Tree growth rates: Estimating growth rates

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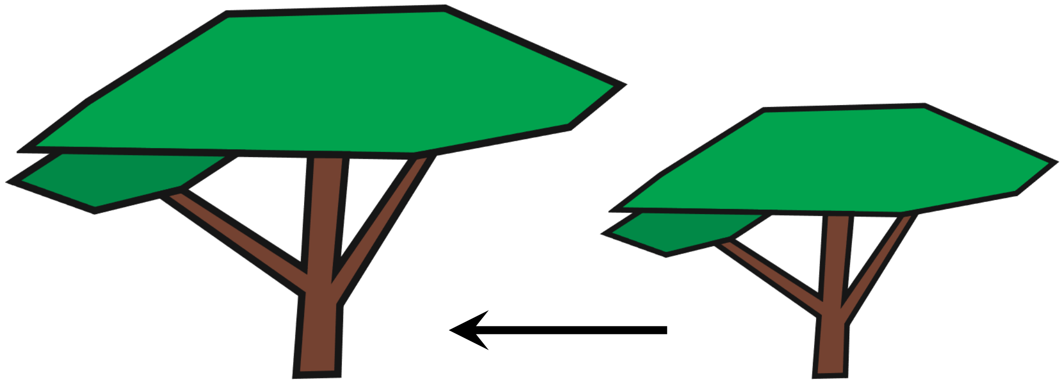
Measuring the growth of an individual

The simplest method of measuring growth:

- G_{Dt} = Diameter growth over the period t to $t + 1$
- D_t = Diameter at t (first census)
- D_{t+1} = Diameter at $t + 1$ (final census)

$$G_{Dt} = D_{t+1} - D_t$$



But: Not a rate.

Measuring the growth of an individual

Add a time term:

- G_{Dt} = Diameter growth over the period t to $t + 1$
- D_t = Diameter at t (first census)
- D_{t+1} = Diameter at $t + 1$ (final census)
- T = census interval length

$$G_{Dt} = \frac{D_{t+1} - D_t}{T}$$

Now G_{Dt} is in units of D per T

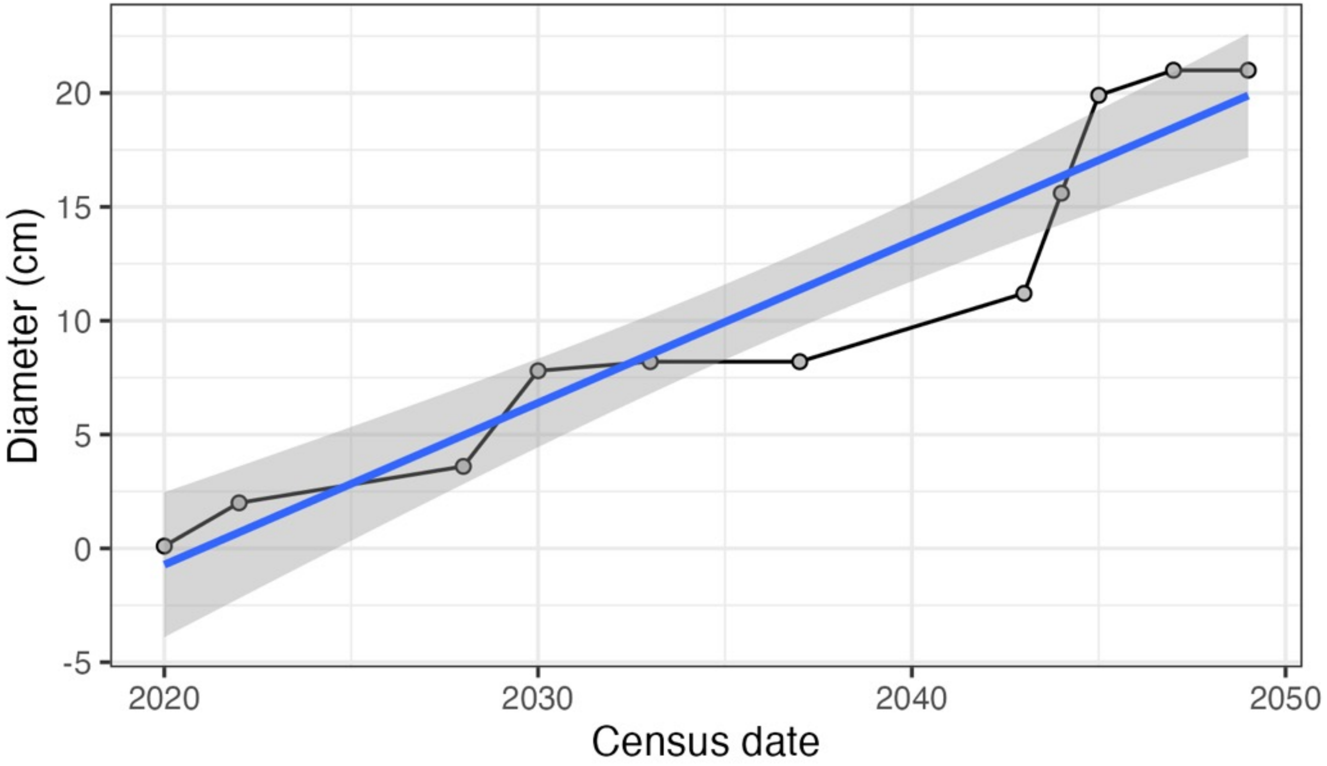
But: Only over a single period for each individual.

Measuring the growth of an individual

Average across time periods:

Two methods:

1. Linear model across all measurements
2. Mean of all consecutive interval rates



$$G_D = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{D_{t_{i+1}} - D_{t_i}}{T}\right)$$

Aggregating to species/size class/plot/site

Simple: Calculate sample means (± standard error)

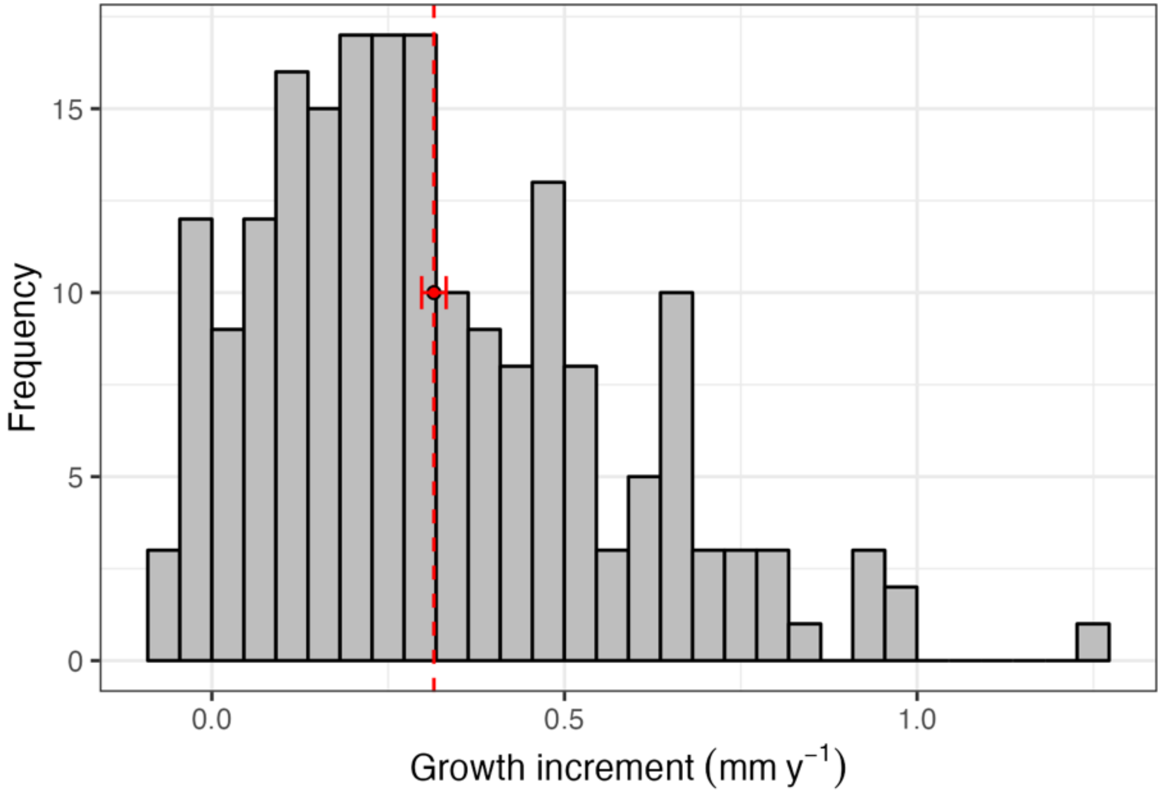
Mixed models: account for non-independence

$G_D \sim 1 + (1|stem\_id)$

$G_D \sim 1 + (1|plot\_id/stem\_id)$

$G_D \sim size\_class + (1|plot\_id/stem\_id)$

$G_D \sim species + (1|plot\_id/stem\_id)$



Stems vs. trees

One tree (`tree_id`), could have multiple stems (`stem_id`).

To calculate growth rates of trees, you can aggregate stems.

Basal area of each stem:

$$B = \sum \left(\pi \frac{D}{2}\right)^2$$

Equivalent diameter:

$$G_e = 2 \times \sqrt{\frac{B}{\pi}}$$

```
s_tree <- seosawr::equivDiamGen(s)
```

Estimating productivity and loss

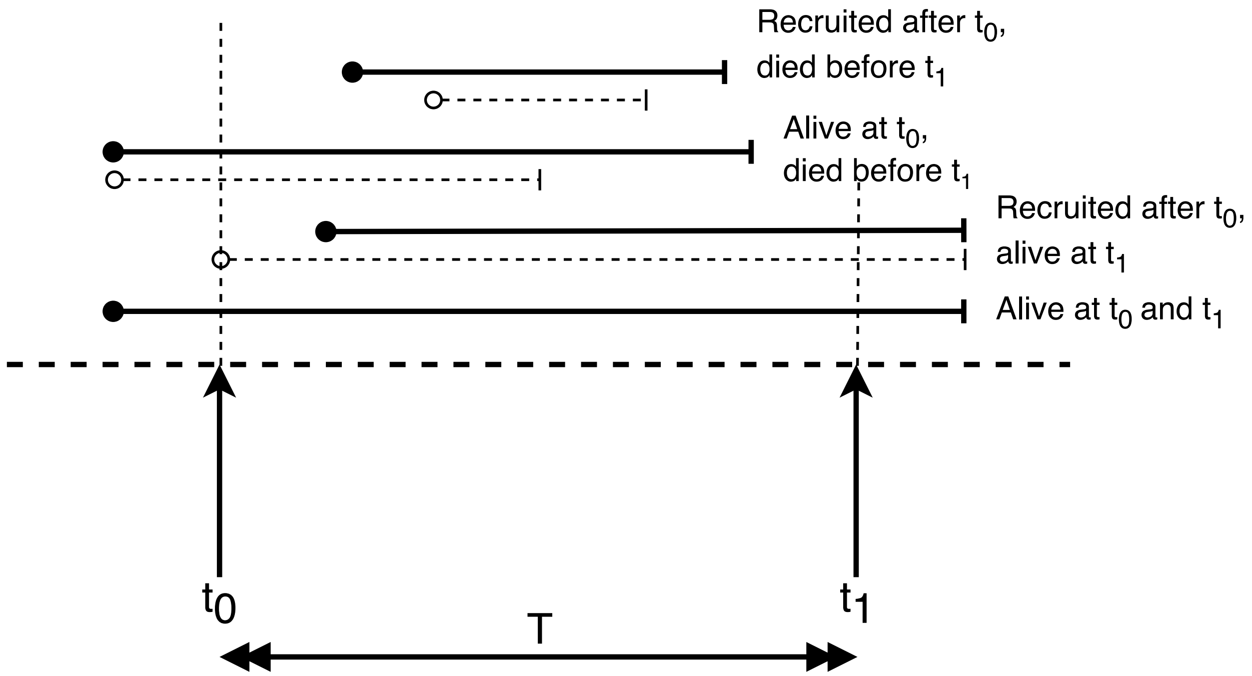
Annual mean biomass: $B_w = (B_T - B_0)\left(B_T / B_0^{\frac{1}{T}}\right)$

Annual production: $P_a = B_w\left((B_T / B_0^{\frac{1}{T}})(1 - B_{s0} / B_T^{\frac{1}{T}})\right)$

Annual loss: $L_a = B_w\left(1 - B_{s0} / B_0^{\frac{1}{T}}\right)$

Biomass change: $\Delta B = P_a - L_a$

- Biomass at final census: B_T
- Biomass of survivors at first census: B_{s0}
- Biomass at first census: B_0
- Census interval (years): T



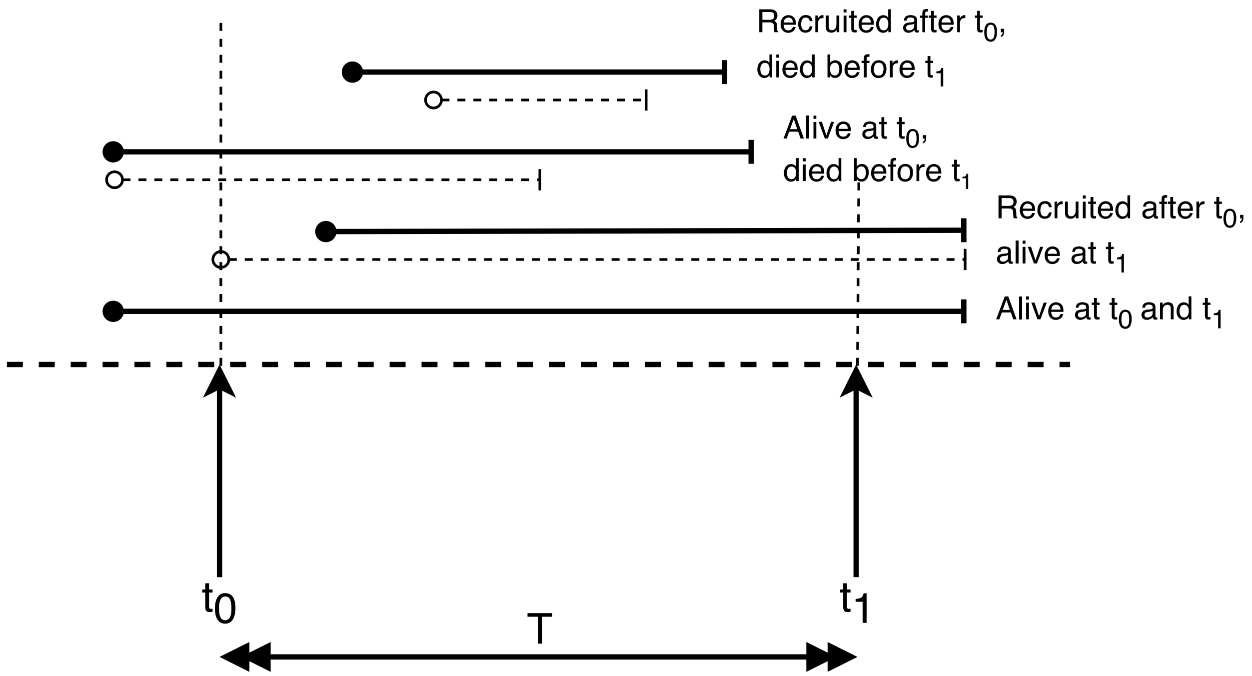
Kohyama et al. (2019)

Estimating recruitment and mortality

Annual Mortality: $M_a = \ (N_0/A)\left[1 - \left(N_{S_T}/N_0\right)^{1/T}\right]$

Annual recruitment: $R_a = M_a\left(N_T - N_{S_T}\right)/\left(N_0 - N_{S_T}\right)$

- Number of individuals in initial census: N_0
- Number of survivors in final census: N_{S_T}
- Number of individuals in final census: N_T
- Plot area: A
- Census interval (years): T



Kohyama et al. (2018)