Approximating uncertainty around indices from stratified-random trawl surveys using the Gamma distribution

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# Introduction

A primary objective of fisheries-independent trawl surveys is to obtain indices of stock size and quantify the uncertainty around these indices. Such information plays a critical role in the assessment and management of fish stocks around the world as they often serve as a leading indicator of change ([Kimura and Somerton, 2006](#ref-kimura2006); [Pennington and Strømme, 1998](#ref-pennington1998)). Surveys indices also influence risk-based decision making; however, such information is typically provided indirectly via estimates of uncertainty from stock assessment models that are calibrated using point estimates of trawlable abundance or biomass. Data limitations often preclude the use of complex assessment models and, as such, many stocks are assessed using survey indices. While model-based indices produced using geostatistical approaches (e.g., [Anderson et al., 2022](#ref-anderson2022); [Thorson et al., 2015](#ref-thorson2015)) are growing in popularity, design-based estimators continue to be widely used. In the Northwest Atlantic, surveys typically follow a stratified-random sampling design with proportional allocation (e.g., [González-Troncoso et al., 2022](#ref-gonzalez2022); [Rideout et al., 2022](#ref-rideout2022)) and indices are obtained using stratified analyses (e.g., [S. Smith and Somerton, 1981](#ref-smith1981)). Unfortunately, the quantification of uncertainty around these estimates remains a challenge. Quantiles from a Student’s t distribution are often used to approximate the uncertainty around stratified estimates; however, the lower limits of this approximation can result in negative values, which is unrealistic ([Cadigan, 2011](#ref-cadigan2011)). We propose an alternate approximation of uncertainty using the Gamma distribution which accounts for the positive and skewed nature of survey indices.

# Methods

Provided data from a stratified-random survey, average trawlable abundance or biomass () and sampling variance () can be estimated using standard design-based formula ([Cochran, 1977](#ref-cochran1977); [S. J. Smith, 1990](#ref-smith1990); [S. Smith and Somerton, 1981](#ref-smith1981)). Instead of using a Student’s t distribution to describe uncertainty and allow negative values, we apply the Gamma distribution by translating and to scale () and shape () parameters as follows:

Provided these values, density and quantile functions for the Gamma distribution can be used to calculate probabilities.For instance, the probability that the index increased from one year to the next can be quantified.

## Simulation

We simulated a redfish-like population using the R package SimSurvey ([Regular et al., 2020](#ref-regular2020)). The simulated population was based on the exponential decay cohort model where parameter settings for mortality, recruitment, and growth were based on assessments of redfish on the Grand Bank. The simulated population were distributed through an area according to the age-year-space covariance with a parabolic relationship with depth. This survey area was 300 x 300 km with 10 km2 cell size and had 30 depth-based strata. We simulated stratified random sampling with a 2 m wide trawl hauled for a distance of 1.5 km. The population and survey were simulated over 20 years. The number of sets in a stratum was proportional to its area (approximately 1 set per 1000 km2) and the minimum set per stratum was 2. The survey simulation was replicated 50 times over the same population.

Average trawlable abundance () and sampling variance () was calculated by year and replicate (20 years across 50 surveys) using standard design-based estimators ([S. J. Smith, 1990](#ref-smith1990); [S. Smith and Somerton, 1981](#ref-smith1981)). Quantiles from a Student’s t distribution are often used to approximate the uncertainty around stratified estimates; however, the lower limits of this approximation can result in negative values, which is unrealistic ([Cadigan, 2011](#ref-cadigan2011)). As an alternate approach, we apply the Gamma distribution by translating and to scale () and shape () parameters as follows:

To compare densities obtained from the Gamma distribution with densities based on an empirical approach, we applied a non-parametric bootstrap to resample the observations (sets) independently within each stratum with replacement. The resampling and calculation of the mean bootstrap estimator were repeated 1000 times with the R package boot ([Canty and Ripley, 2021](#ref-canty2021)). Therefore, each survey simulation had 1000 bootstrapped total abundance values for each year.

# Results and Discussion

The Gamma probability density distribution showed high variability among survey simulations at Year 20 (Figure 1). The bootstrapped estimates of each survey simulation also showed a similar pattern with the gamma probability distribution at Year 20 (Figure 2). When looking at the distribution of individual survey simulations, the gamma distribution showed a wider but very close approximation to the bootstrapped estimates distribution (Figure 3). Further quantitative analysis is required to assess the performance of these methods for calculating the confidence intervals.

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# Figures

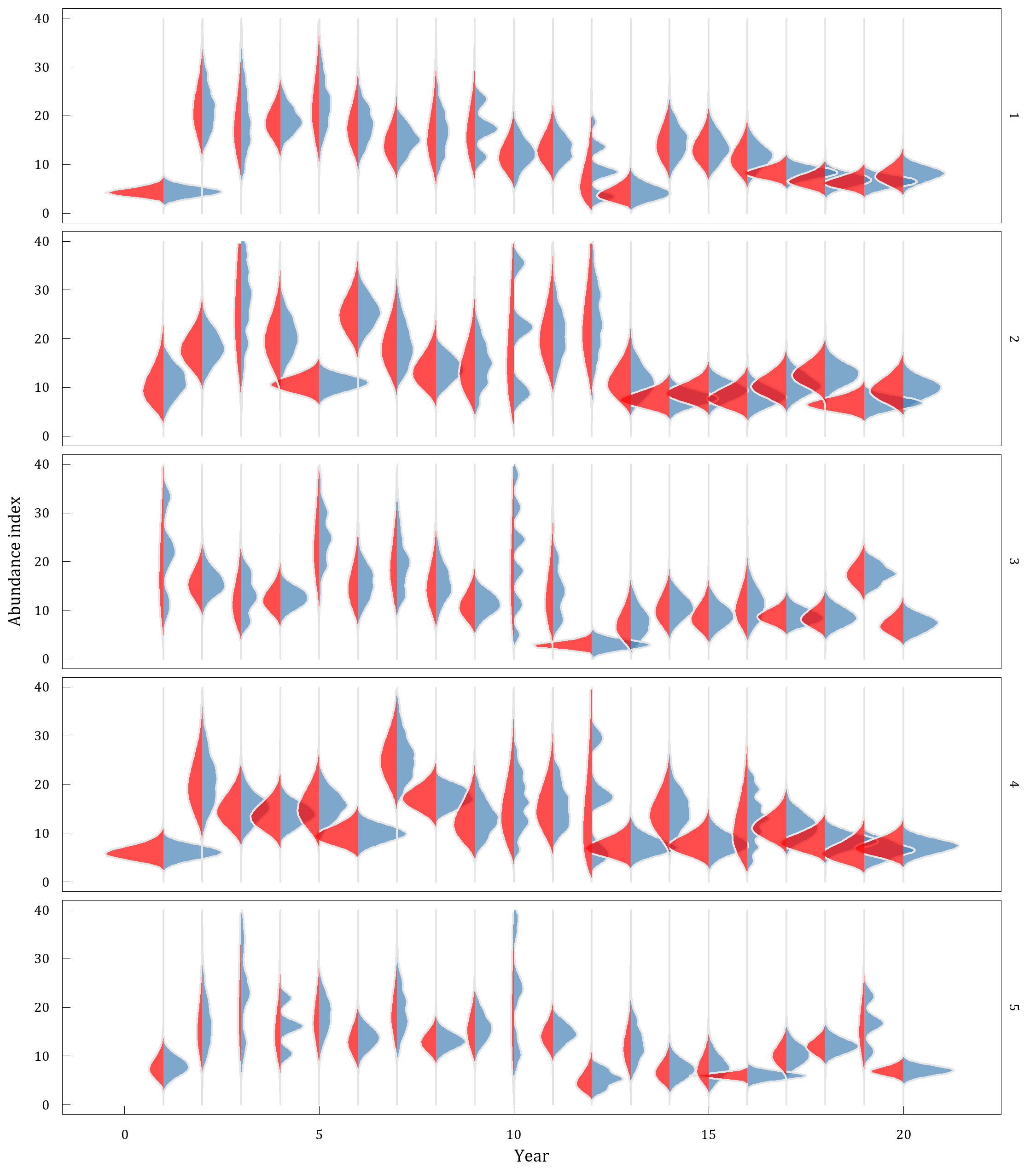


Fig 1: The bootstrap and gamma distributions estimated for five 20 year survey simulations. The red area shows the density distribution from 1000 bootstrapped samples from each year and survey replicate. The blue area shows the gamma probability distribution from each year and survey replicate based on the mean and standard deviation of the design-based index.

# Appendix A

TODO

# Colophon

This version of the document was generated on 2022-06-16 20:51:19 using the R markdown template for SCR documents from [NAFOdown](https://github.com/nafc-assess/NAFOdown).

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