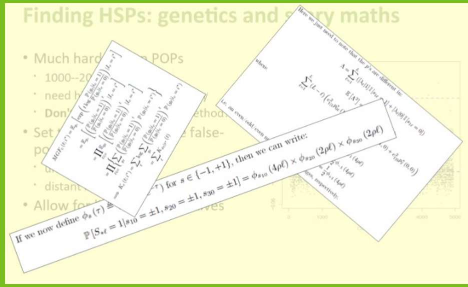
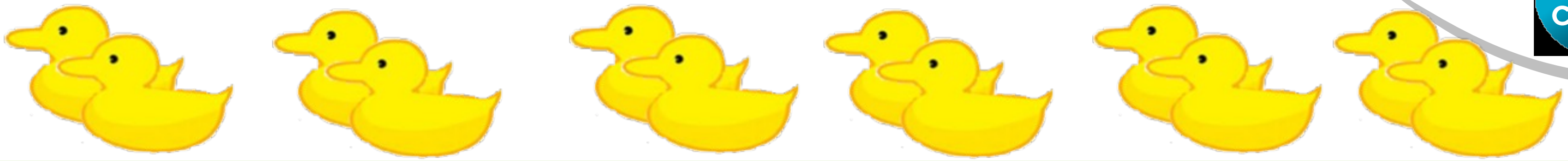


Close-Kin Mark-Recapture: estimating N, **M**, and what else?

Mark Bravington, CSIRO: June 2021



Acknowledgements

People (at CSIRO except as noted)		Organizations (Aus. except as noted)
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Campbell Davies	Matt Lansdell	DaRT PL
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Eric Anderson: NOAA	Toby Patterson	ICCAT: global
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Jess Farley	Craig Proctor	Flinders Uni
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Peter Grewe	Robin Waples: NOAA	Bergen Uni: Norway
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Peta Hill	Tore Schweder	Alaska DFG / NMML Seattle
		Lenfest Ocean Program: global

CKMR is...

Biopsies from juves & adults (dead is OK) over a few years

Some idea about age/sizes

You have 1 mother

Chance it's *this* ♀ $= 1/N_{♀}$

This formula is *too simple* for realistic situations...

CKMR is...

Biopsies from juves & adults (dead is OK) over a few years

Some idea about age/sizes

You have 1 mother

Chance it's *this* ♀ = $1/N_{♀}$

Check genetics...

... repeat for all pairs in sample

... estimate adult ♀ abundance!

... ditto for ♂ adults

"1/N" too simple for most species, but can adjust for time, age, size, mortality...

Absolute abundance just from biopsying a few % of catch

- no $urvey$, no CPUE, no live-relea$e, no (?) dodgy assumptions...

CKMR is...

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Absolute abundance just from biopsying a few % of catch

- no \$urvey\$, no CPUE, no live-relea\$e, no (?) dodgy assumptions...

and *more*: not "just" absolute abundance

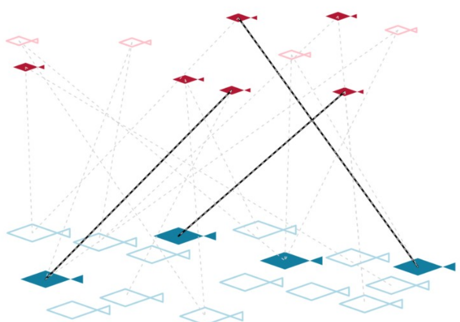
This talk is *not* a complete instructional on CKMR ;)

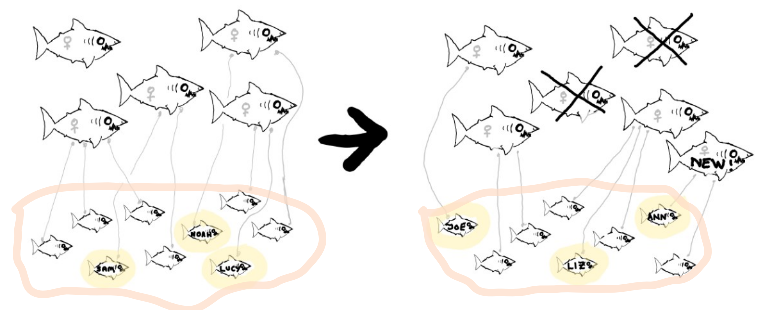
CKMR is...

Parents are “marked” by their sampled offspring

cross-cohort half-sibs

Direct recapture (POPs) and **Indirect** (XHSPs)



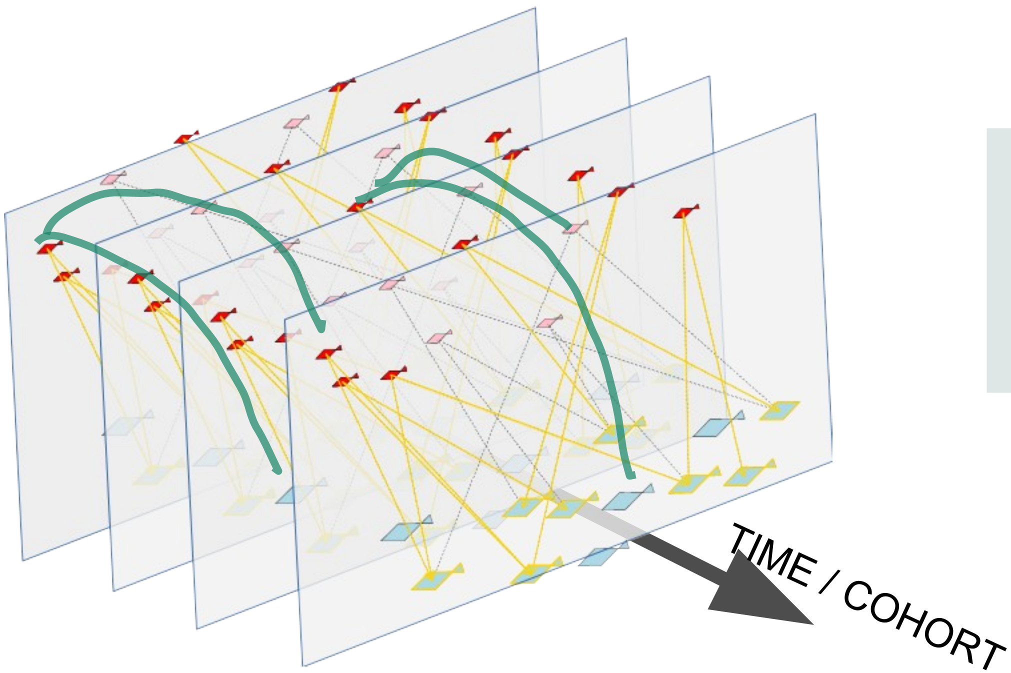


CKMR is... part 2

cross-cohort half-sibs

Parents are “marked” by their sampled offspring

Direct recapture (POPs) and **Indirect** (XHSPs)



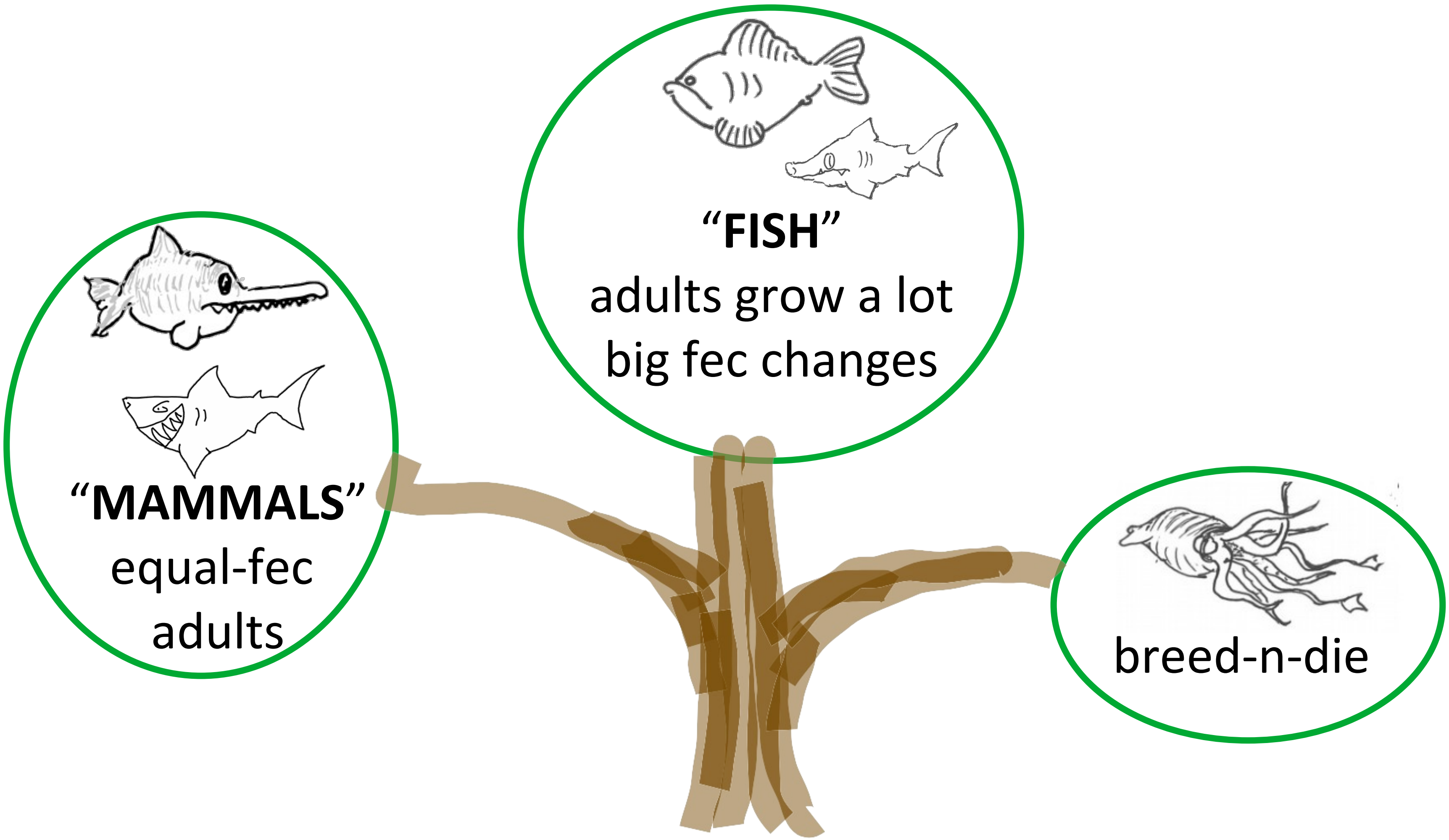
- Lots of comparisons
- Different prob formulae
- More parameters than just “N”

To **fit** CKMR data, always build it into proper age-based pop dyn (stock assessment)

But, heuristic *explanations* are important too

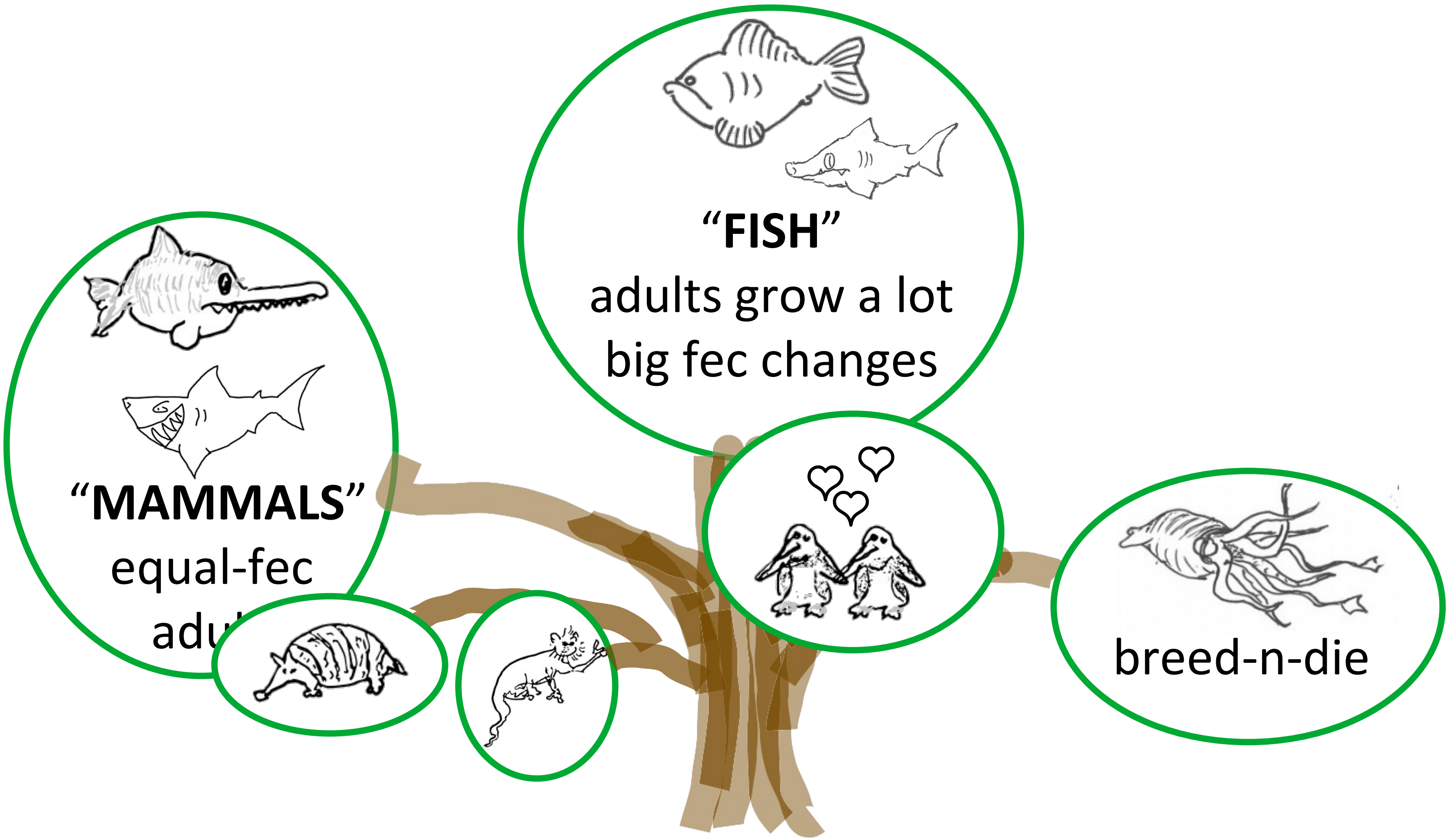
CLOSE-KIN TREE OF LIFE

simplified version!



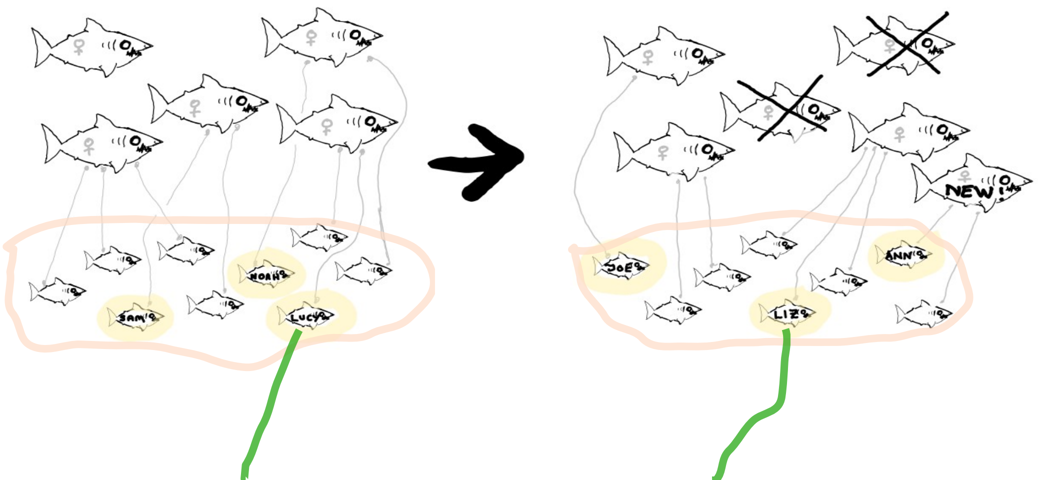
CLOSE-KIN TREE OF LIFE

still simplified !



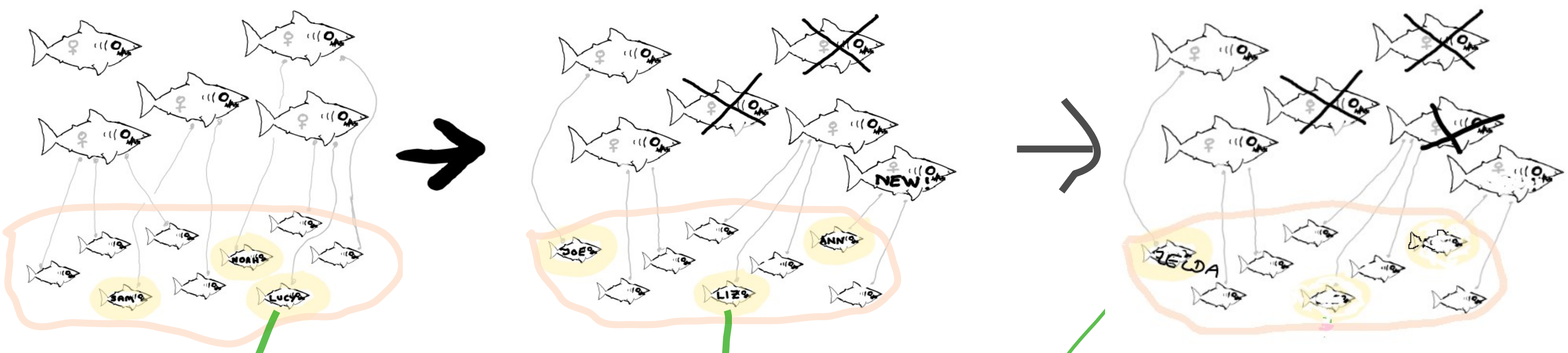
ETC … ETC ….

Mammals: mortality and abund from XHSPs



Pr[Lucy’s mum is also Liz’s mum]

Mammals: mortality and abund from XHSPs

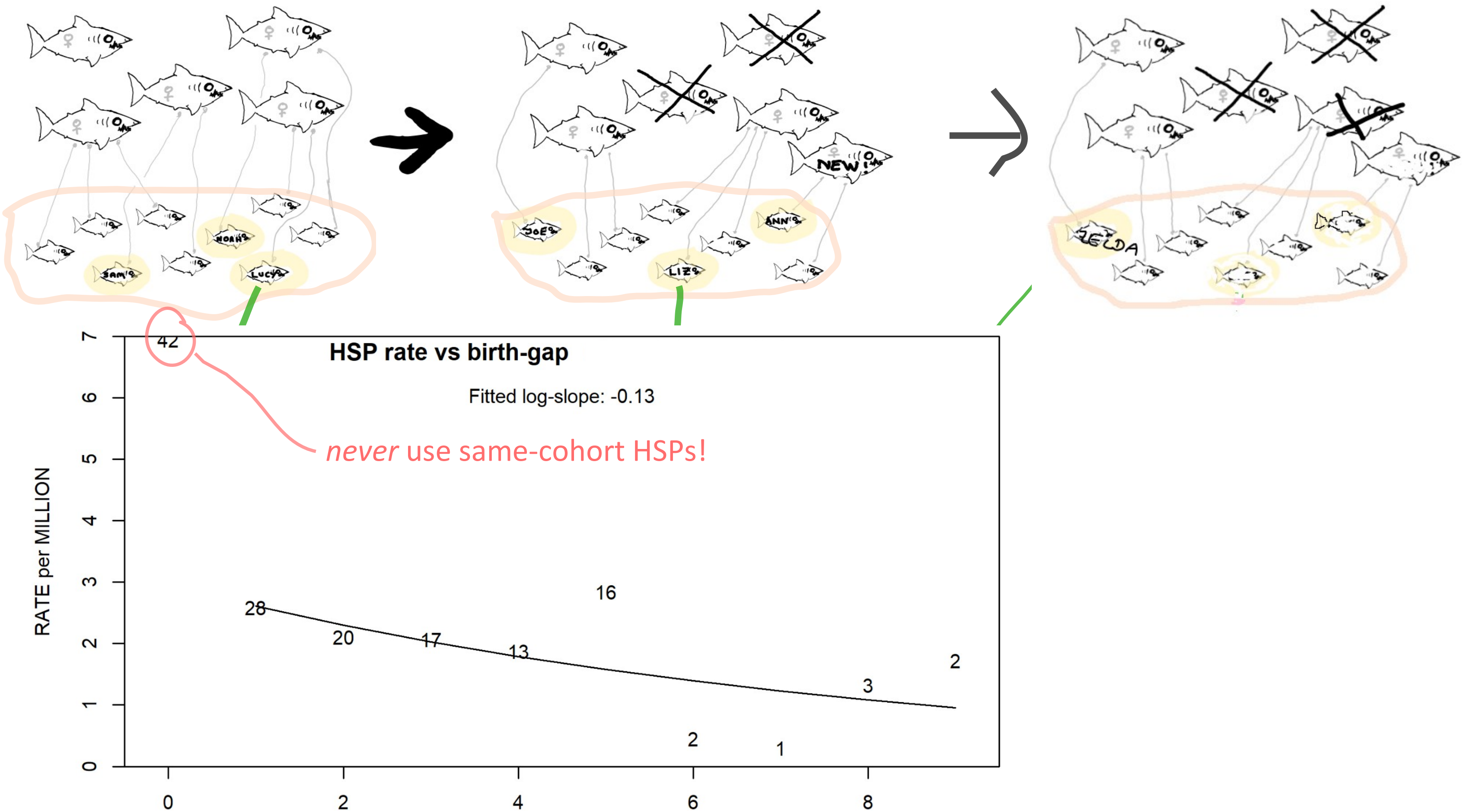


Pr[Lucy’s mum is also Liz’s mum]

>

Pr[Lucy's mum is also Zelda's mum]

Mammals: mortality and abund from XHSPs



Mammals: the lot

POPs	=>	N
HSPs	=>	Z
Z = F + M	=	C/N + M
M	=	Z - C/N

- all just for Adults, of course
- N, C time-varying--- fit it all in a model, don't adhockerize
- do separately by sex
- caveat blah blah etc

This is fine for **Mammals**,
but *too simple* for **Fish**

Fish: are harder than Mammals

- Fec driven by size
- Adults grow--- a lot
- Population has adults of all different sizes

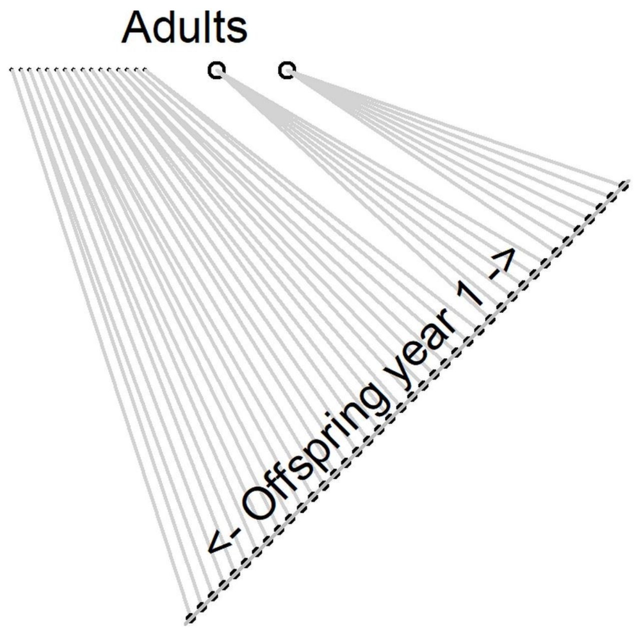
Simplifications for sake of the talk:

- age rather than size drives everything
  - -- real models should use *both* to avoid bias
- no ageing error etc
- just using one sex: MotherOPs, Maternal HSPs
- everything *backdated* to offspring's birth

all of which can be expanded properly in real models

Fish: what *is* “absolute abundance” in CKMR ?

Pr[Amy is Julian’s mum] = $\dfrac{\text{Reprod Output}_{\text{Amy}} \text{ @ Julian's birth}}{\textbf{T}\text{otal }\textbf{R}\text{ep.}\textbf{O}\text{ut.}_{♀} \text{ @ J's birth}}$



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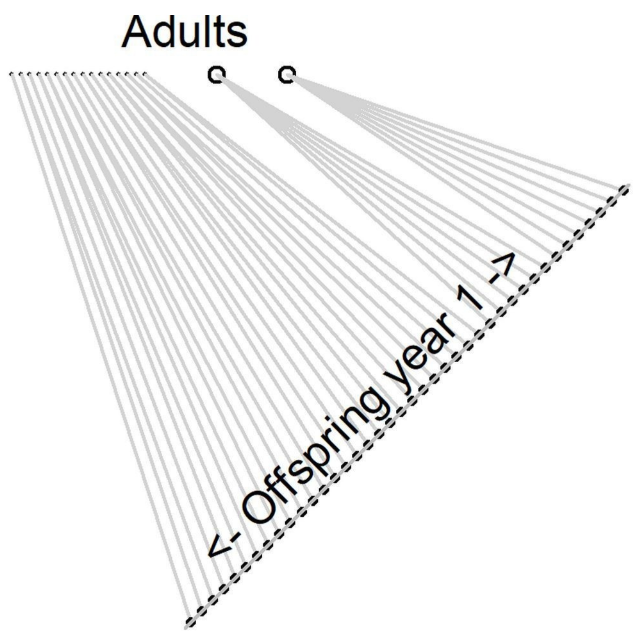
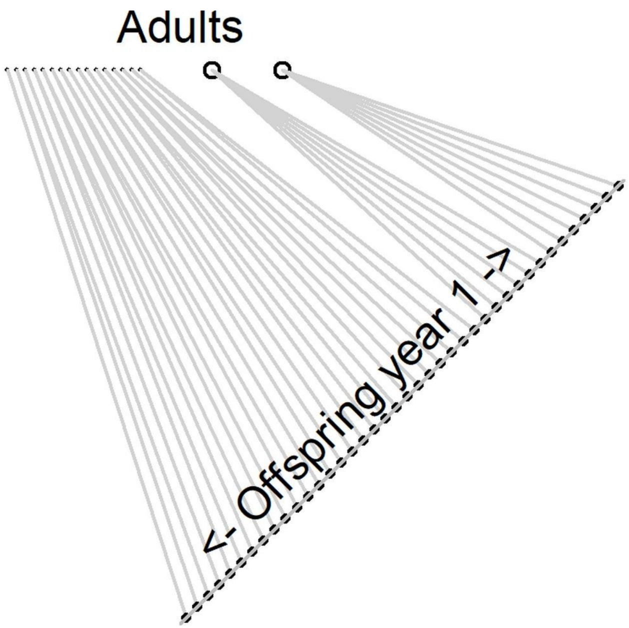


Empirical Pr[MOP|small] = 0.042 ≈ 1/24

=> **TRO** ≈ 24*smalls* := $N_{\text{equiv SMALL}}$

Fish: what *is* "absolute abundance" in CKMR ?

Pr[Amy is Julian's mum] = Reprod Output$_{Amy}$ @ Julian's birth
----
Total **R**ep.**O**ut.$_{♀}$ @ J's birth



Empirical Pr[MOP|small] = 0.042 ≈ 1/24

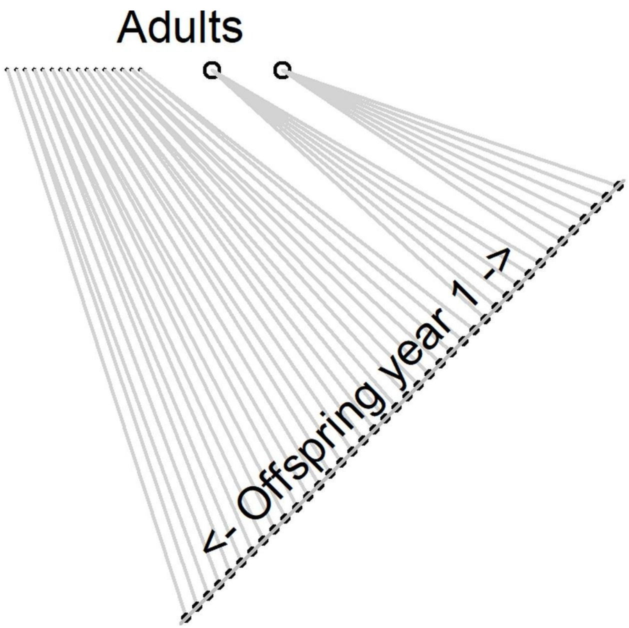
=> **TRO** ≈ 24*smalls* := $N_{\text{equiv SMALL}}$

Empirical Pr[MOP|BIG] = 0.163 ≈ 1/6

=> **TRO** ≈ 6*bigs* := $N_{\text{equiv BIG}}$

Fish: what *is* "absolute abundance" in CKMR ?

Pr[Amy is Julian's mum] = $\frac{\text{Reprod Output}_{\text{Amy}} \text{ @ Julian's birth}}{\textbf{T}\text{otal } \textbf{R}\text{ep.}\textbf{O}\text{ut.}_{♀} \text{ @ J's birth}}$



Empirical Pr[MOP | small] = 0.042 ≈ 1/24

=> **TRO** ≈ 24*smalls* := $N_{\text{equiv SMALL}}$

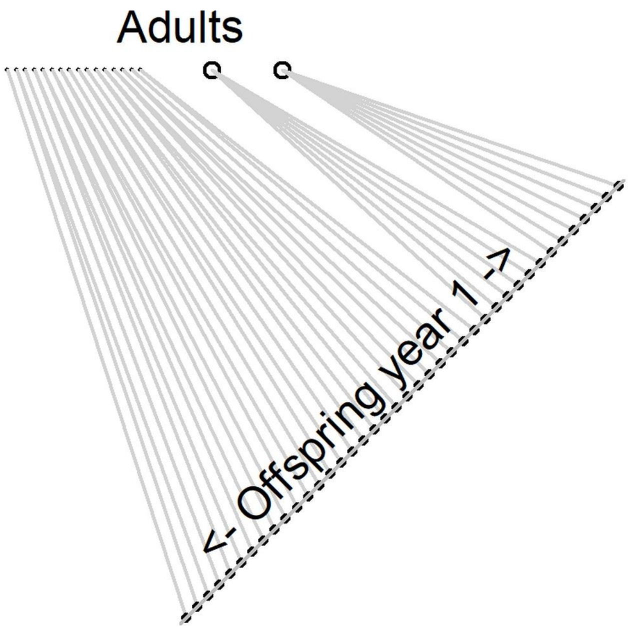
same thing; different units

Empirical Pr[MOP | BIG] = 0.163 ≈ 1/6

=> **TRO** ≈ 6*bigs* := $N_{\text{equiv BIG}}$

Fish: what *is* “absolute abundance” in CKMR ?

Pr[Amy is Julian’s mum] = $\dfrac{\text{Reprod Output}_{\text{Amy}} \text{ @ Julian's birth}}{\textbf{T}\text{otal }\textbf{R}\text{ep.}\textbf{O}\text{ut.}_{♀} \text{ @ J's birth}}$



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same thing; different units

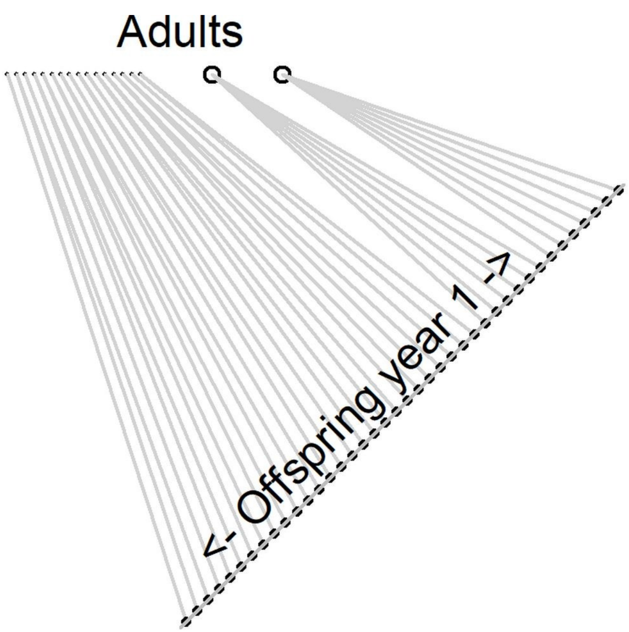
Empirical Pr[MOP | BIG] = 0.163 ≈ 1/6

=> **TRO** ≈ 6*bigs* := $N_{\text{equiv BIG}}$

$\text{Relfec}_{\text{BIG}♀} \approx 4 * \text{Relfec}_{\text{small}♀}$

Fish: what *is* "absolute abundance" in CKMR ?

$$\text{Pr[Amy is Julian's mum]} = \frac{\text{Reprod Output}_{\text{Amy}} \text{ @ Julian's birth}}{\textbf{T}\text{otal }\textbf{R}\text{ep.}\textbf{O}\text{ut.}_{\female} \text{ @ J's birth}}$$



For **fish**, POPs *do* tell you absolute abundance...

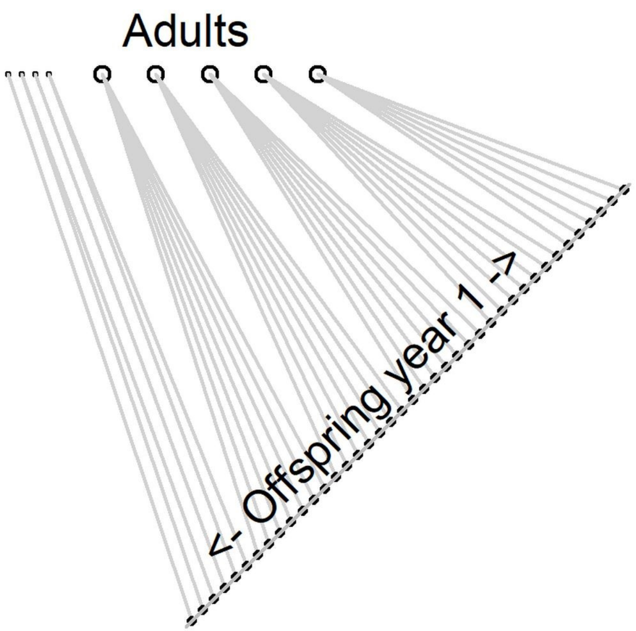
... but *you* still have to pick the *units* ...

$\text{Relfec}_{\text{BIG}\female} \approx 4 * \text{Relfec}_{\text{small}\female}$

Fish: what *is* “absolute abundance” in CKMR ?

Pr[Amy is Julian’s mum] = $\dfrac{\text{Reprod Output}_{Amy} \text{ @ Julian's birth}}{\textbf{T}\text{otal }\textbf{R}\text{ep.}\textbf{O}\text{ut.}_{♀} \text{ @ J's birth}}$

Older population, same TRO



Empirical Pr[MOP | small] = 0.038 ≈ 1/27

=> **TRO** ≈ 27*smalls* := $N_{\text{equiv SMALL}}$

Empirical Pr[MOP | BIG] = 0.170 ≈ 1/6

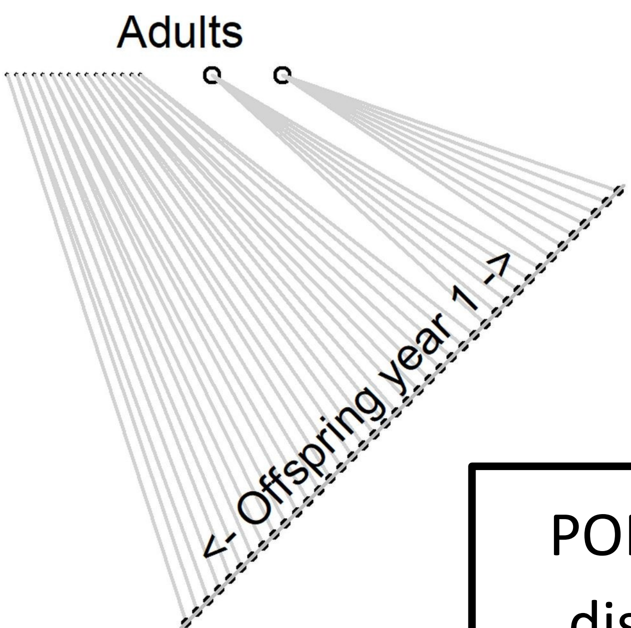
=> **TRO** ≈ 6*bigs* := $N_{\text{equiv BIG}}$

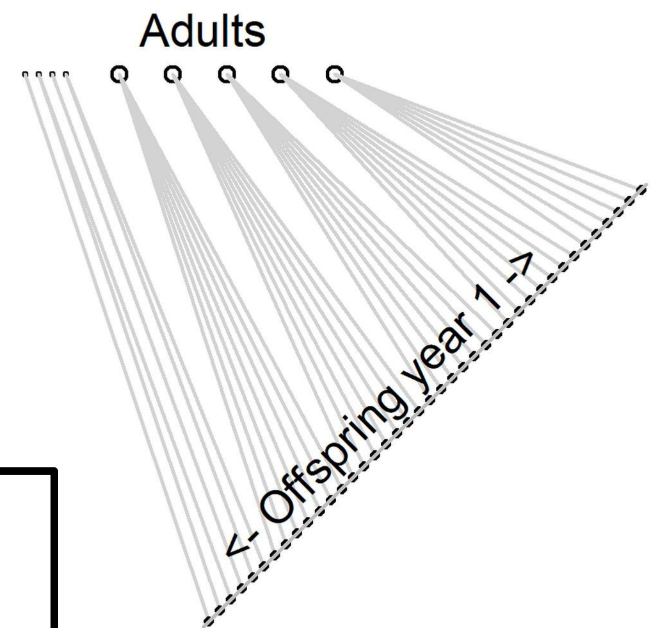
$\text{Relfec}_{\text{BIG}♀} \approx 4 * \text{Relfec}_{\text{small}♀}$

I was too lazy to make the empirical TROs exactly the same as before...

Fish: what *is* “absolute abundance” in CKMR ?

$$\Pr[\text{ Amy is Julian's mum}] = \frac{\text{Reprod Output}_{\text{Amy}} \text{ @ Julian's birth}}{\textbf{T}\text{otal }\textbf{R}\text{ep.}\textbf{O}\text{ut.}_{\text{♀}} \text{ @ J's birth}}$$

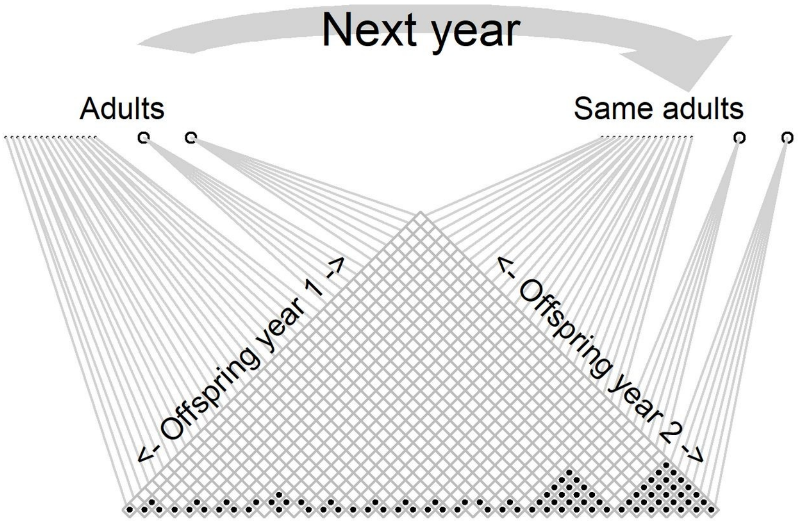


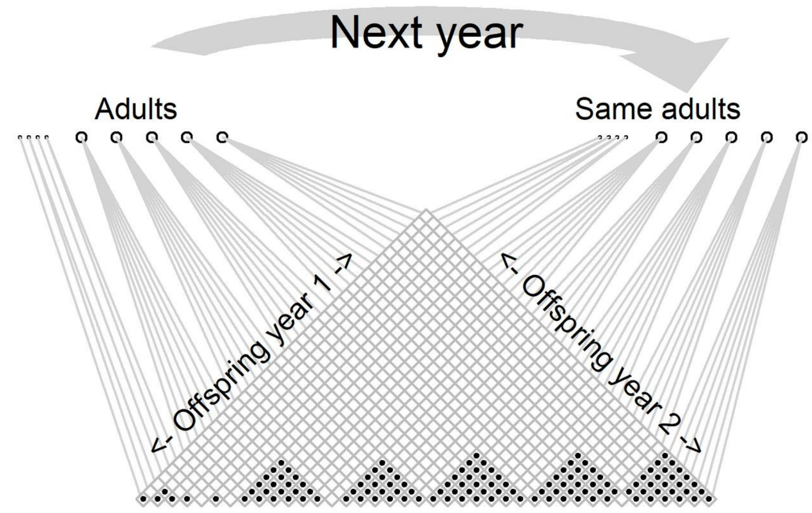


POPs alone do not distinguish these

unless you “know” selectivity or other magic

Fish: but... what about HSPs ?





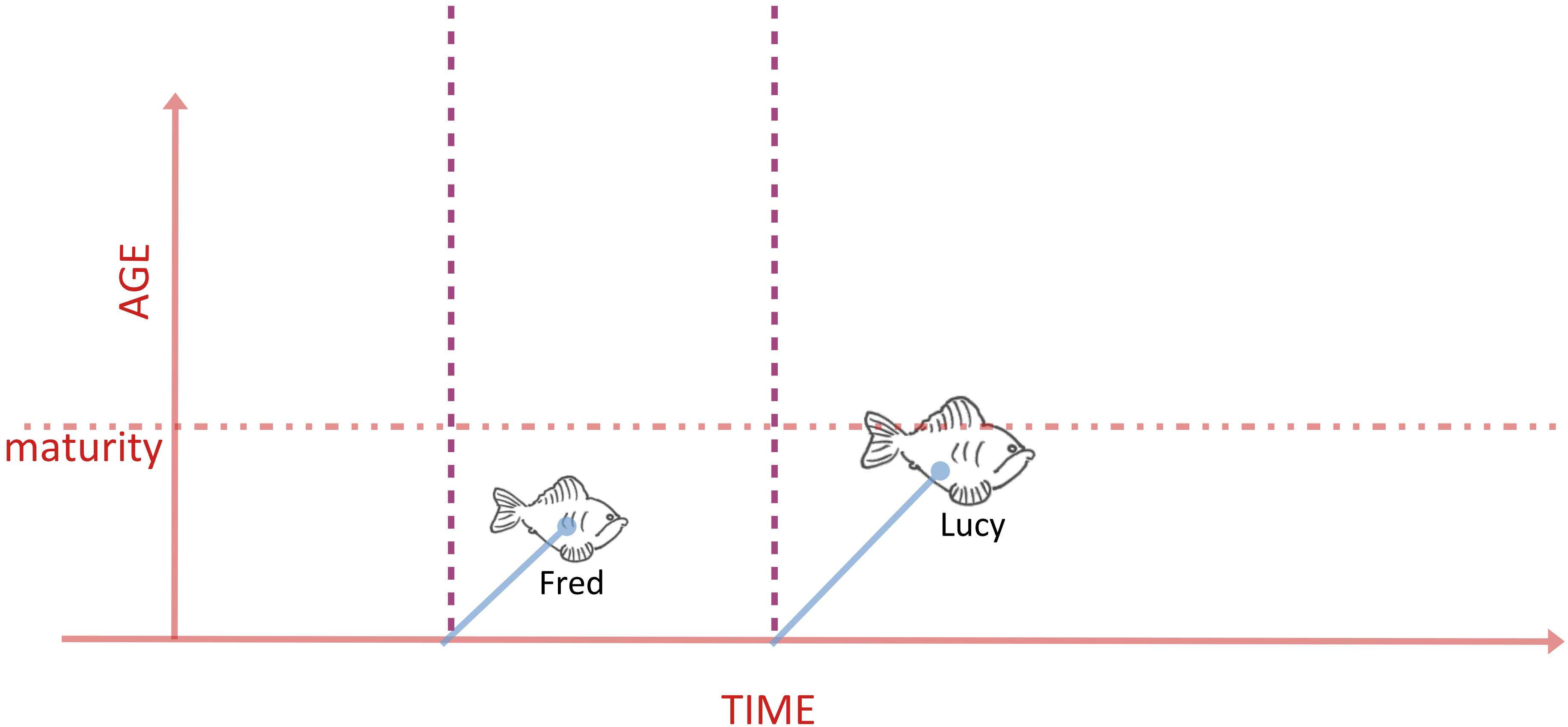
Same POP story; very different HSPs!

Quadratic impact of indiv fec variations

How can we use that?

HSPs: how do the probs work?

Pr[Fred & Lucy are MHSP] = ?



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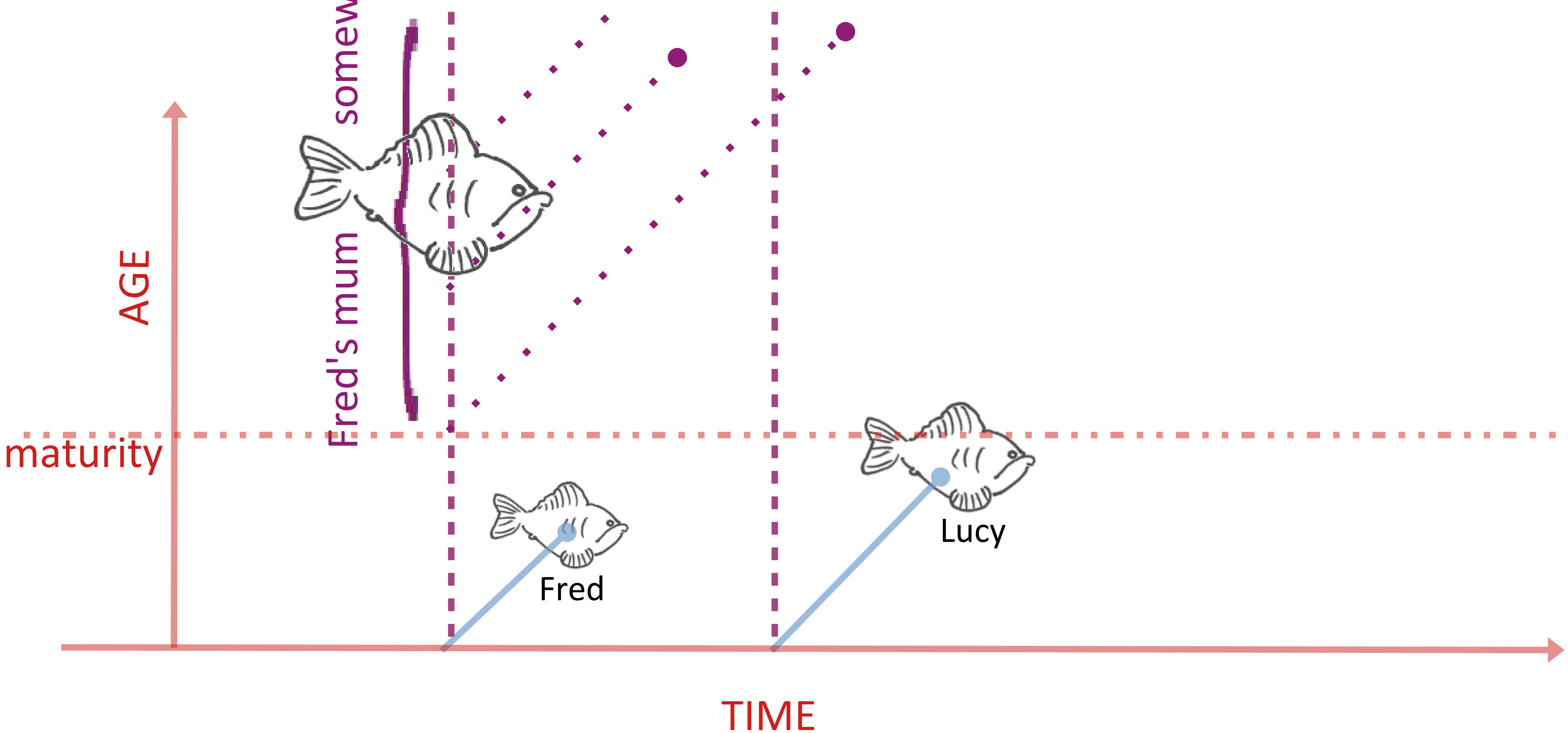

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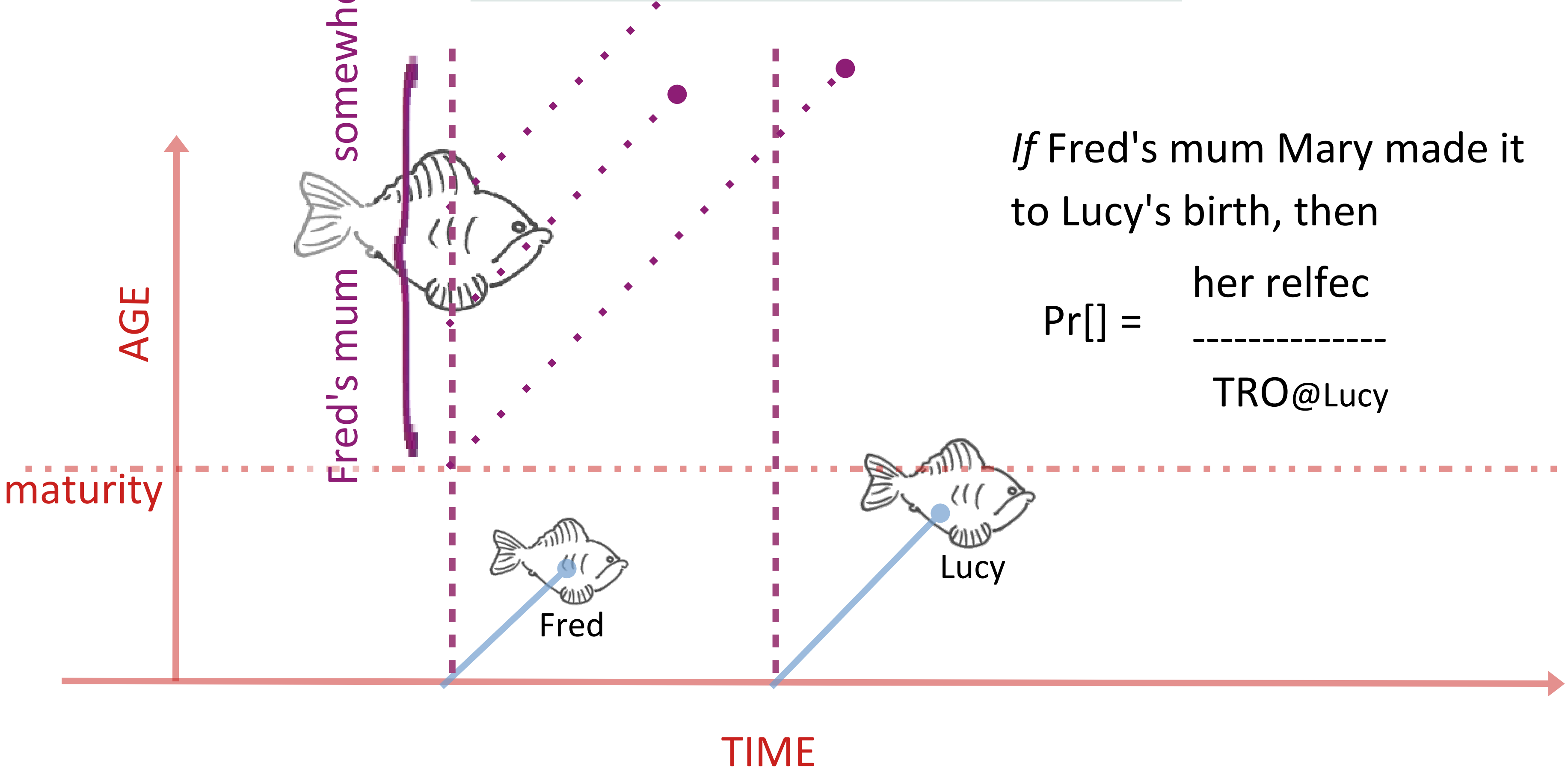
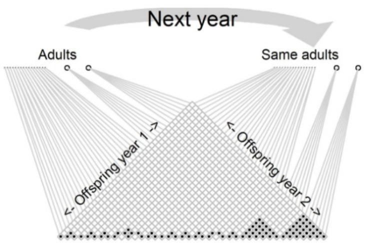
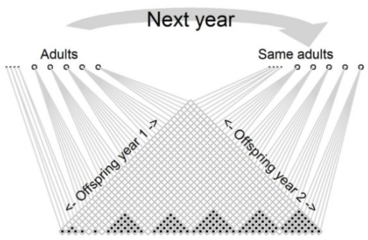


If Fred's mum Mary made it to Lucy's birth, then

$$\Pr[] = \frac{\text{her relfec}}{\text{TRO@Lucy}}$$

Fish: but... what about HSPs ?





Same POP story; very different HSPs!

Quadratic impact of indiv fec variations

How can we use that?

Heuristic explanation

#HSPs @ short gap => TRO in units of $N_{\text{equiv-AVERAGE-PARENTS}}$

Don't actually try to calculate like this ... use yer model... let statistics do the hard work...

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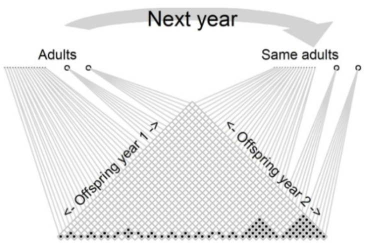

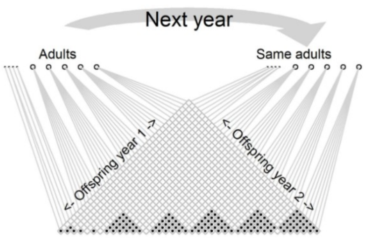

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"Average parent" is *fec-weighted* average adult

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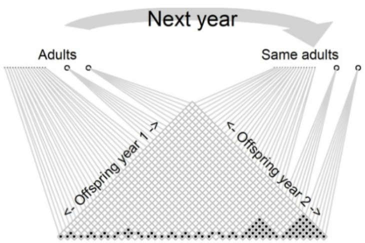

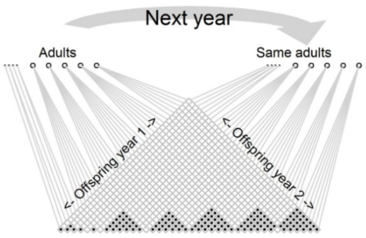

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From POPs, find equiv-age with numerically same TRO as HSPs

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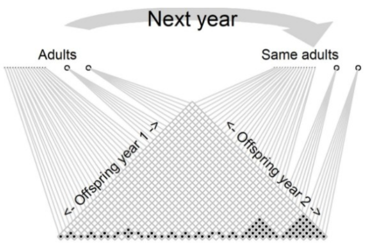

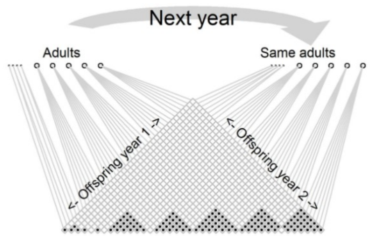

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... choose eg expo distro of N_a to match fec-wt'd mean

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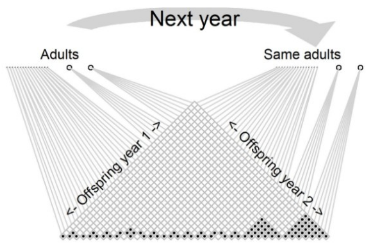

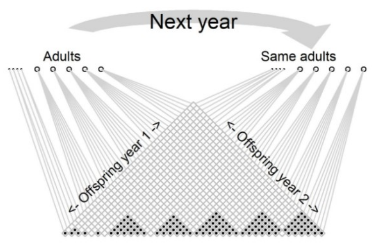

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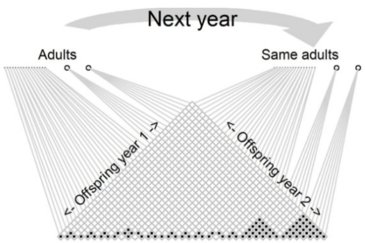
From POPs, find equiv-age with numerically same TRO as HSPs

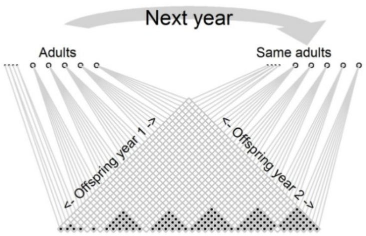
... choose eg expo distro of N_a to match fec-wt'd mean

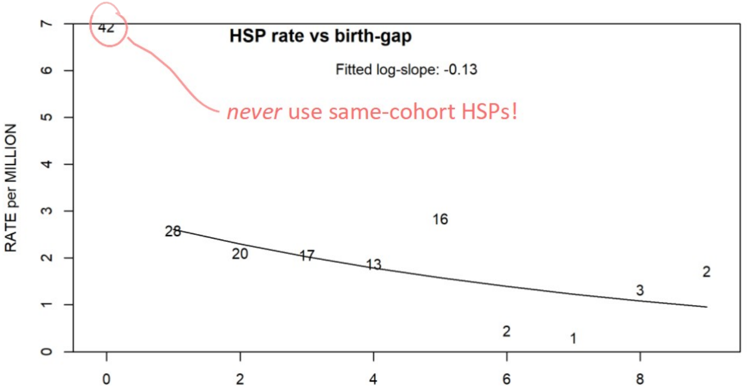
so... ratio HSPs::POPs (given fecs-at-age) => average adult age

Don't actually try to calculate like this ... use yer model... let statistics do the hard work...

Fish: POPs & HSPs together

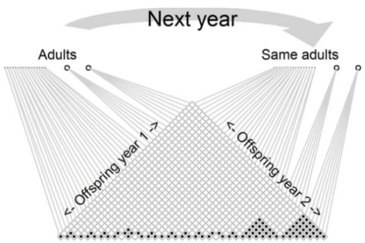


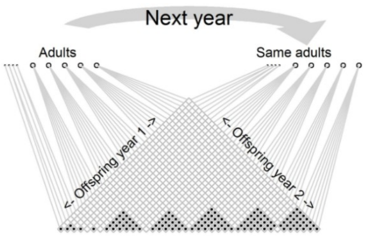


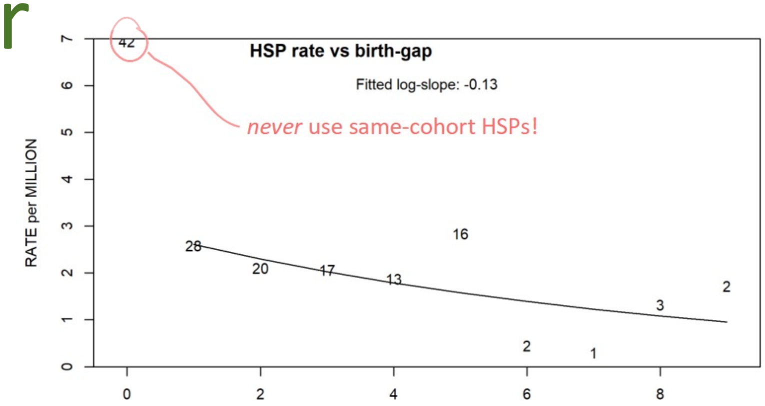


POPs => TRO, fec@age

Fish: POPs & HSPs together



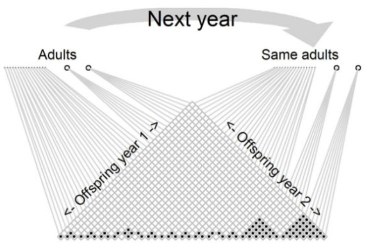


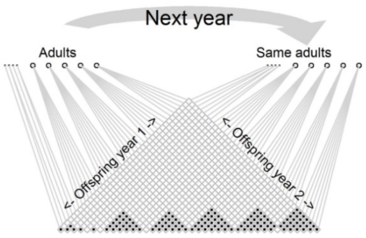


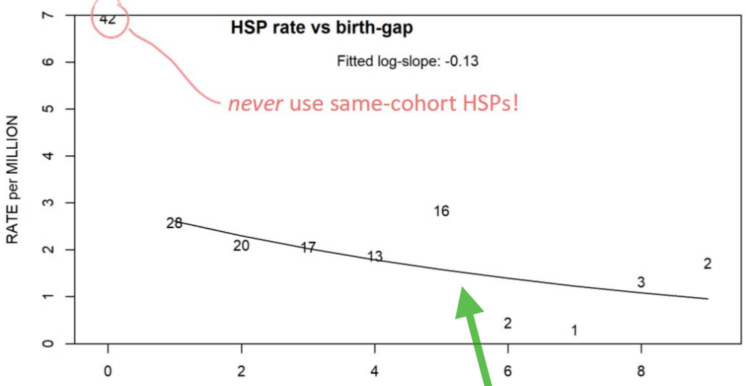
POPs => TRO, fec@age

& HSPs short-gap::POPs => mean age

Fish: POPs & HSPs together

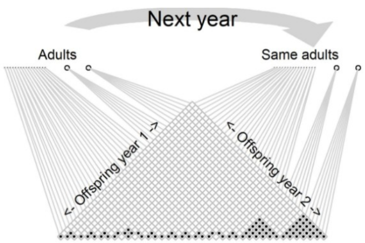


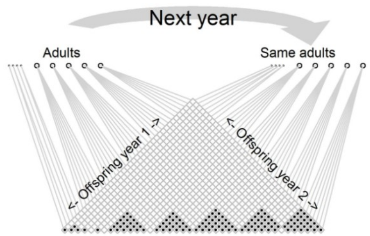


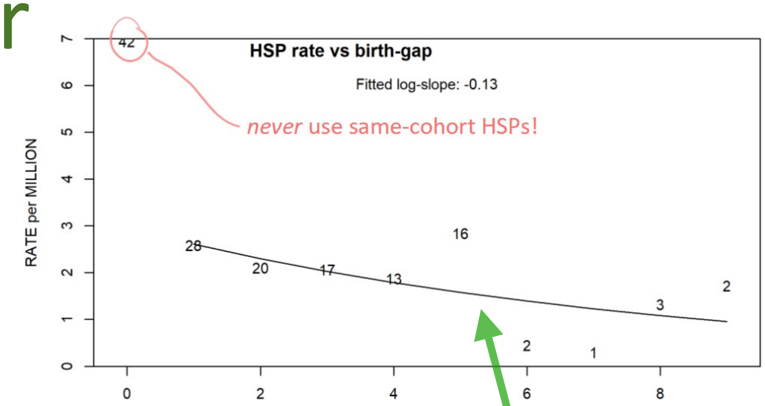


POPs	=>	TRO, fec@age
& HSPs short-gap::POPs	=>	mean age
& Age distro, fec@a	=>	growth-compensation

Fish: POPs & HSPs together







POPs	=>	TRO, fec@age
& HSPs short-gap::POPs	=>	mean age
& Age distro, fec@a	=>	growth-compensation
& HSP gap-slope	=>	Z

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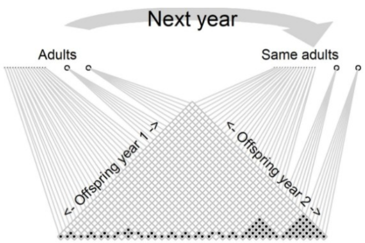

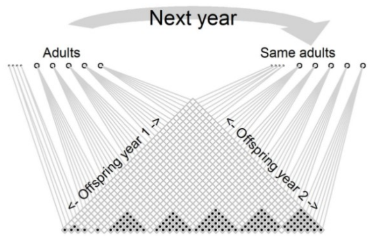

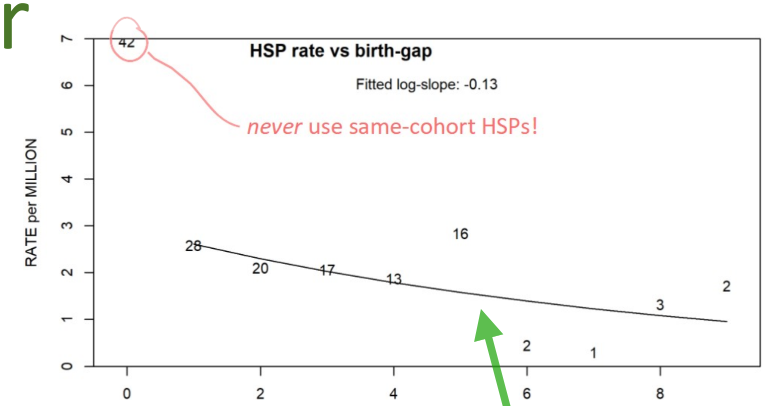

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CSIRO

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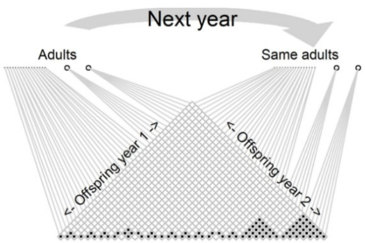

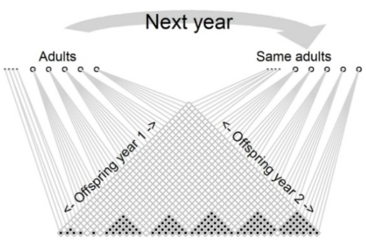

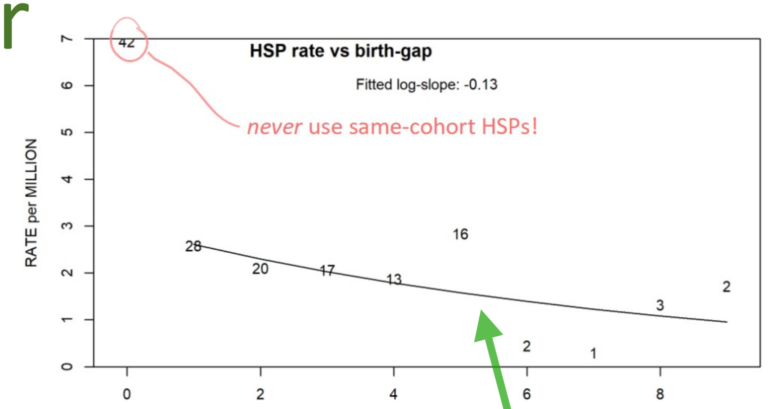

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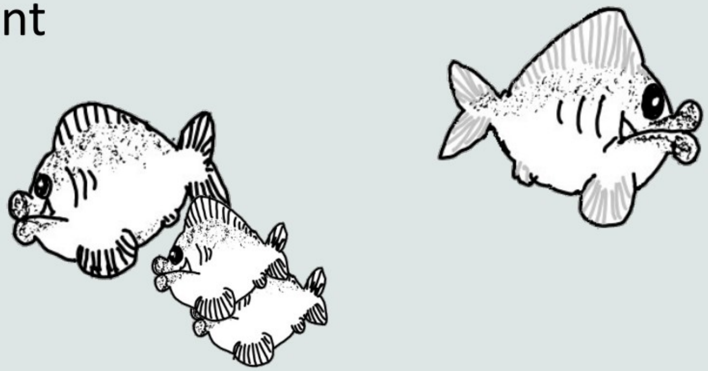
- And stuff varies over time..
- and you can't use same-cohort (zero-gap) HSPs...
- so it is all inextricably and intricately linked...
- so **build CKMR data into your model directly**

Fish: *Notogorgius poutii*

severe simulation!



1. Fecundity strongly size-dependent

2. Catch (@age) mostly adults,

   some juves

3. Constant *m* in ages caught

4. Inessential simplifications:

   i age known, age not length is driver of fec, sel

   ii only females used/modelled

   iii constant recruitment really, *mean* recruitment might be constant, but cohorts vary

5. Non-equilib incl. changing sel during study

6. Also selection for CKMR sampling

7. **No** other response data used not even A@L

~140 POPs, 60 HSPs

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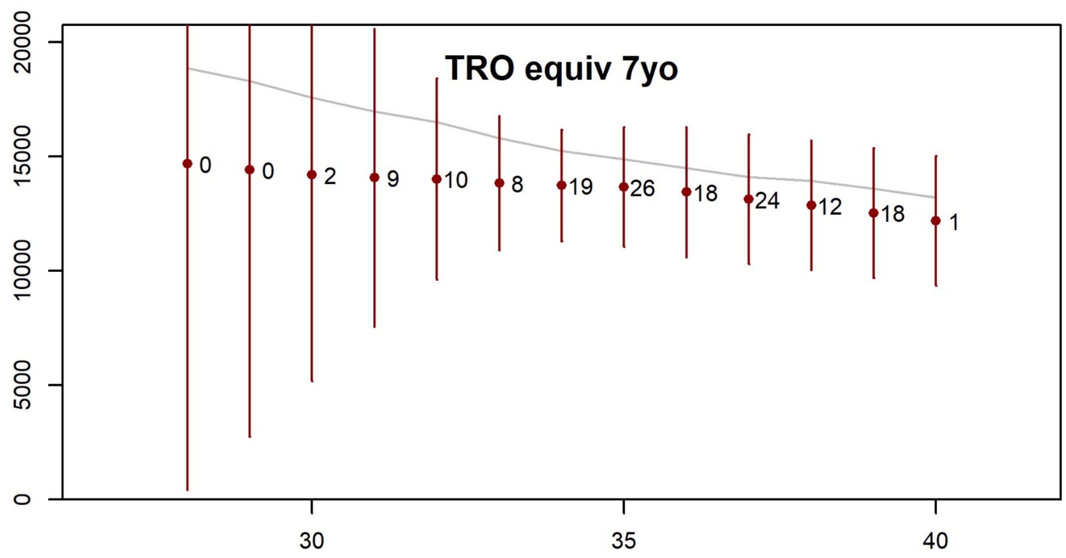
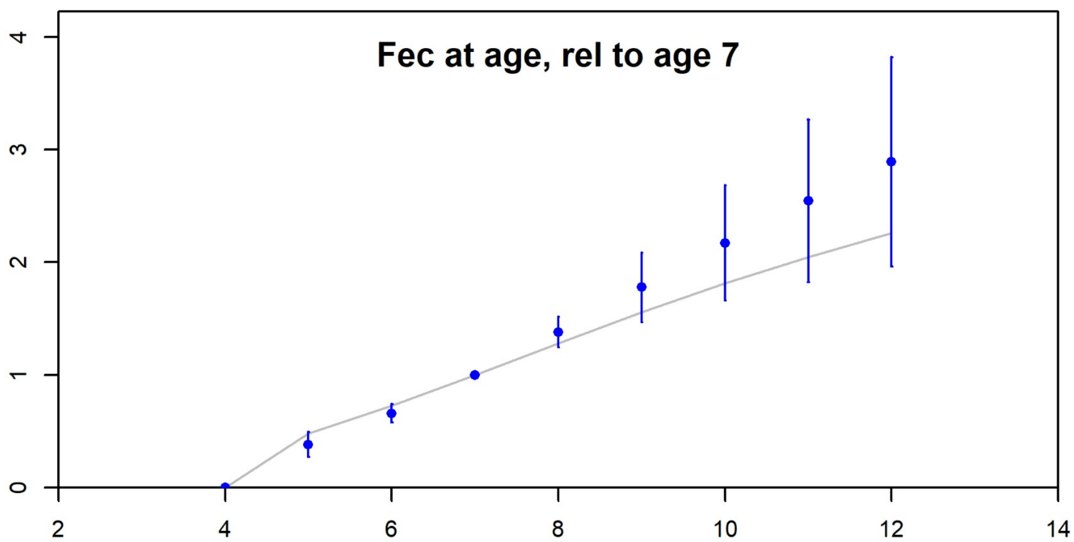


True M: 0.20

Est M: 0.26; SE 0.07

True SPRR: 0.59

Est SPRR: 0.57; SE 0.05



These results (my first attempt BTW) are not bad.

Quantifiable uncertainty.

No *need* for other data tho A@L data would help a bit.

More $amples => better CV

Fish: A real-data story (SBTuna, of course)

~2012: first CKMR model, on SBT with POPs only

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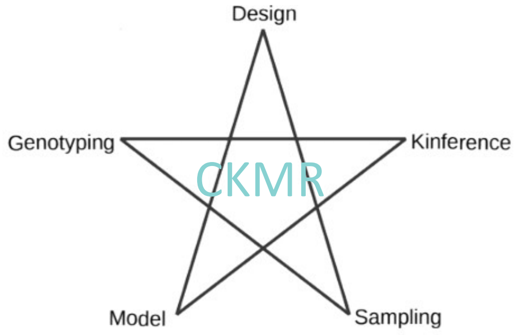
2019: ... finally figured out why

2020: N_{equiv} as a concept

Things to be aware of...

- CKMR only directly tells you about *adults*
    - including re Z (ie M)
- Can't inform on *age-specific* M within adults
- CKMR is not good at picking up cohort strengths
    - "just" tracks TRO... unle$$ you have deep pocket$
- For "mammals", you can't get adult age compo this way
    - but you may not care
- There are plenty of ways to stuff up CKMR
    - so... don't ;) !



Summary

Biopsies from juves and adults eg from catches **plus** *some size/age info:*

absolute abundance of adults

relative **fecundity-at-size** ♀ *and* ♂

And *if you also know catch-at-age, and have growth curve*

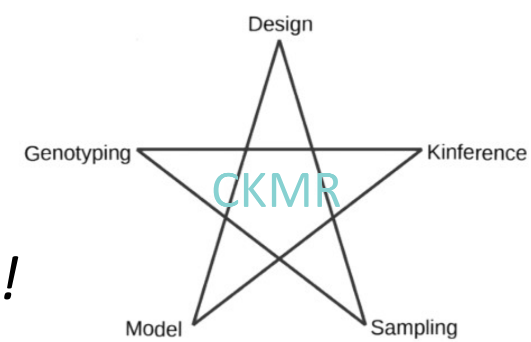
natural mortality averaged across adults

And current **SPRR** etc

And **connectivity** on management timescale (1 generation)

Q: How precise is it?

A: Depends how much you want to spend!



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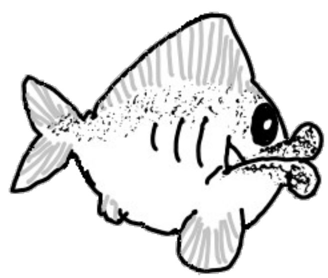
natural mortality ... lts

And current **SPRR** etc

And **connectivity** on management ti ... generation)

The end.
Thanks!



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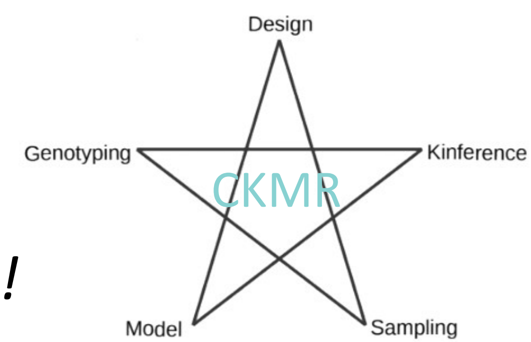

For fun-lovers

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$$\sum_a N_{b_{\text{F}}a} \times \frac{\text{fec}_a}{\text{TRO}_{b_{\text{F}}}} \times \mathbb{P}\left[\text{surv}\right] \times \frac{\text{fec}_{a+\Delta}}{\text{TRO}_{b_{\text{L}}}}$$

$$\text{TRO}_y = \sum_a N_{ya} \times \text{fec}_a$$