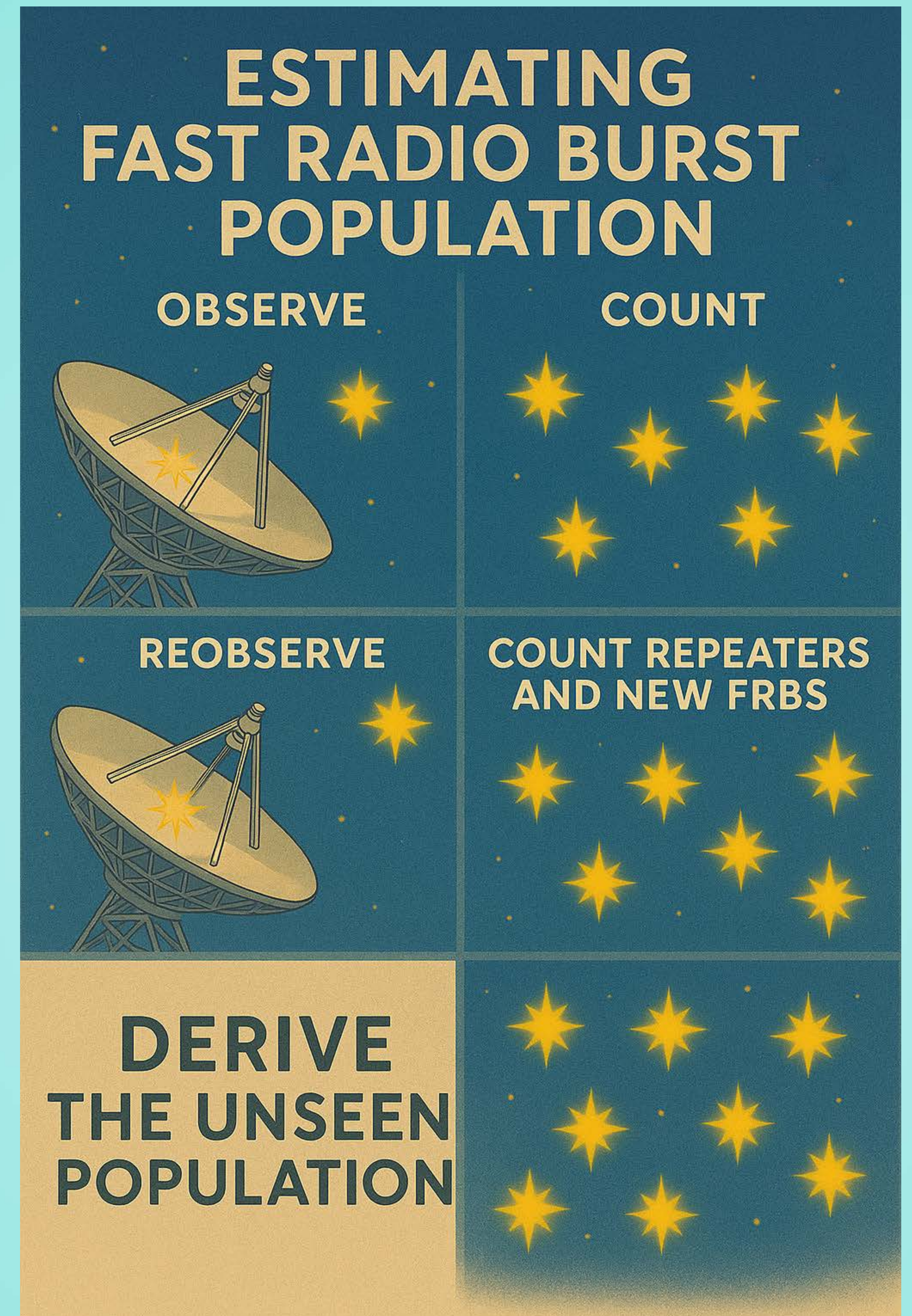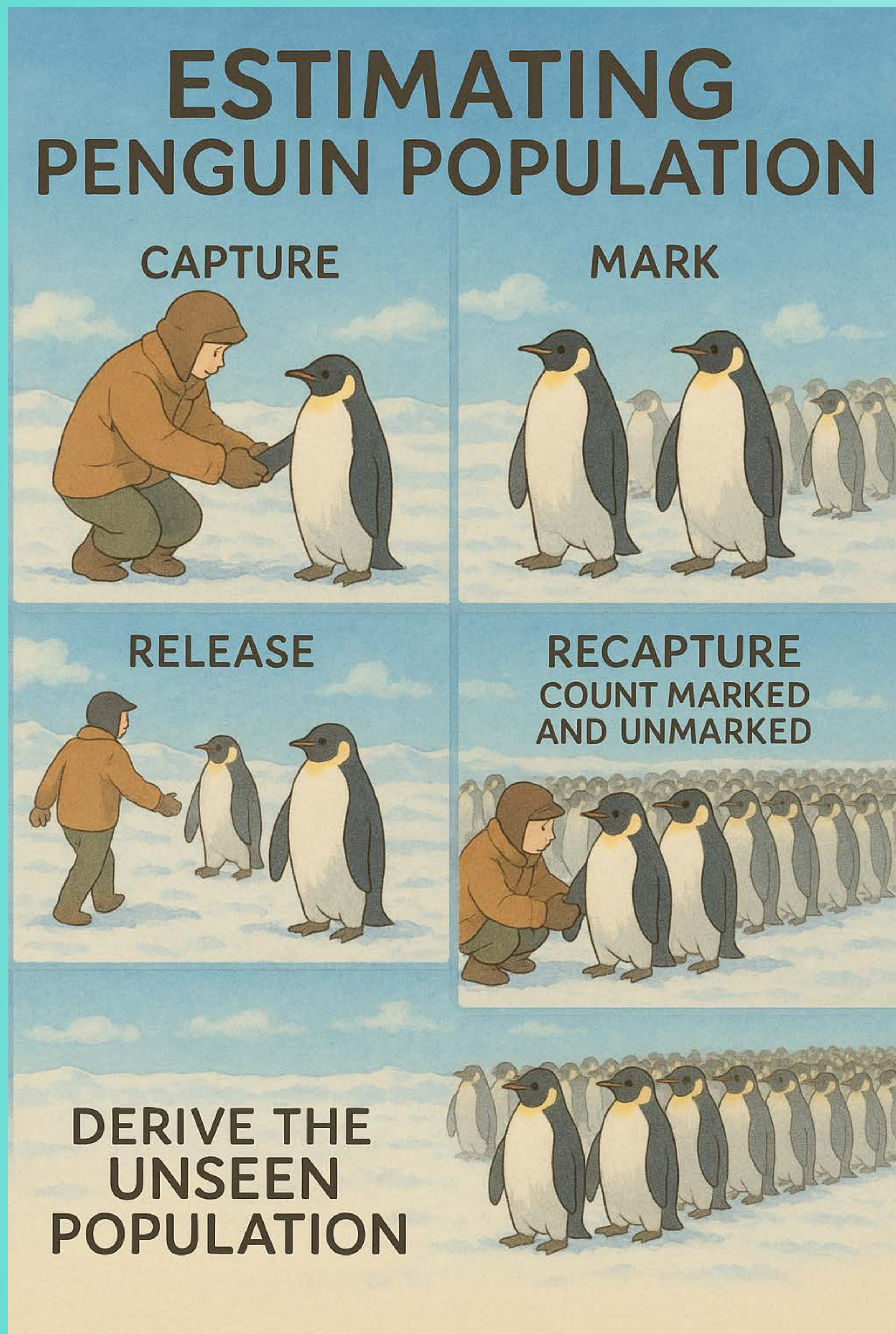# WHAT CAN WE LEARN FROM ECOLOGY?

ABOUT 10000 FRBS ARE MISSING (95% OF THE POPULATION) IN THE FIRST CHIME FRB CATALOGUE

How many Fast Radio Bursts are we missing?

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ESTIMATING PENGUIN POPULATION

CAPTURE | MARK

RELEASE | RECAPTURE COUNT MARKED AND UNMARKED

DERIVE THE UNSEEN POPULATION

ESTIMATING FAST RADIO BURST POPULATION

OBSERVE | COUNT

REOBSERVE | COUNT REPEATERS AND NEW FRBS

DERIVE THE UNSEEN POPULATION

Graphics were made with ChatGPT

- Estimating wildlife population from limited observations is a classical problem in ecology. For example, how many fishes in a pond if you can only observe a few times? A simple count is difficult and is almost impossible. Furthermore, it will usually underestimate the true population.
- It turns out that it is a simple statistical problem. One such method is called capture-recapture model and it is widely used in ecology, epidemiology, and social science.
- The idea is very simple. Let's estimate the total number of penguins. In the first observation, you count and mark the penguins you observed (capture). You then let them go (release). After a while, you observe again (recapture) and count the number of penguins that you marked last time and the new ones. Even with two observations, we can estimate the unseen population.
- Various non-parametric estimators can be used for this purpose. Here, we used the Chao1 estimator and abundance-based coverage estimator (ACE) as examples.

- Observing FRBs is similar to a capture-recapture process. We observe and count the number of detected FRBs (capture). After a while, we observe again and we find new FRBs and repeating FRBs (recapture). By using capture-recapture modelling, we can estimate the unseen population of FRBs.
- Chao1 estimator of the total population (Chao 1984): $S_{chao1} = S_{obs} + F_1^2/2F_2$, where S_{obs} is the total number of observed FRBs, F_1 is the number of FRBs observed once and F_2 is the number of FRBs observed twice. The confidence interval (C.I.) can also be derived analytically (Chao 1987).
- The ACE estimator takes rare repeating cases into account. The formulation is more complicated; readers can refer to Chao & Lee (1992).
- Using the first CHIME FRB catalogue, we count the number of FRBs detected once and multiple times. We calculate the unseen population by using Chao1 and ACE. Here are the results:

    S_{chao1} = 9932 with a 95% C.I. of 5572-17369
    ACE = 8247 with a 95% C.I. of 2728-28932

References
Chao, A. 1984, Scandinavian Journal of Statistics, 11, 265
Chao, A. 1987, Biometrics, 43, 783
Chao, A., Lee, S.-M. 1992, Journal of American Statistical Association, 87, 210
Kirsten, F. et al. 2024, Nature Astronomy, 8, 337
Yamasaki, S. et al. 2024, MNRAS, 527, 11158

If all FRBs are repeating FRBs (Kirsten+ 2024), there should have about 10000 FRBs in the catalogue. We are missing 95% of the population! Our simple statistical estimate is not far from Yamasaki+ (2024).

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