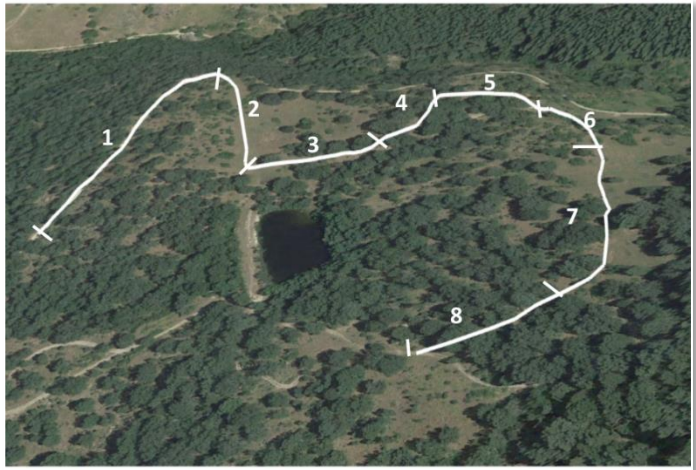
The generalised abundance index approach

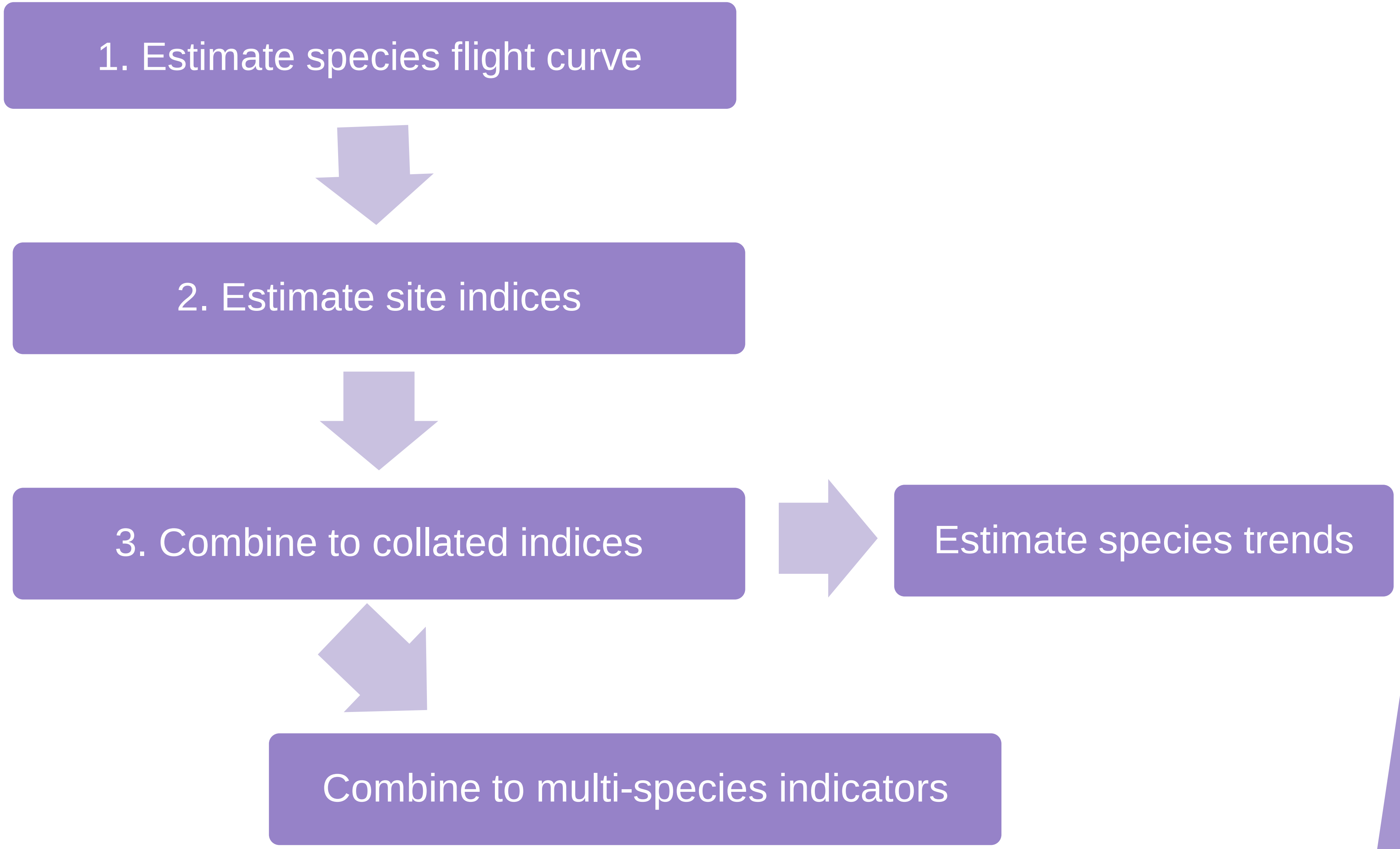
Emily Dennis

How do we account for missing data?

- Infrequent sampling
- Missed weeks – poor weather, illness, holidays
- Sites not visited in all years



Overview of modelling steps



Butterfly CONSERVATION EUROPE

ELSEVIER

Biological Conservation
Volume 12, Issue 2, September 1977, Pages 115-134

A method for assessing changes in the abundance of butterflies

https://doi.org/10.1016/0006-3207(77)90065-9

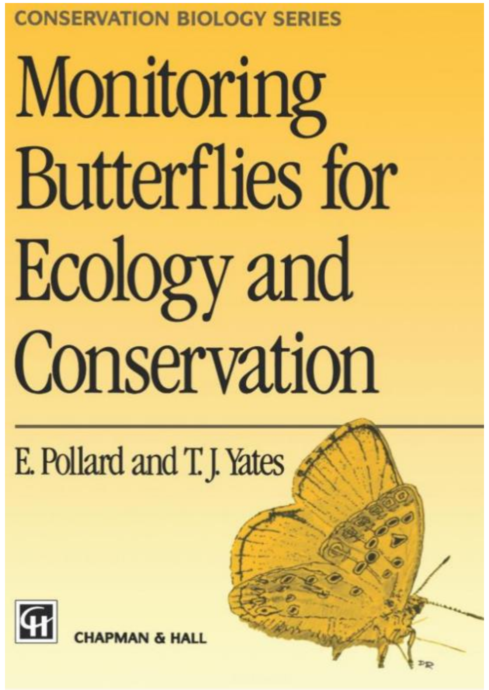
E. Pollard

Ecological Entomology

Calculation of collated indices of abundance of butterflies based on monitored sites

D. MOSS, E. POLLARD

First published: February 1993 |
https://doi.org/10.1111/j.1365-2311.1993.tb01083.x



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Original Articles

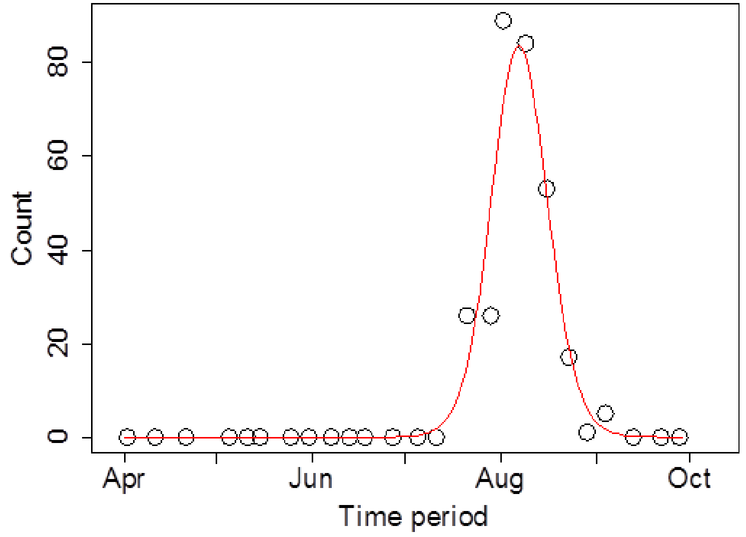
Application of generalized additive models to butterfly transect count data

Peter Rothery & David B. Roy

Pages 897-909 | Published online: 02 Aug 2010

https://doi.org/10.1080/02664760120074979

- A generalized additive model (GAM) is fitted to each site and year individually
- Excludes data where peak flight period is unrecorded or more than 30% data requires estimation
- For the UK, nearly 40% of monitored 10km grid squares were excluded



Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

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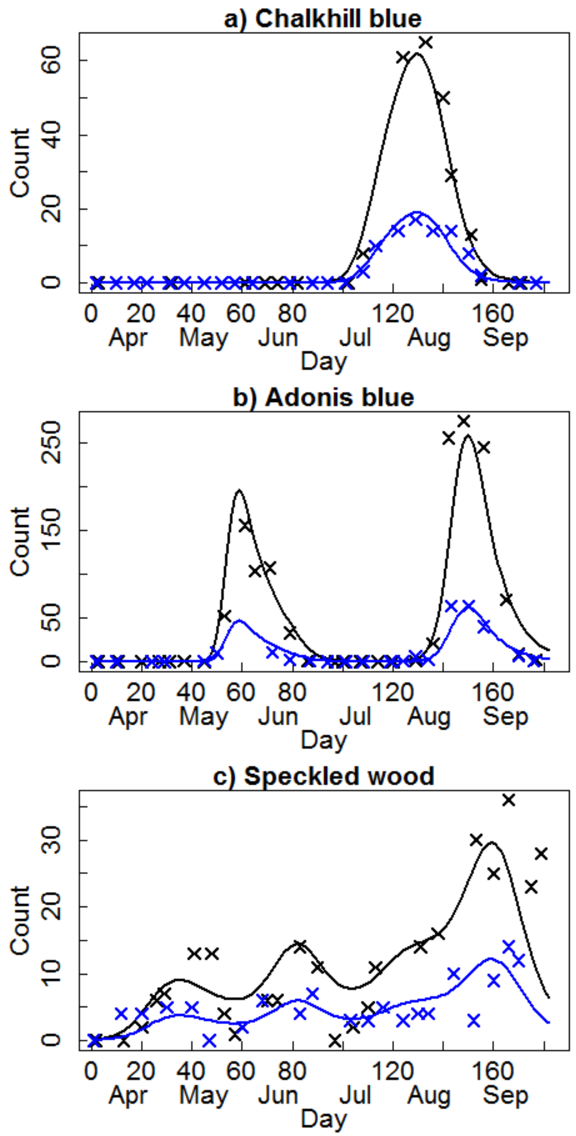
Standard Paper | Free Access

Indexing butterfly abundance whilst accounting for missing counts and variability in seasonal pattern

Emily B. Dennis, Stephen N. Freeman, Tom Brereton, David B. Roy

First published:26 March 2013 | https://doi.org/10.1111/2041-210X.12053 (open)

- A GAM is used to estimate a common flight period across sites for each year.
- More robust indices and trends than single-site GAM or linear interpolation
- Greater use of data
- Disadvantage – can be slow when there are lots of data



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Journal of Applied Ecology
BRITISH ECOLOGICAL SOCIETY

Standard Paper | Open Access

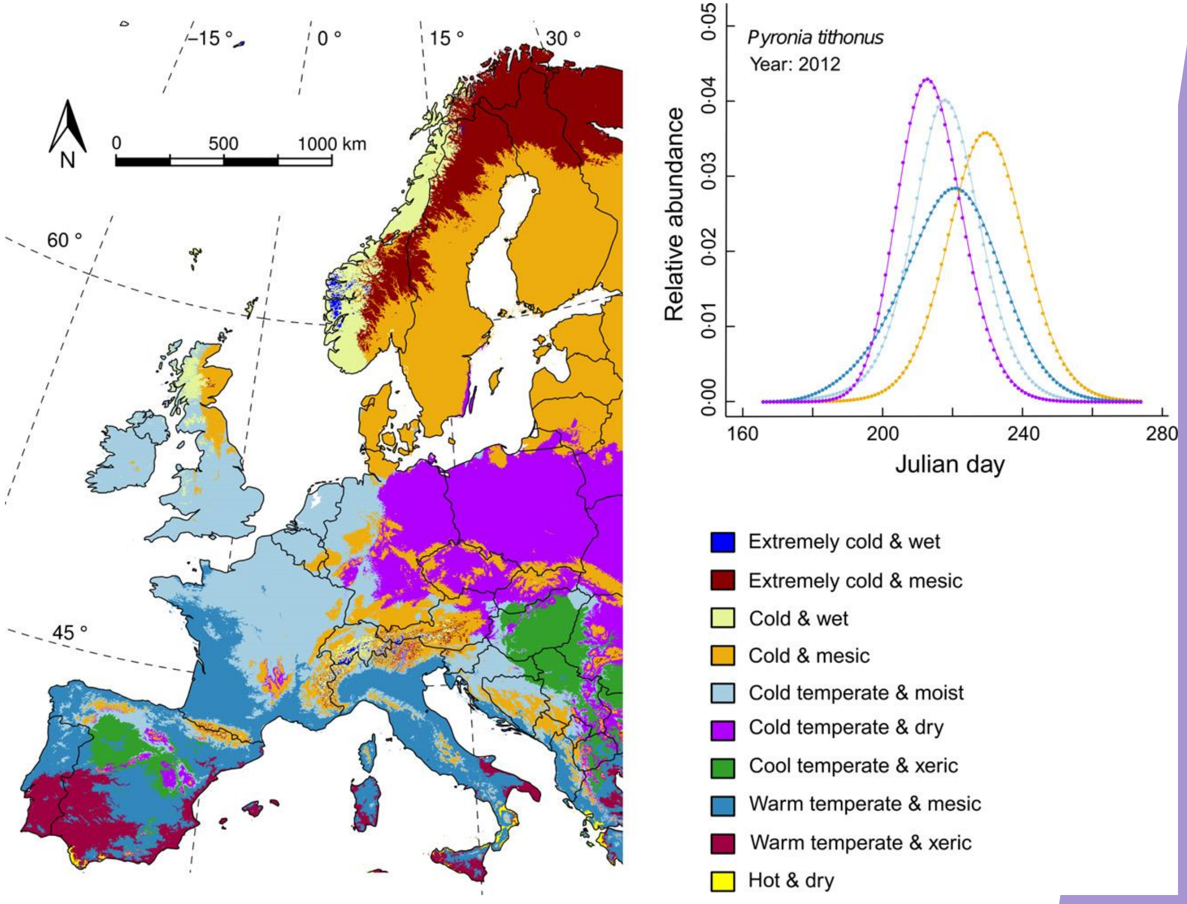
A regionally informed abundance index for supporting integrative analyses across butterfly monitoring schemes

Reto Schmucki, Guy Pe'er, David B. Roy, Constantí Stefanescu, Chris A.M. Van Swaay, Tom H. Oliver, Mikko Kuussaari, Arco J. Van Strien, Leslie Ries, Josef Settele, Martin Musche ... See all authors

First published:28 October 2015 | https://doi.org/10.1111/1365-2664.12561 | Citations: 14

https://doi.org/10.1111/1365-2664.12561 (open)

- Varying flight curves with biogeographical region
- Adapted for latest EU indicators under the ABLE project



Butterfly Conservation Europe

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BIOMETRICS 72, 1305–1314
December 2016

DOI: 10.1111/biom.12506

A Generalized Abundance Index for Seasonal Invertebrates

Emily B. Dennis,[1,3,*] Byron J. T. Morgan,[1] Stephen N. Freeman,[2] Tom M. Brereton,[3] and David B. Roy[2]

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SUMMARY. At a time of climate change and major loss of biodiversity, it is important to have efficient tools for monitoring populations. In this context, animal abundance indices play an important rôle. In producing indices for invertebrates, it is important to account for variation in counts within seasons. Two new methods for describing seasonal variation in invertebrate counts have recently been proposed; one is nonparametric, using generalized additive models, and the other is parametric, based on stopover models. We present a novel generalized abundance index which encompasses both parametric and nonparametric approaches. It is extremely efficient to compute this index due to the use of concentrated likelihood techniques. This has particular relevance for the analysis of data from long-term extensive monitoring schemes with records for many species and sites, for which existing modeling techniques can be prohibitively time consuming. Performance of the index is demonstrated by several applications to UK Butterfly Monitoring Scheme data. We demonstrate the potential for new insights into both phenology and spatial variation in seasonal patterns from parametric modeling and the incorporation of covariate dependence, which is relevant for both monitoring and conservation. Associated R code is available on the journal website.

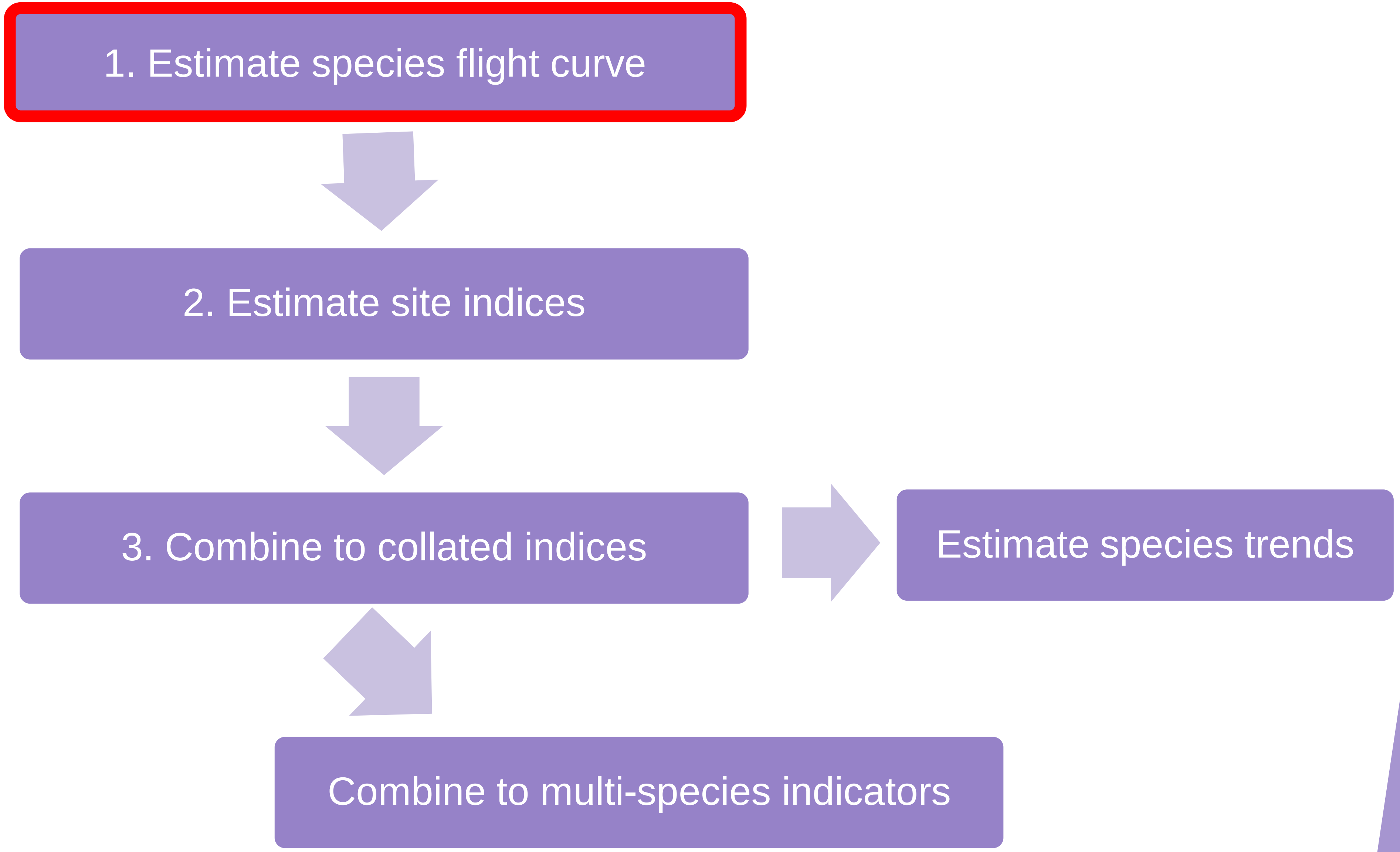
KEY WORDS: Butterflies; Citizen science; Concentrated likelihood; Normal mixtures; Phenology; UKBMS.

https://doi.org/10.1111/biom.12506 **(open)**

The GAI approach offers three options for describing seasonal variation:

- Flexible spline/GAM across sites each year
- Parametric description for each brood using Normal distributions
  - Phenology estimation, incorporating covariates
- “Stopover model”
  - Mechanistic description with certain assumptions
    - estimates adult lifespan
  - Relevant paper: https://doi.org/10.1111/1365-2664.12208 (open)

Overview of modelling steps



1. Estimate species flight curve

For each year:

$$\lambda_{i,j} = N_i a_{i,j}$$

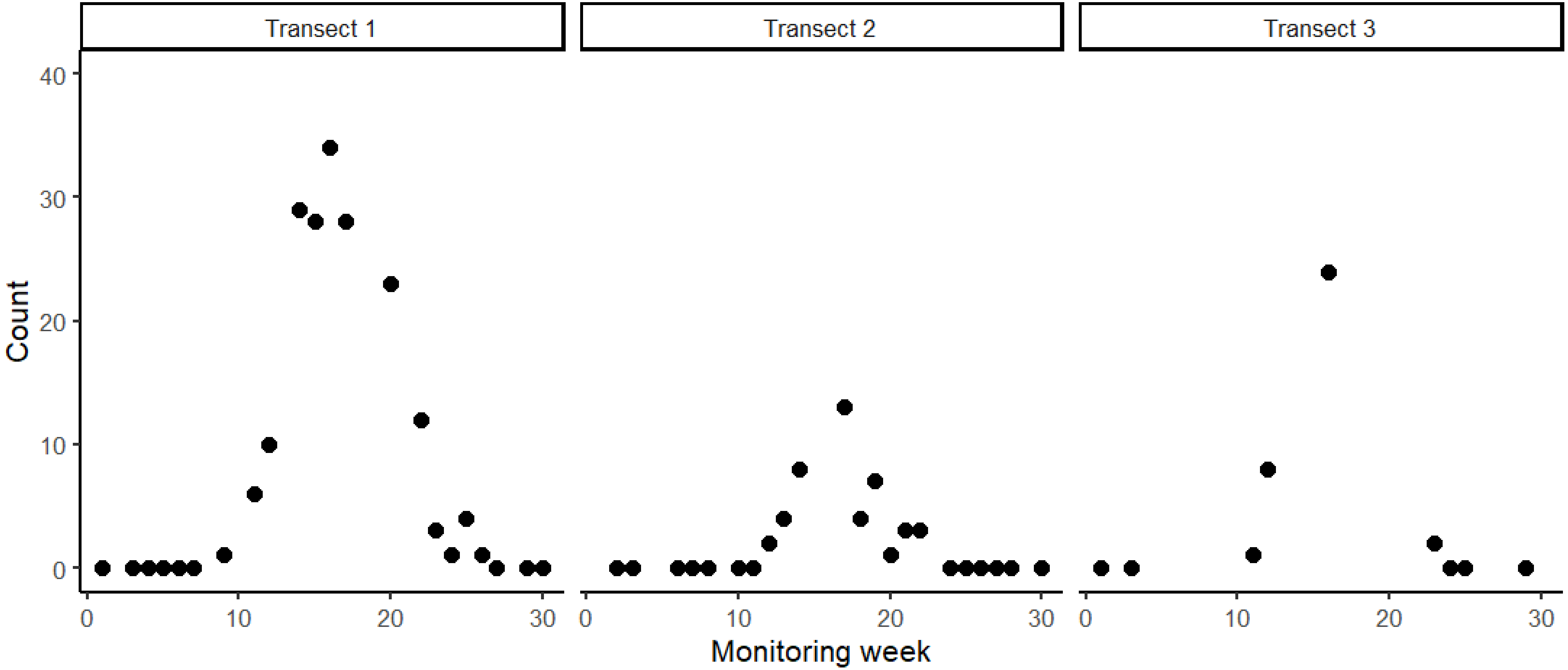
Expected count (Poisson)

Site abundance

Seasonal variation

- We use a flexible curve to describe the species flight pattern across sites within a BMS or biogeographical region
- The “height” of the curve is reflected by the site effect
- Efficient modelling of the site effects N_i
    - concentrated likelihood – up to 75 times faster than previous method

1. Estimate species flight curve



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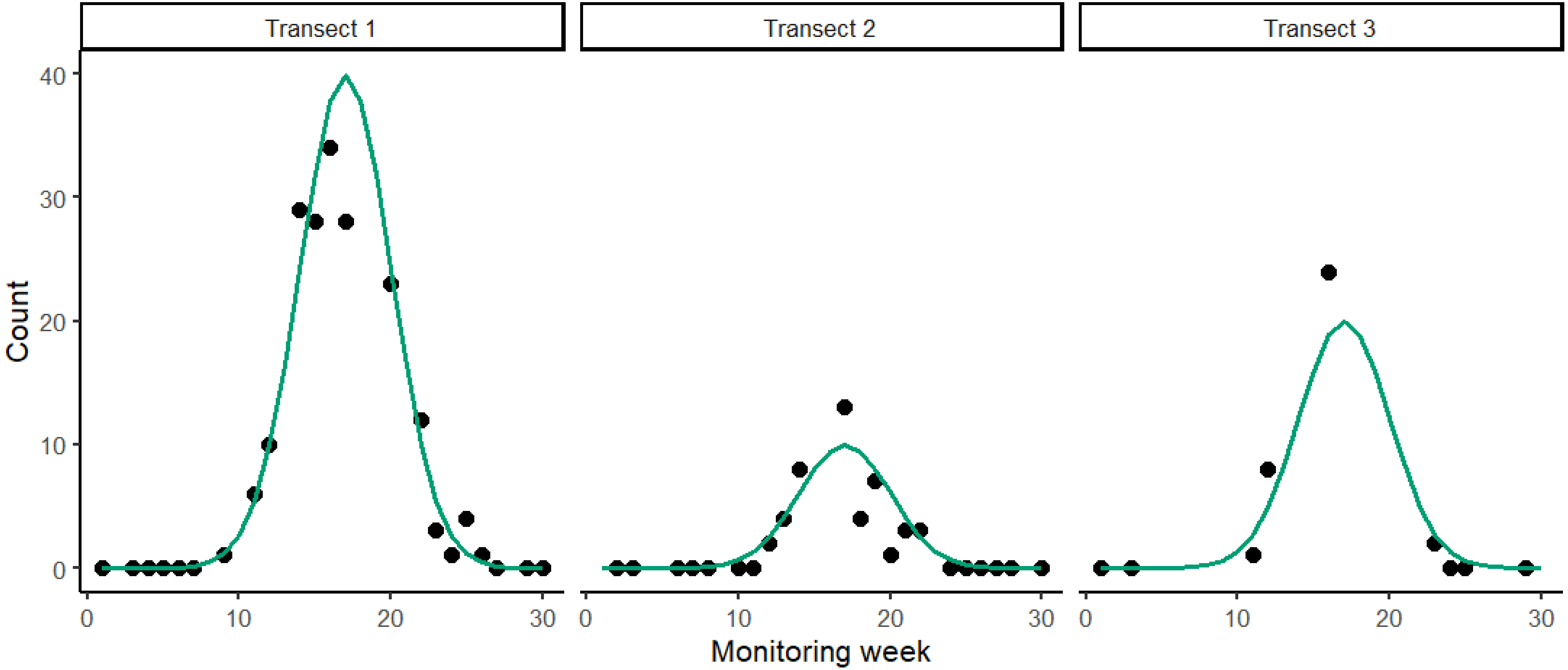

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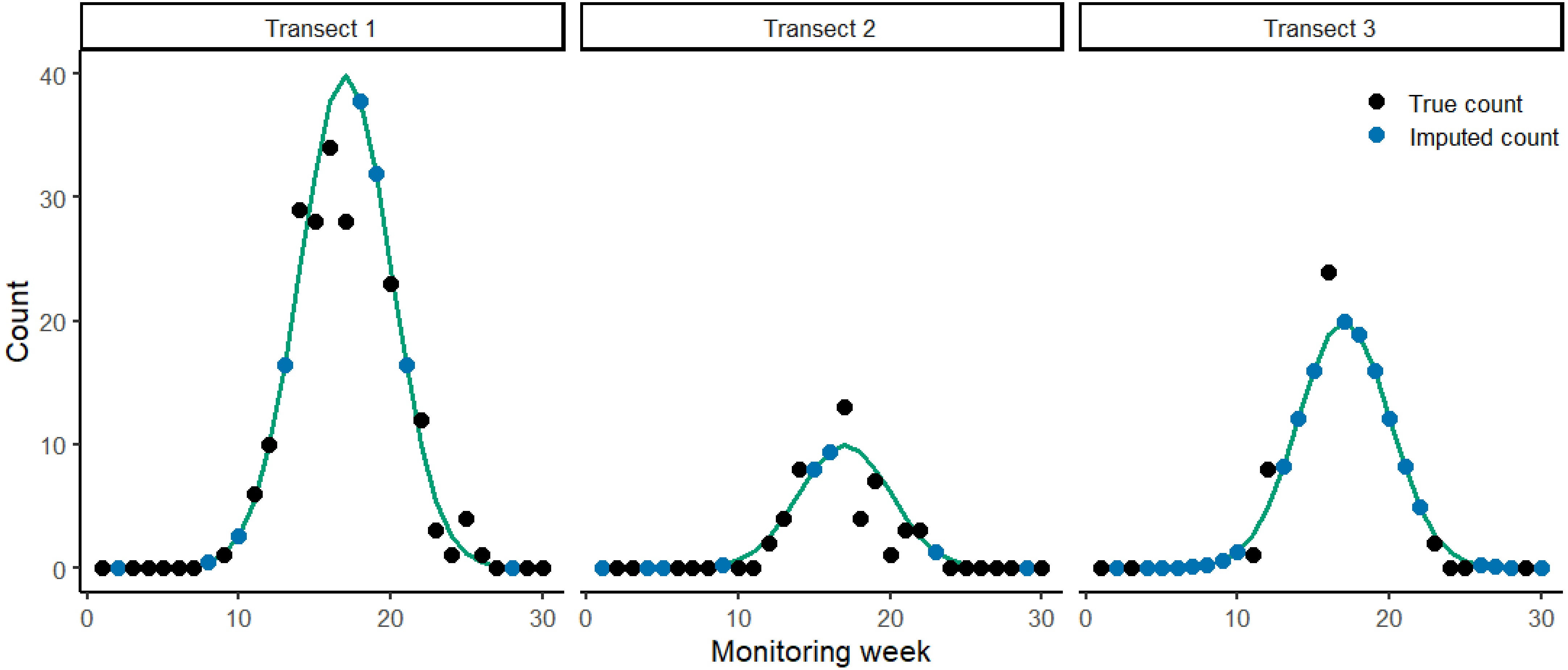

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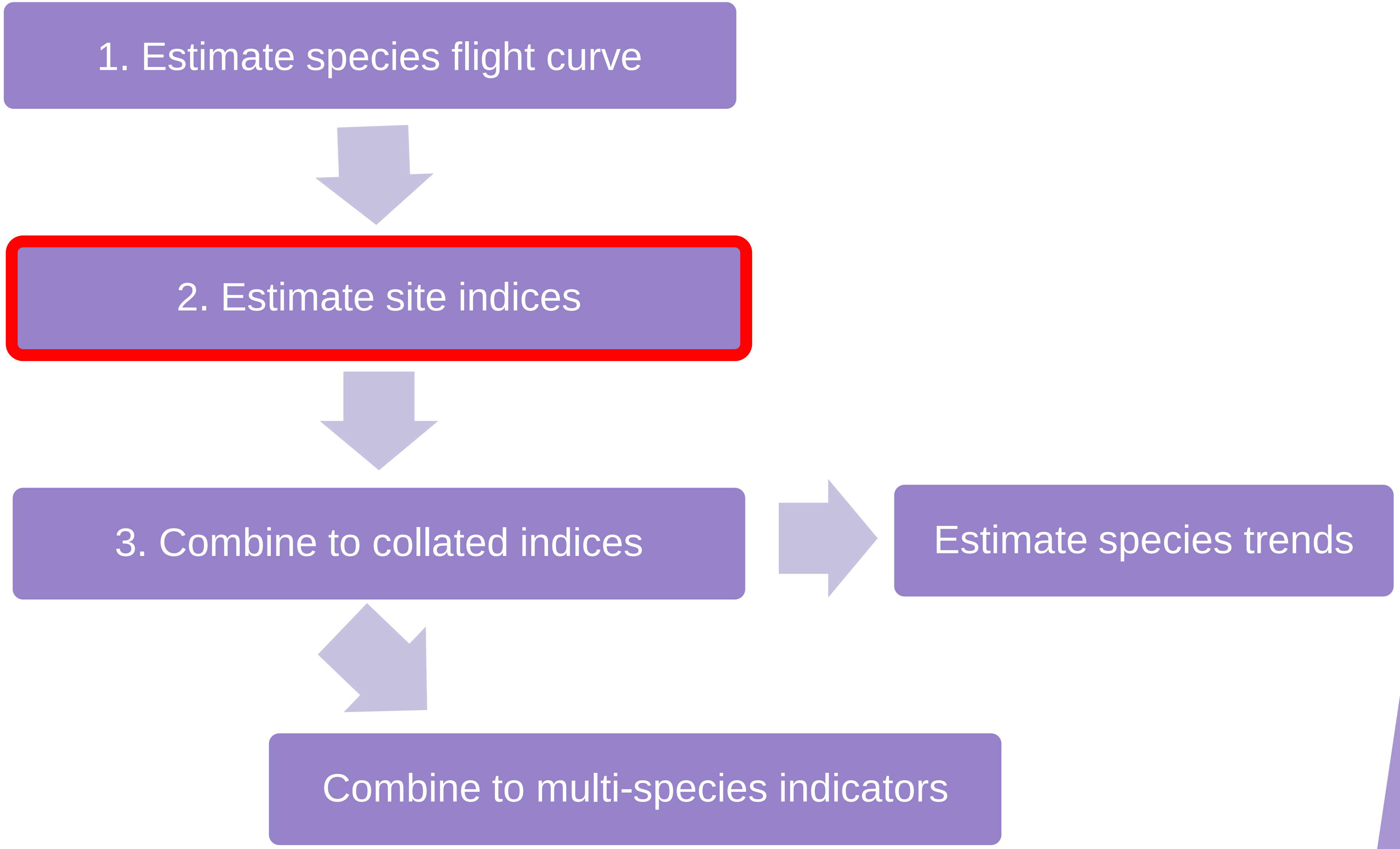


2. Combine to site indices

For each year:

$$N_i = \frac{\sum_j y_{i,j}}{\sum_j a_{i,j}}$$

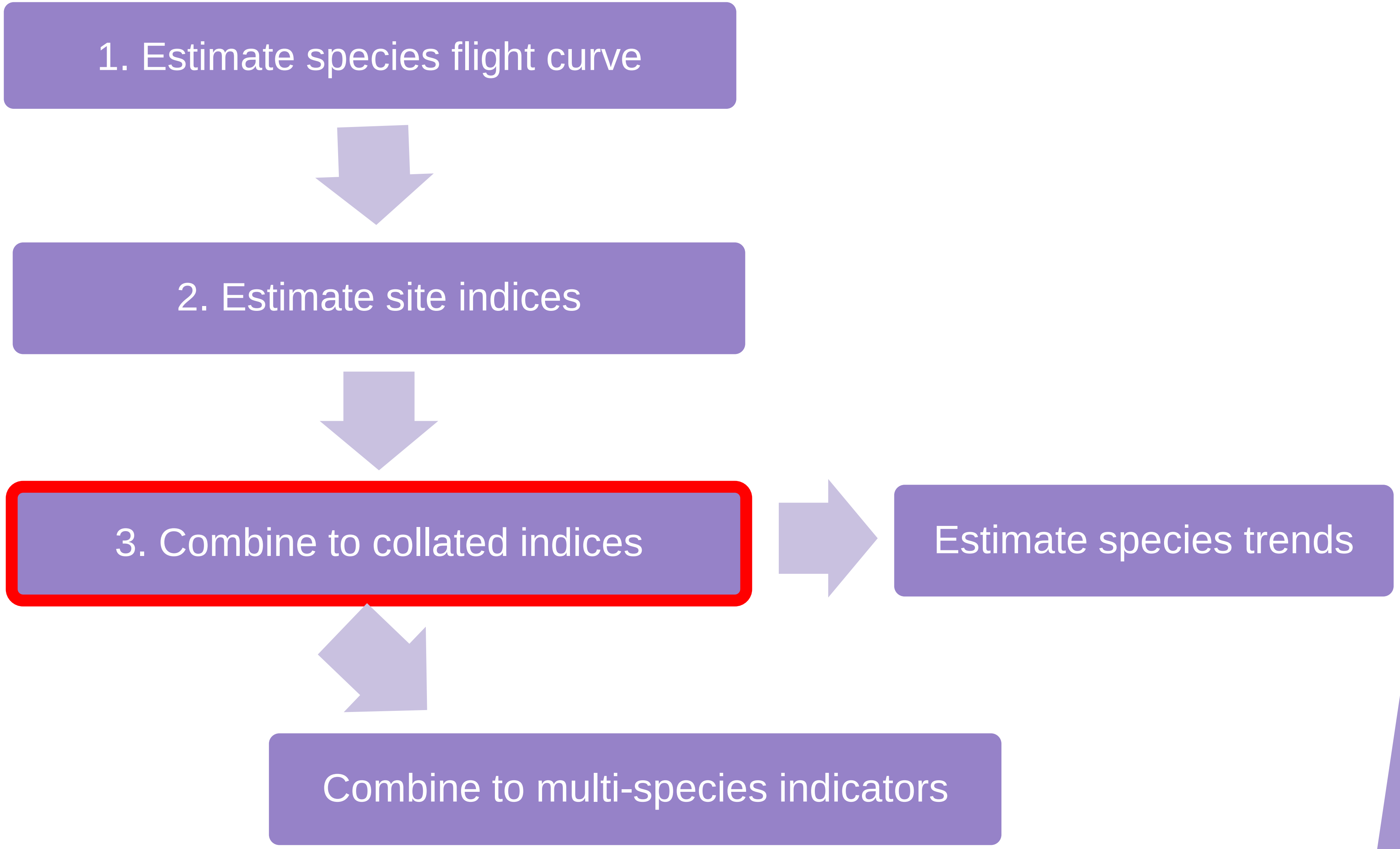
Real counts, summed across visits

Site index

Estimated flight curve, summed across visits

Site indices for each site and year for a given species

Overview of modelling steps



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3. Combine to collated indices

We need to account for the fact that not all sites are monitored every year.

So we fit a Poisson generalised linear model (GLM):

$$N_{i,k} \sim \alpha_i + \beta_k$$

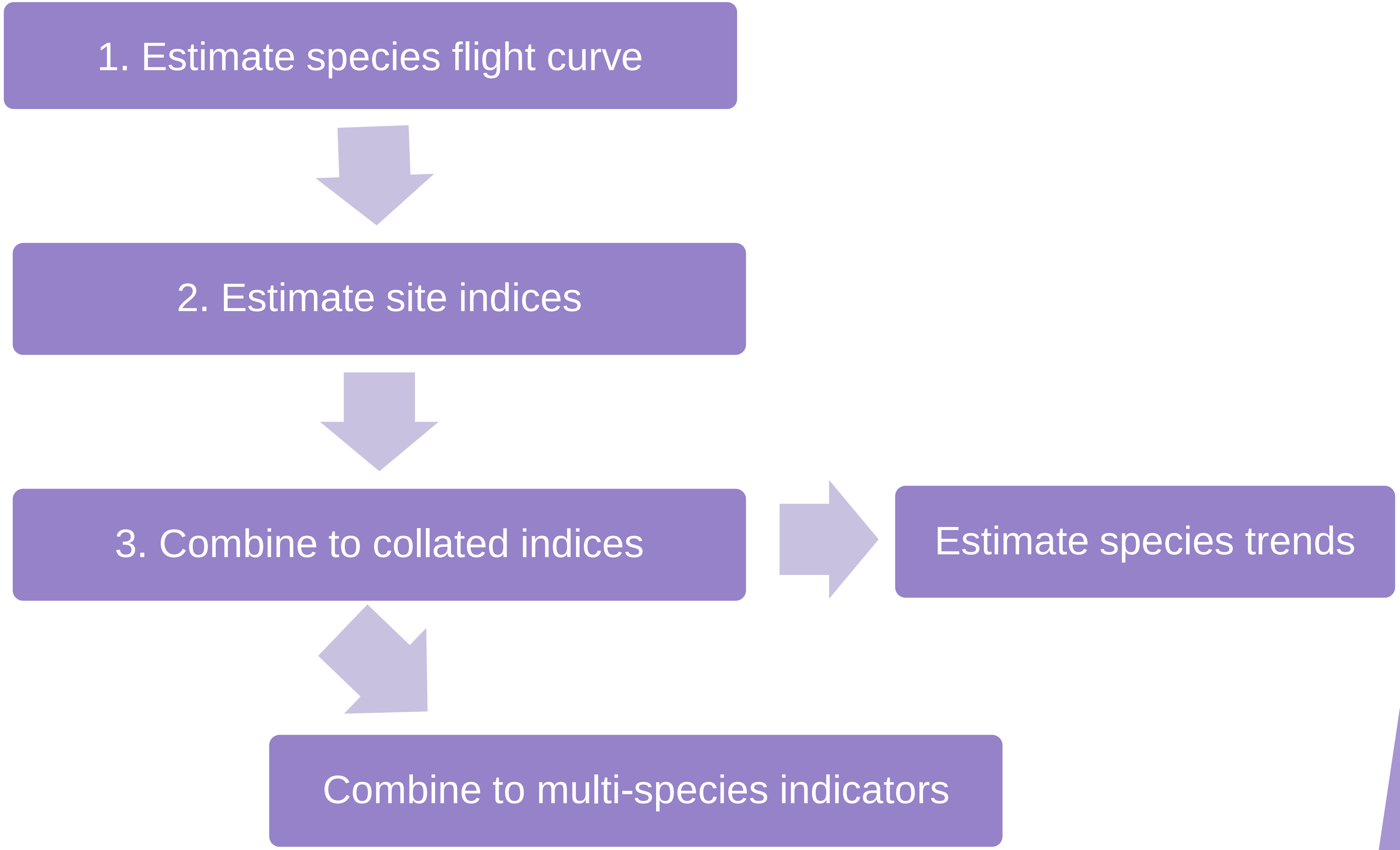
Site index

Site effect

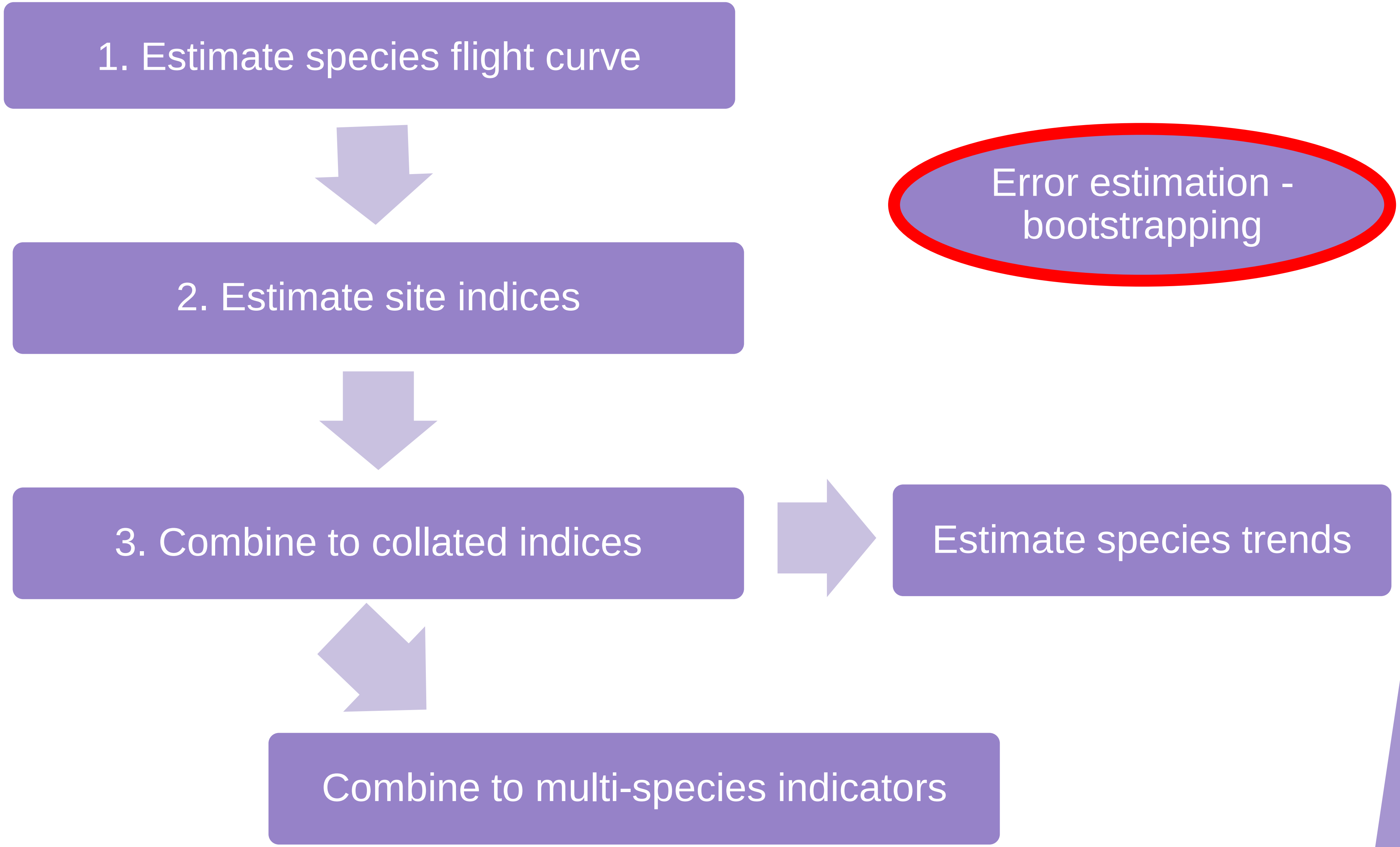
Year effect

- Account for some years/sites being better than others
- Also weight by the proportion of the flight curve sampled
  - Well sampled sites contribute more
- We can then obtain expected total butterfly counts/densities
- And convert to collated indices to consider changes in relative abundance over time

Overview of modelling steps



Overview of modelling steps



Bootstrapping to measure uncertainty

What is bootstrapping?

Randomly resample from the data (with replacement) many times and apply method to each data resample

Why bootstrap?

Flexibly account for uncertainty from various sources, including multiple stages of model fitting

How does it work in practice?

1. Resample the data
2. Apply the work flow to each data resample
3. Calculate confidence intervals by taking (95%) quantiles

(e.g. for collated indices, trends, multi-species intervals)

Overview of modelling steps

1. Estimate species flight curve

2. Estimate site indices

3. Combine to collated indices

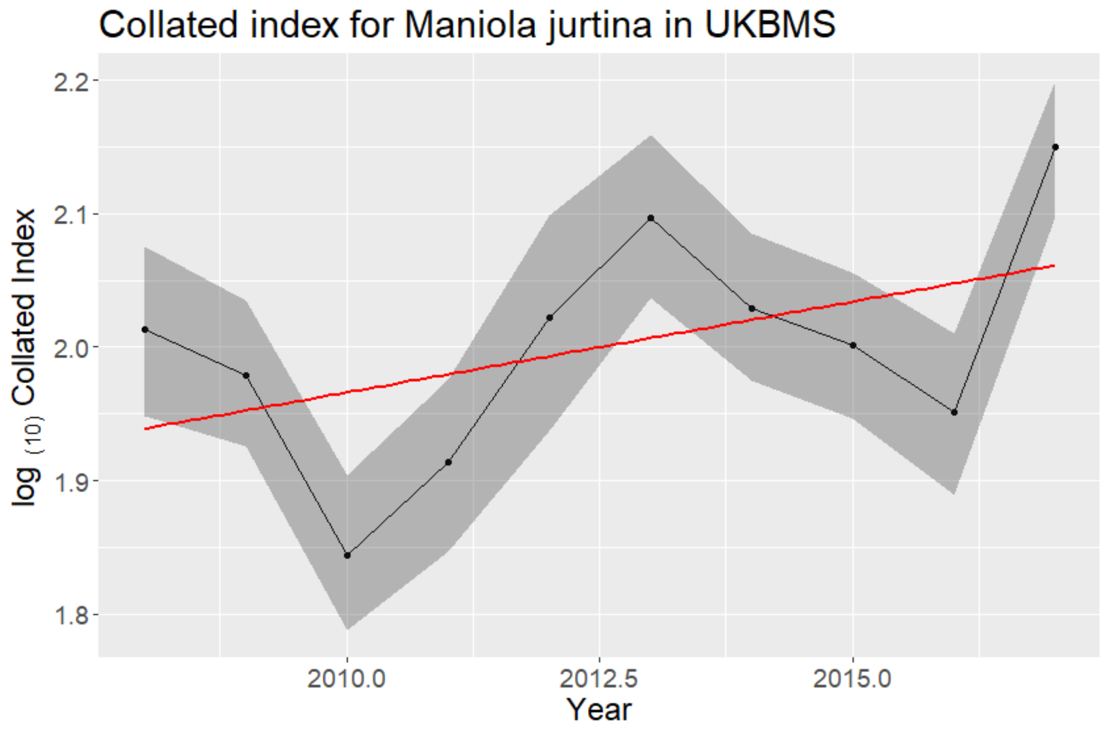
Estimate species trends

Combine to multi-species indicators

Calculating species trends

- Fit a linear regression to the species collated index
- Apply to each bootstrap to quantify uncertainty
- Package rtrim:

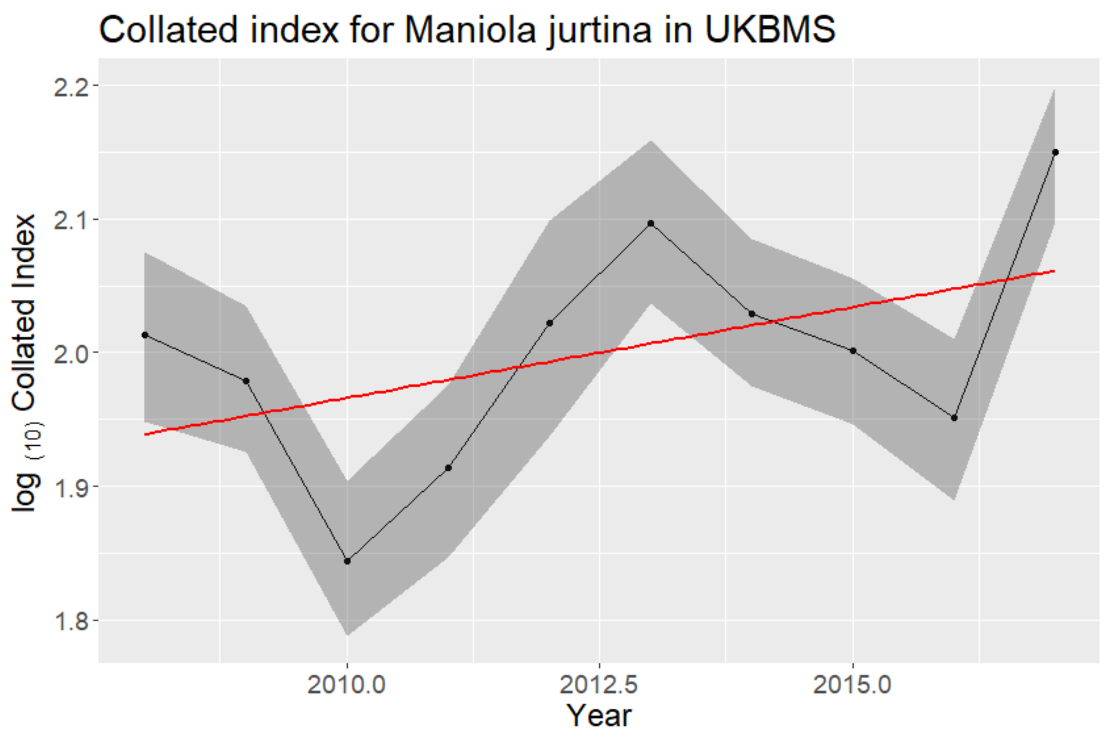
https://cran.r-project.org/web/packages/rtrim/index.html



Date period	Rate of change	% change	Class
2008-2017	1.032 (1.019, 1.045)	32.5%	Moderate increase

Calculating species trends

Category	Description
Strong increase	Significant increase > 5% per year
Moderate increase	Significant increase but less than 5% per year
Uncertain	No significant change, changes likely to be greater than 5% per year
Stable	No significant change, changes likely to be less than 5% per year
Moderate decline	Significant decrease but less than 5% per year
Strong decline	Significant decrease of >5% per year



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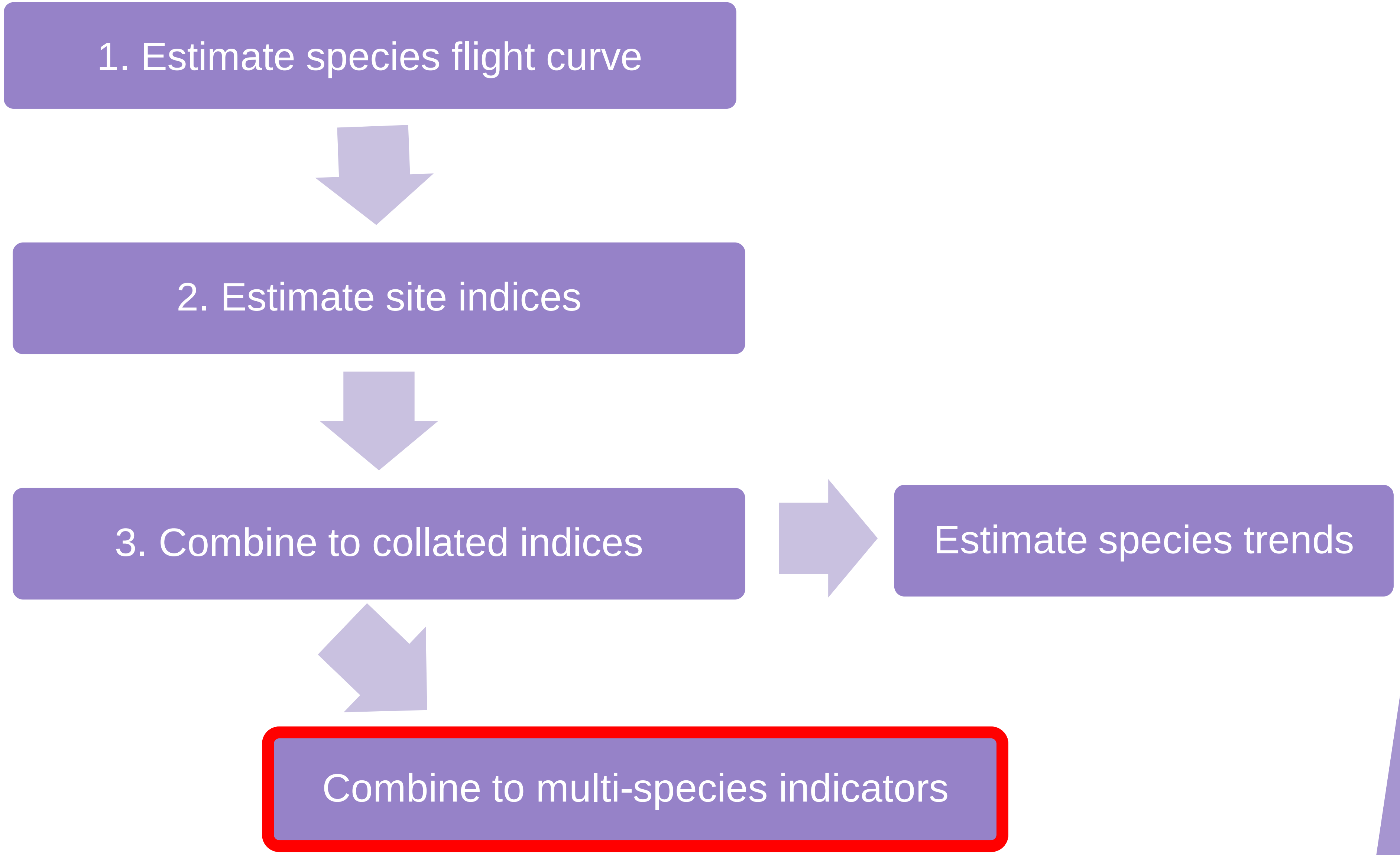

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Multi-species indicators

- Take the geometric mean of the species collated indices

For *M* species and year *k*

$$I_k = \exp\left\{\frac{1}{M}\sum_{m=1}^{M}\log\frac{n_{m,k}}{n_{m,1}}\right\}$$

- Common indicator approach e.g. Living Planet Index
- Account for late entries
- The doubling of one species compensates the halving of another species

Species	Year 1	Year 2
A	100	50
B	100	200
Arithmetic mean	100	125
Geometric mean	100	100

Multi-species indicators

- Existing tools
  - Soldaat et al. MSI tool
    - https://doi.org/10.1016/j.ecolind.2017.05.033
    - https://www.cbs.nl/en-gb/society/nature-and-environment/indices-and-trends--trim--/msi-tool
  - BRCindicators R package
    - https://github.com/BiologicalRecordsCentre/BRCindicators
    - New methods in development

- Bootstrapping allows for straightforward calculation of confidence intervals

Multi-species indicator example