

Capture-mark-recapture approaches

Lee Hsiang Liow

Natural History Museum and Centre for Planetary Habitability, University of Oslo, Norway

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CENSUS VERSUS SAMPLING

1920 Census 2,649,775 persons in Norway

2022 UN estimates 5,434,319

2022 SSB estimates 5,435,536

2024 (AI generated based on listed sources) 5,590,000



CENSUS VERSUS SAMPLING



1920 Census 2,649,775 persons in Norway

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2024 (AI generated based on listed sources) 5,590,000

Q1 What is the difference between a census and a sample?

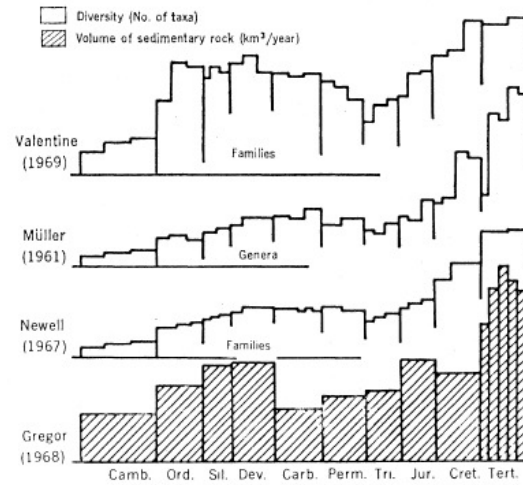
Q2 Why not always do a census?

Q3 Why are the UN and SSB numbers different?

Q4 Discuss the 2024 number!

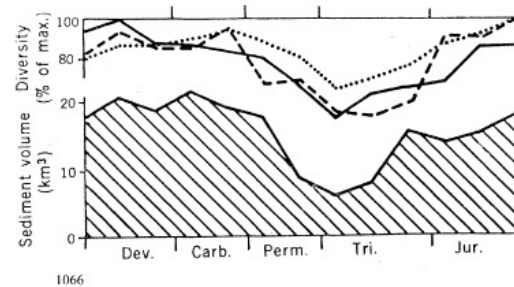


SAMPLING IN THE FOSSIL RECORD



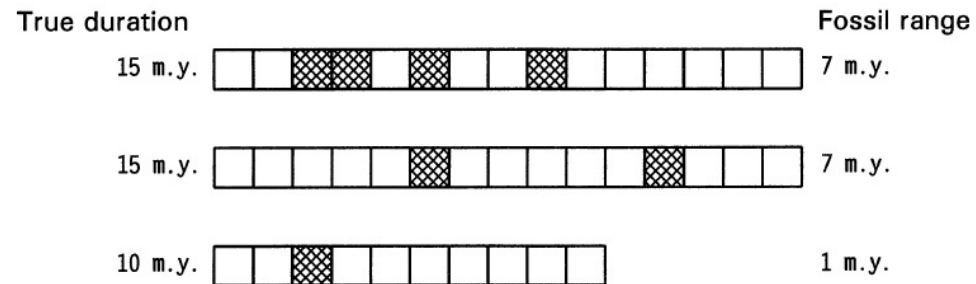
Raup 1972: Taxonomic diversity during the Phanerozoic. *Science*

- “systematic biases exist in the raw data actual diversity picture may be quite different from that afforded by a direct reading of the raw data.”
- “In spite of the fact that the patterns in Fig. 1 are correlated, a causal relationship is by no means demonstrated.”



SAMPLING IN THE FOSSIL RECORD

Foote & Raup 1996 Fossil preservation and the stratigraphic ranges of taxa. *Paleobiology*



$R = \text{Prob}(\text{preservation at least once in interval})$

$(1 - R) = \text{Prob}(\text{non-preservation})$

In general, $\text{Prob}(\text{range} = t \text{ if duration} = T)$:

$$= (1 - R)^T \quad \text{if } t = 0$$

$$= T(1 - R)^{(T-1)}R \quad \text{if } t = 1$$

$$= (T - t + 1)(1 - R)^{(T-t)}R^2 \quad \text{if } t > 1$$

t is observed range (discrete)

T is true range

Note the use of “observations” and “non-observations”

FOSSIL RECORD DATABASES

Rethinking/Revisting material from the first week

Sepkoski J. J., Jr (1992). A compendium of fossil marine animal families, 2nd edition. *Contributions in biology and geology*, 83, 1–156.



Family stratigraphic ranges (first and last observations in time)

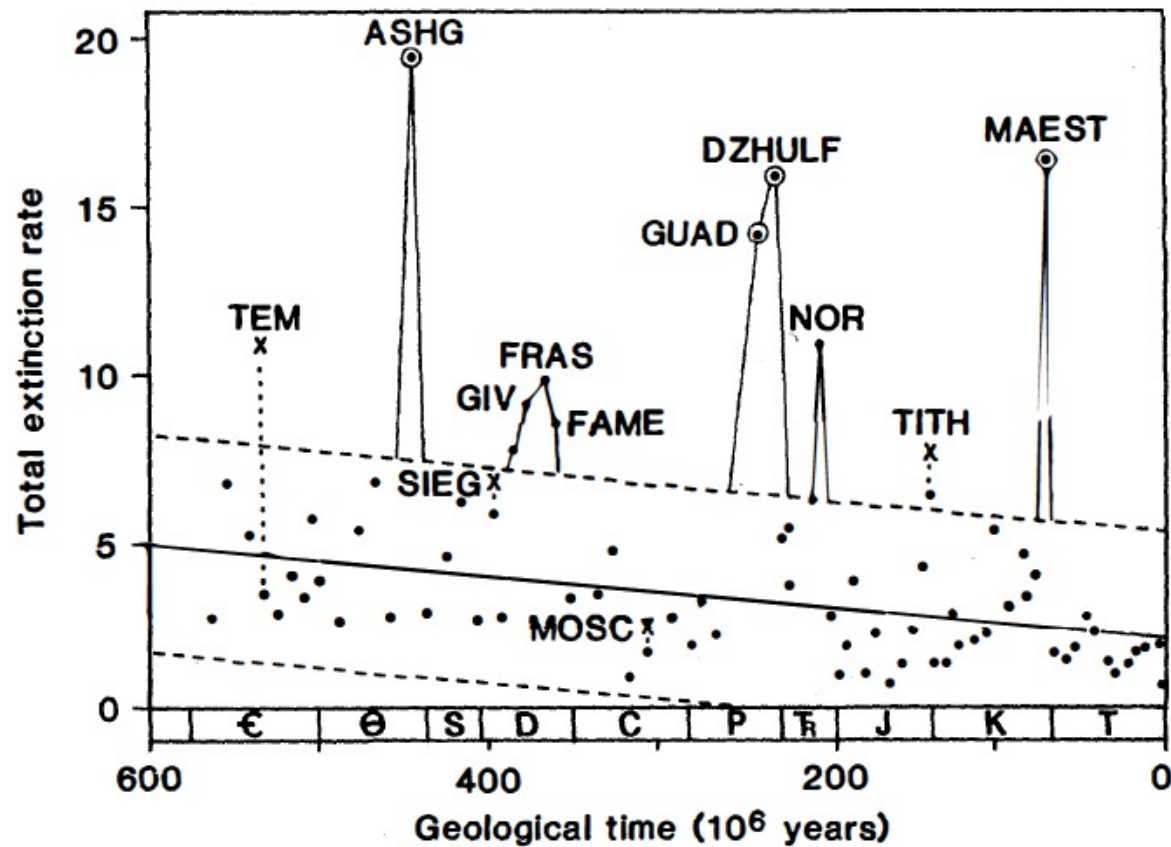
Huge community effort; NSF funding



Taxon observations in space and time
(species, genus etc, multiple observations)
Much more information!

FOSSIL RECORD DATABASES: MASS EXTINCTIONS

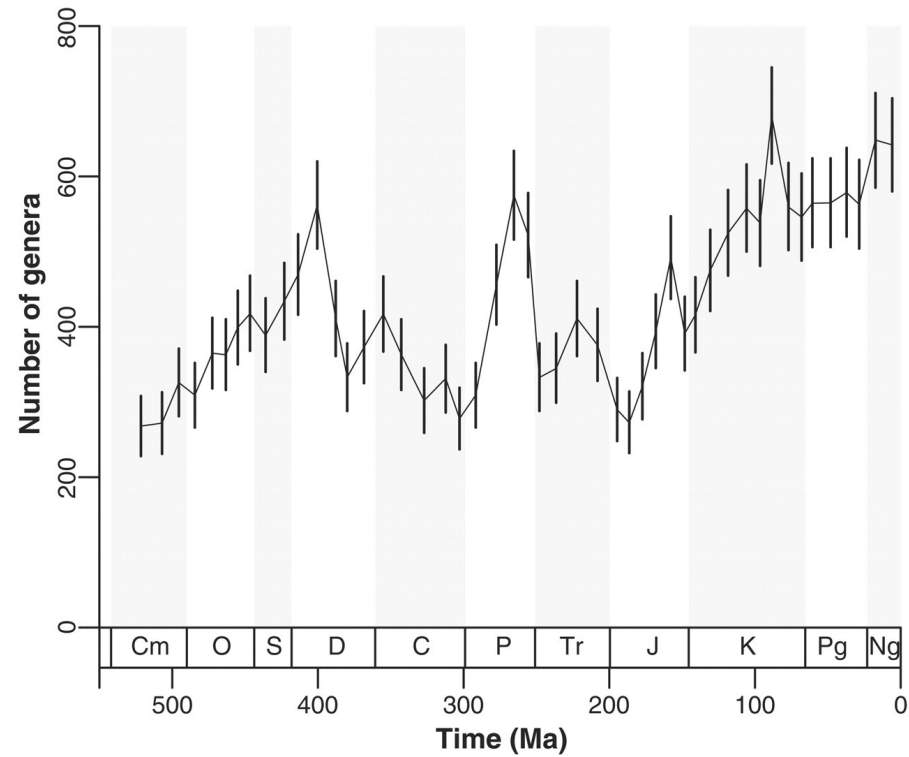
Rethinking/Revisting material from the first week



Raup & Sepkoski. 1982: Mass extinctions in the marine fossil record. *Science*

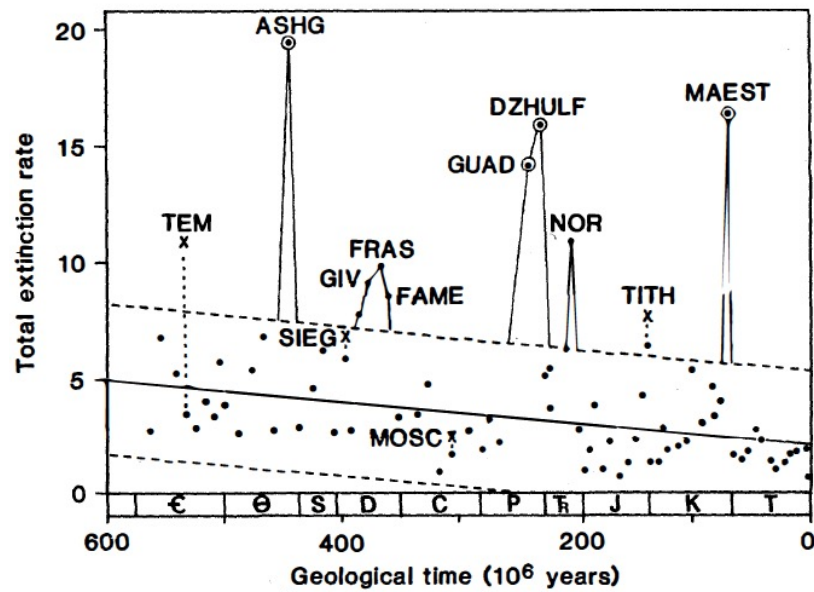
LESS DRAMATIC TRENDS WITH STANDARDIZATION

Rethinking/Revisting material from the first week

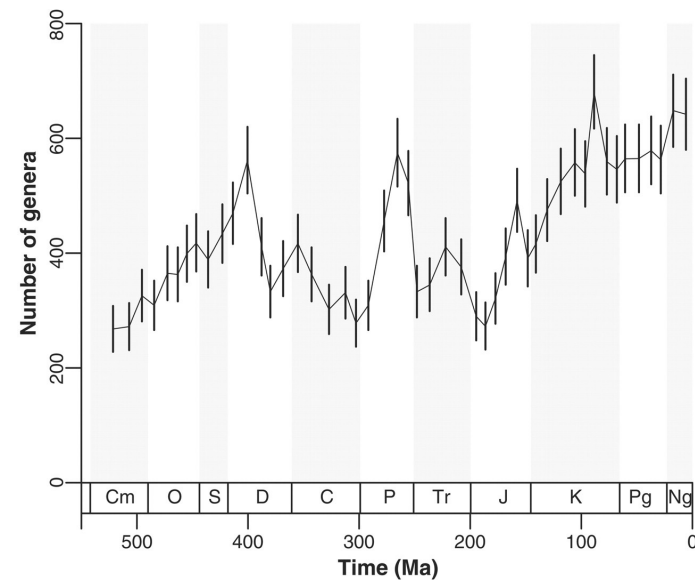


Alroy, J. *et al.* 2008 Phanerozoic Trends in the Global Diversity of Marine Invertebrates. *Science*

Rethinking/Revisting material from the first week

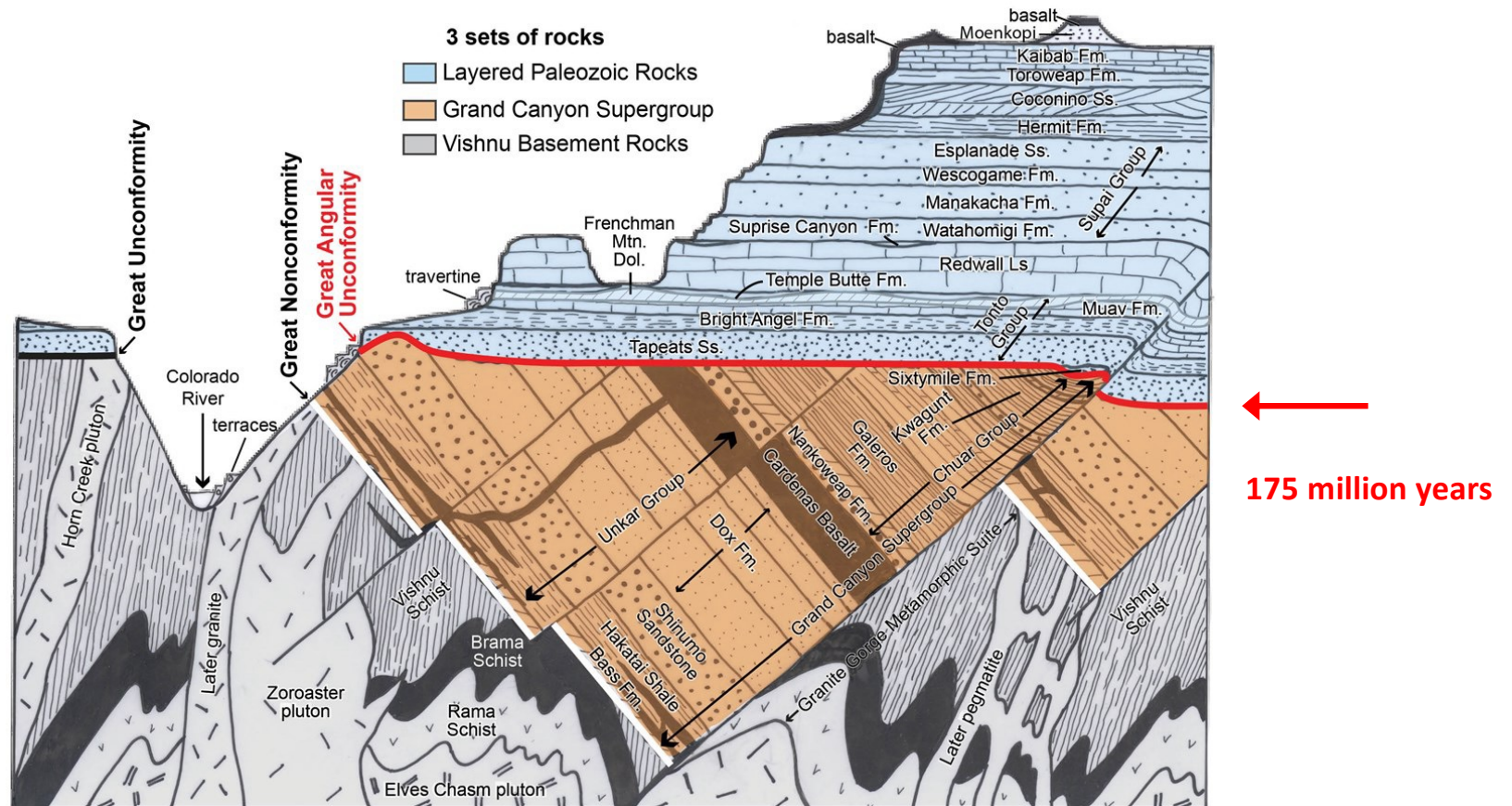


- Family level data
- First and last observations
- Range through



- Genus level data
- Observations in time intervals
- Sampling-standardized

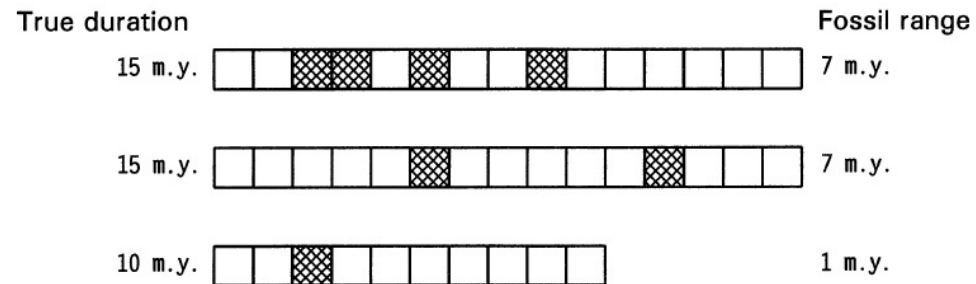
Some sampling gaps are not recoverable, ever



https://en.wikipedia.org/wiki/Great_Unconformity

Some sampling gaps are not recoverable, ever

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SWITCHING GEARS TO RATS/MICE

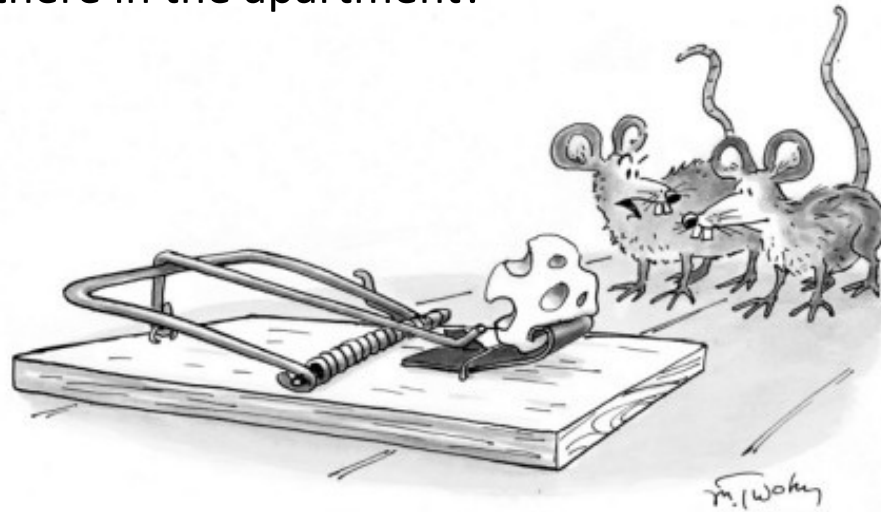


SWTICHING GEARS TO RATS/MICE

Day 1: caught 10 rats

Day 2: caught 2 rats

How many rats are there in the apartment?



"Careful—it might be a trap!"

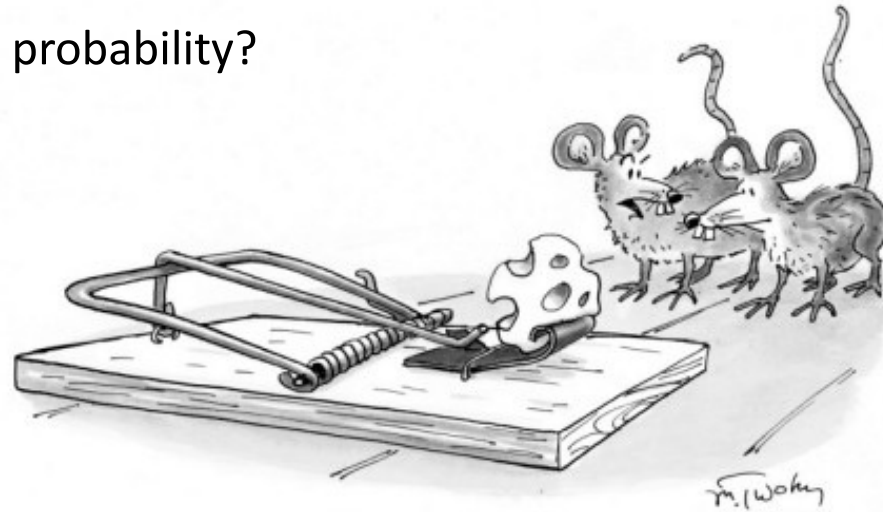
THE ESSENCE OF CAPTURE RECAPTURE APPROACHES



Day 1: caught 10 rats, put tags on them

Day 2: caught rats in the same place. 2 had your tags, but 8 didn't

What is the capture probability?



"Careful—it might be a trap!"

THE ESSENCE OF CAPTURE RECAPTURE APPROACHES



Day 1: caught 10 rats, put tags on them

Day 2: caught rats in the same place. 2 had your tags, but 8 didn't

What is the capture probability?

$2/10=0.2$

How many rats are there in that "place?"



"Careful—it might be a trap!"

$$\frac{\text{marked Day 2}}{\text{total for Day 2}} = \frac{\text{marked Day 1}}{\text{Estimated Total}}$$

THE ESSENCE OF CAPTURE RECAPTURE APPROACHES

Day 1: caught 10 rats, put tags on them

Day 2: caught rats in the same place. 2 had your tags, but 8 didn't

What is the capture probability?

$2/10=0.2$

How many rats are there in that "place?"

50



"Careful—it might be a trap!"

$$\frac{\text{marked Day 2}}{\text{total for Day 2}} = \frac{\text{marked Day 1}}{\text{Estimated Total}}$$

The **Lincoln–Petersen method** (Petersen–Lincoln index)

Short fun read: Laplace estimates population of France in 1783
<https://rss.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1740-9713.2014.00754.x>

THE ESSENCE OF CAPTURE RECAPTURE APPROACHES



Day 1: caught 10 rats, put tags on them

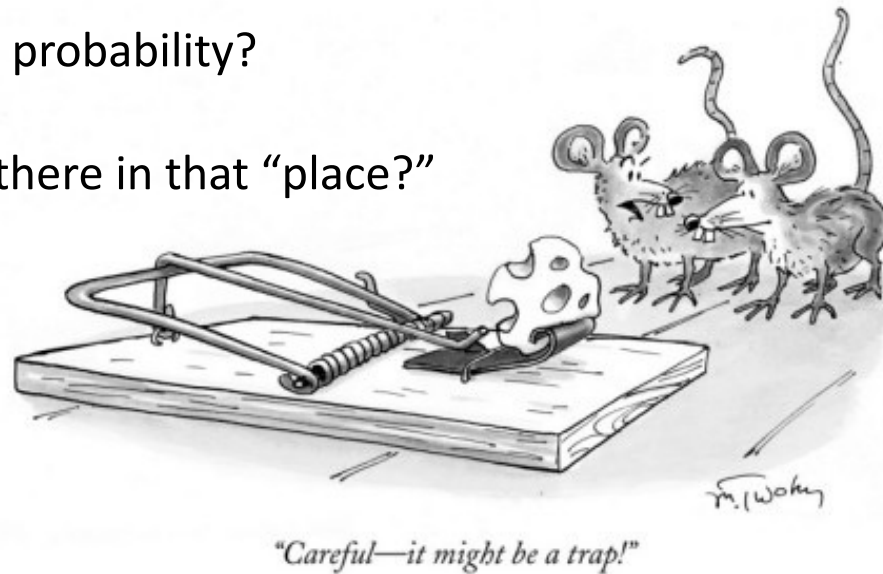
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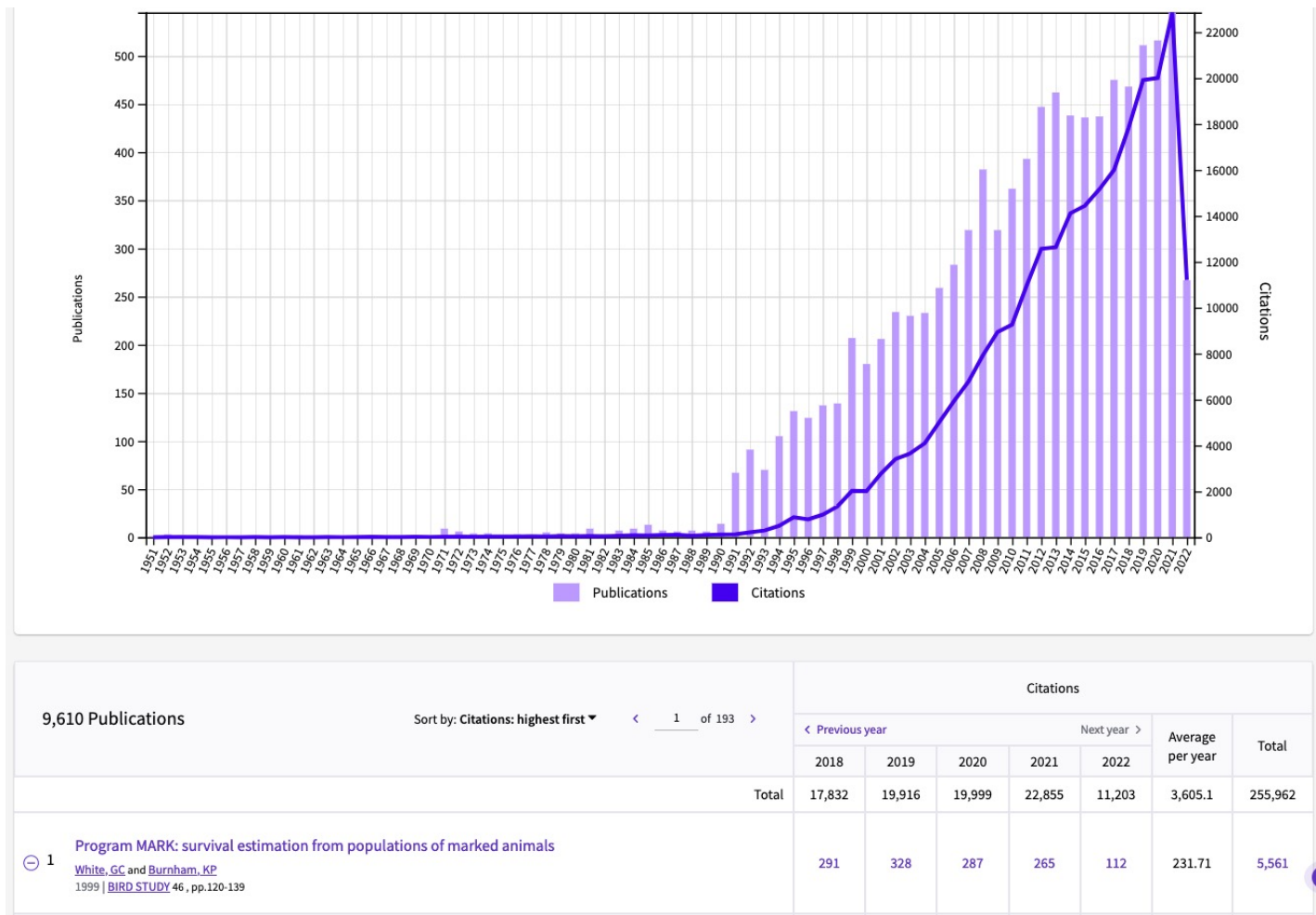
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Q4 What are the assumptions here made in this approach?

THE GROWTH OF CAPTURE RECAPTURE APPROACHES



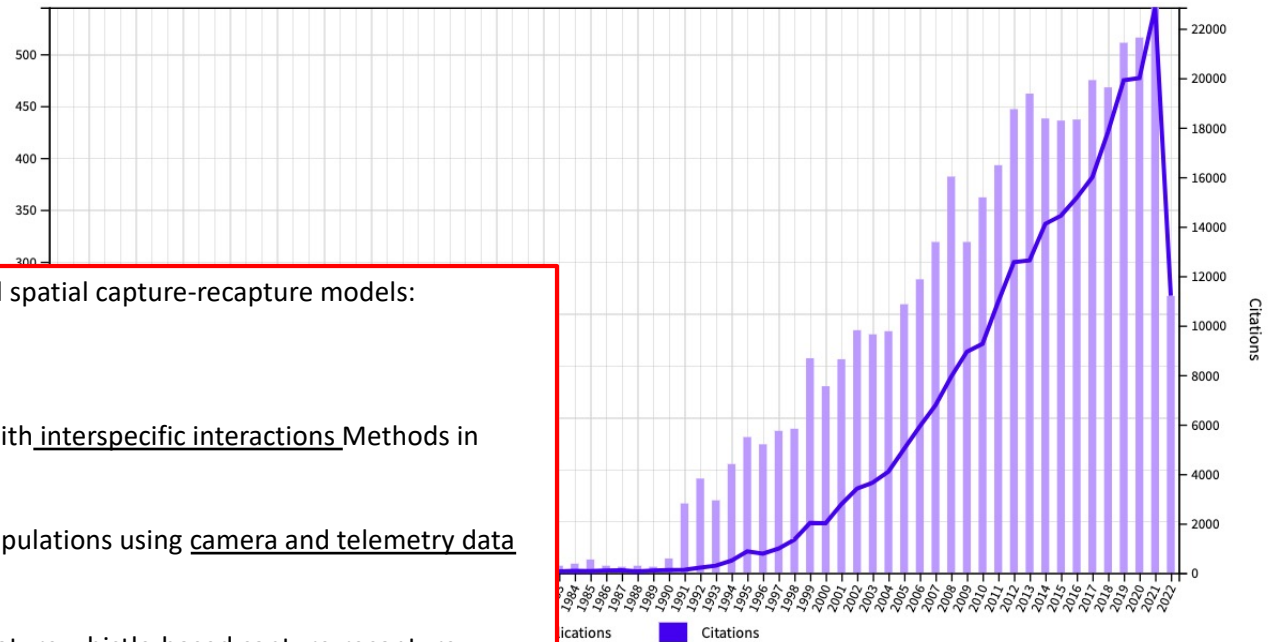
THE GROWTH OF CAPTURE RECAPTURE APPROACHES

Gardner et al. 2022 Integrated animal movement and spatial capture-recapture models: Simulation, implementation, and inference
Ecology

Zhao et al. 2022 Spatial dynamic N-mixture models with interspecific interactions Methods in Ecology and Evolution

Margenau et al. 2022 Monitoring partially marked populations using camera and telemetry data Ecological applications

Sharpe et al. 2024 A comparison of photo-ID and signature whistle-based capture-recapture abundance estimates of common bottlenose dolphin
Marine Mammal Science



9,610 Publications		Sort by: Citations: highest first ▾		1 of 193		Citations								
						◀ Previous year					Next year ▶		Average per year	Total
						2018	2019	2020	2021	2022				
Total						17,832	19,916	19,999	22,855	11,203	3,605.1	255,962		
①	Program MARK: survival estimation from populations of marked animals White, GC and Burnham, KP 1999 BIRD STUDY 46, pp.120-139					291	328	287	265	112	231.71	5,561		

SHORT HISTORY OF ESTIMATION TAXONOMIC RICHNESS AND DIVERSIFICATION RATES and relationship to CMR

Nichols & Pollock 1983 Estimating taxonomic diversity, extinction rates, and speciation rates from fossil data using capture-recapture models. *Paleobiology* 9, 150–163

Foote & Raup 1996 Fossil preservation and the stratigraphic ranges of taxa. *Paleobiology*

Foote 1999/2001 (Boundary crossers method)

Alroy et al. 2001 (sampling standardization)

Connolly and Miller papers 2001-2 using CMR (Connolly is an ecologist)

Foote 2003 (few people use this) – CMR-like, but accounts for origination and extinction within time interval (but see robust design)

(Liow et al. 2008) My own first capture recapture paleo-paper – I met Nichols in 2006; short course paper with Nichols

Silvestro, Schinitzler & Liow Syst bio 2014 Pyrate model paper (not the software itself)

Warnock et al. 2020 RevBayes (starting from birth death models but dropping the “relationships”)