Integrating Time-series of Reef Fish Community Monitoring Data

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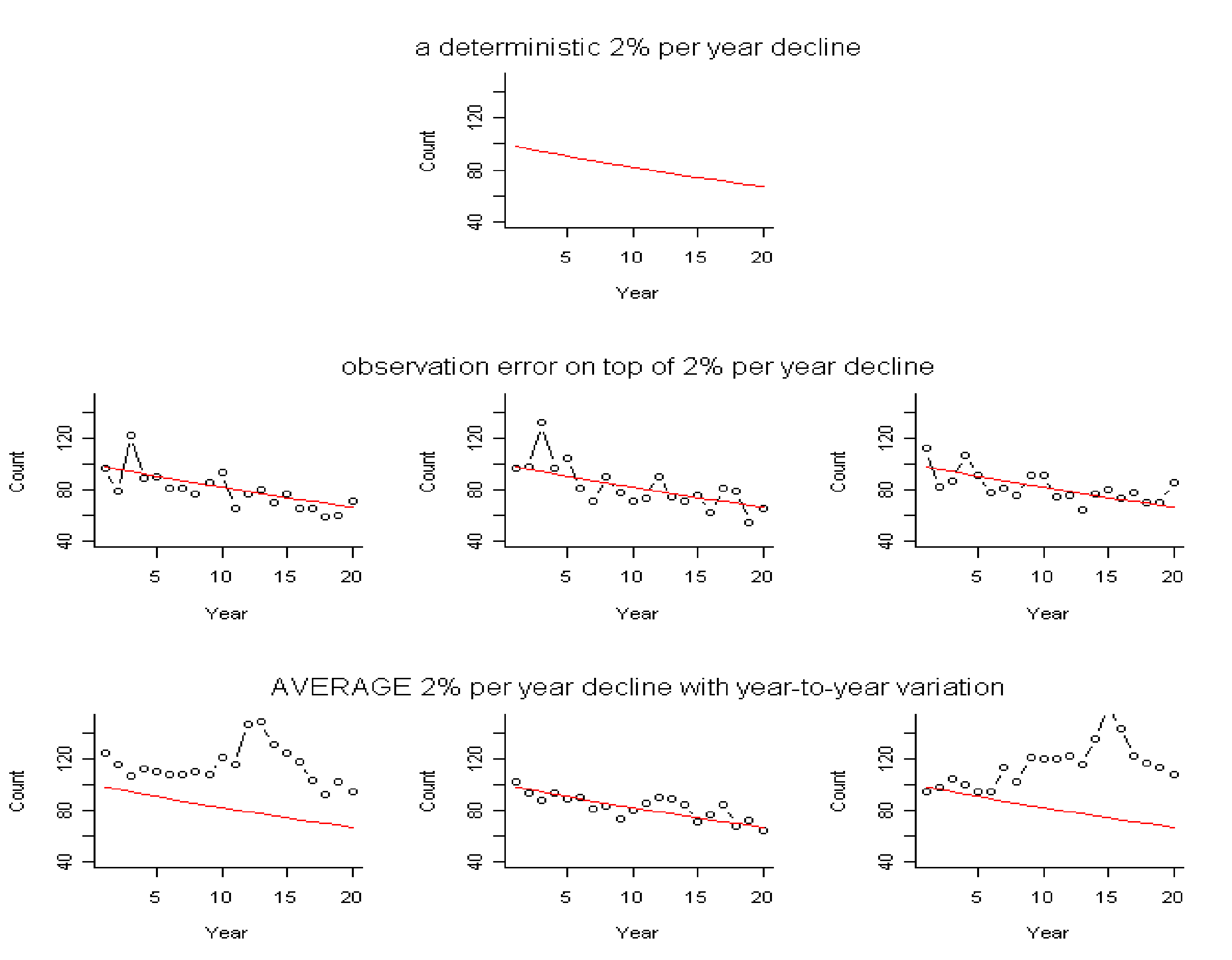
Study overview

Goal: To develop estimates of reef fish population trends using data collected from multiple monitoring programs and incorporating **temporal variability in population growth rates** plus **variability from observation error**.

How: Use Multivariate Auto-regressive State Space (MARSS) models to analyze changes in abundance as stochastic process through time, with multiple observations of that population process

Time varying population growth leads to a “random walk”



Every year, decline 2%

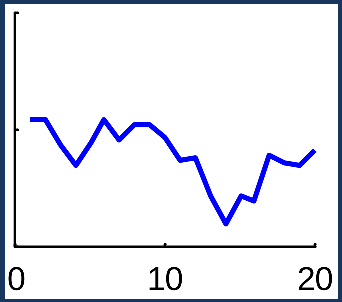
Every year, decline 2% but there is observation error

Average yearly decline is 2%, but actual declines vary from year to year

Typical ways time-varying population growth is included in MARSS models

- Year-to-year uncorrelated variability with some (estimated) constant mean and variance

- Year-to-year correlated variability; mean growth rate is changing



- Variability that is modeled as a (estimated) function of measured or known factors (temp, Ph, salinity, month^n, year^n)

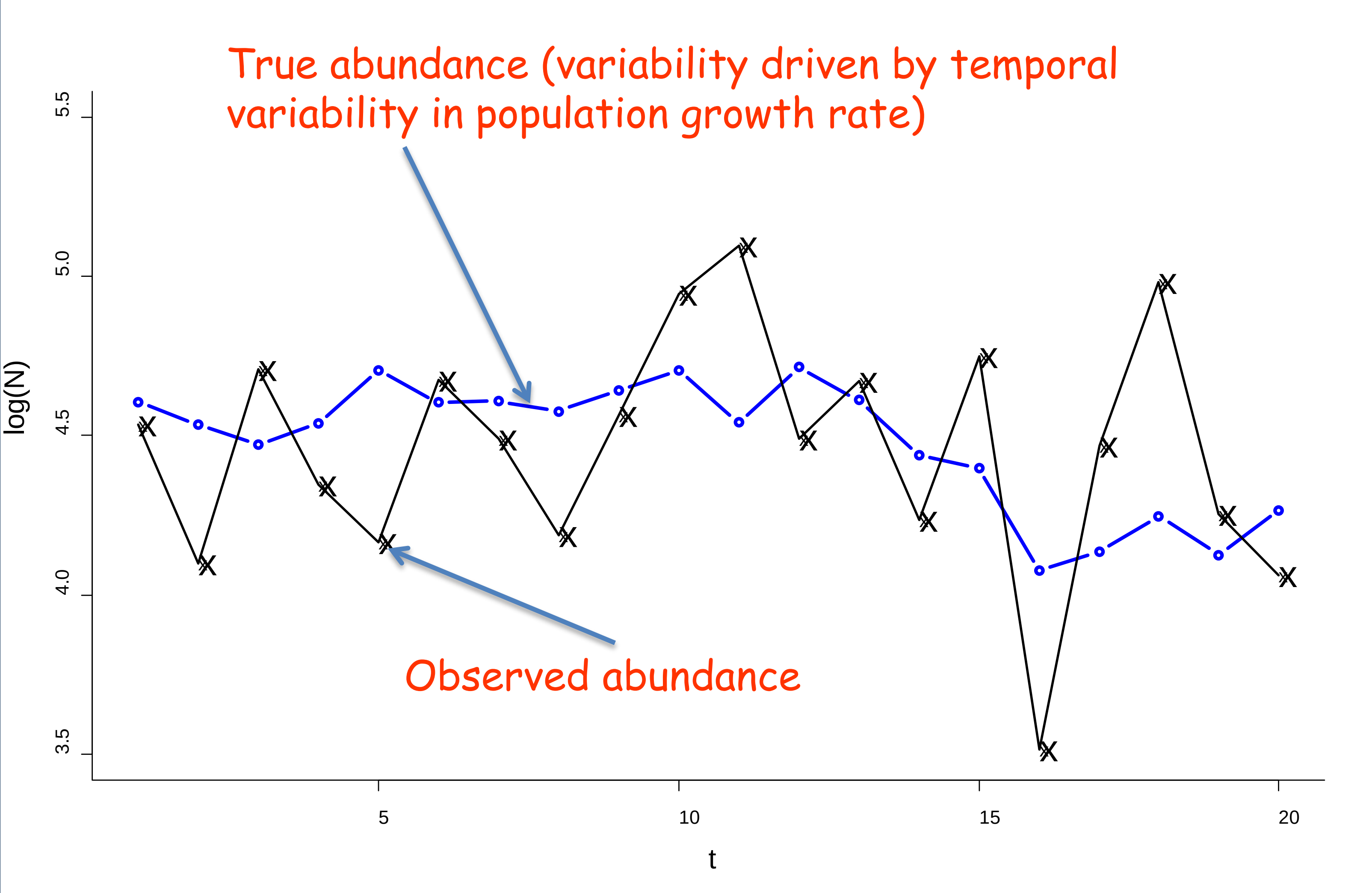
A second type of variability in reef fish (and other) monitoring data

- Temporal variability reef fish population dynamics

❖ Observation error

The variability due to observation error is difficult to estimate because it arises from changes in detectability and is a complex (often unknown) function of the environment.

Stochastic abundances observed with error "state-space" model



Application: estimation of long-term mean population growth rates and population index for Florida reef fish

REEF Fish Survey Project – Volunteer divers, average 60 minute search time, multiple habitats, $\log_{10}$ abundance categories; "Citizen science" survey

SEFSC/NOAA Reef Fish Long-term Monitoring Program –Visual Count, 15m circular plots, randomized over habitats, 5 min counts; Prof. scientific survey

Data from Molasses Reef (Florida Keys, US), 1993-2010 (REEF) and 1993-2008 (RVC). 1,741 REEF surveys and 227 RVC surveys.

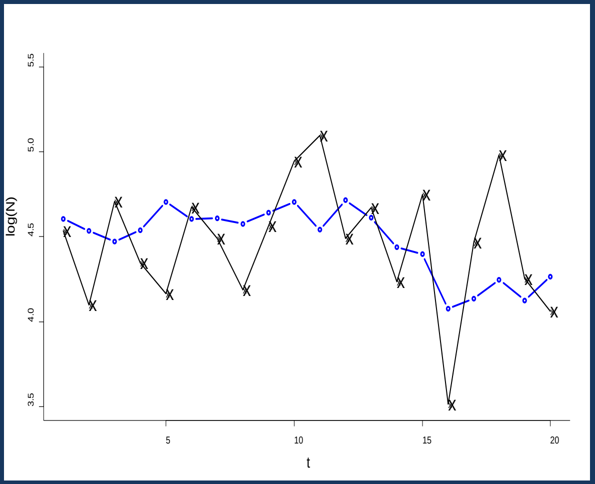
Analysis approach: MARSS models

Multivariate Auto-regressive State Space

State $\mathbf{x}_t = \mathbf{B}\mathbf{x}_{t-1} + \mathbf{u} + \mathbf{w}_t \quad \text{where} \quad \mathbf{w}_t \sim MVN(0, \mathbf{Q})$

Obs $\mathbf{y}_t = \mathbf{Z}\mathbf{x}_t + \mathbf{a} + \mathbf{v}_t \quad \text{where} \quad \mathbf{v}_t \sim MVN(0, \mathbf{R})$

- Well established, flexible and widely used in quantitative fields
- Combines a process and obs. model
- Simple framework for many different data and population structure
- Estimates of the unseen "true" state
- Merge multivariate time-series data

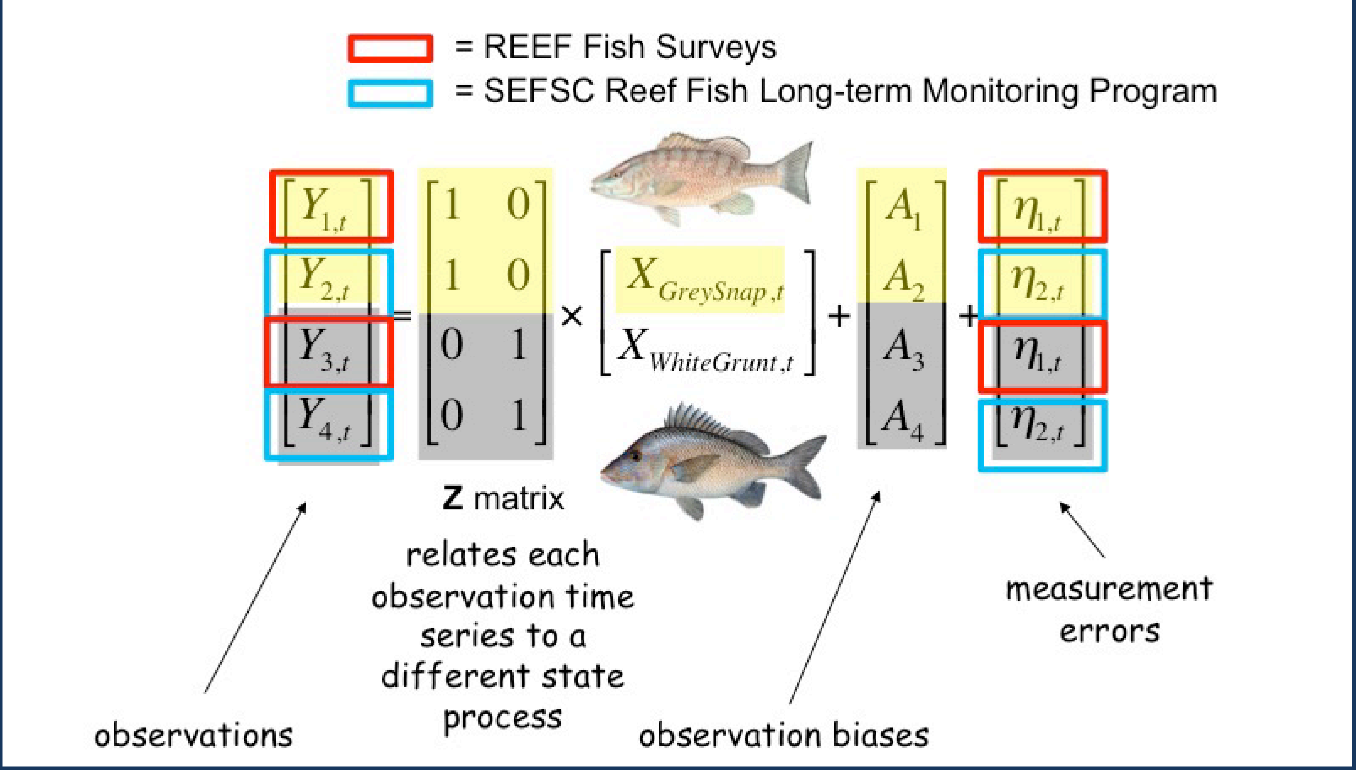


Analysis assumptions

Simultaneously model trends in abundance in each of 10 species on Molasses Reef:

- Variance in year-to-year population growth rates is unique to each species
- Observation errors are unique to each survey method (but shared across species)
- For a single spp, both surveys are reporting information on the same unobserved true population abundance through time.

Model
(showing 2 spp instead of 10 actually used)



All analyses were carried out in the R open source software environment using the MARSS Package (freely available on CRAN; Holmes, E.E., E.J. Ward. 2010. Analysis of multivariate time-series DATA using the MARSS package. Google: MARSS CRAN)

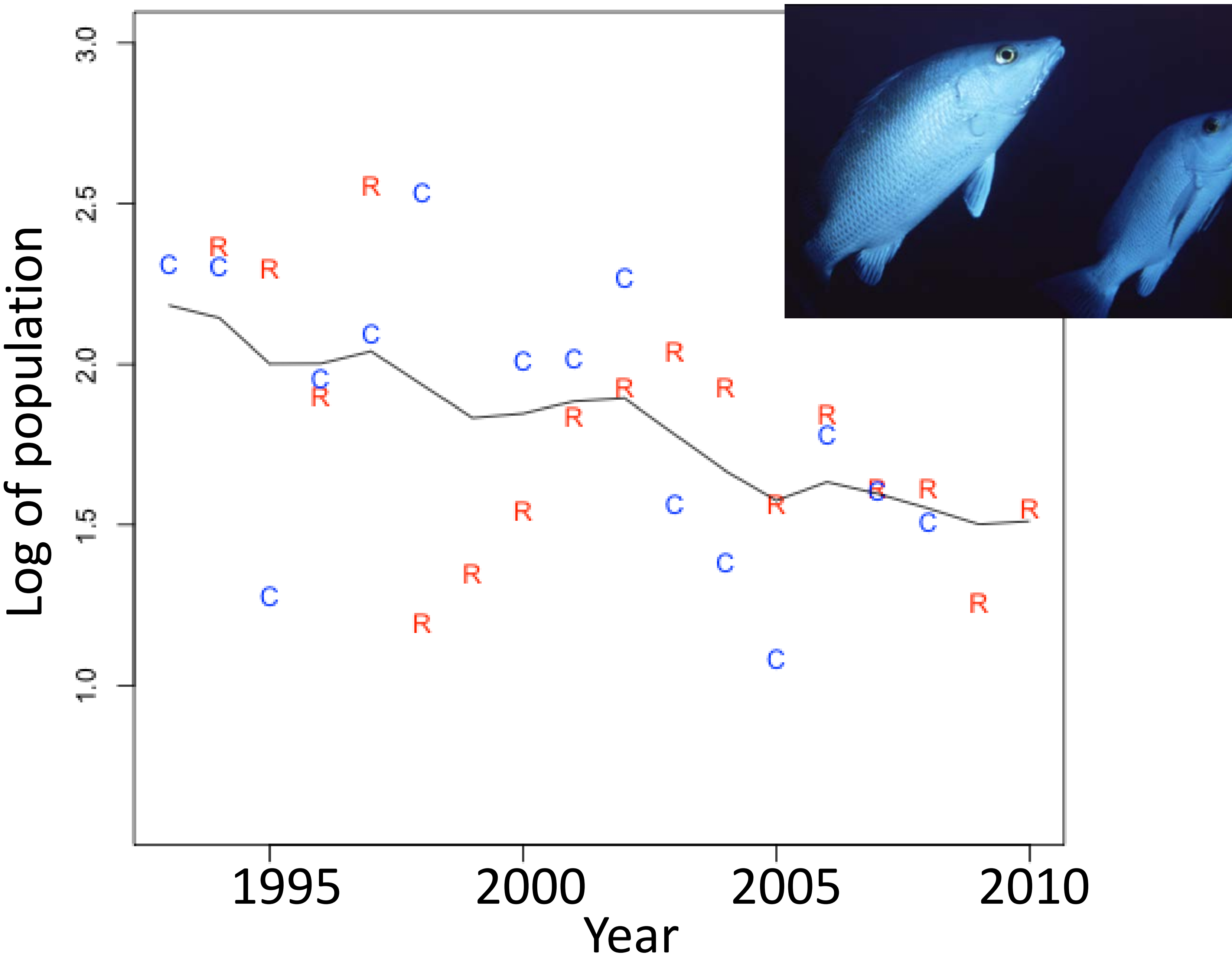
Results

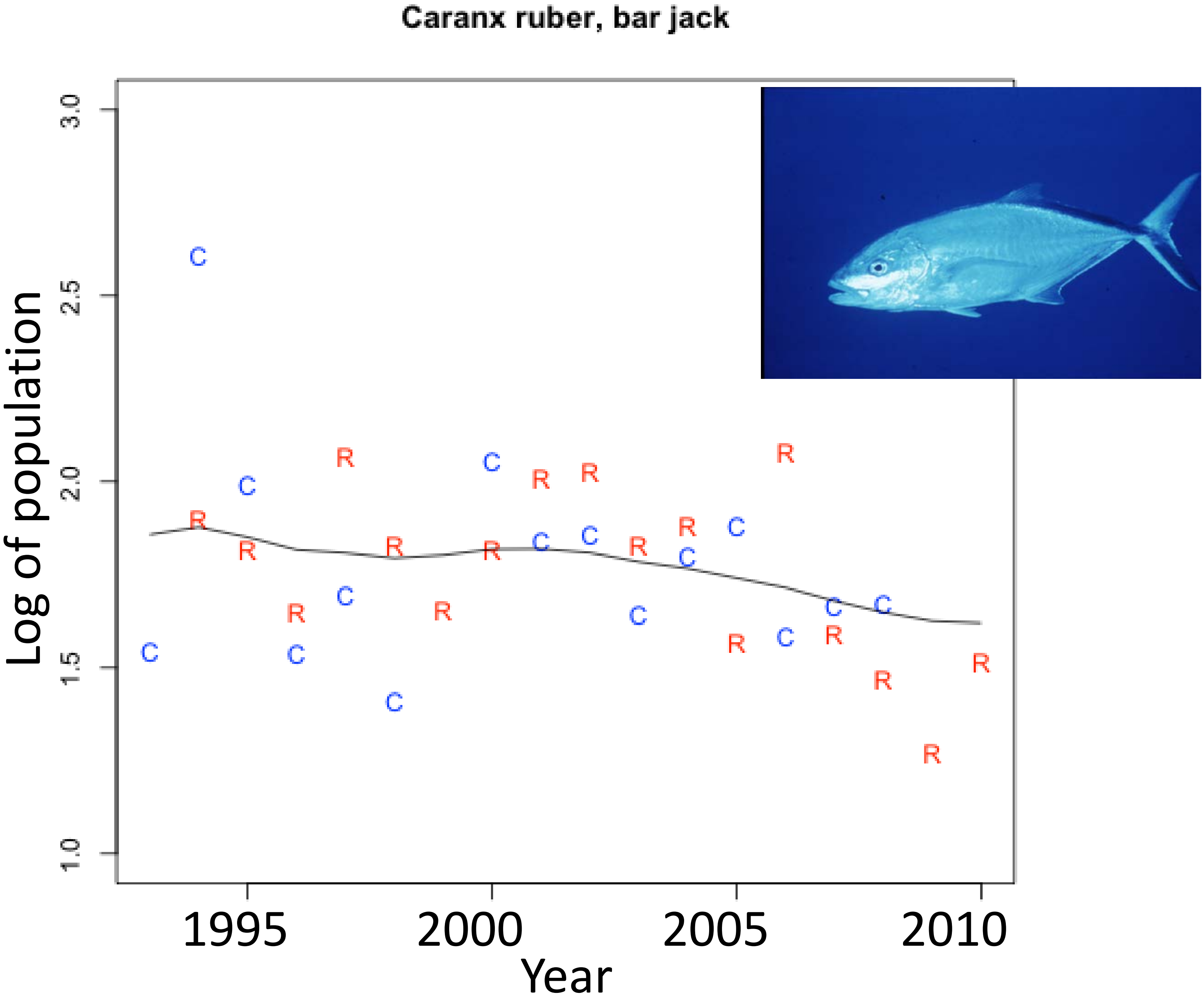
‘R’ is average annual abundance score based on REEF surveys.

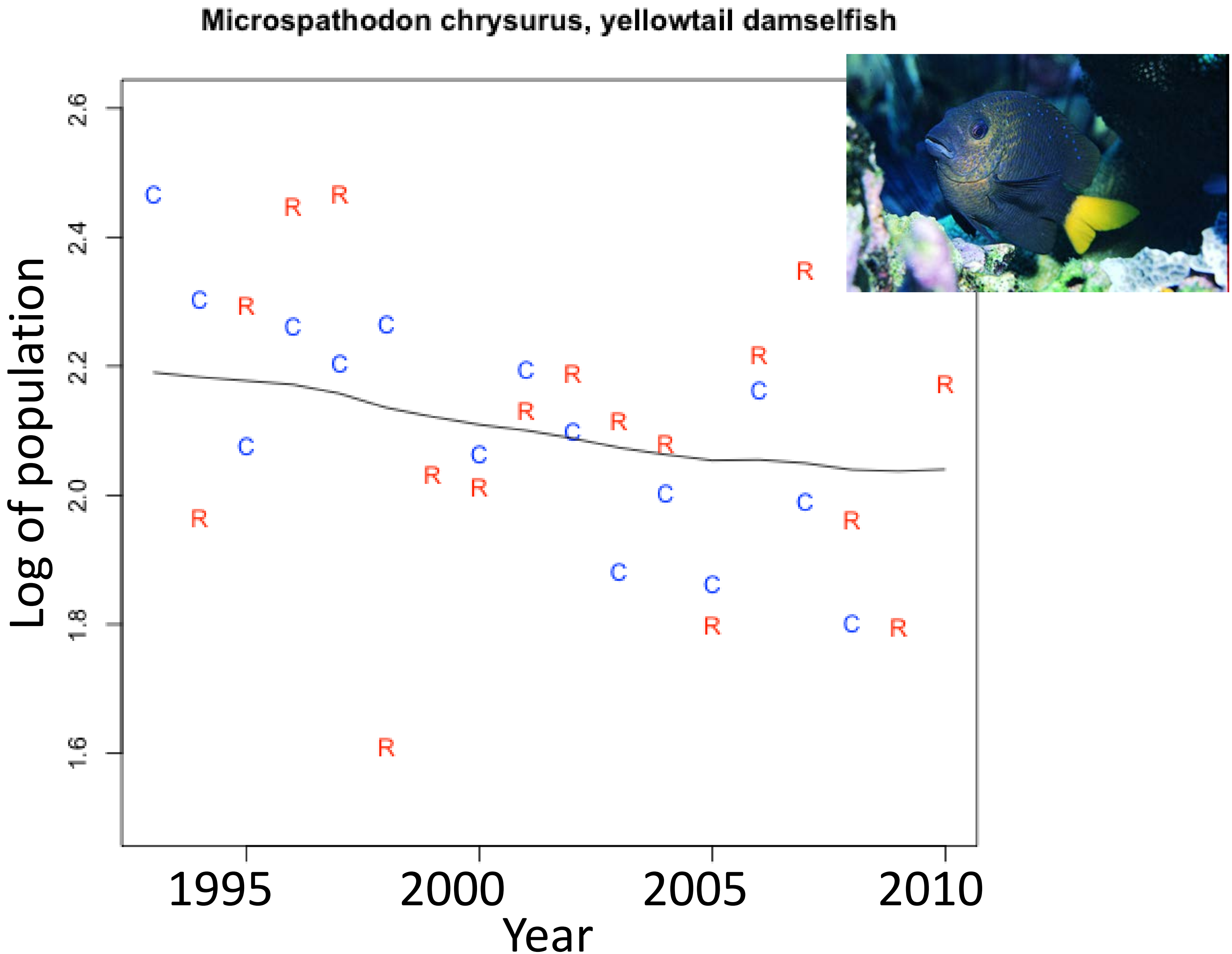
‘C’ is average annual density based on RVC surveys ($\log_{10}$+1 transformed).

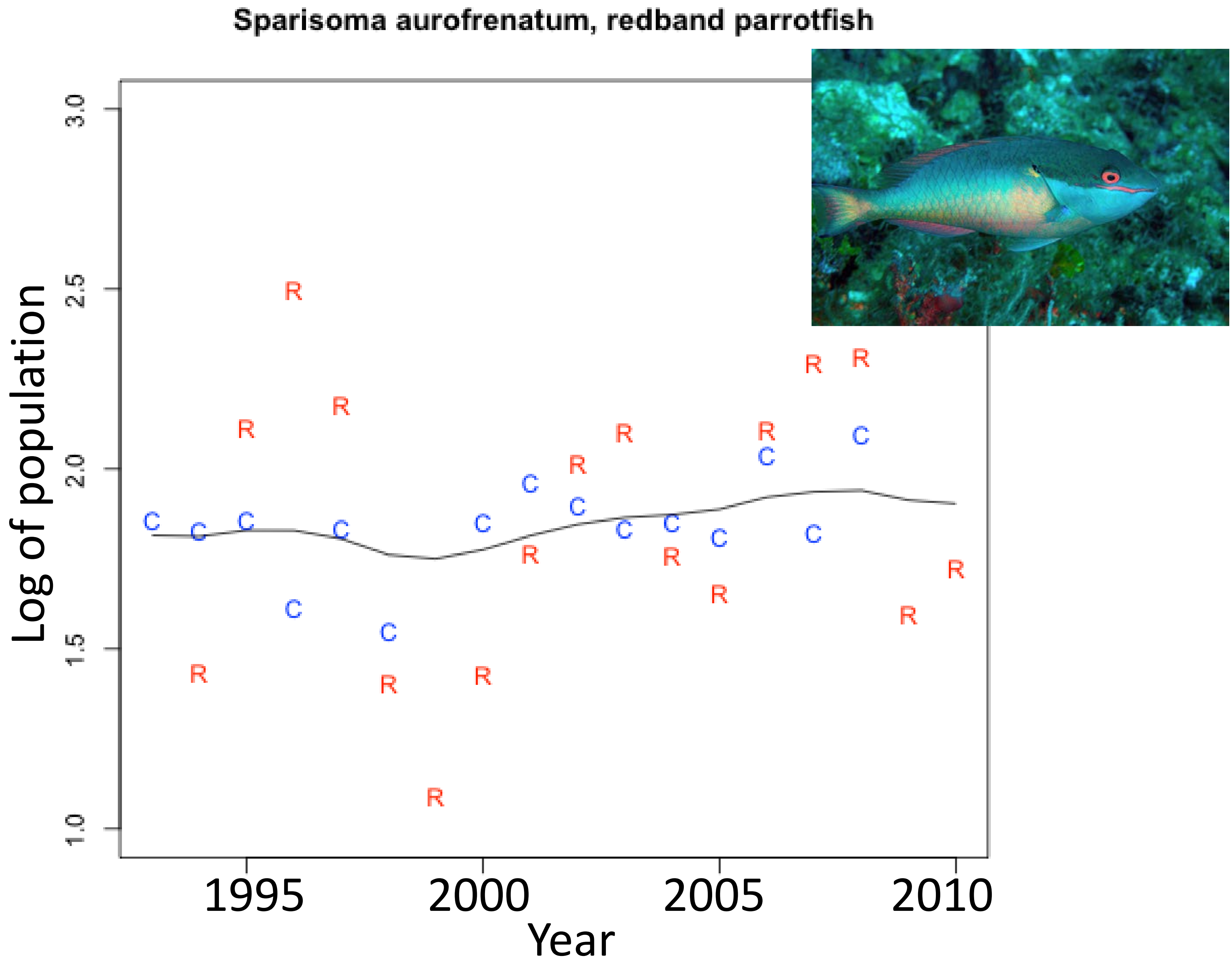
The black line represents the model results, showing an estimated “true” population abundance removing the observation error but leaving in the process error

Lutjanus griseus, grey snapper



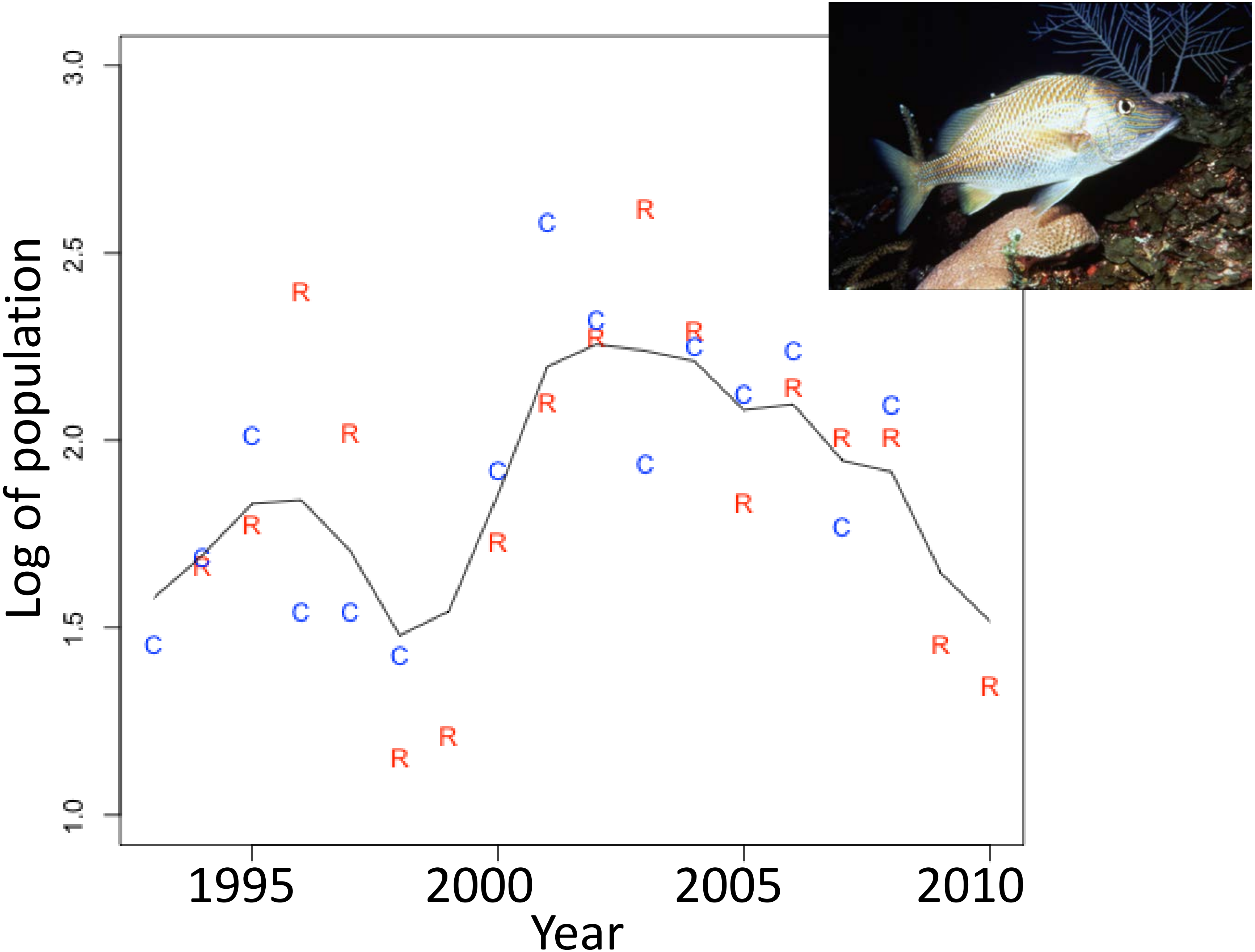

Caranx ruber, bar jack
Log of population
3.0
2.5
2.0
1.5
1.0
1995
2000
2005
2010
Year


Microspathodon chrysurus, yellowtail damselfish
Log of population
2.6
2.4
2.2
2.0
1.8
1.6
1995
2000
2005
2010
Year



Sparisoma aurofrenatum, redband parrotfish
Log of population
3.0
2.5
2.0
1.5
1.0
1995
2000
2005
2010
Year

Haemulon plumierii, white grunt



Key results

Observation errors were similar –
REEF: variance of 0.07
RVC: variance of 0.06

Average species process variance (population stochasticity) was 0.01, with the a high of 0.05 (white grunt). *These are fairly typical levels for vertebrates.*

Summary

The REEF program yields valuable information separate from but comparable to “professional” long-term monitoring programs.

Variability in the time series data from both methods was dominated by observation error rather than year-to-year variability in population growth..

This multivariate approach provides a more accurate estimate of the true states of reef fish populations through time.


REEF
www.REEF.org