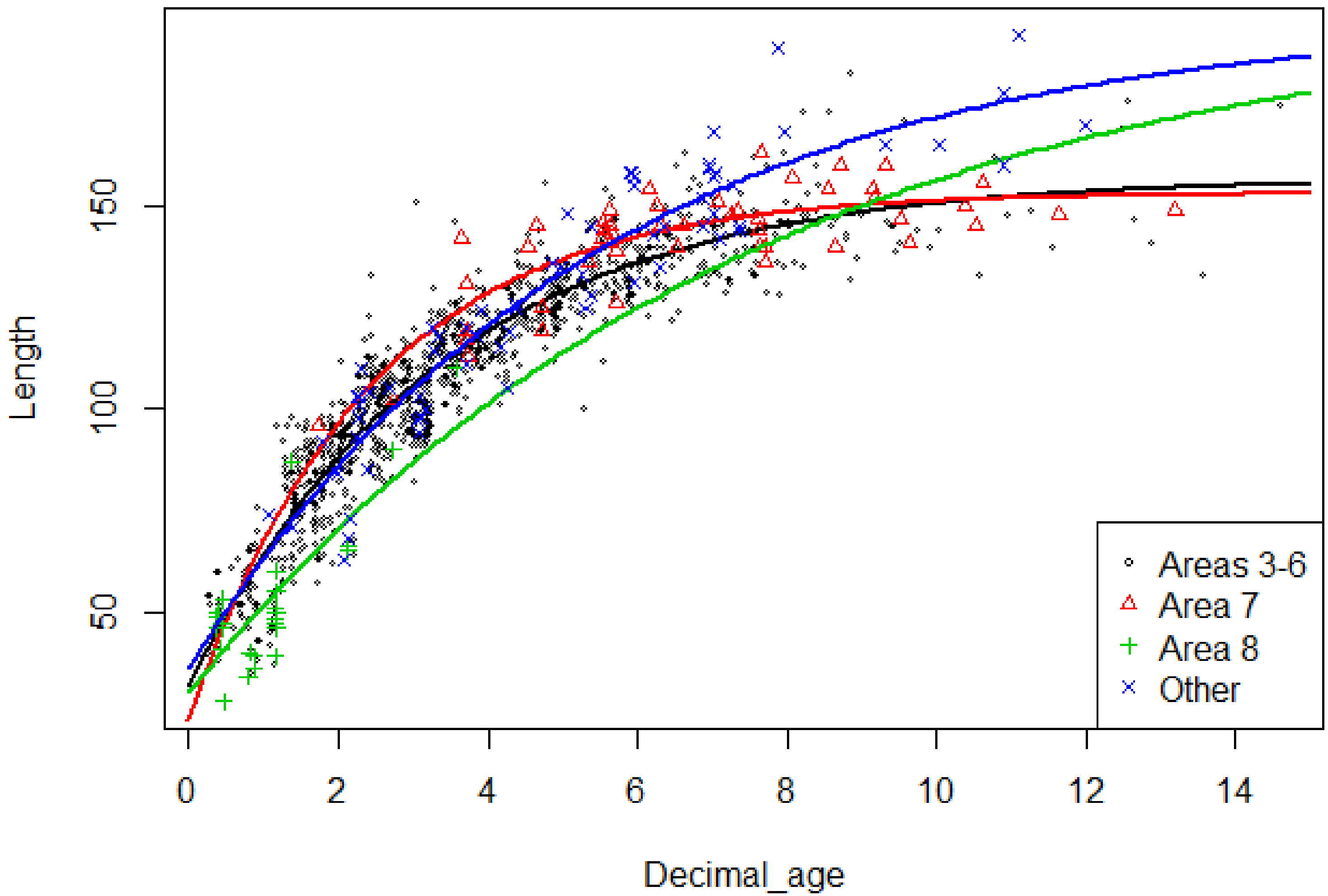
- So spatial term came out highly significant
- Can plot spatial map of predicted length at any specified age

Spatial GAM results



VB fit to combined areas based on spatial GAM



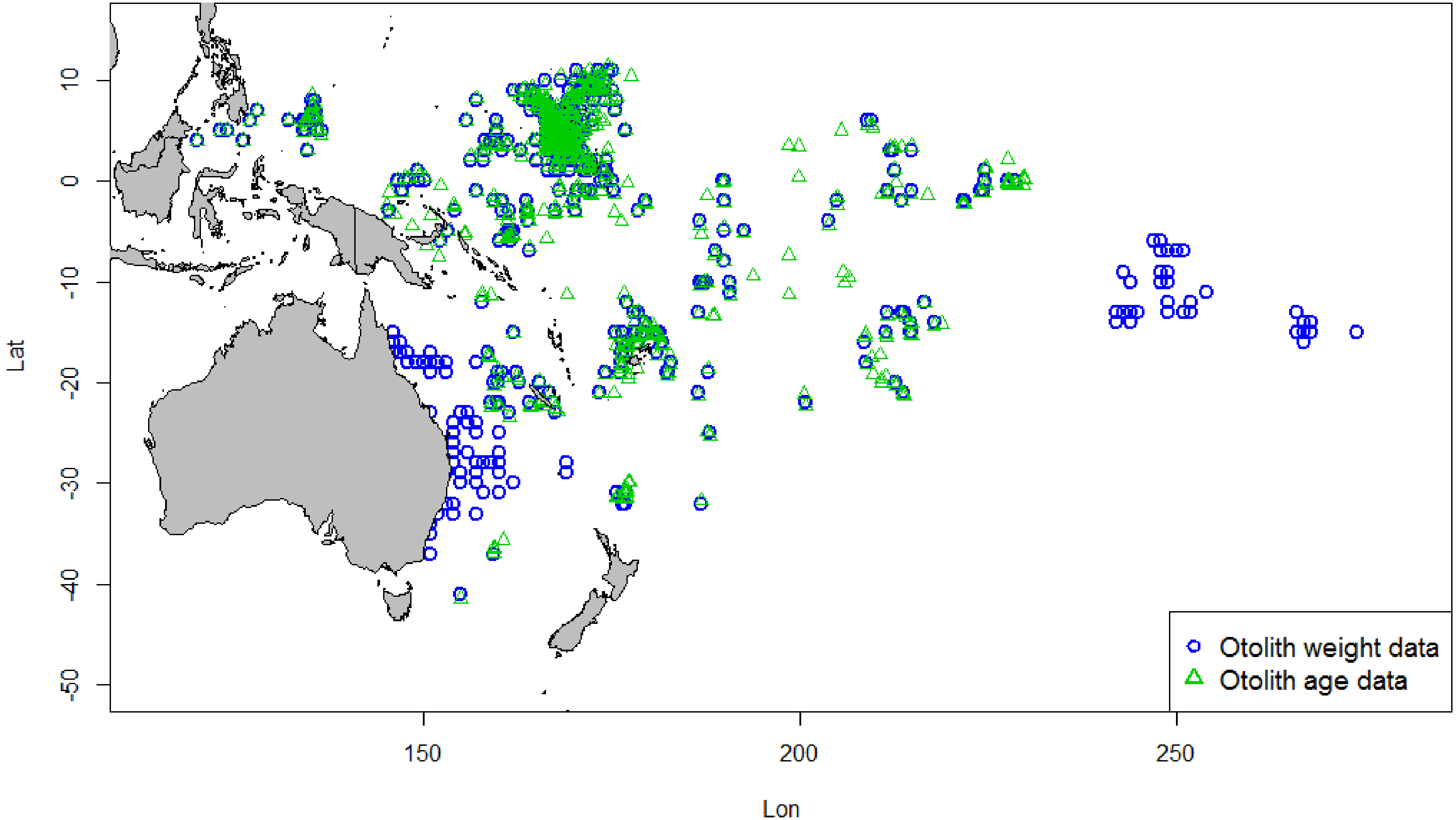
Discussion

- Fairly strong evidence of spatial variation in growth across Pacific
- However, limited sample sizes and age/length ranges by regions make full assessment difficult
- Good to get otolith data from further east to see if trend toward larger fish continues
- Otolith weight data may be able to help with last two points…

Using otolith weight to investigate spatial variation in growth

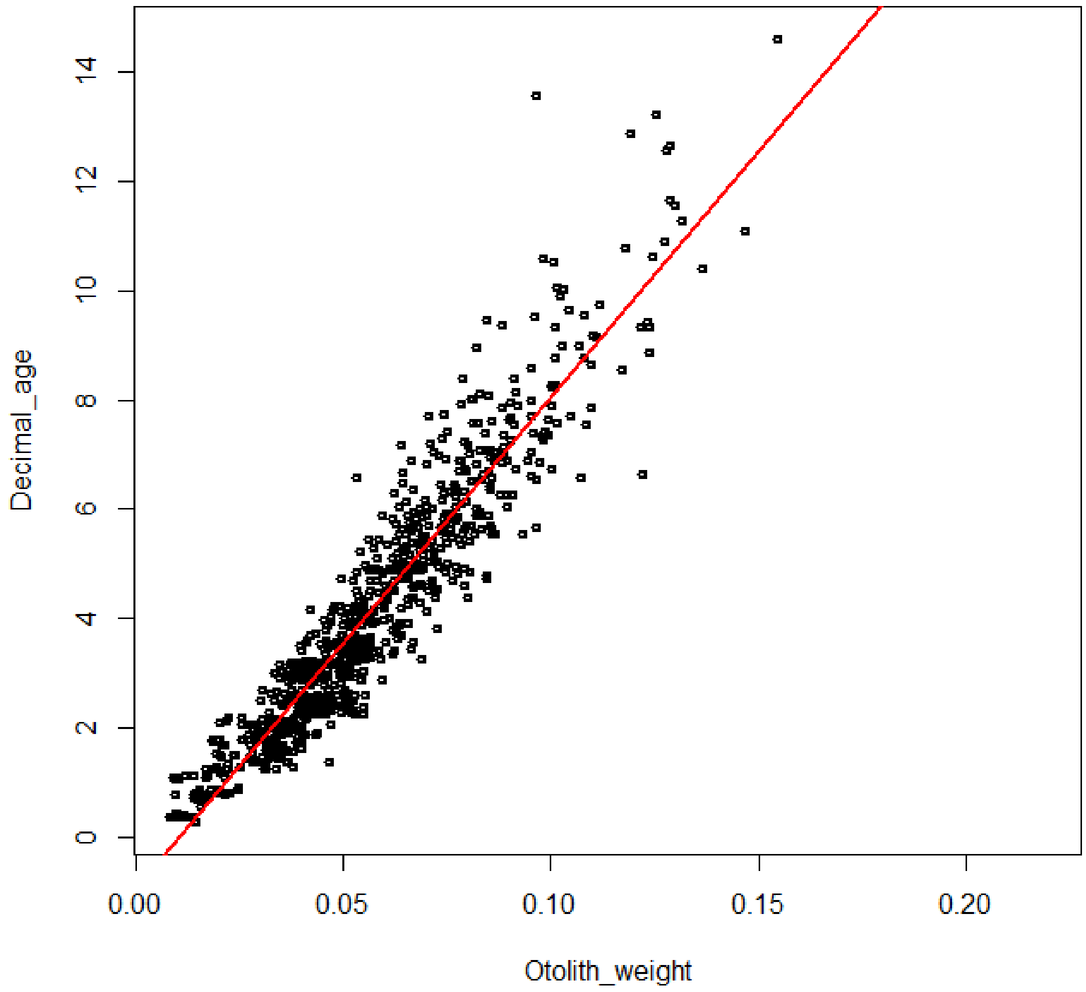
- Often have otolith weight information from samples without age estimates
- Correlation between otolith weight and fish age is often strong
- Therefore, may be useful to use otolith weight in place of age in spatial GAMs to increase sample sizes and spatial range of data
- Tried this approach for bigeye in the Pacific

Otolith weight vs age sample locations

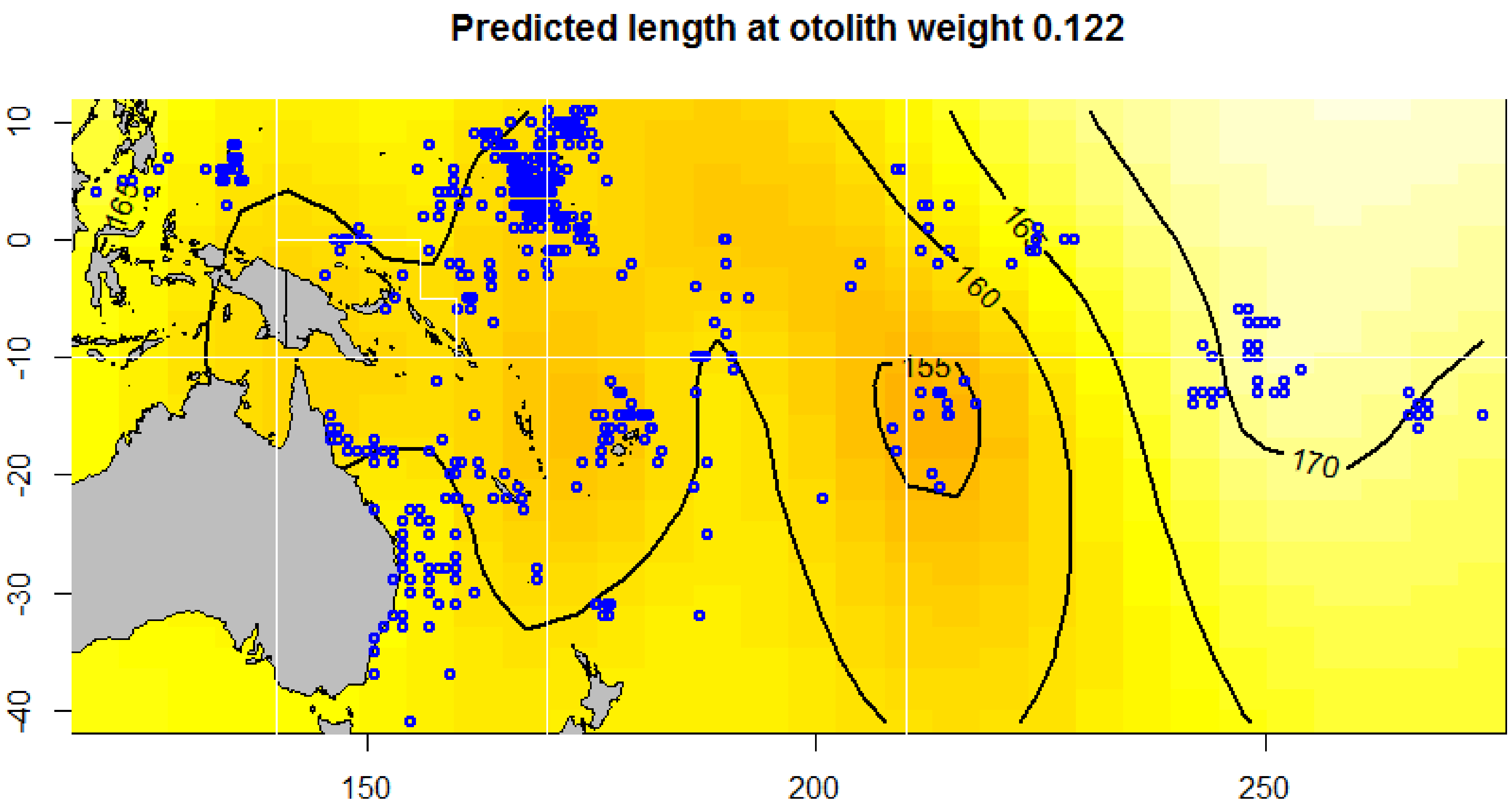


CSIRO

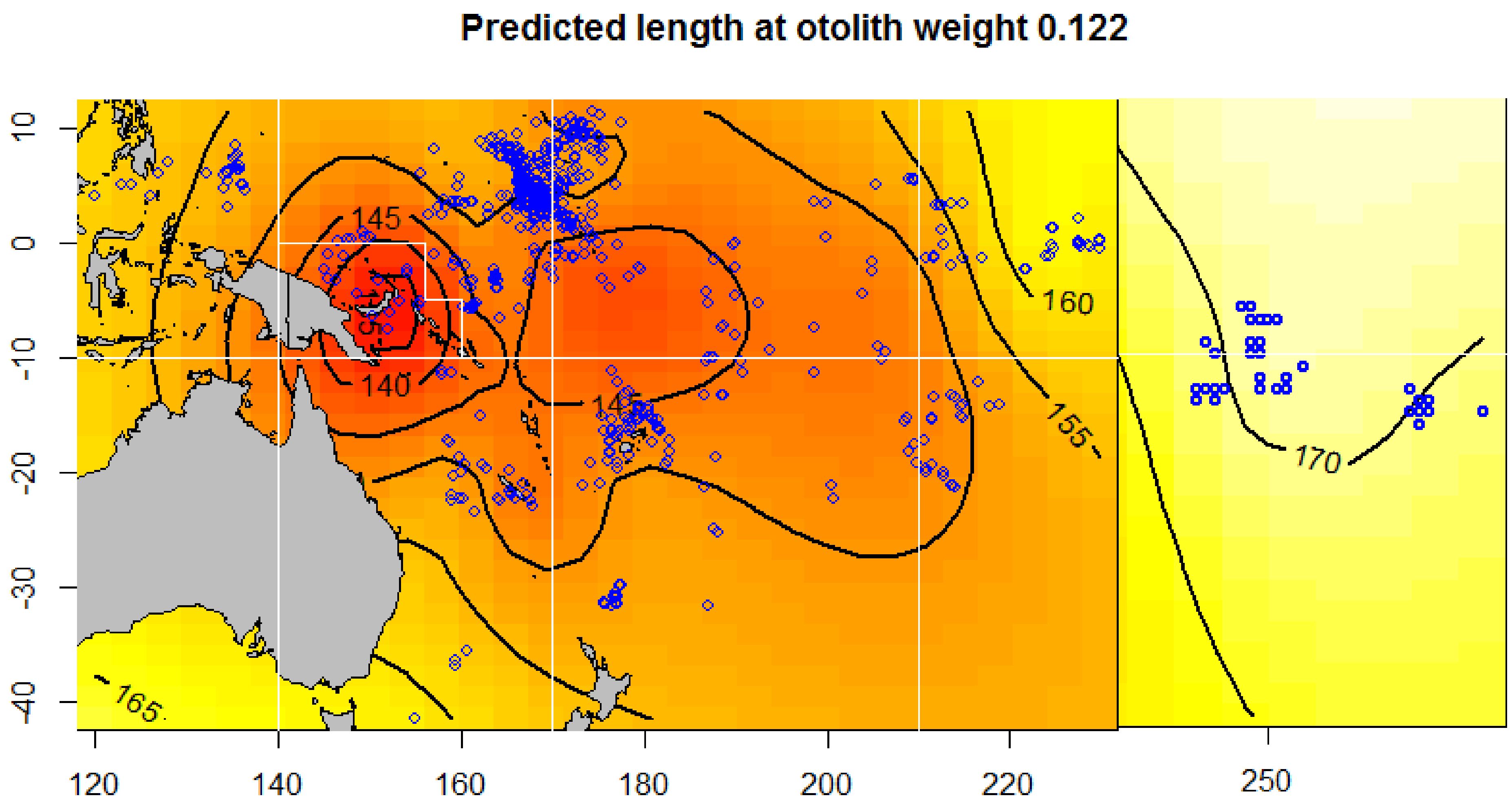
Otolith weight vs age

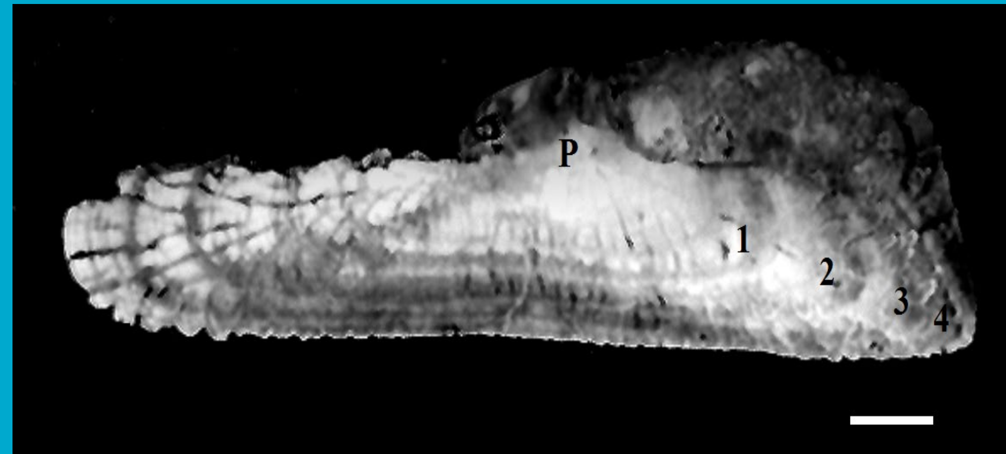


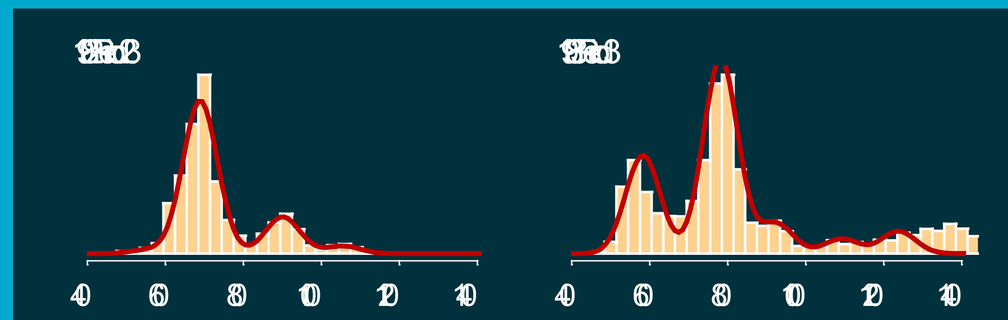
Spatial GAM results using otolith weight



Spatial GAM results using otolith weight







Integrating multiple data sets into growth models

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Why an integrated model?

- A single source of data does not generally contain complete growth information
- Different data sources contain information about different portions of the life cycle and different aspects of growth
- Using multiple data sources enables us to check for biases and inconsistencies

Sources of growth information

Three common data sources:

- Release and recapture length and time at liberty data from tag-recapture experiments
- Direct age data obtained from hard-parts (e.g. otoliths) and fish length
- Length-frequency data from commercial catches

LEP maximum likelihood approach

- Develop a likelihood for each data set separately
- Multiply likelihoods together to obtain an overall likelihood to be optimized (assuming data sets are independent)
- Requires growth function to be of form L_∞*f(age,θ)
  (e.g. for VB, f = 1-exp{-k(age-t0)},* θ=*{k,t0})*
- To allow for individual variability in growth, model L_∞ as a random variable (optional)

Tag-recapture component

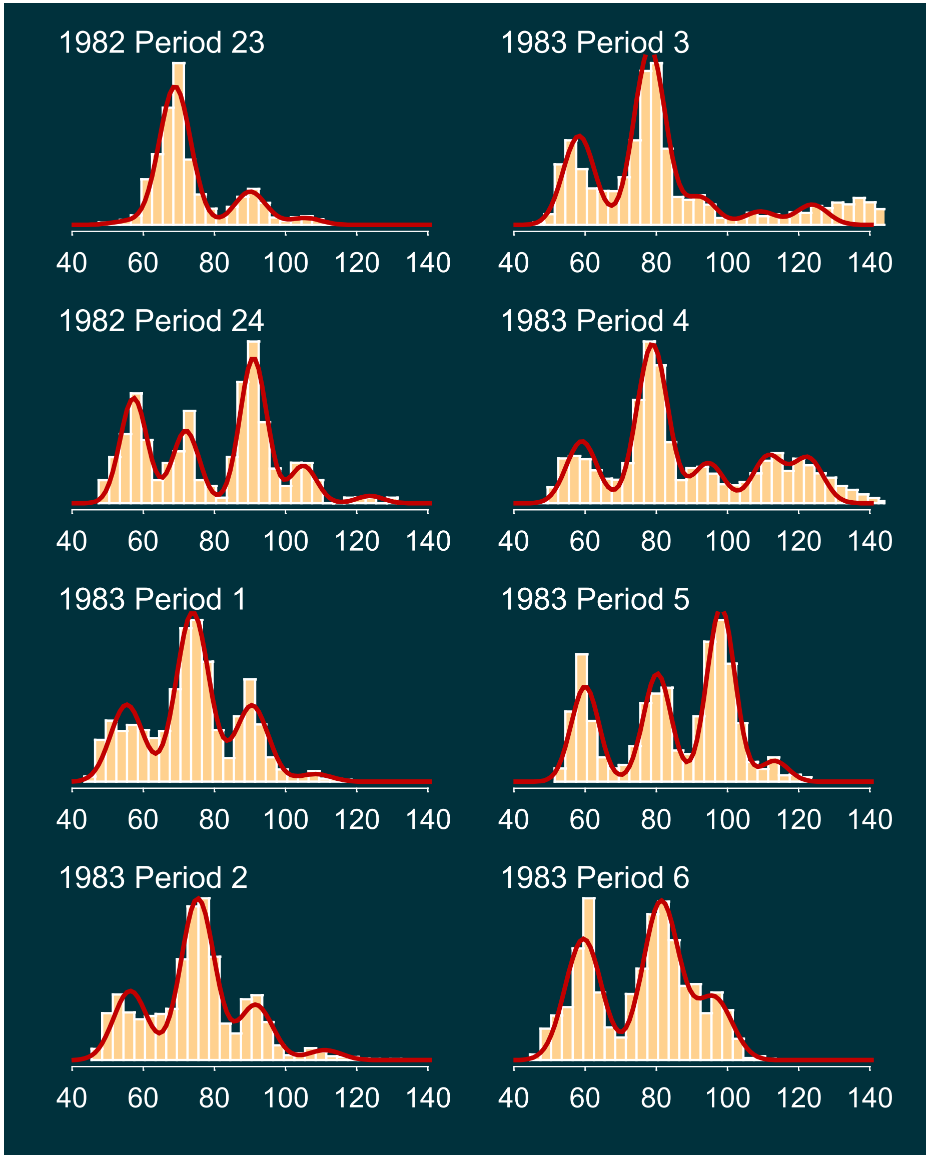
- Model the joint density of release and recapture lengths
- Age at release unknown
- Model it as a random variable, *A*
- For many species, reasonable to assume $A \sim \log N(\mu_A , \sigma_A{}^2)$

Otolith component

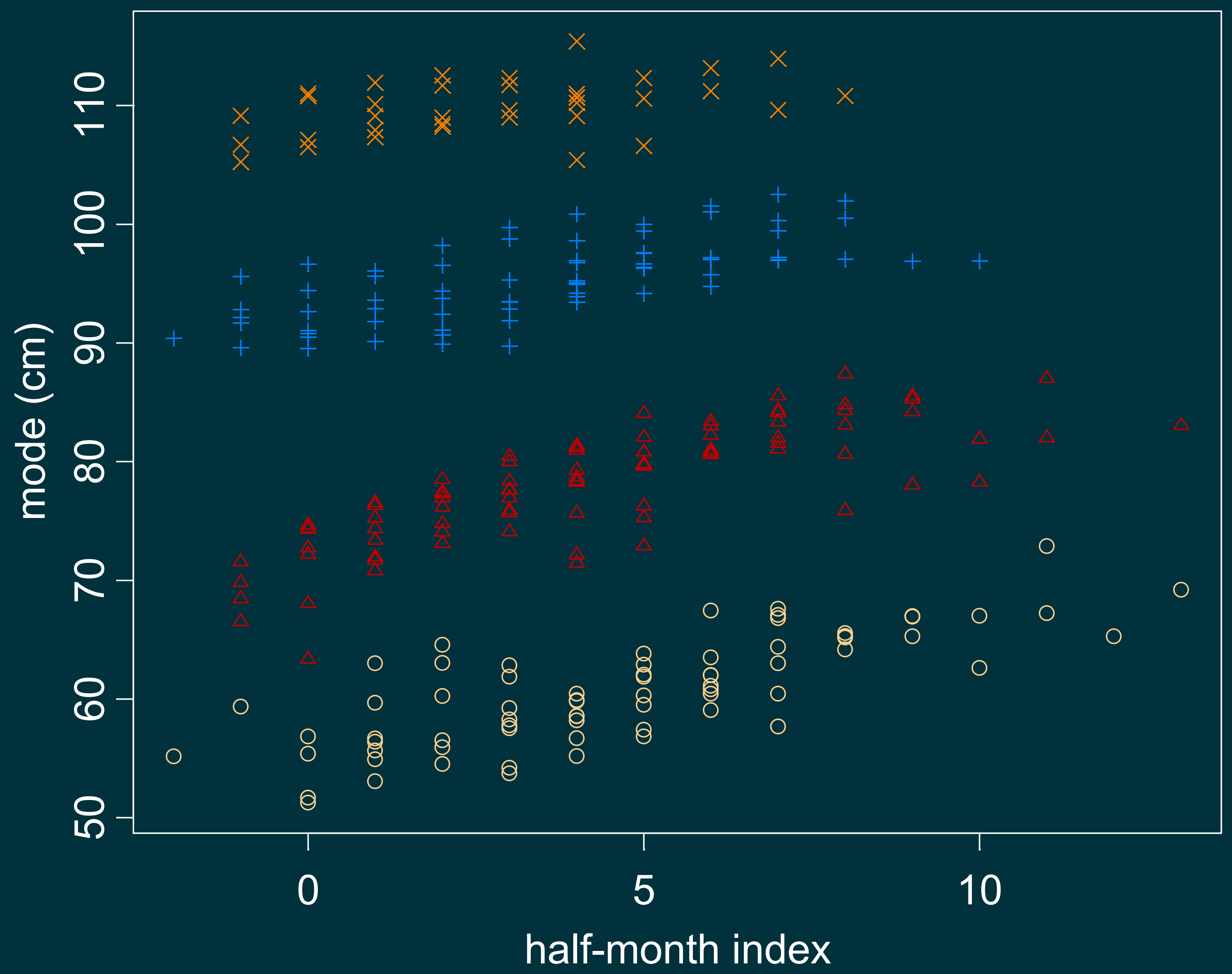
- Assign an age to each fish based on the number of annual or daily increments
- In case of annual increments, estimate decimal age using an assumed average date of birth and date of band formation for the population
- Model fish length as a function of age, treating the ages as exact

Length-frequency component

- Step 1: Decompose the length-frequency distributions into modes using a Gaussian mixture model
- Step 2: Model mean fish length using the estimated modes and their standard errors obtained in Step 1


1982 Period 23
1983 Period 3
1982 Period 24
1983 Period 4
1983 Period 1
1983 Period 5
1983 Period 2
1983 Period 6
40
60
80
100
120
140

CSIRO



mode (cm)
50
60
70
80
90
100
110
0
5
10
half-month index

Investigating compatibility of otolith and tag-recapture data using simulations

Simulate VB growth data with parameter values:

- n.tag = 500
- n.oto = 500
- **Linf=200**
- sig.Linf=5
- **k=0.4**
- **t0= -0.5**
- sig.err=5

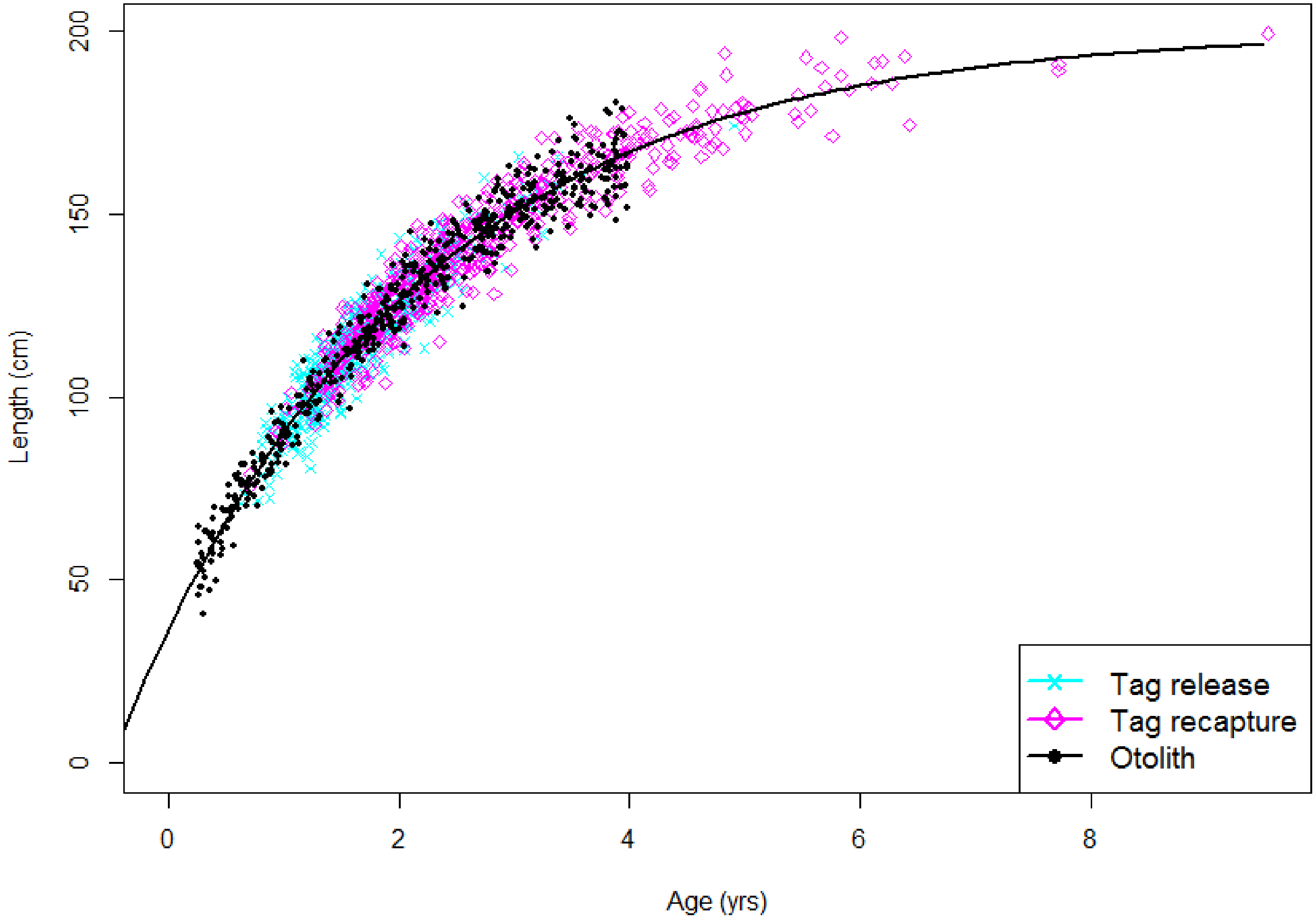
Simulate tag-recapture data

- TAL = rgamma(n.tag, 1, 1) *# time at liberty*
- a1 = rlnorm(n.tag, 0.5, 0.3) + a0 *# release age*
- a2 = a1 + TAL *# recapture age*
- Linf.tag = rnorm(n.tag, Linf, sig.Linf) *# fish-specific Linf*
- L1 = Linf.tag*f(a1-t0,k) + rnorm(n.tag, 0, sig.err) *# release length*
- L2 = Linf.tag*f(a2-t0,k) + rnorm(n.tag, 0, sig.err) *# recap length*

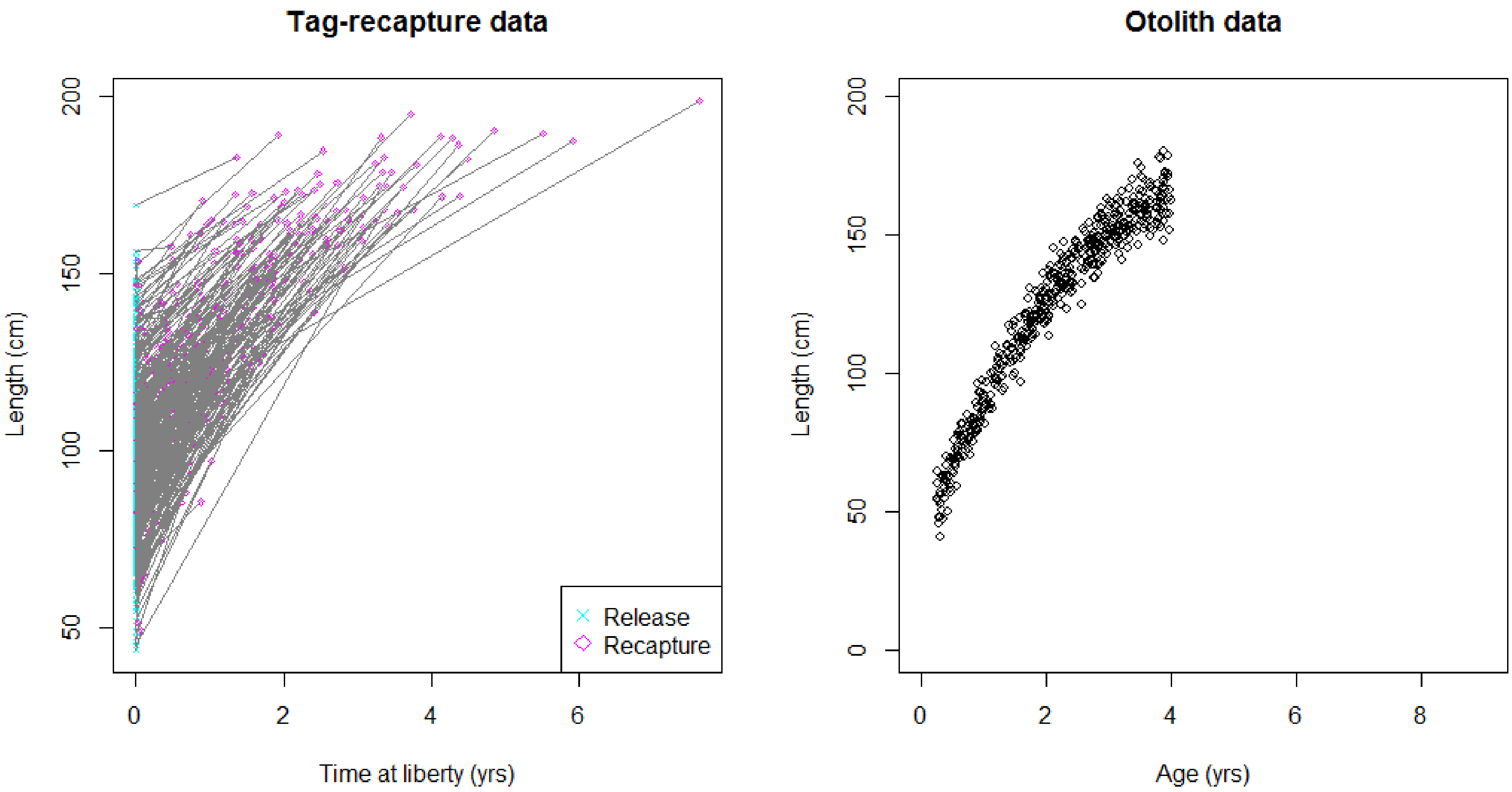
Simulate otolith data

- a.oto = runif(n.oto, 0.25, 4)
- Linf.oto = rnorm(n.oto, Linf, sig.Linf)
- L.oto = Linf.oto*f(a.oto-t0,k) + rnorm(n.oto, 0, sig.err)

Simulated data sets



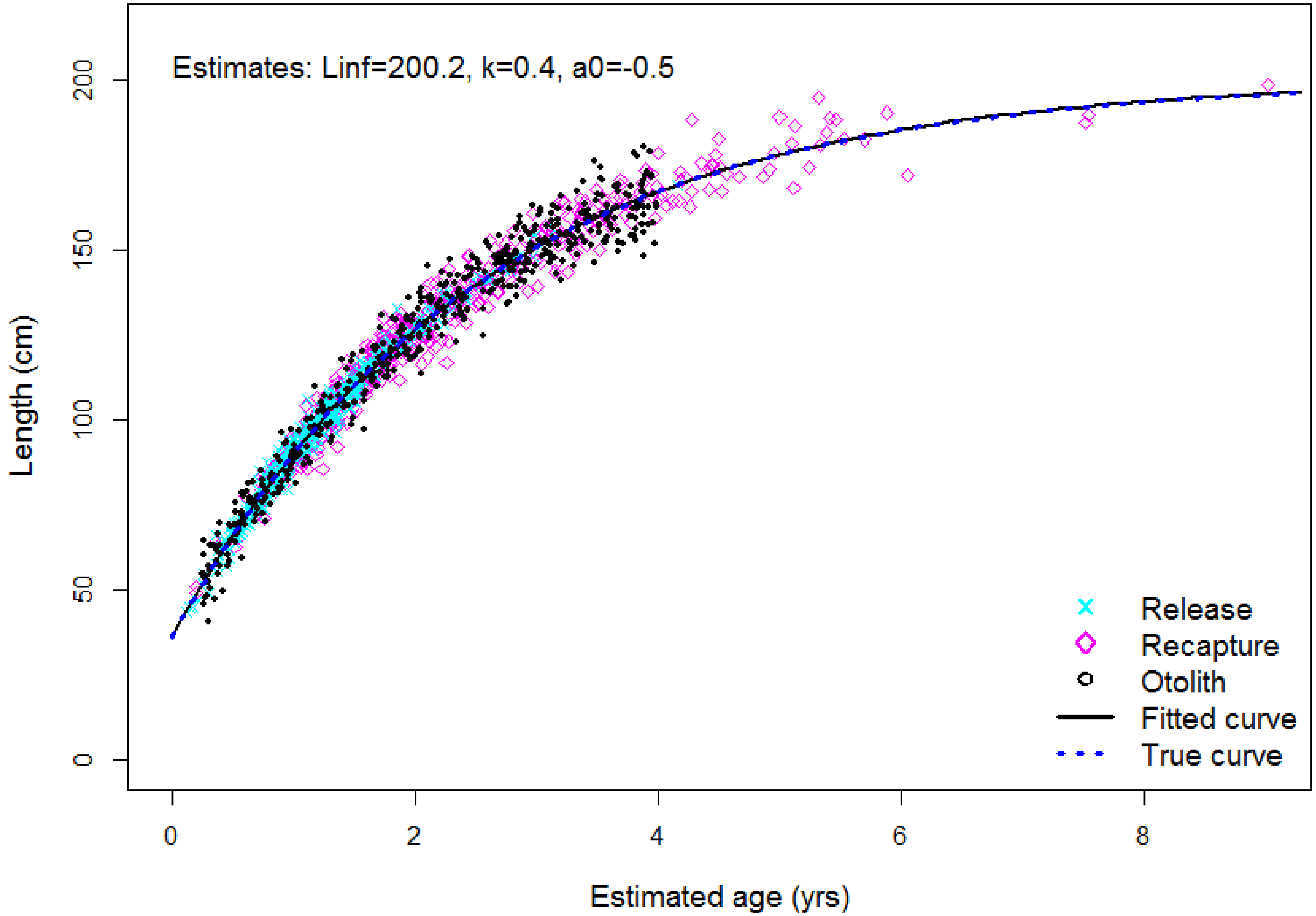
Simulated data sets



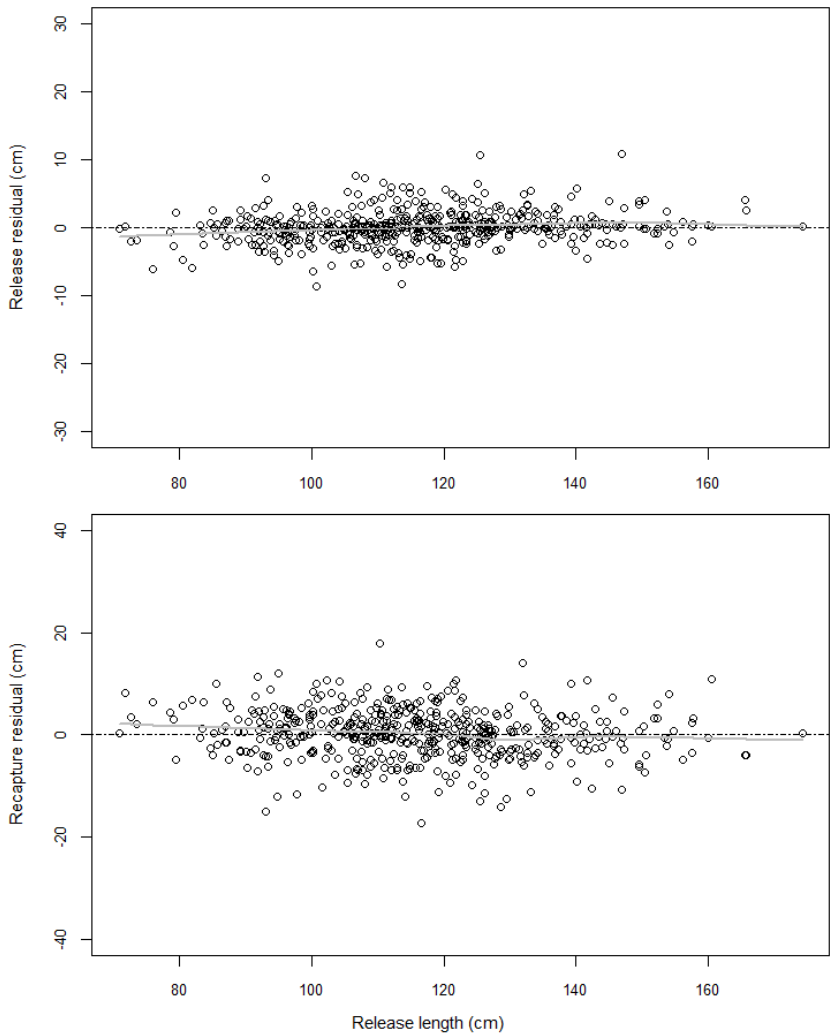
Assessing model fit for tag-recapture data

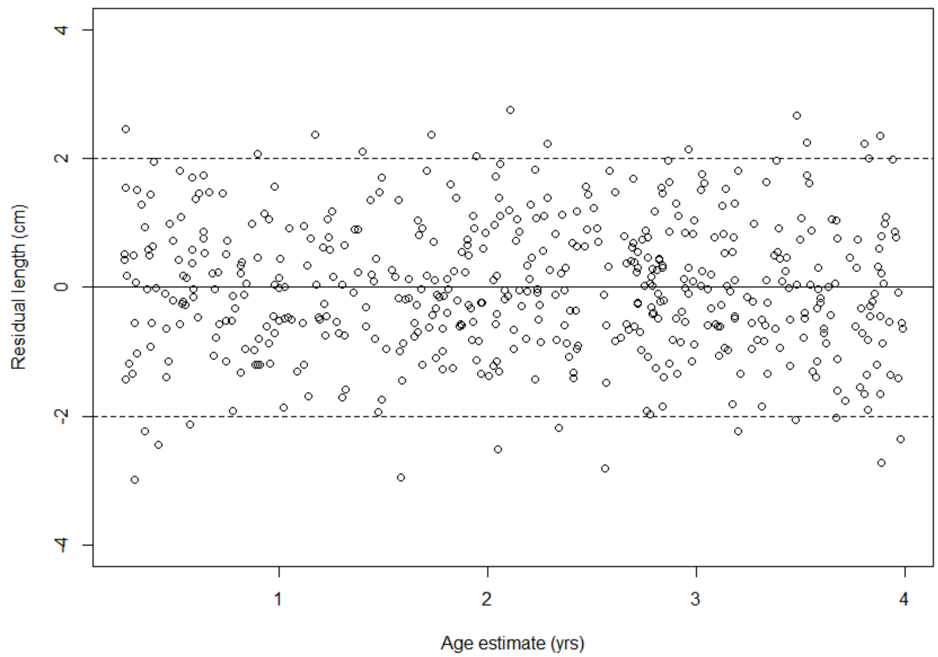
- To calculate fitted release and recapture lengths requires an estimated value of *A* for each fish
- Obvious approach is to use mean of posterior distribution for *A* conditioned on a fish's release and recapture lengths
- However, this approach yields biased estimates of *A*
- Thus, we use alternative approximately conditionally unbiased estimator proposed in Laslett et al. (2004)

Integrated model results: fitted curve

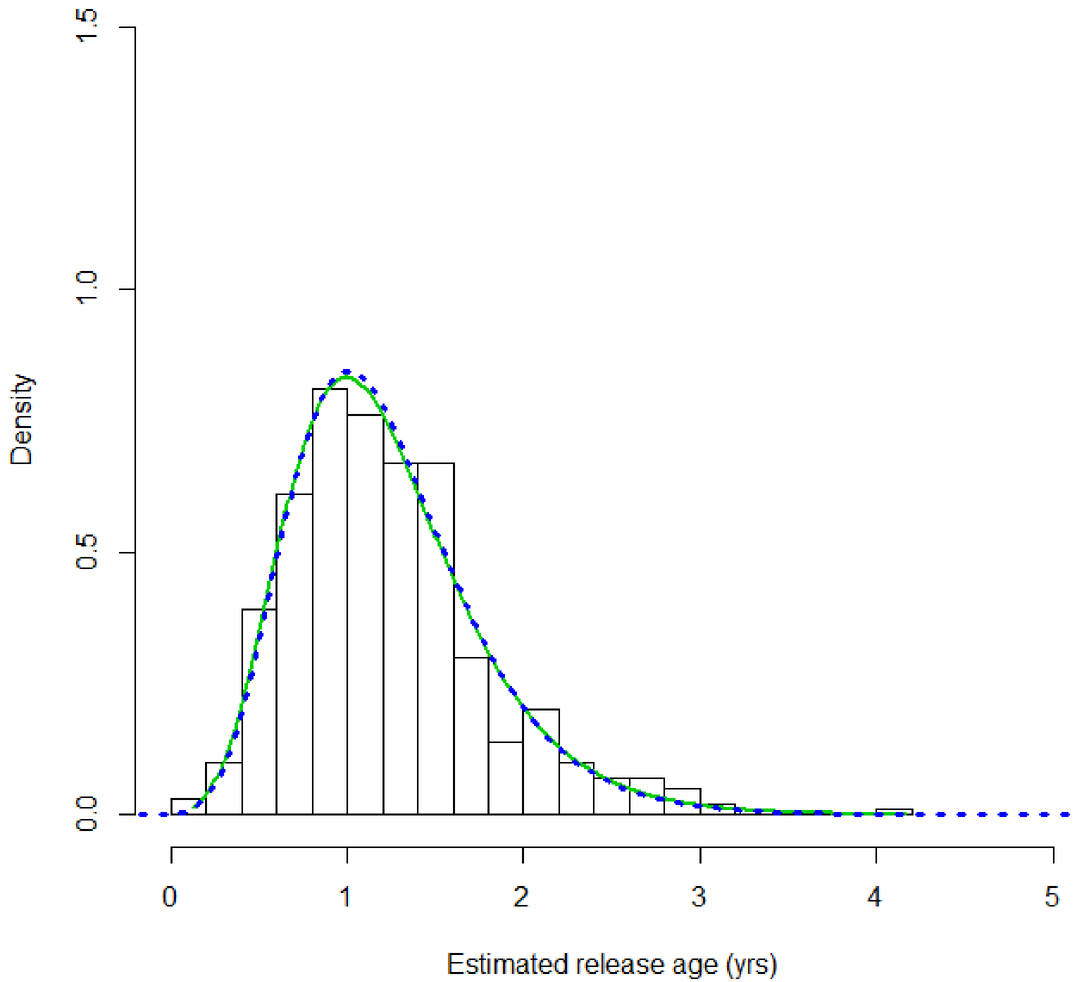


Integrated model results: residuals

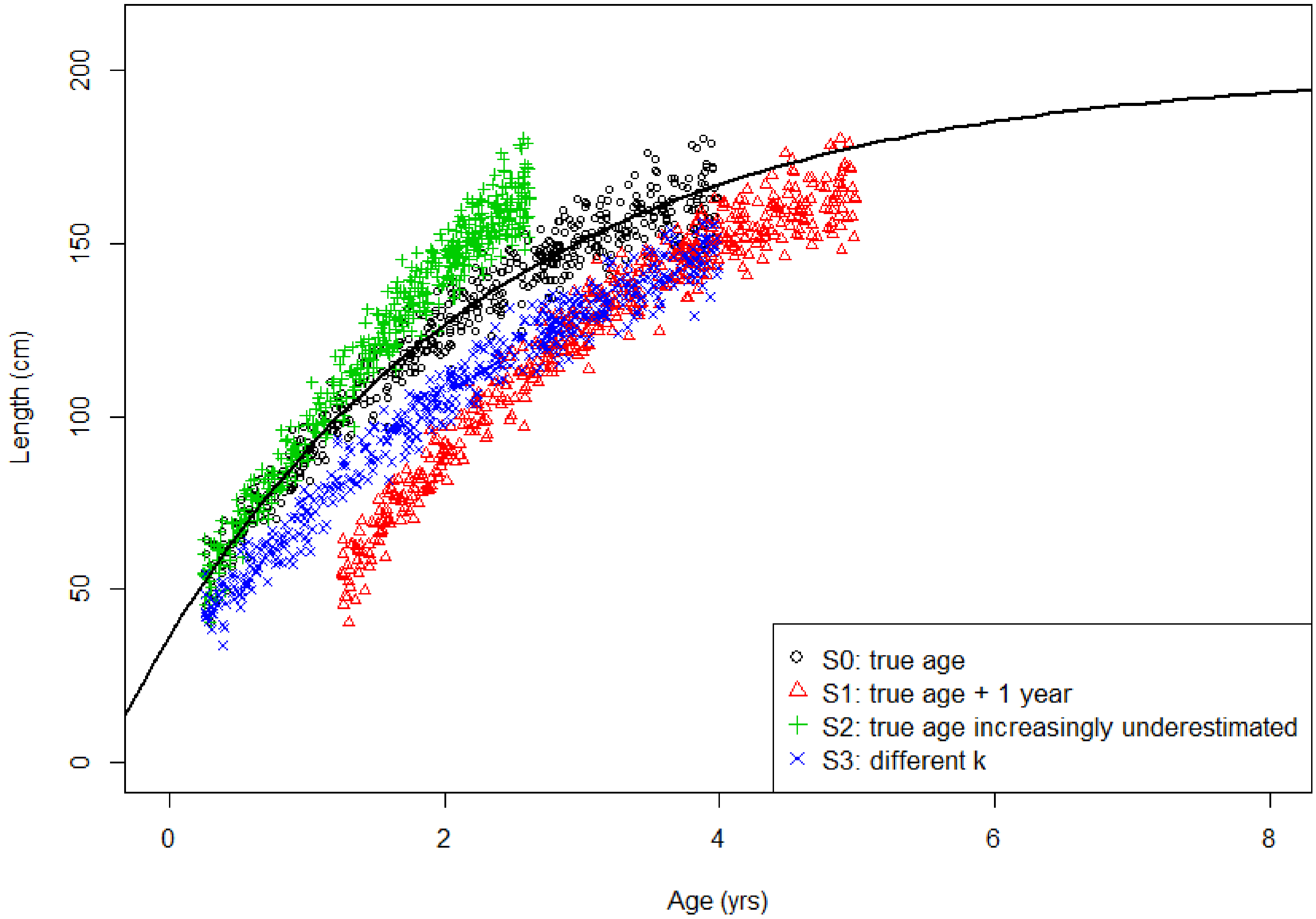




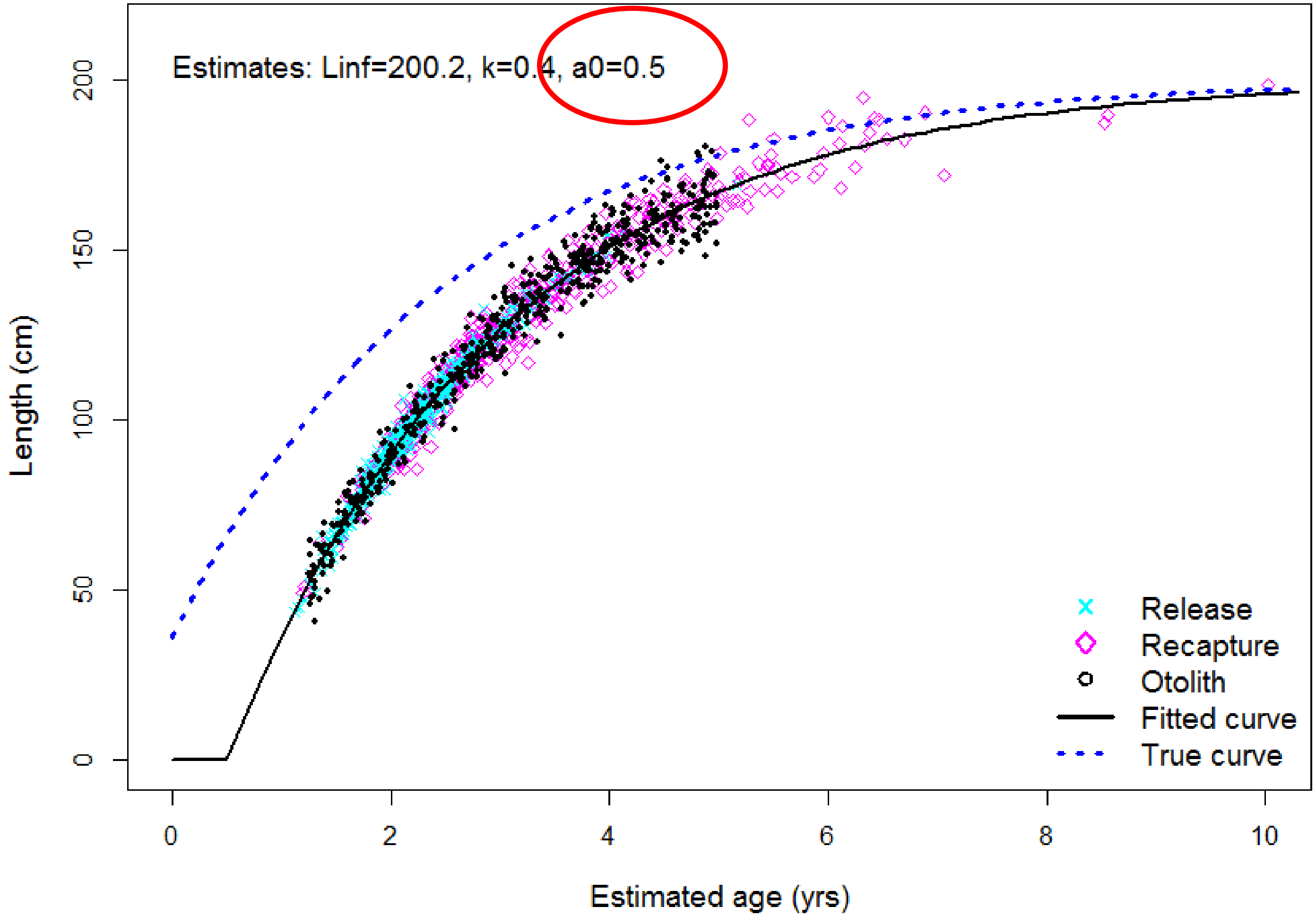
Estimated release age distribution



Alternative scenarios for otolith data



S1 results: true otolith age +1



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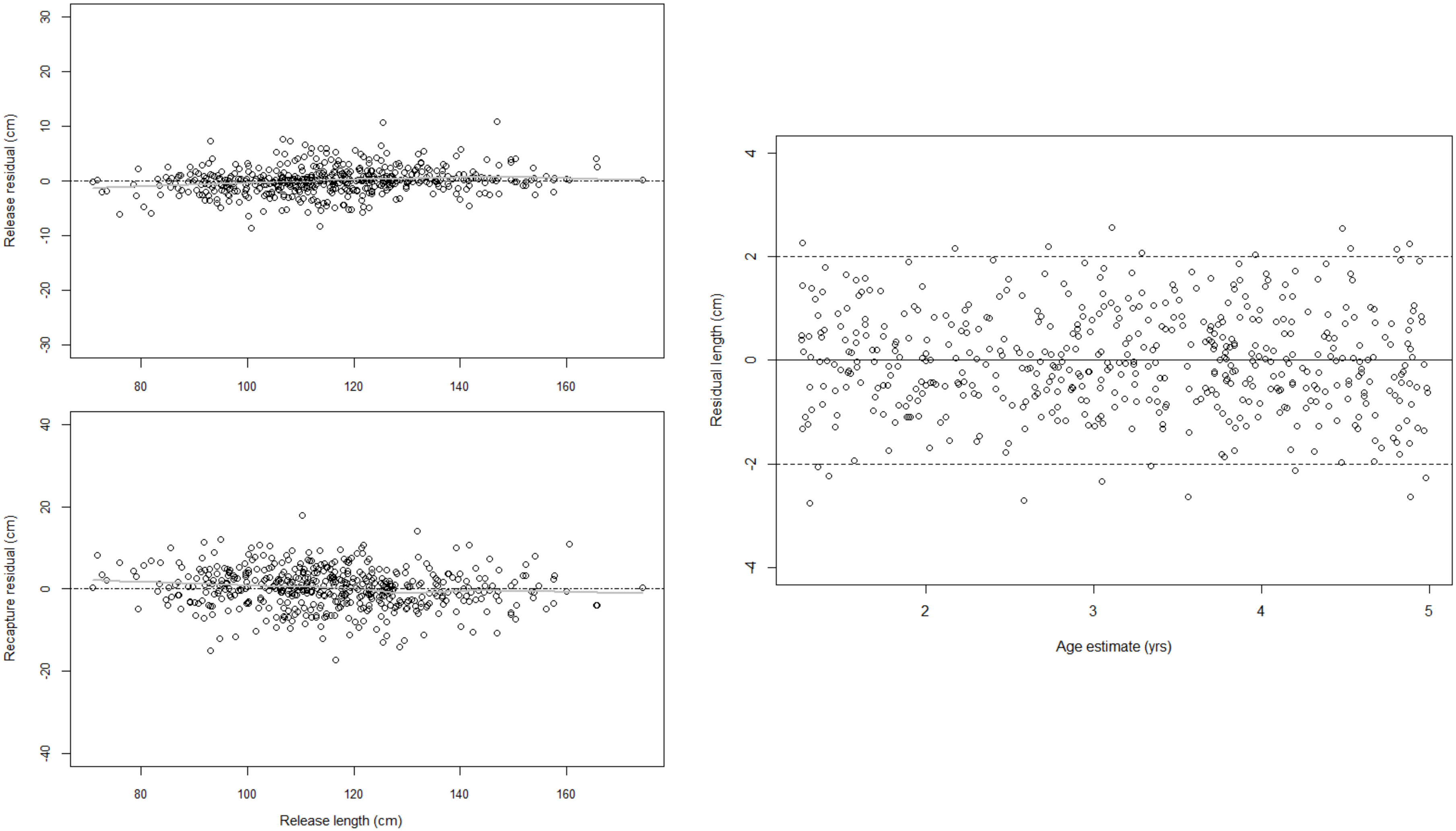
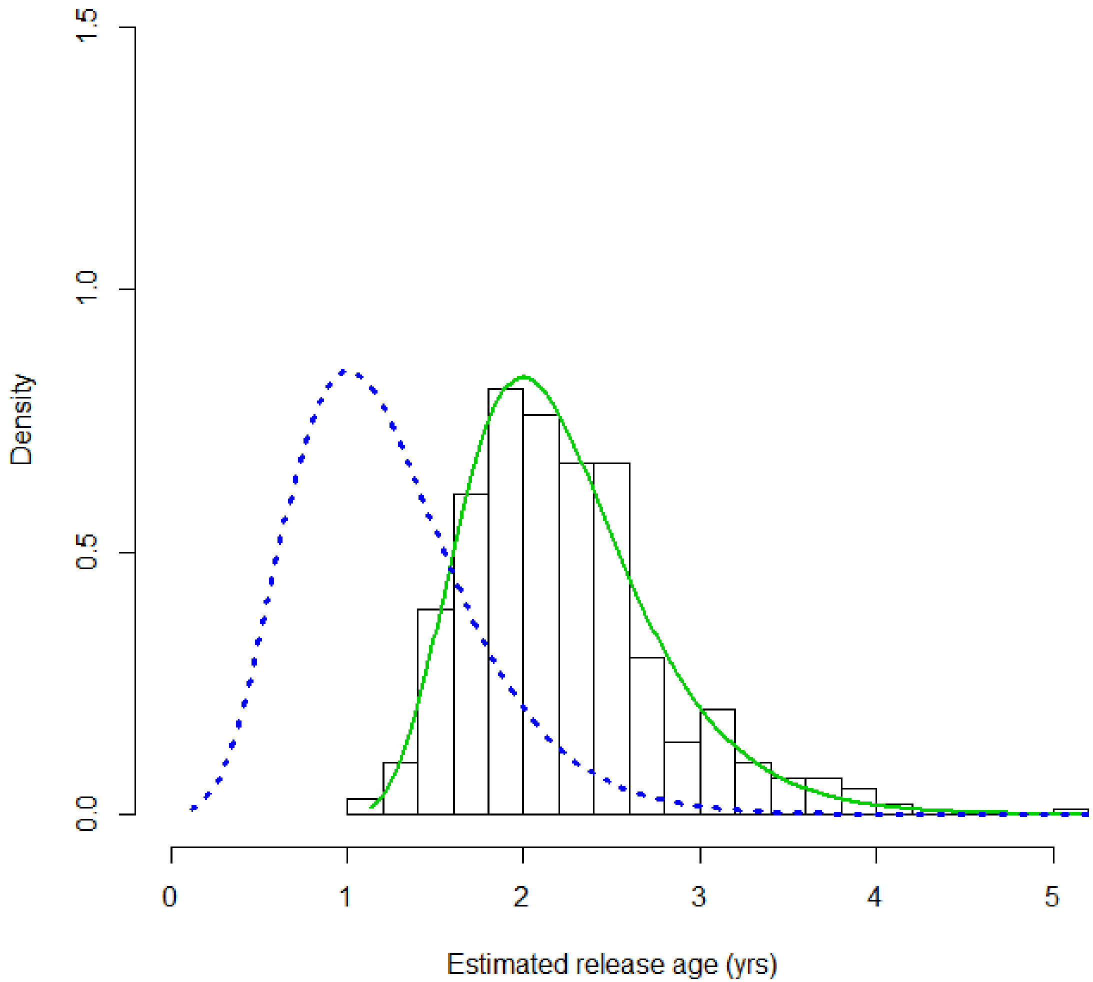
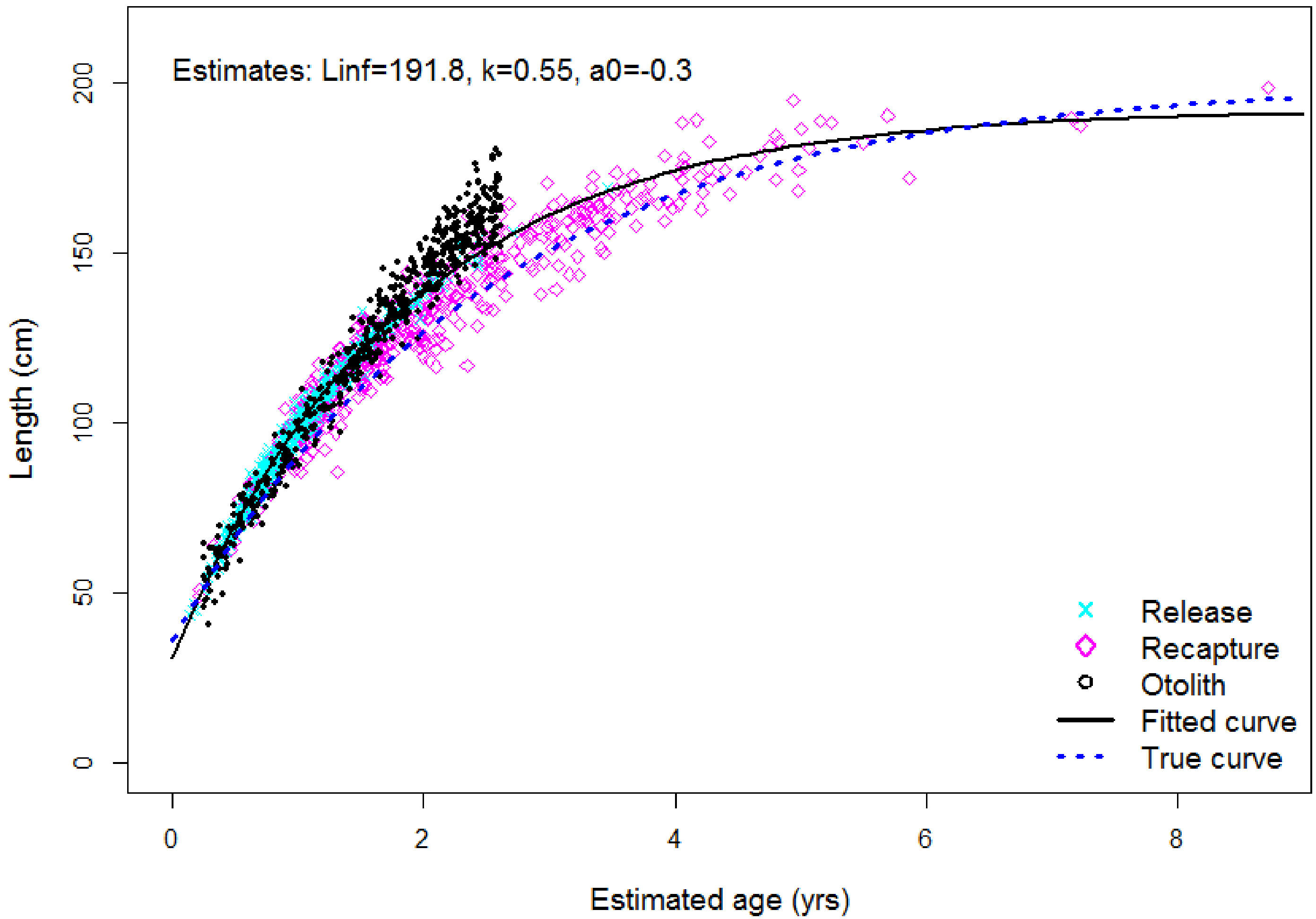


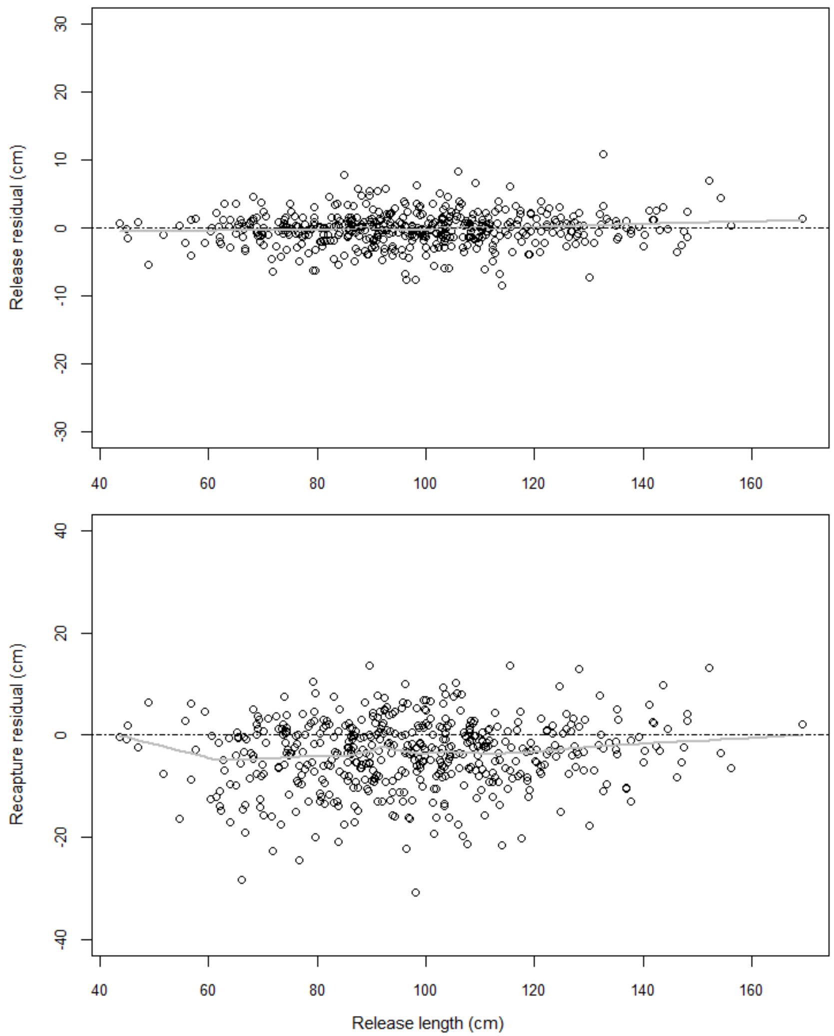
S1 results: true otolith age +1

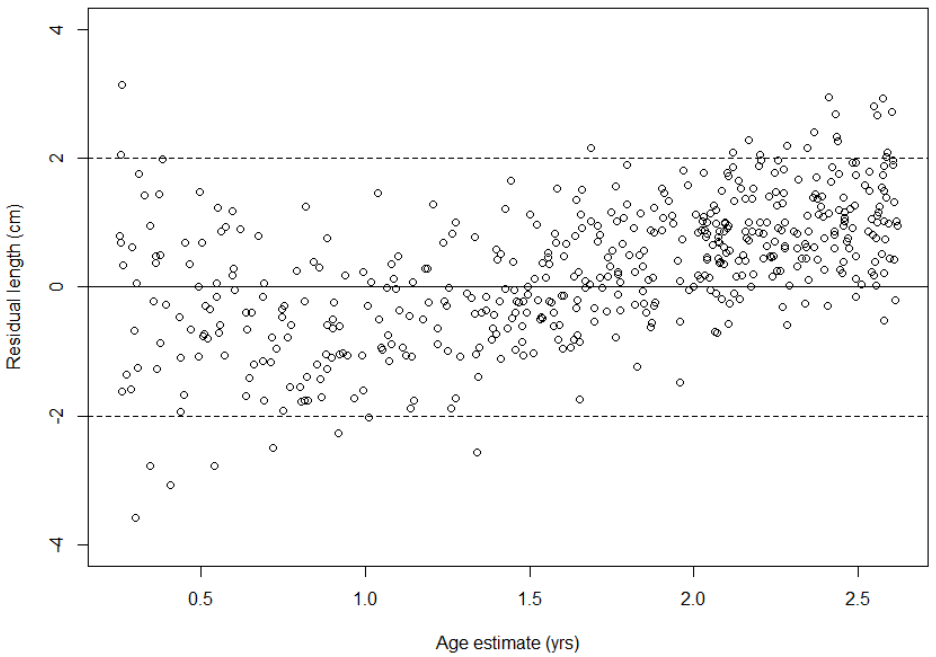


S2 results: true age increasingly underestimated



S2 results: true age increasingly underestimated





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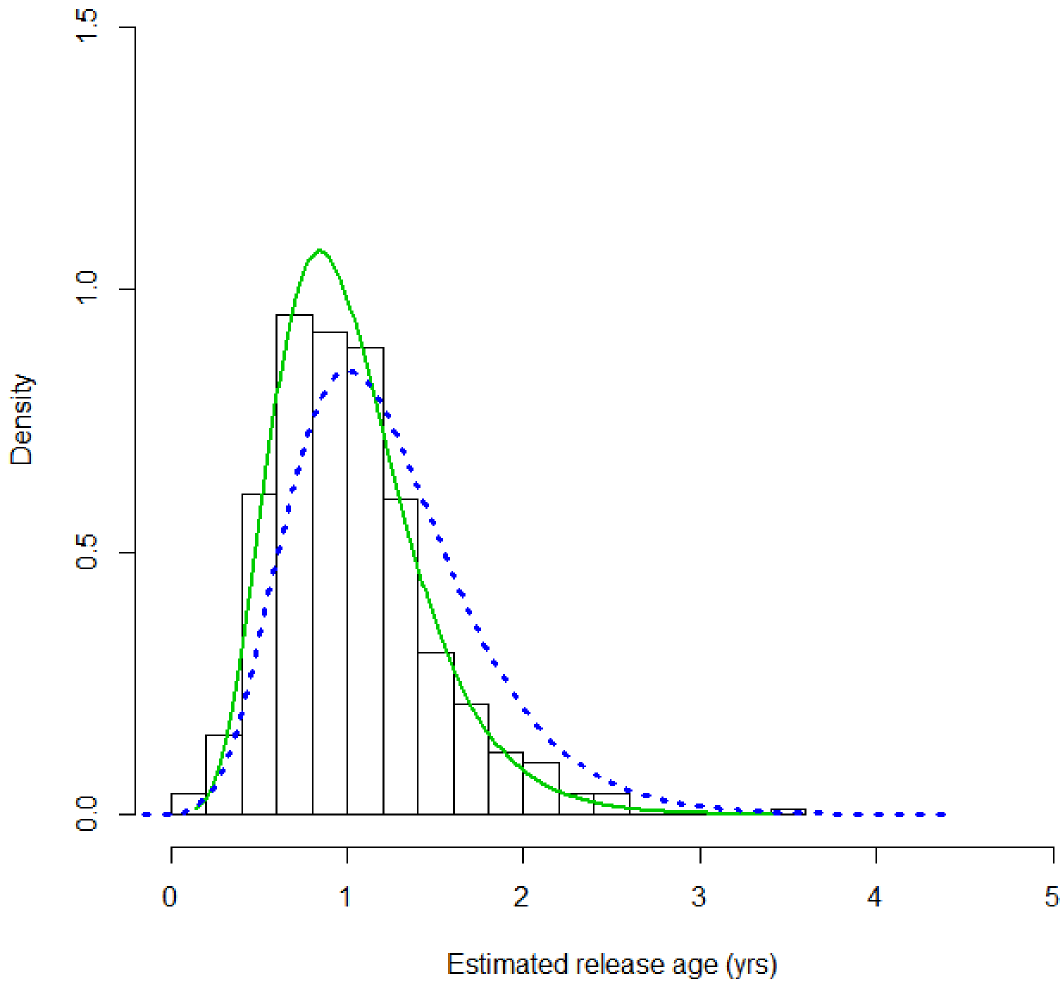
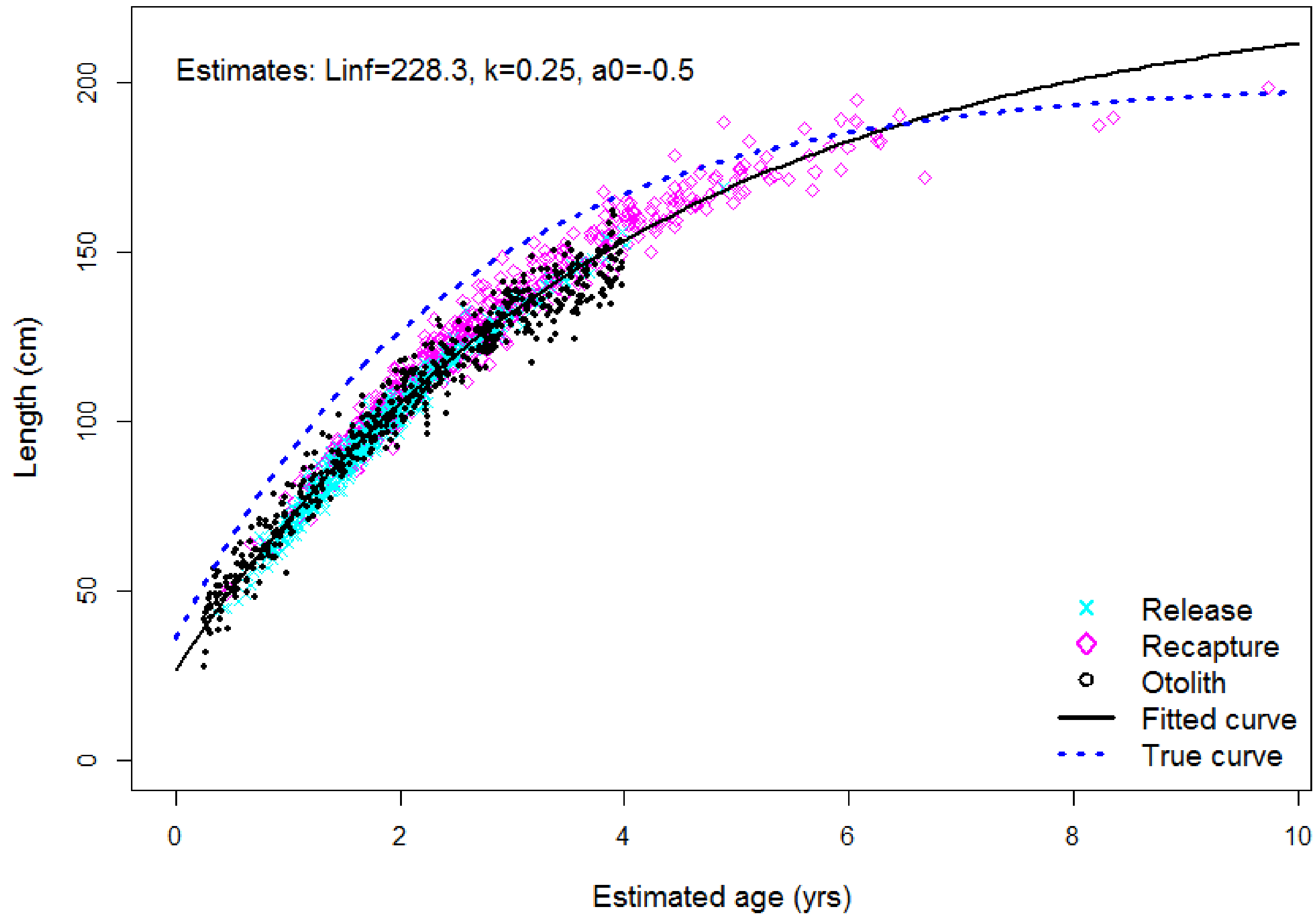


S3 results: different *k* for otolith data



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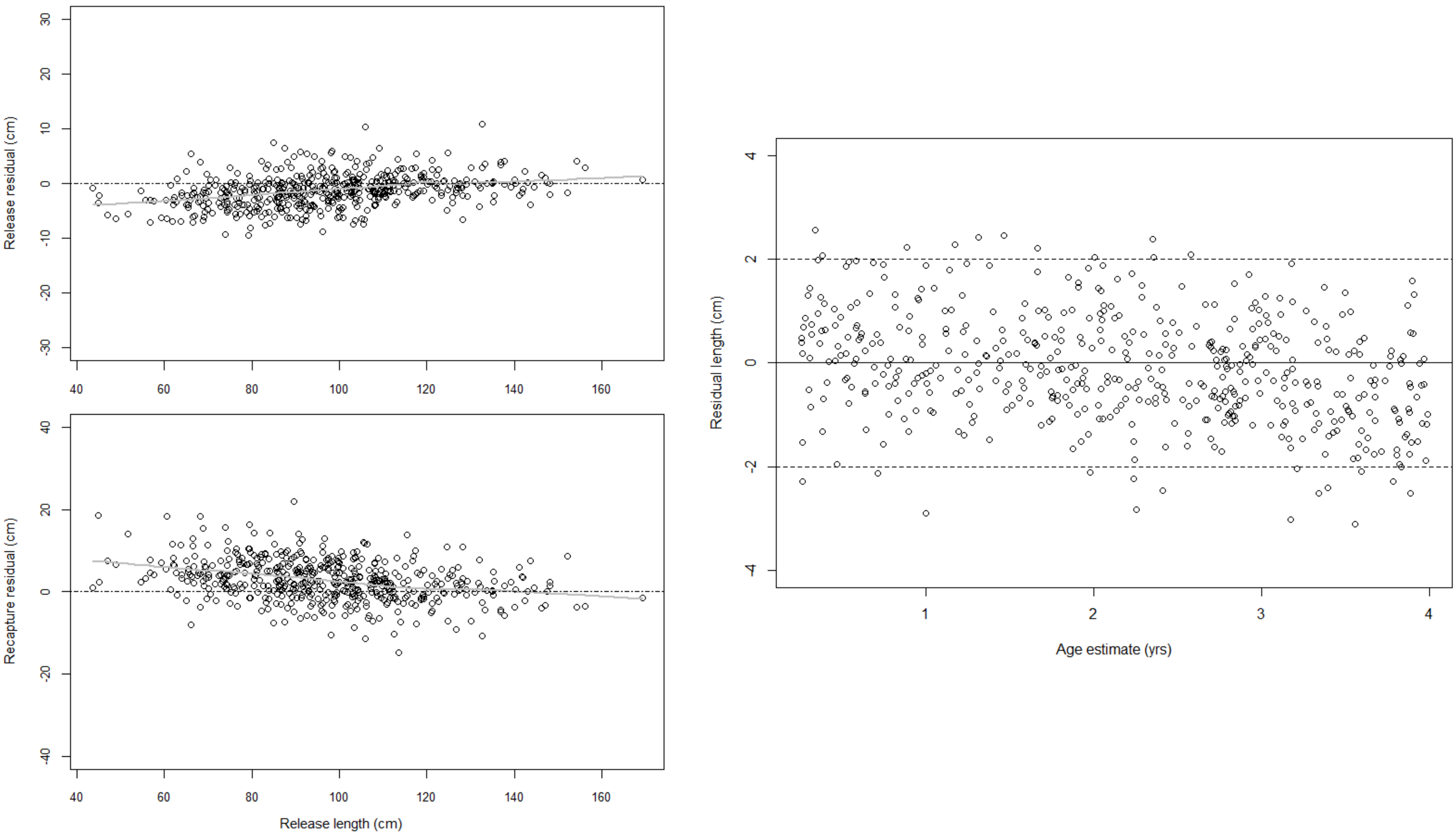

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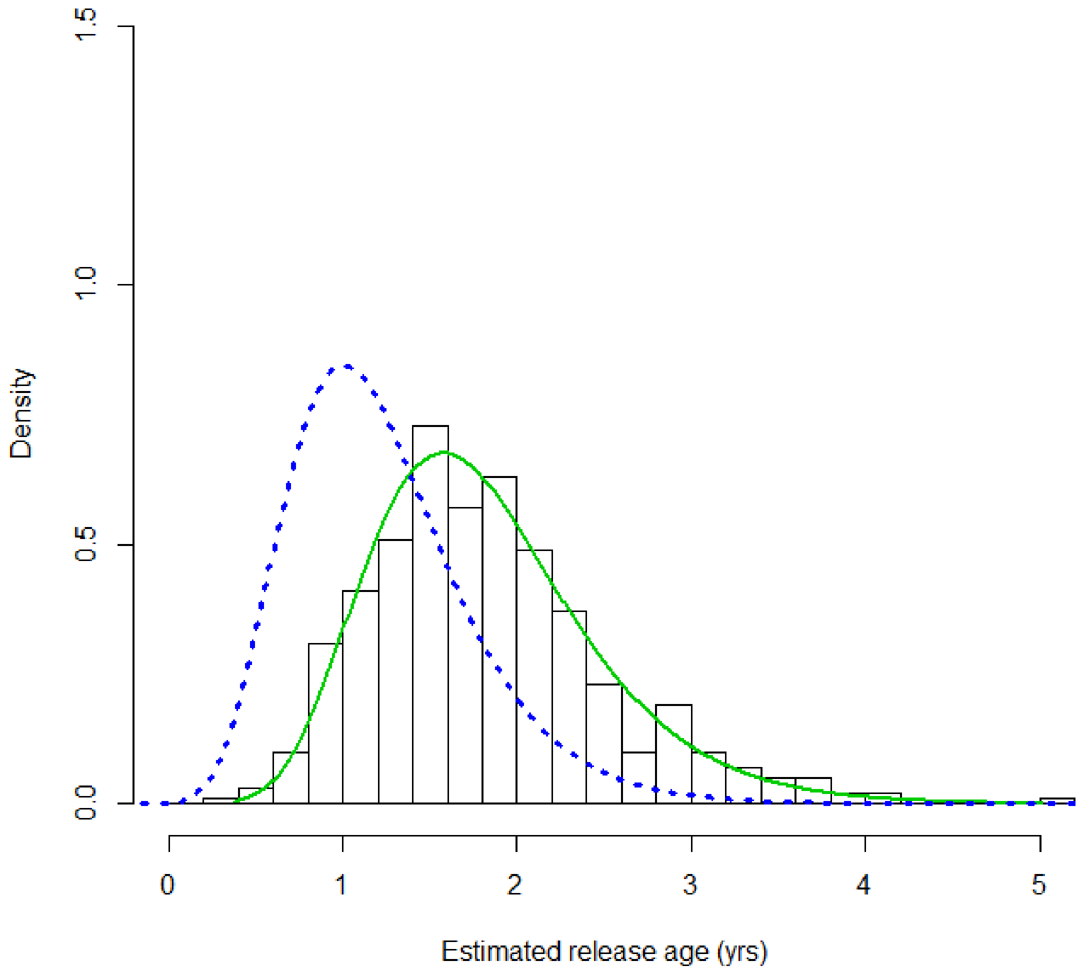

Discussion

- Can be many benefits to having multiple data sources, but only if they are unbiased
- Might expect residuals to reveal problems, but not always obvious when tag-recapture data are involved (due to ability of model to manipulate release age estimates)
- Ability to determine biases/incompatibility in tag-recapture and otolith data sets will depend on:
  - nature of the biases (e.g. not possible to detect with Scenario 1)
  - sample sizes and age/length ranges of data sets