

Capture-mark-recapture approaches

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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



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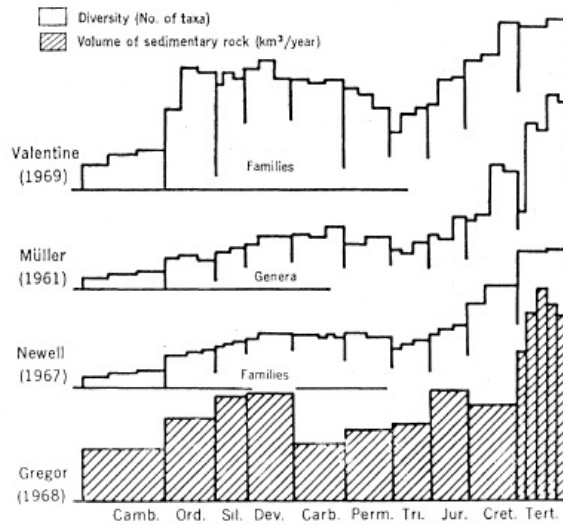
Q1 What is the difference between a census and a sample?

Q2 Why not always do a census?

Q3 Why are the UN and SSB numbers different?

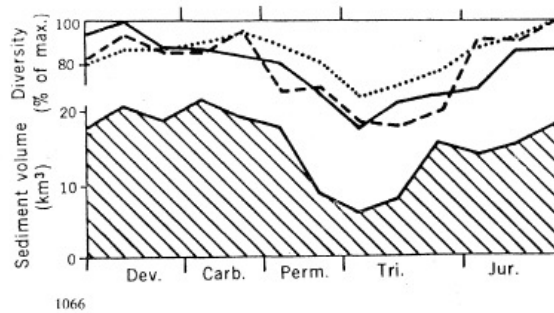


SAMPLING IN THE FOSSIL RECORD



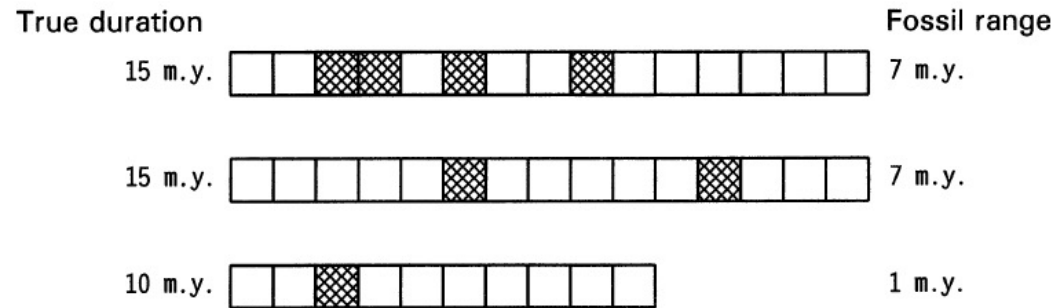
Raup 1972: Taxonomic diversity during the Phanerozoic. *Science*

- “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

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



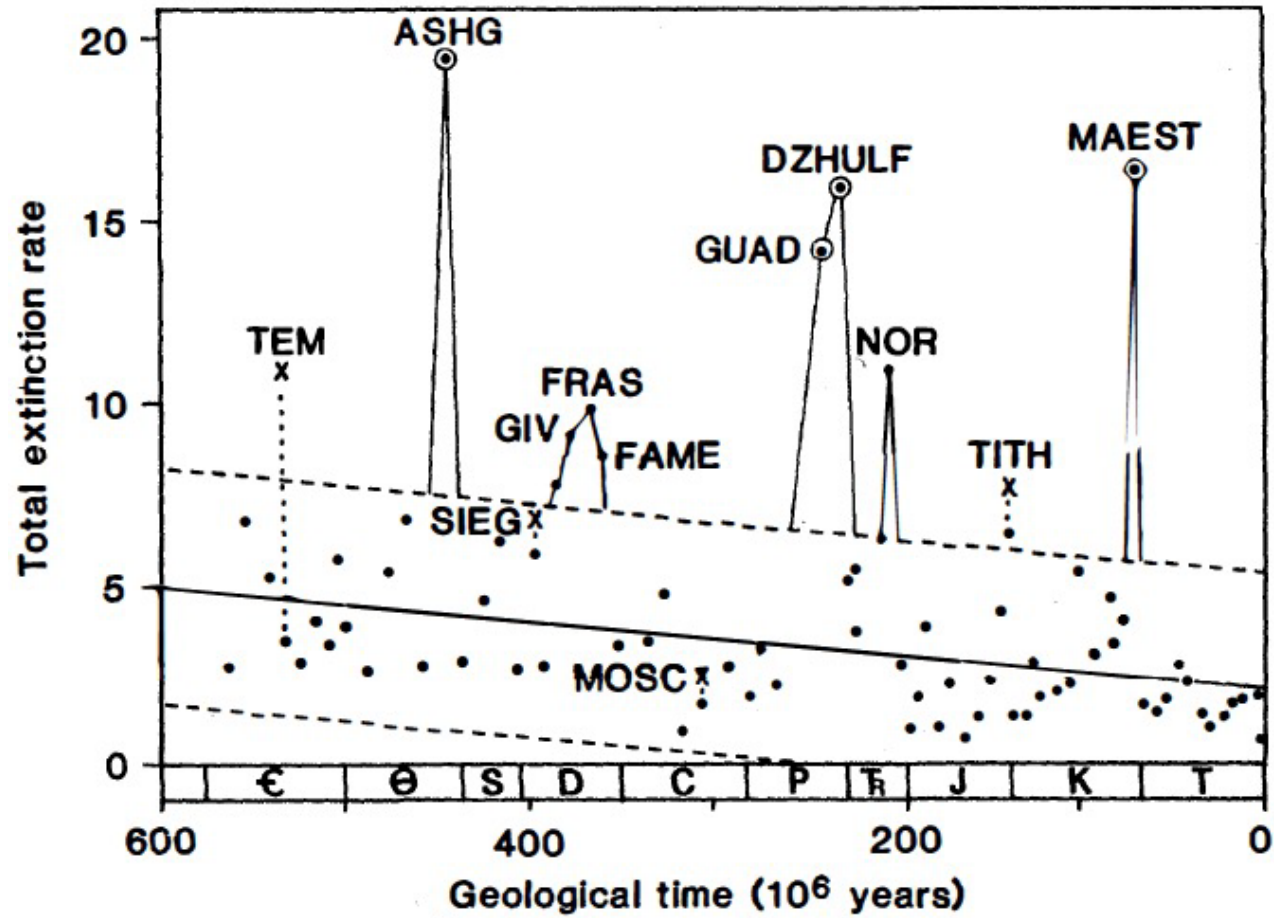
Family stratigraphic ranges (first and last observations in time)

Huge community effort; NSF funding



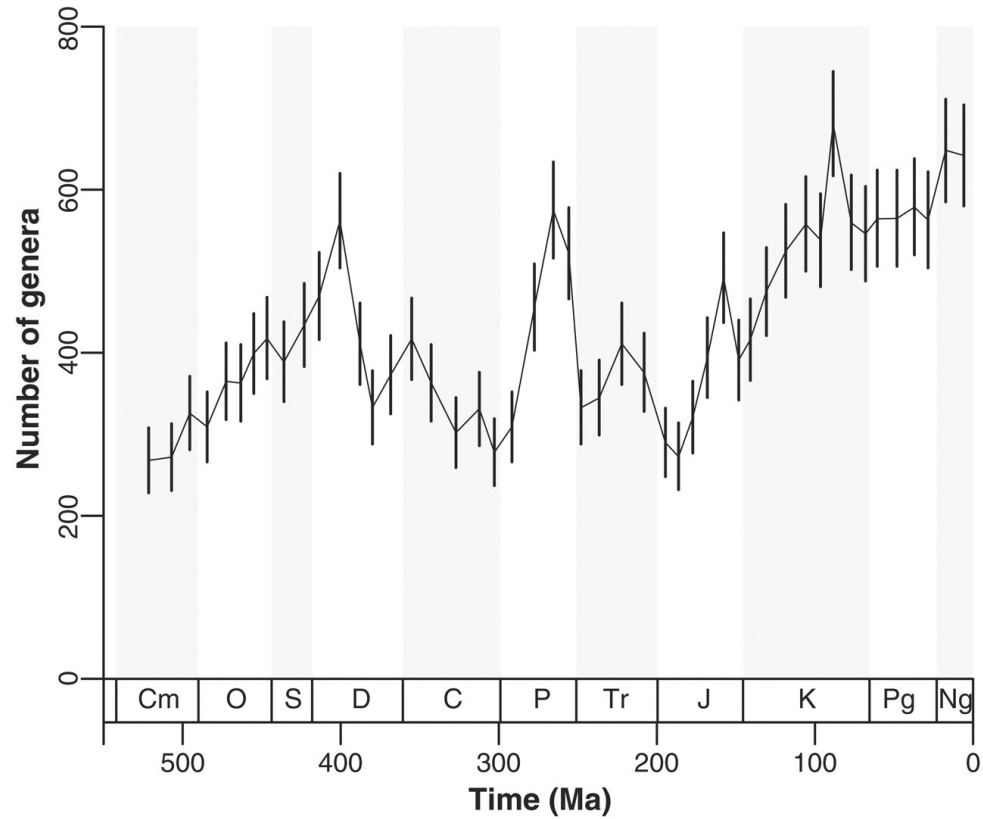
Taxon observations in space and time
(species, genus etc, multiple observations)
Much more information!

FOSSIL RECORD DATABASES: MASS EXTINCTIONS

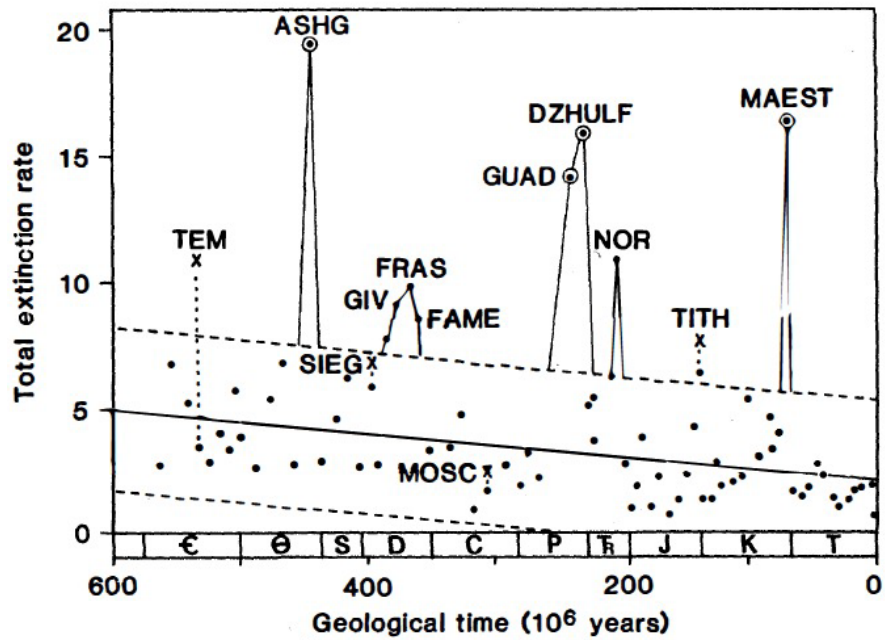


Raup & Sepkoski. 1982: Mass extinctions in the marine fossil record. *Science*

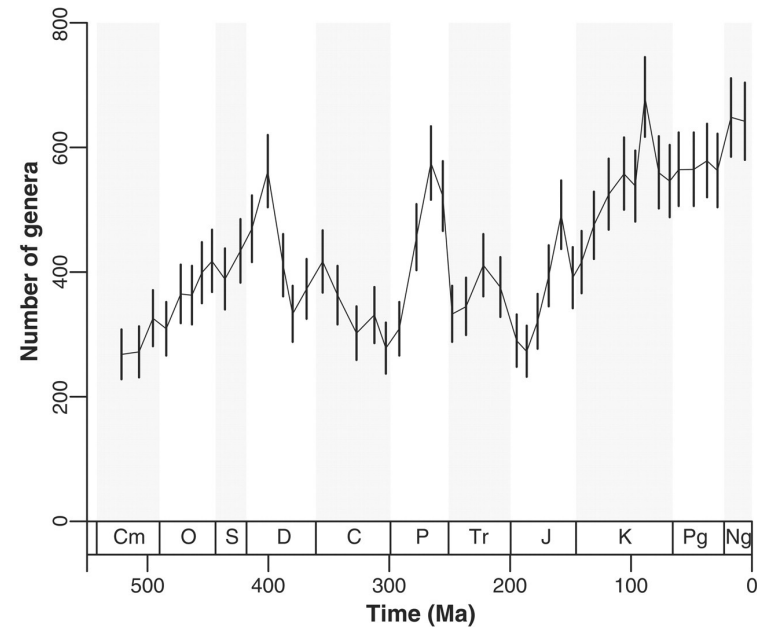
LESS DRAMATIC TRENDS WITH STANDARDIZATION



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



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



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

SWITCHING GEARS TO RATS/MICE

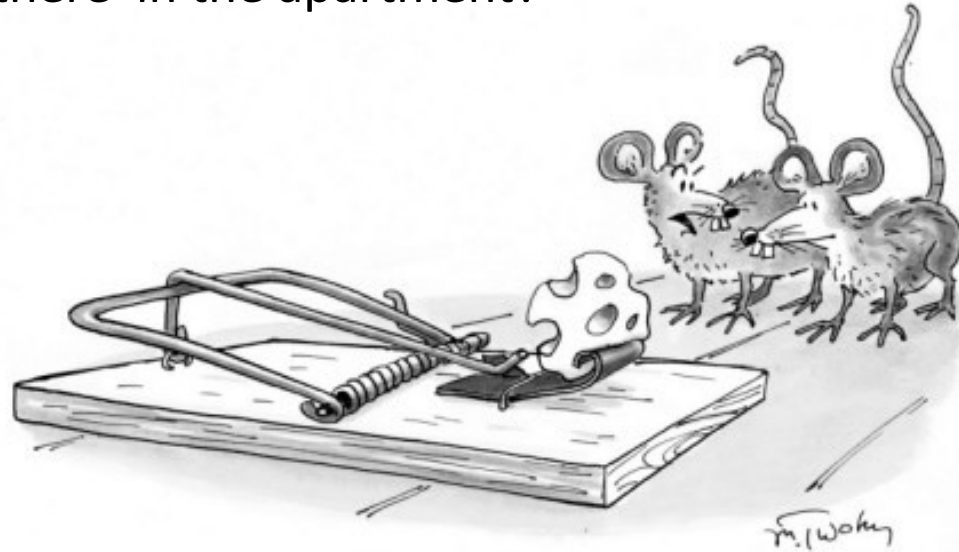


SWTICHING GEARS TO RATS/MICE

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

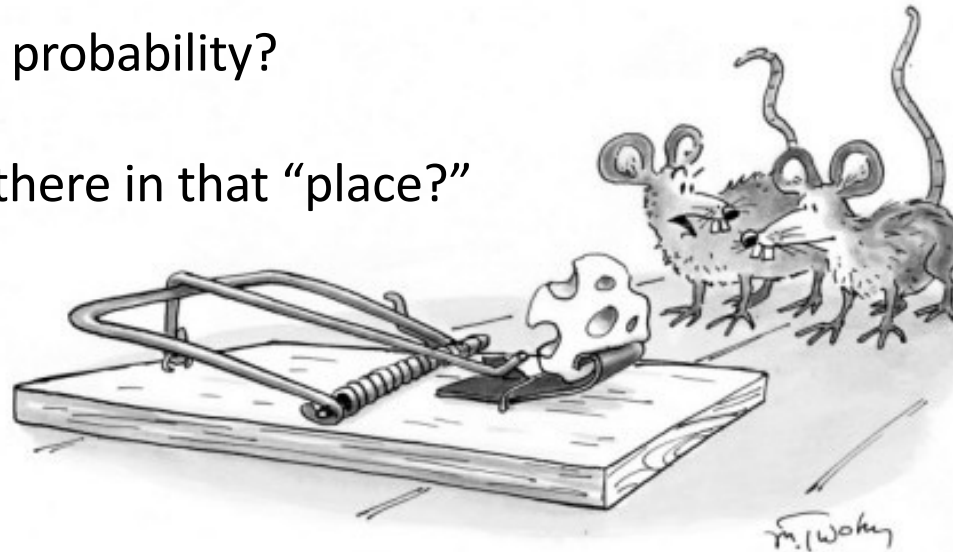
Day 2: caught rats in the same place. 2 had your tags, but 8 didn't

What is the capture probability?

$2/10=0.2$

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

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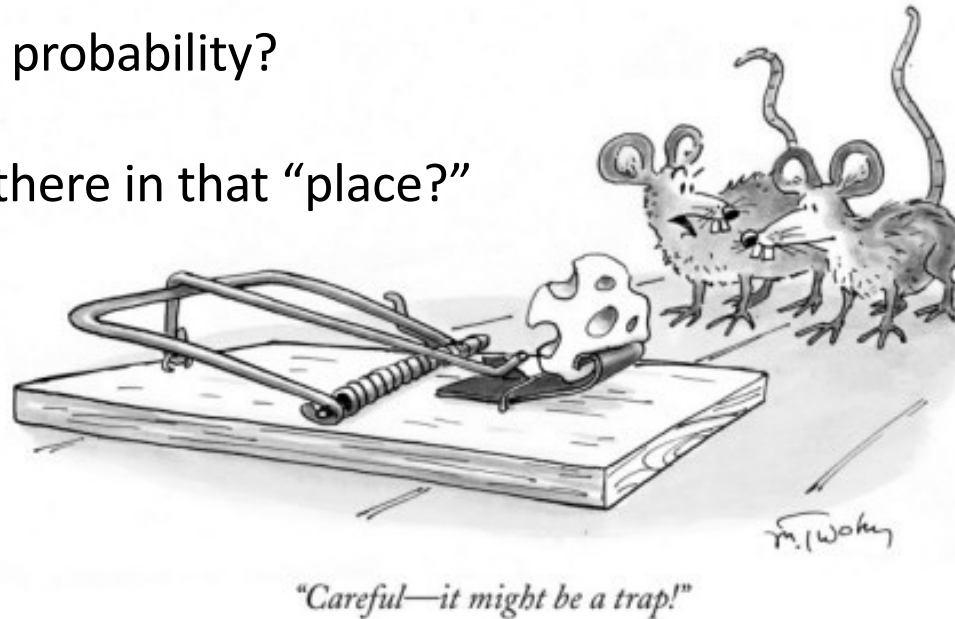
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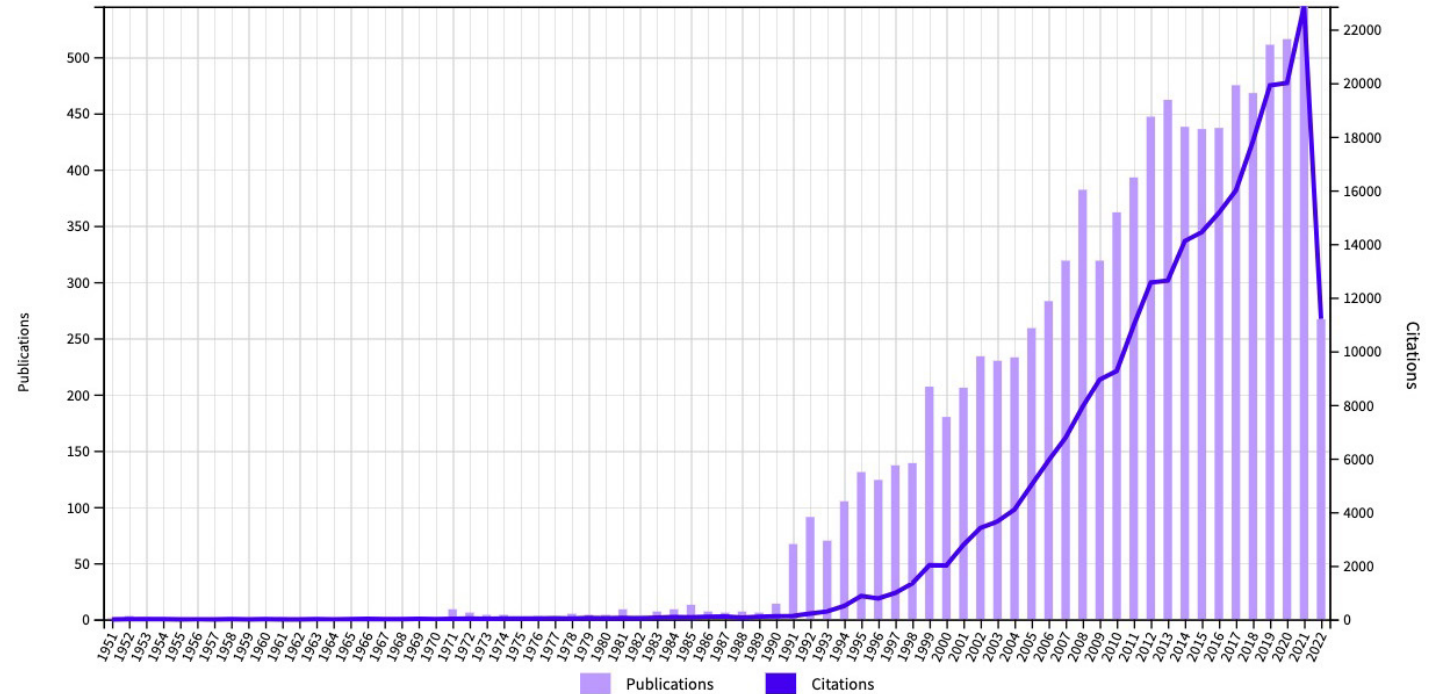
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Q4 What are the assumptions here made in this approach?

THE GROWTH OF CAPTURE RECAPTURE APPROACHES



9,610 Publications

Sort by: Citations: highest first < 1 of 193 >

Citations

< Previous year

Next year >

	2018	2019	2020	2021	2022	Average per year	Total
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Total	17,832	19,916	19,999	22,855	11,203	3,605.1	255,962
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1

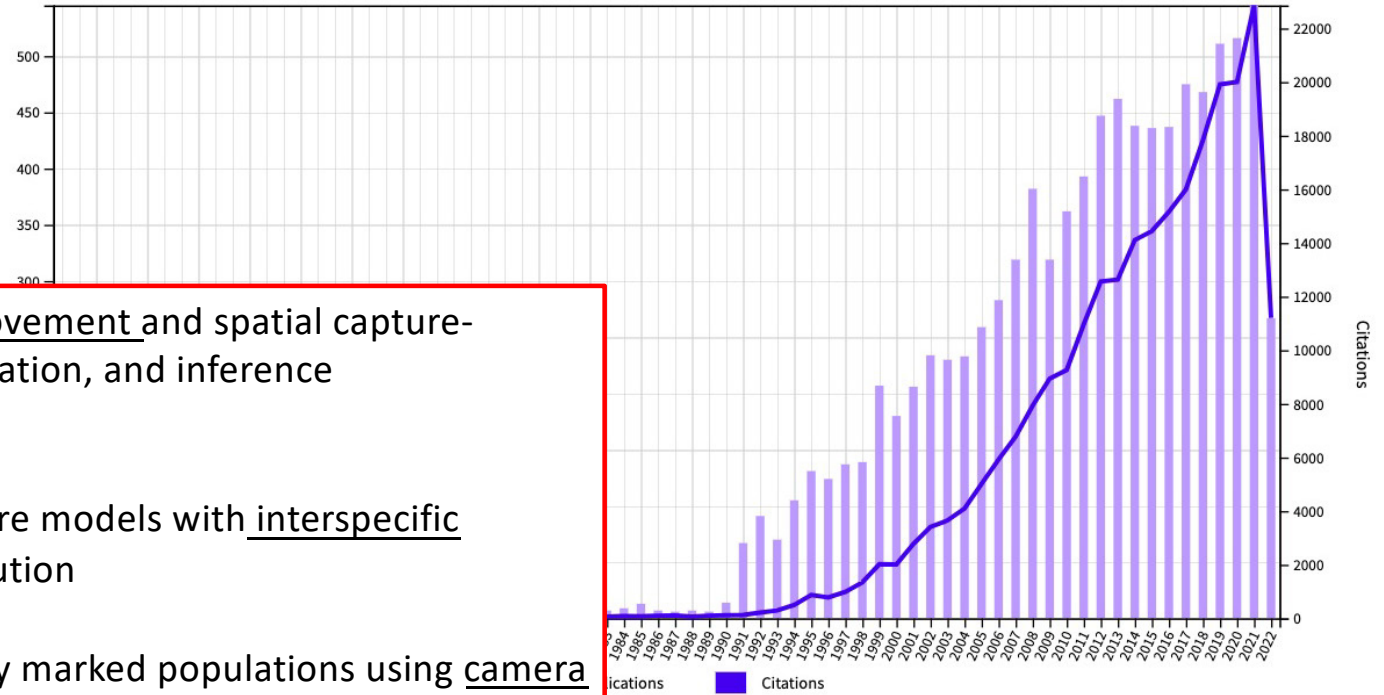
[Program MARK: survival estimation from populations of marked animals](#)

[White, GC and Burnham, KP](#)

1999 | [BIRD STUDY](#) 46 , pp.120-139

291	328	287	265	112	231.71	5,561
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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

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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

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”)