Best practices for use of Population Viability Analysis to forecast seabird populations

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Please note results are preliminary

Population Viability Analysis (PVA)

- Population Viability Analysis (PVA) is the use of a mathematical model to forecast future population sizes, based on assumed or estimated demographic rates

- Despite the wide application of PVAs, there have been a number of criticisms of their use

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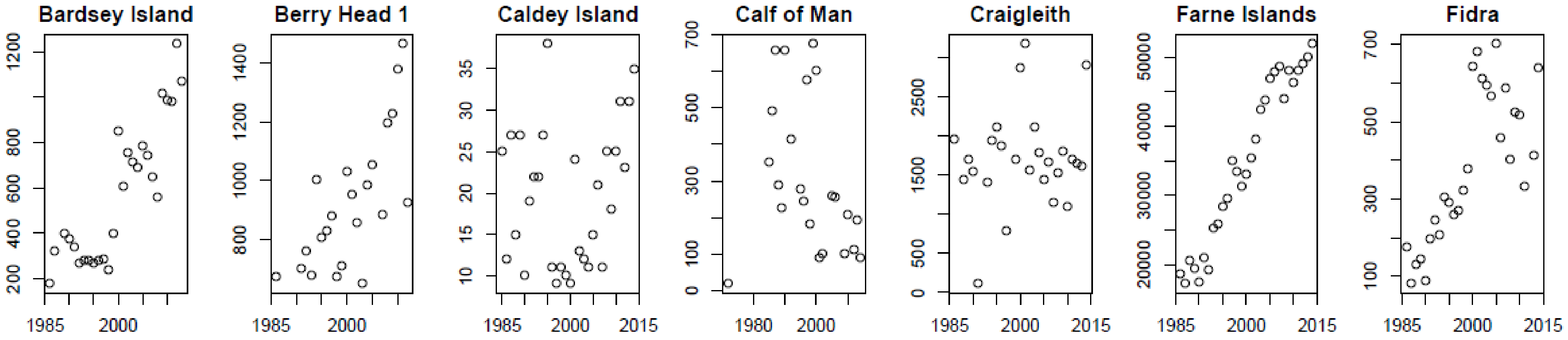
PVAs and seabirds

The key issue motivating the work is the fact that data coverage for seabirds is far from complete:

- the quantity and types of data available for seabird breeding colonies are highly variable, with data being **sparse** for many colonies

- Often need to borrow data on demographic rates from other, better studied colonies or **pooling regions** – how should we choose which colonies to borrow from?



Objectives

- Evaluate different methods for conducting PVAs within the context of specific seabird species
- to establish the most appropriate generic method to use in which circumstances

Northern gannet
Black-legged kittiwake
Herring gull
Common guillemot
Razorbill
European shag
Northern fulmar
Great cormorant

Arctic skua
Sandwich tern
Little tern
Common tern
Lesser black-backed gull
Great black-backed gull
Atlantic puffin

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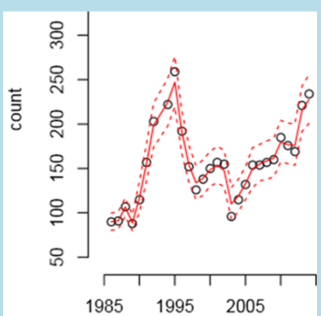
Selected PVA methods

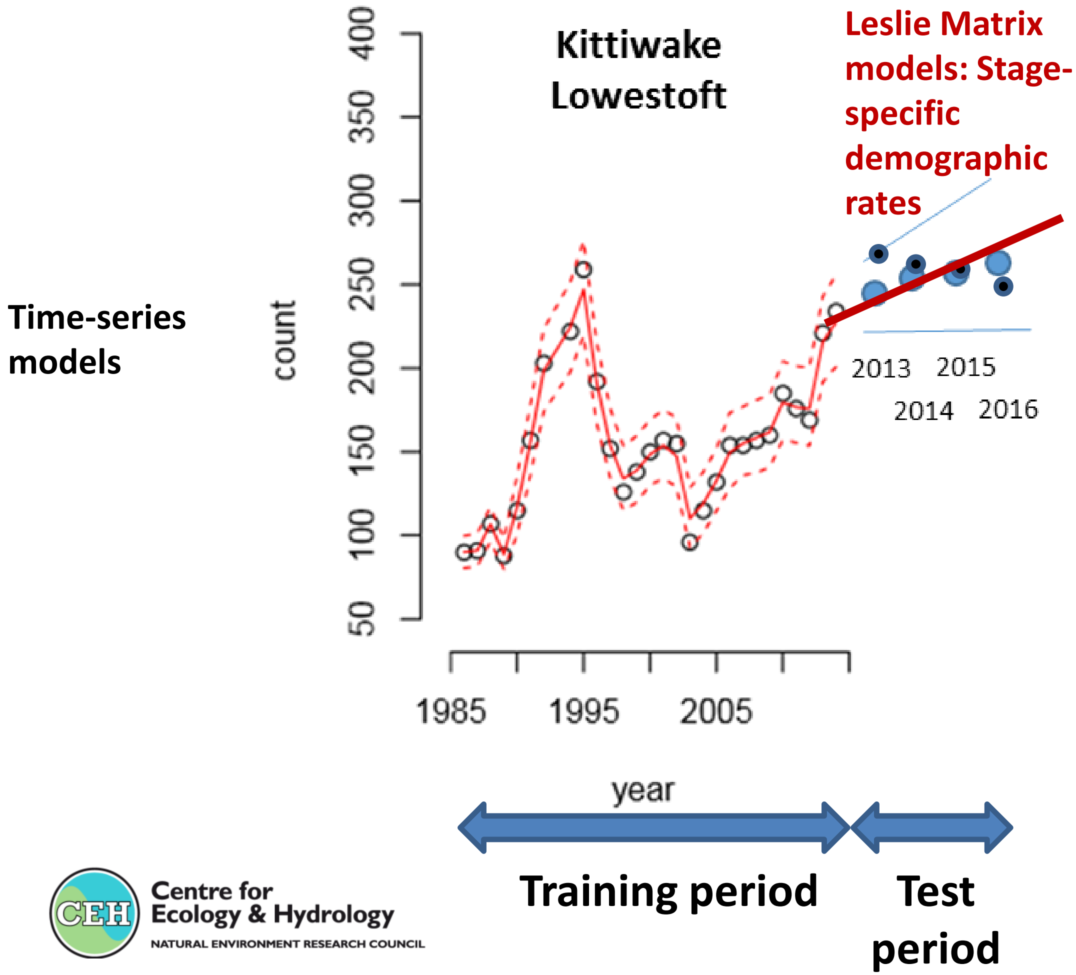
Models based on breeding success & survival	Deterministic Leslie matrix model
	Stochastic Leslie matrix model
Models based on all available data	Bayesian state space versions of the Leslie matrix model (Integrated Population Models)

$$\boldsymbol{N}_t = L_t \boldsymbol{N}_{t-1} \qquad \boldsymbol{L} = \begin{bmatrix} r_1 & r_2 & r_3 & \cdots & r_{A-1} & r_A \\ s_1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & s_2 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & 0 & 0 \\ 0 & 0 & 0 & s_{A-2} & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{A-1} & 0 \end{bmatrix}$$

Models based on time series of abundance 	Simple growth model (Dennis, 1991)
	Ricker logistic model
	Gompertz model
	State-space versions of these models (allowing for observation error)

Model testing methods

We applied these PVA methods to data for a 'training' period (e.g., all available years up to 2012) and assessed how accurately each method predicts observed count data that have been collected during a 'test' period (e.g., 2013-2016):



COUNTS: Seabird Monitoring Programme data – colony level, all available from 1986-2017

BREEDING SUCCESS: Seabird Monitoring Programme data – colony level, all available from 1986-2017

SURVIVAL: species level, BTO report (Horswill & Robinson, 2015)

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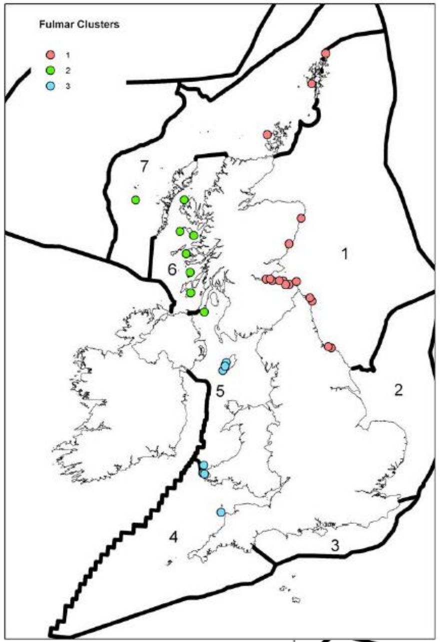
Data pooling

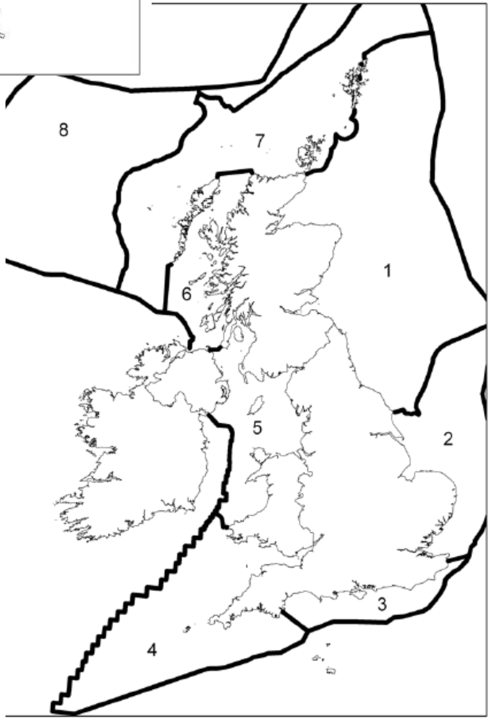
- A fairly small proportion of colonies have local data on breeding success, and very few have local data on survival
- There is therefore interest in whether **regional pooling** can improve performance
- Which **regional classification** is best…
  - Ecological regions (BTO)
  - Management
    - OSPAR
    - ICES
    - MSFD
  - Geographic
    - SMP regions
    - JNCC Regional Seas

'Ecologically coherent' regions for abundance -Fulmar (Cook & Robinson 2010)

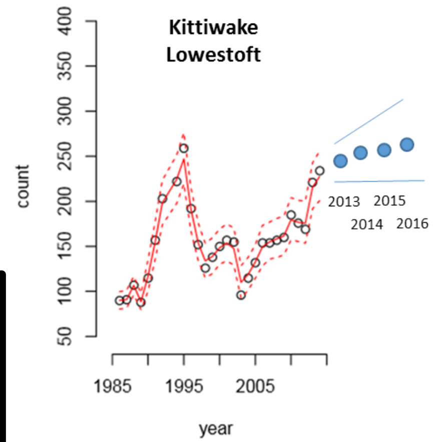


SMP regions

JNCC Regional Seas



Testing process



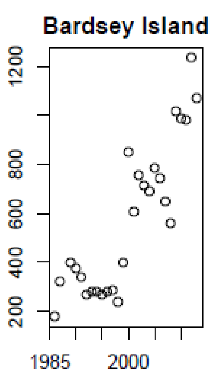
Fit population models to empirical data for training period

Or

Project forward using Leslie Matrix and most recent count

Generate predictions of abundance for test period, along with associated estimate of uncertainty

Assessment of performance



Observed count data for test period

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Bayesian state space versions of the Leslie matrix model (Integrated Population Models): ONLY IN FORTH-TAY REGION

Results

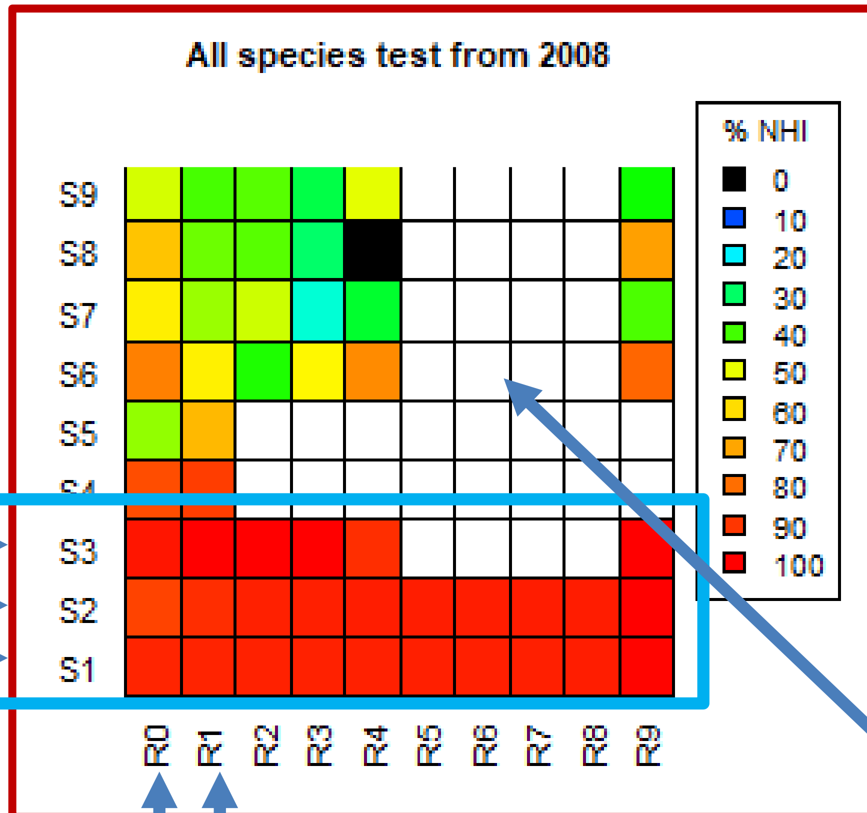
% results that are not "highly implausible"

Abundance time-series methods

Simple growth

Stochastic LM

Deterministic LM



Colony level

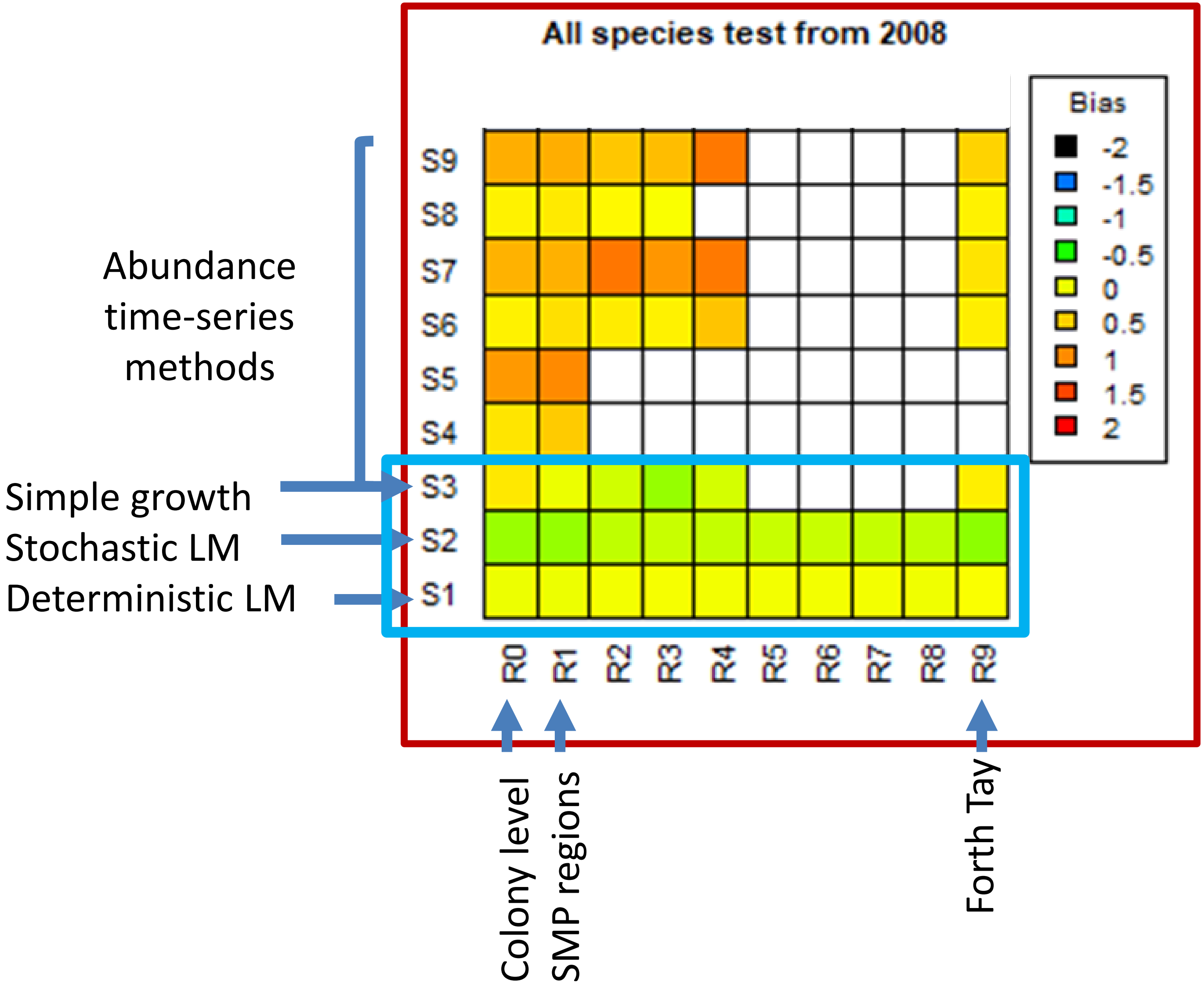
SMP regions

- LM methods perform better – more biological constraint
- Abundance methods often lead to highly implausible results

WHITE: method could not be applied

Results: systematic bias

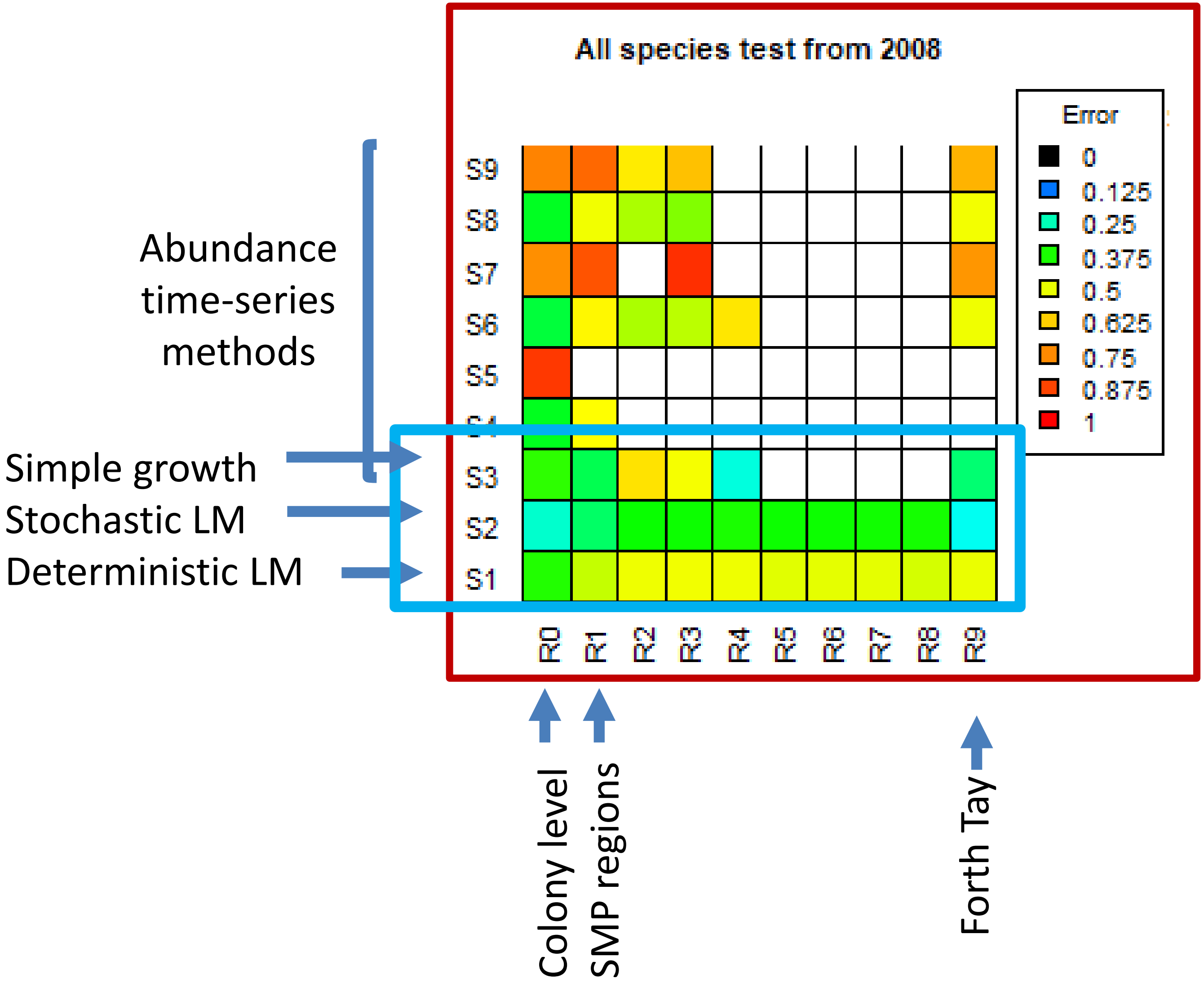
mean of log(predicted/observed)



- LM methods show less bias, tendency for stochastic LM to underestimate
- Abundance methods tend to systematically over-estimate

Results: absolute error

mean of |log(predicted/observed)|



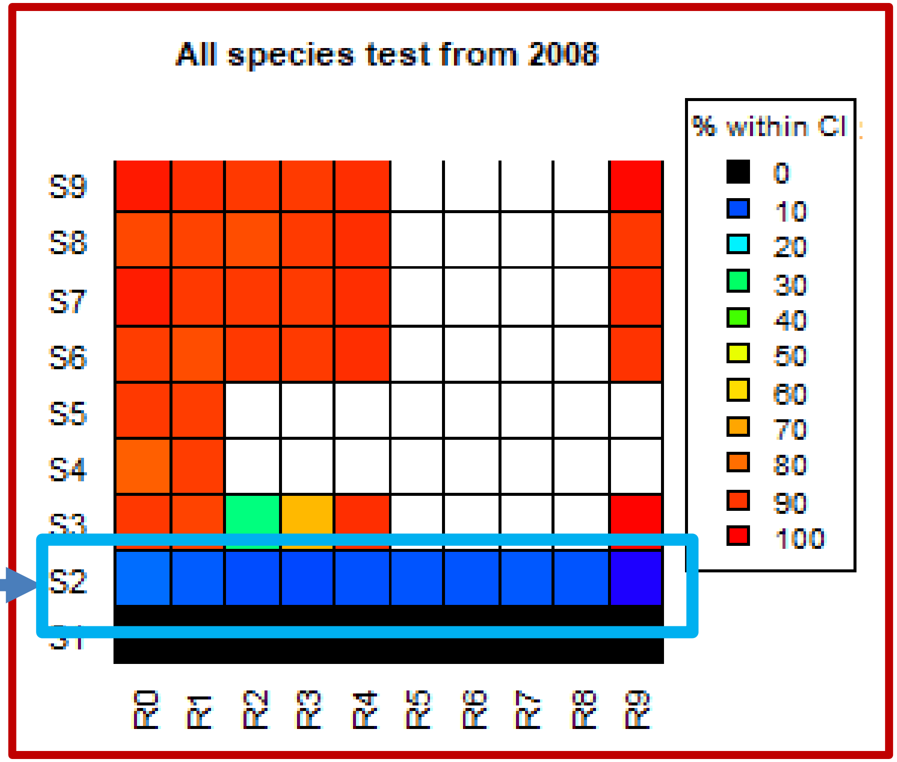
- LM methods show lower absolute error
- Stochastic LM lower error than deterministic
- Well-studied regions have lower absolute error

Results: uncertainty

% of observed counts within 95% prediction interval

Abundance time-series methods

Stochastic LM



- Stochastic LM method shows poor capturing of uncertainty – ***importance of parameters***

- Abundance time-series methods often include observation in CI

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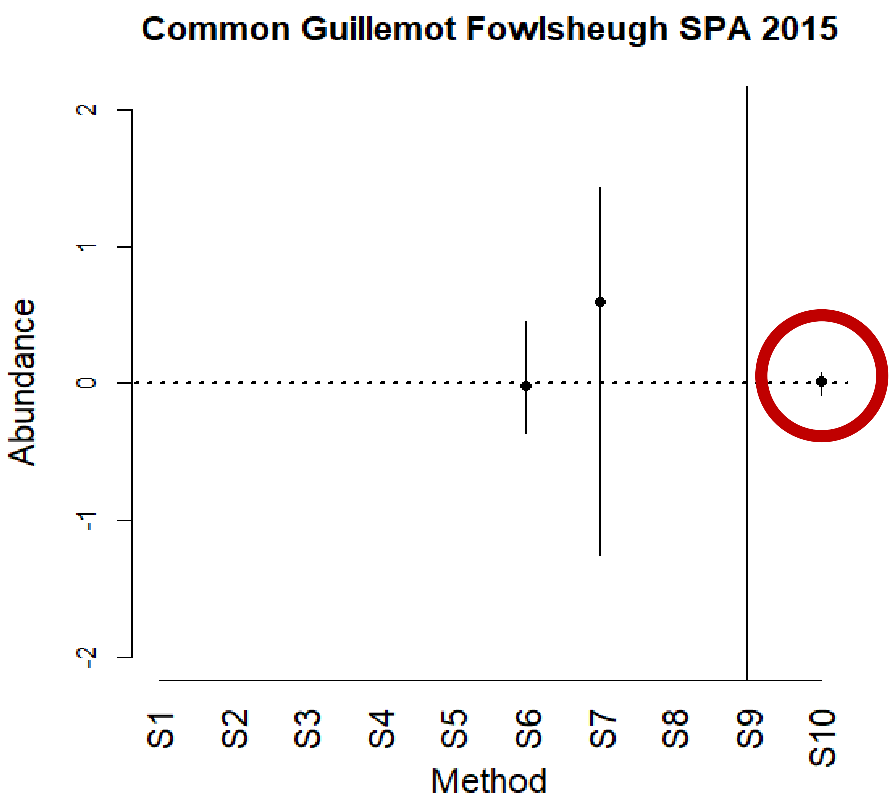
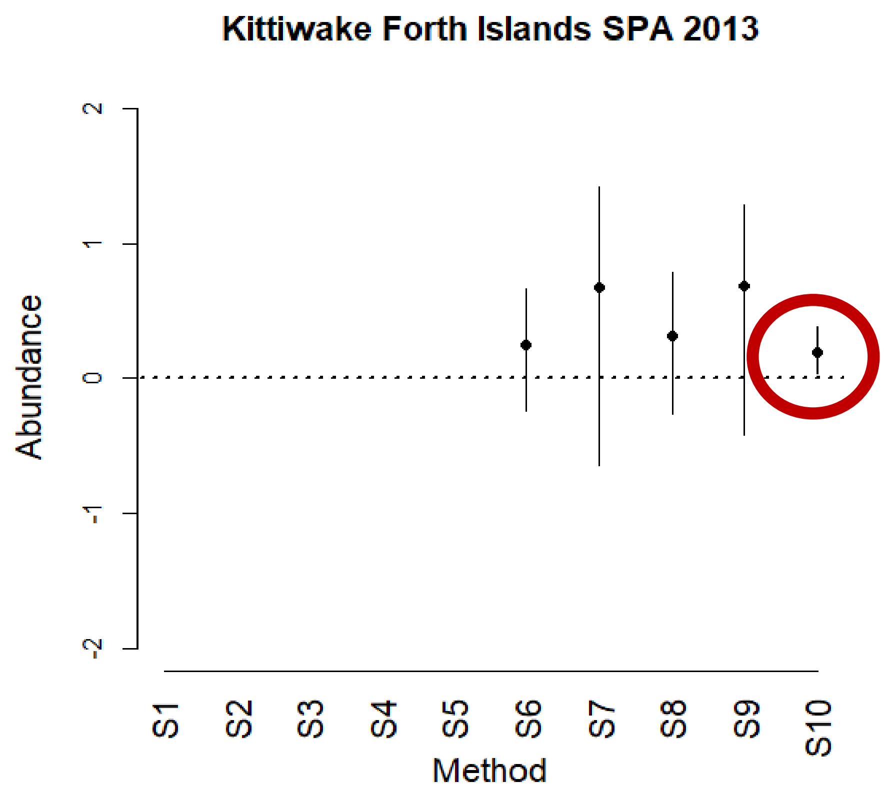
Results: IPM Models in Forth-Tay Region





The IPM approach had lower bias and lower levels of error than any other method, and did not yield highly implausible results.

The best coverage (92%) is for the IPM – this is close to the nominal level of 95%.

Conclusions

Results so far suggest the <u>Bayesian state space model (IPM)</u> that uses *both* data sources has the best overall performance

<u>Leslie matrix</u> approaches can also perform relatively well

But <u>time series approaches</u> tended to perform poorly – lacking biological constraint, and abundance data are often insufficient to rule out such parameter values

Regional Pooling

How does performance varies in relation to the definition of the regions used for spatial pooling of information used in the PVA?

Critical for Leslie matrix methods, where regional pooling is widely used in practice in data-sparse situations where no other PVA method is feasible……

Conclusions

Local, site-level approaches that avoid regional pooling generally had the lowest levels of bias and error, but can be used in far fewer situations

The ICES (R2) and Regional Seas (R3) classifications, can be applied in few situations and had higher rates of bias and error

The regions with more divisions (CRA, CRB, MSFD, OSPAR should be used in preference to these

Some evidence that the breeding success classification performs marginally better than the abundance classification

Benefit in using local data within the Leslie matrix, rather than regional pooling, where data allow this

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Further work

- Survival rates and standard deviations (stochastic LM)

- Density dependence in demographic rates

- Metapopulations

- Environmental change

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Thank you



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