Modelling *Calanus finmarchicus* in the Irminger Sea: From Individuals to Populations

Douglas C. Speirs & Michael R. Heath

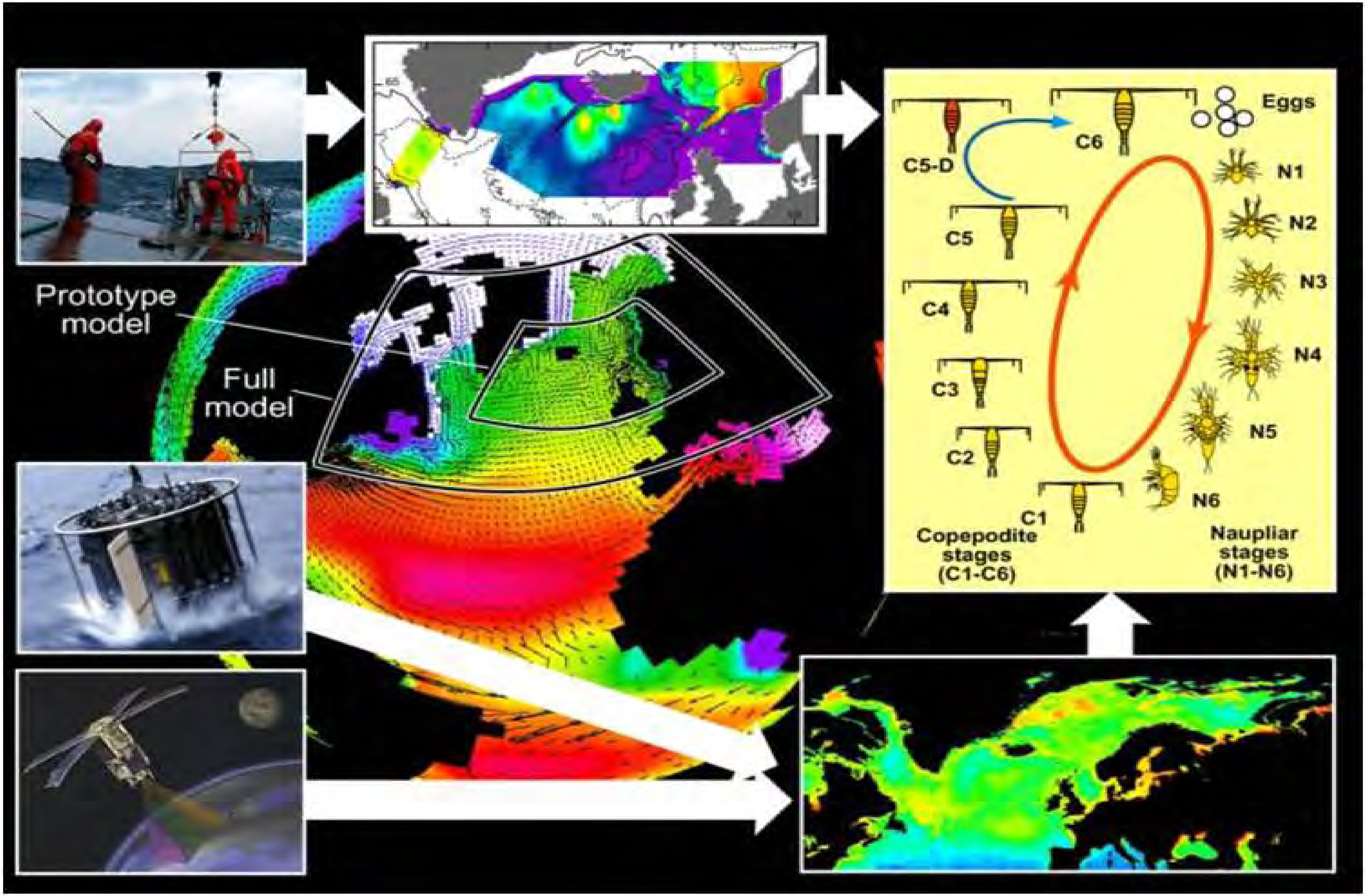
Marine Population Modelling Group
Department of Mathematics & Statistics
University of Strathclyde

5th International Zooplankton Production Symposium, Pucon, Chile 14th-18th March 2011

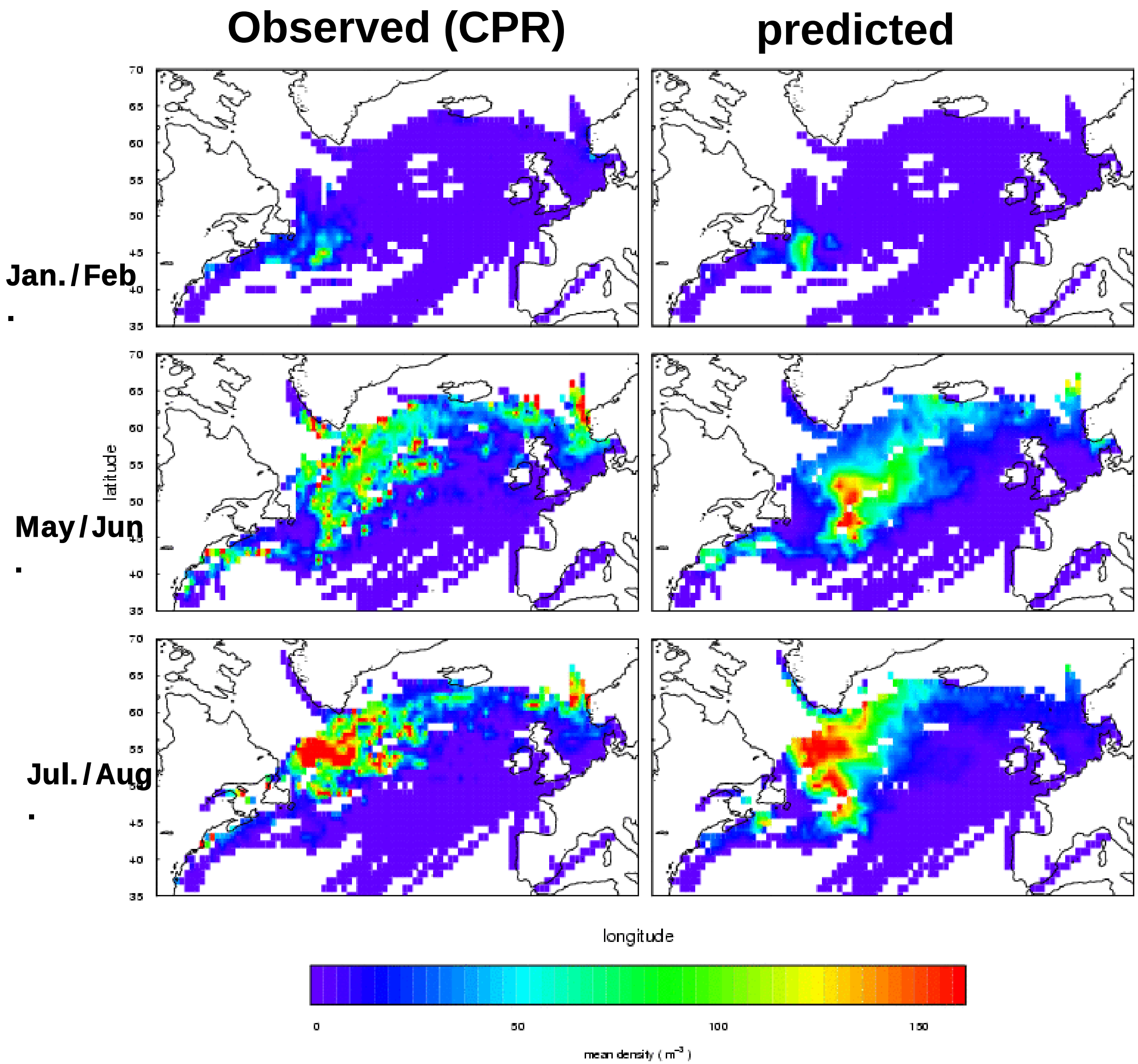
Talk Overview

- Background to the MarProd *Calanus finmarchicus* model (Speirs *et al.* 2006, MEPS 173-192)
- Background to the MarProd Irminger Sea *Calanus* data (Heath *et al.* 2008, Prog. Oceanog. 39-88)
- How well does the *Calanus* model do in the Irminger Sea?
- Parameter estimation by Simulated Annealing
- Fitting to the MarProd Irminger Dataset
- Conclusions

MarProd *Calanus* Model

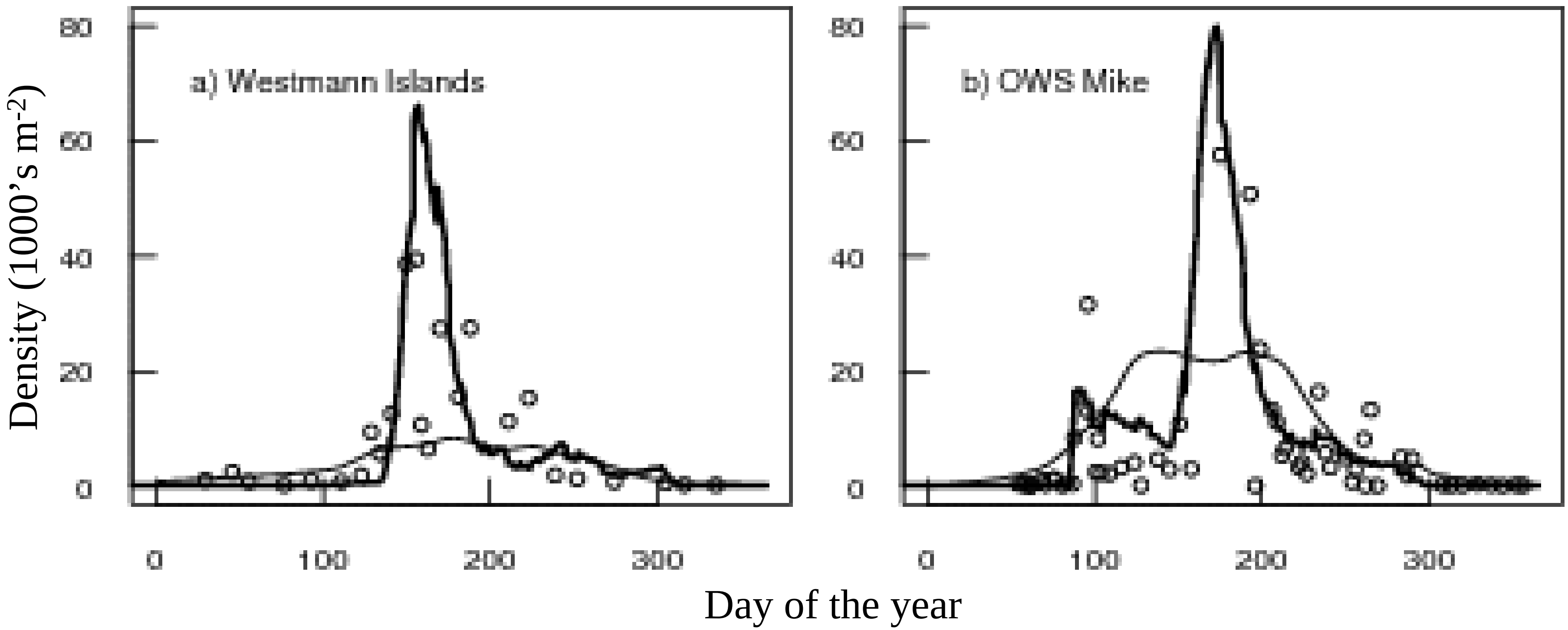


Spatio-temporal predictions



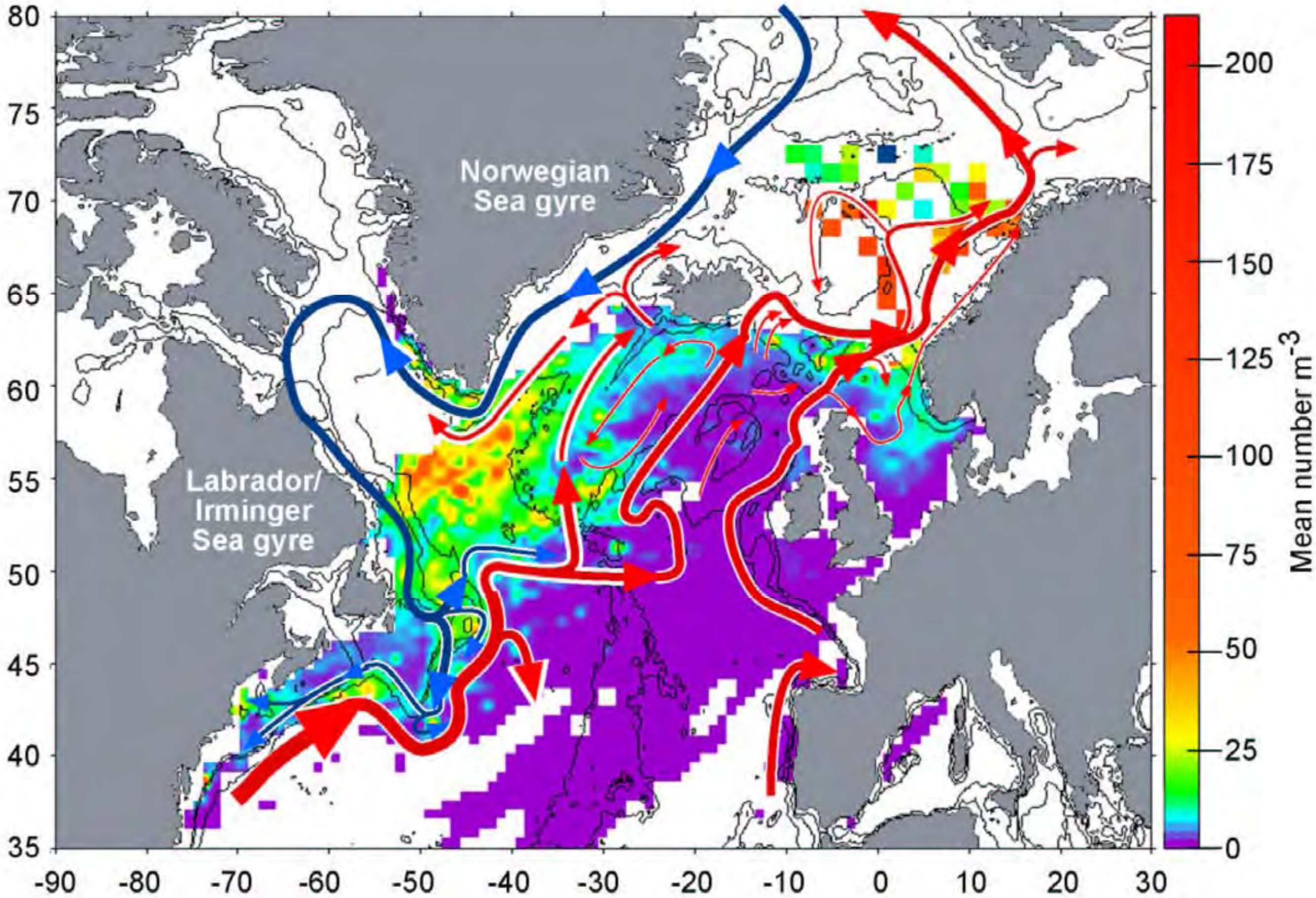
Point time series comparisons

Modelled (thick solid line) and observed (points) C5+C6 *C. finmarchicus* in the top 100m (thin line shows a CPR-derived estimate)



University of Strathclyde Science

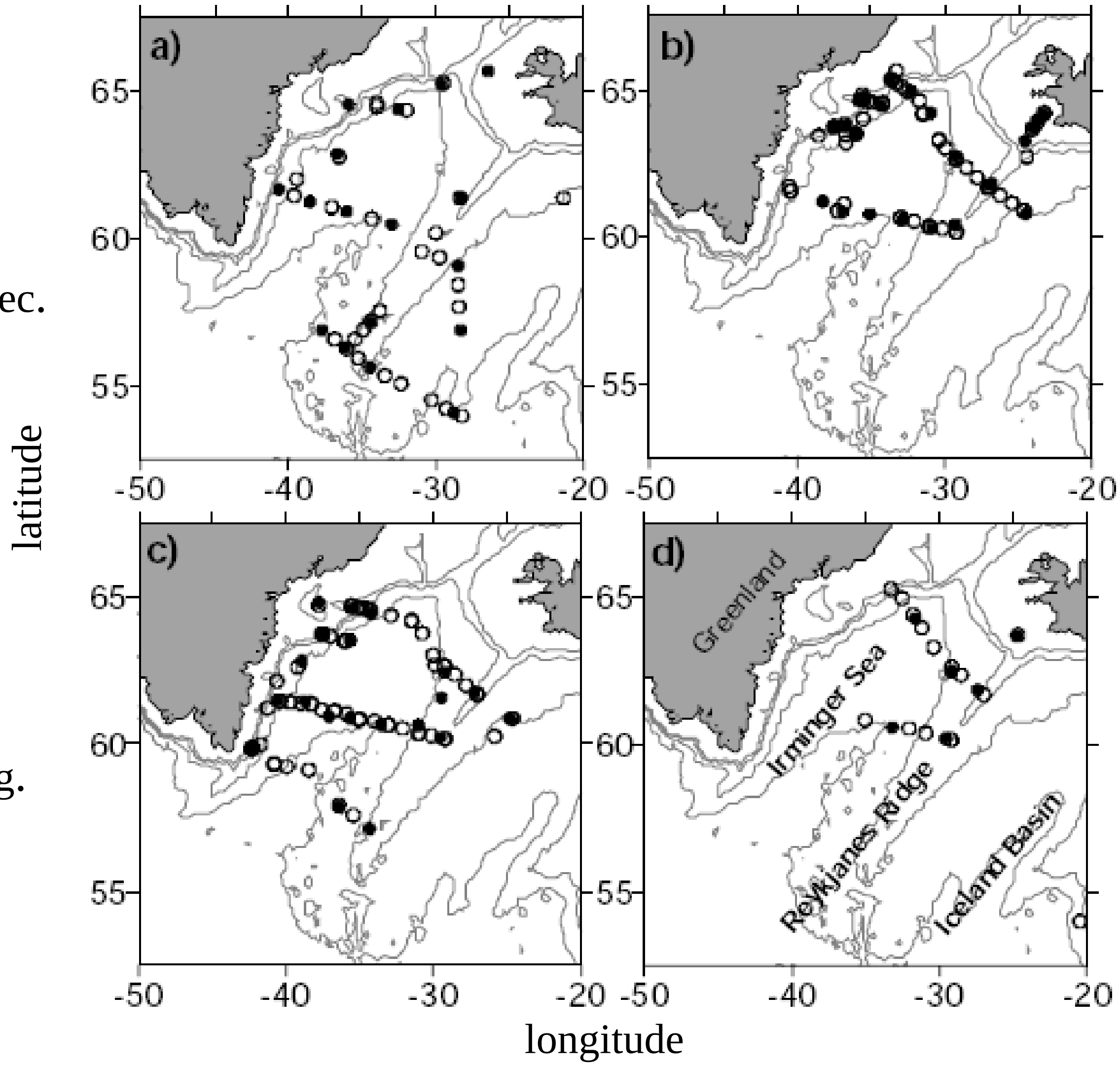
Calanus finmarchicus distribution in relation to major ocean currents



MarProd RSS *Discovery* Cruises

D258
Winter 2001
8th Nov.- 12th Dec.

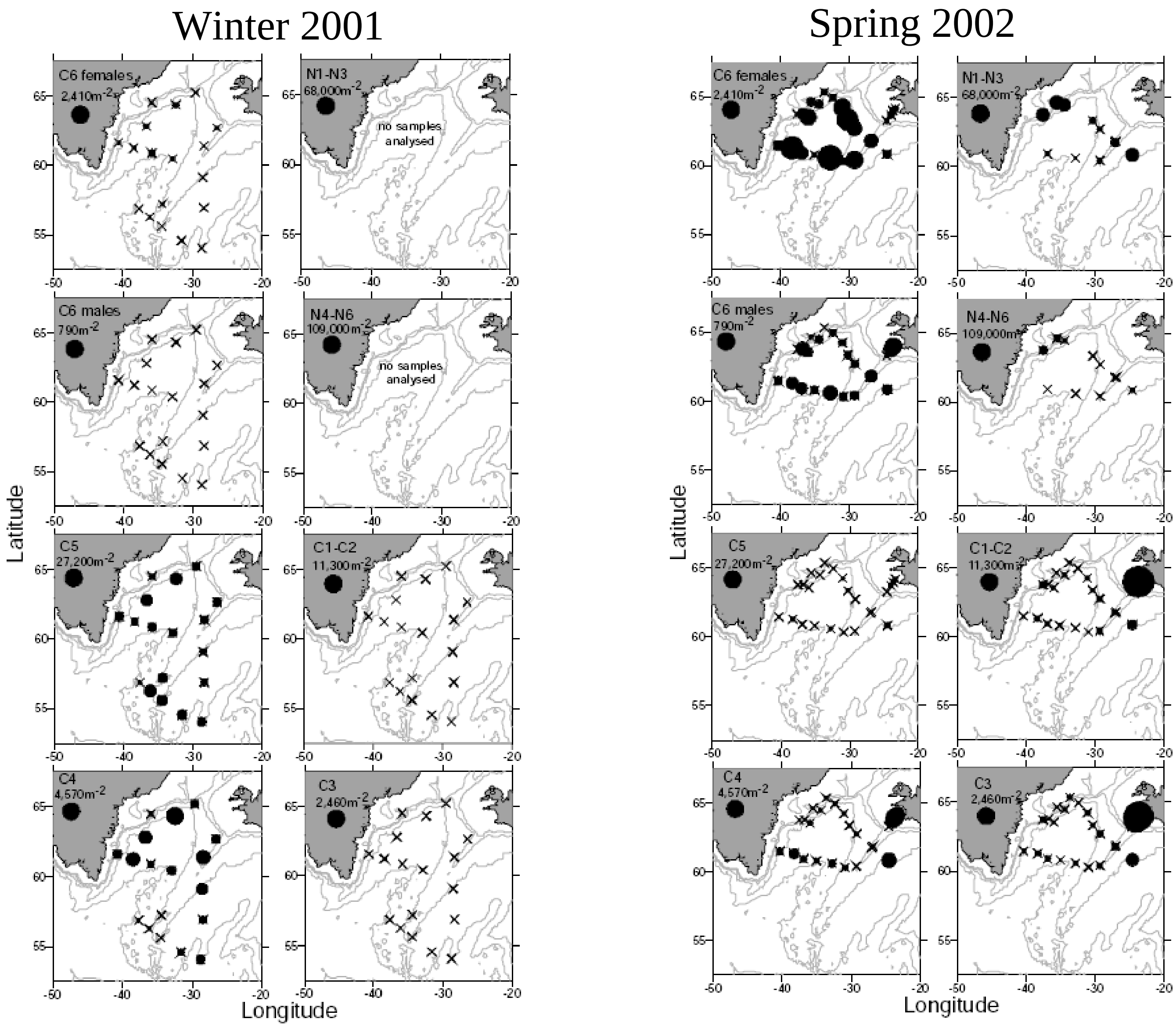
D262
Spring 2002
21st Apr.- 24th May



D264
Summer 2002
28th Jul.- 23rd Aug.

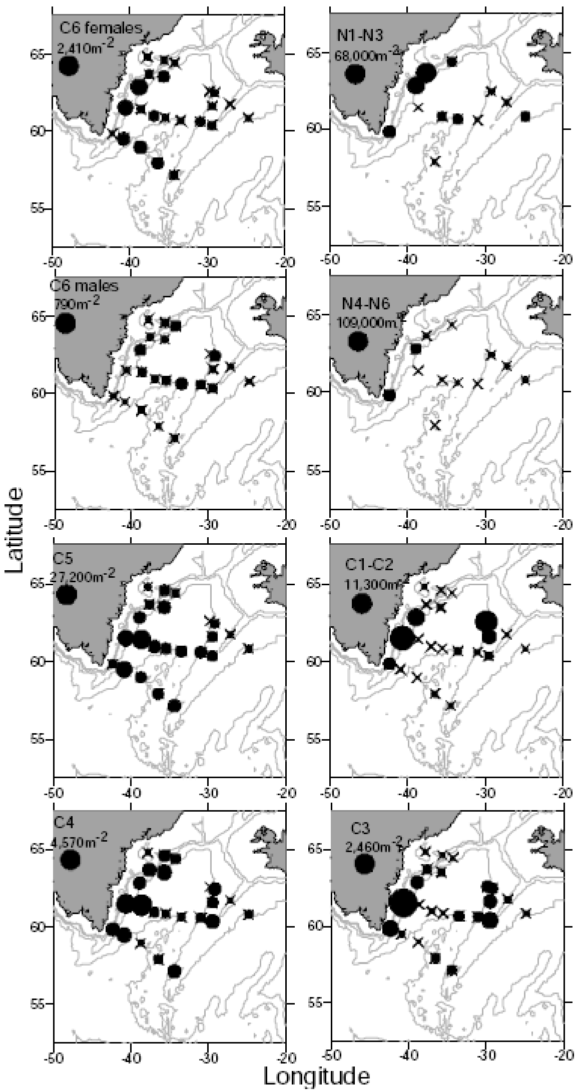
D267
Winter 2002
15th Nov.- 14th Dec.

C. Fininmarchicus stage abundances

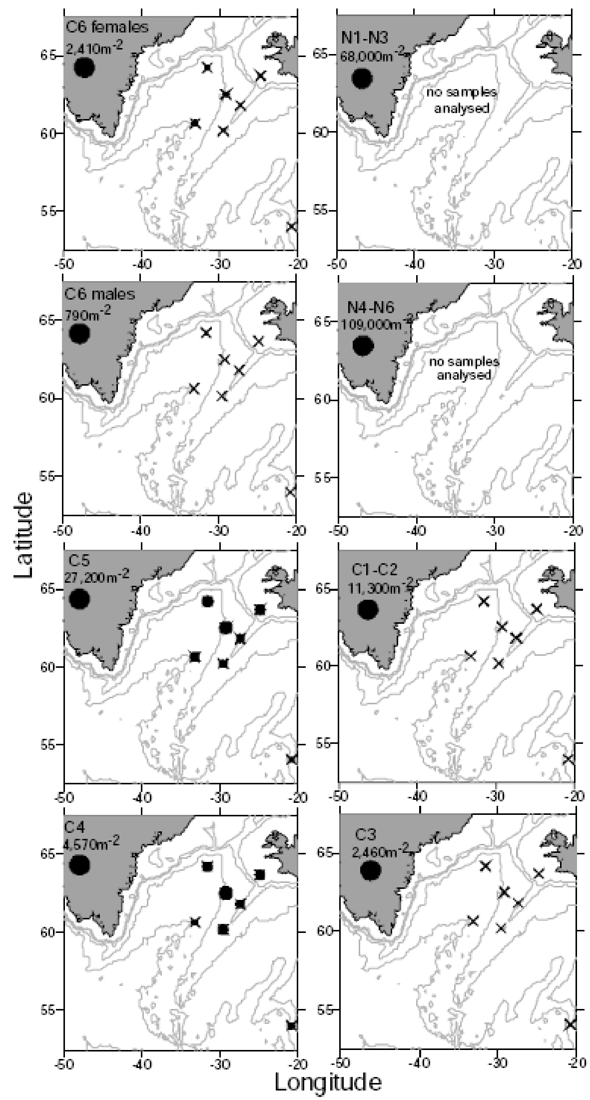


C. Fininmarchicus stage abundances

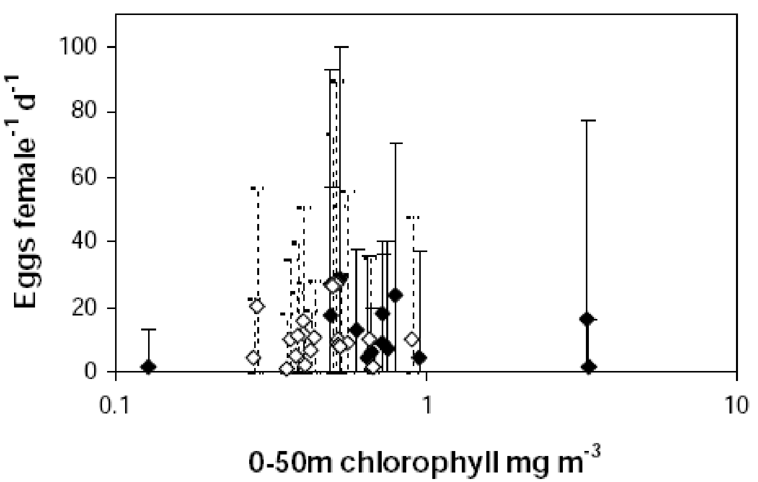
Summer 2002

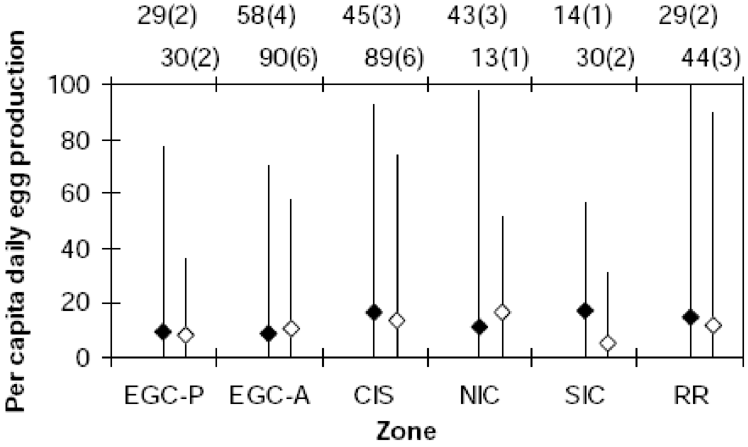


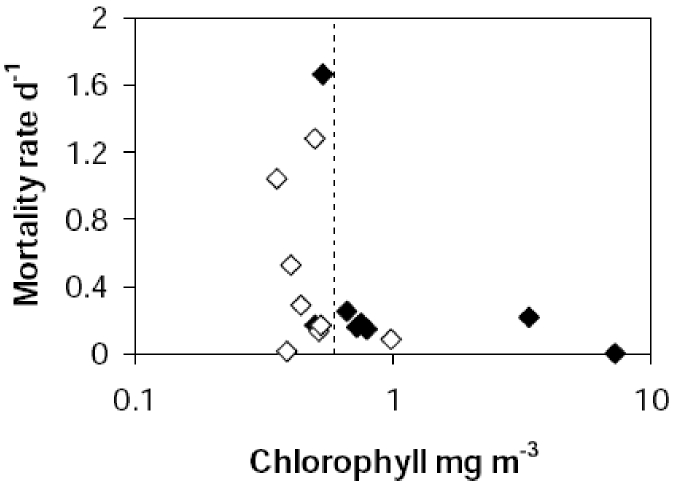
Winter 2002



Egg production and naupliar mortality



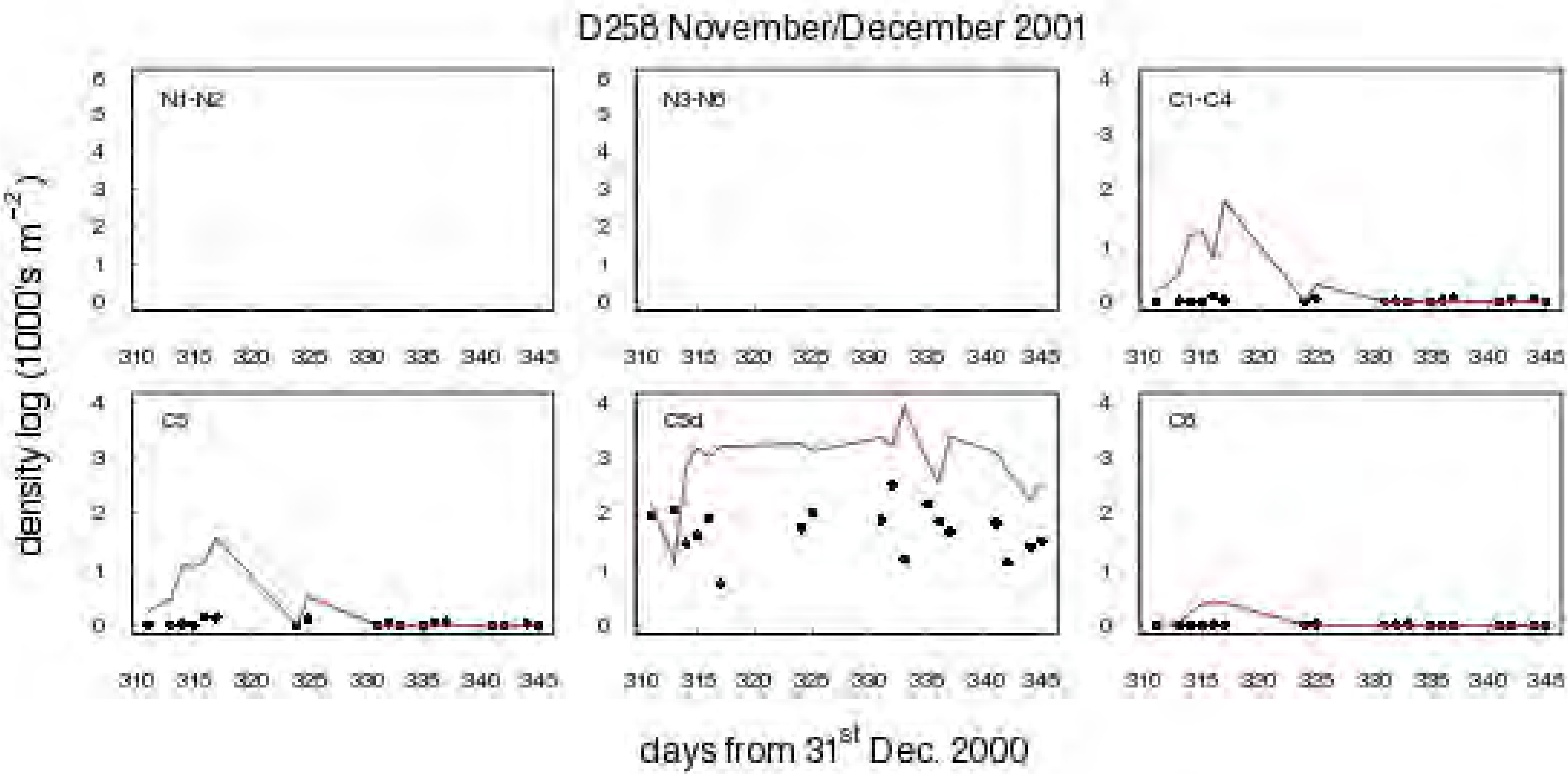




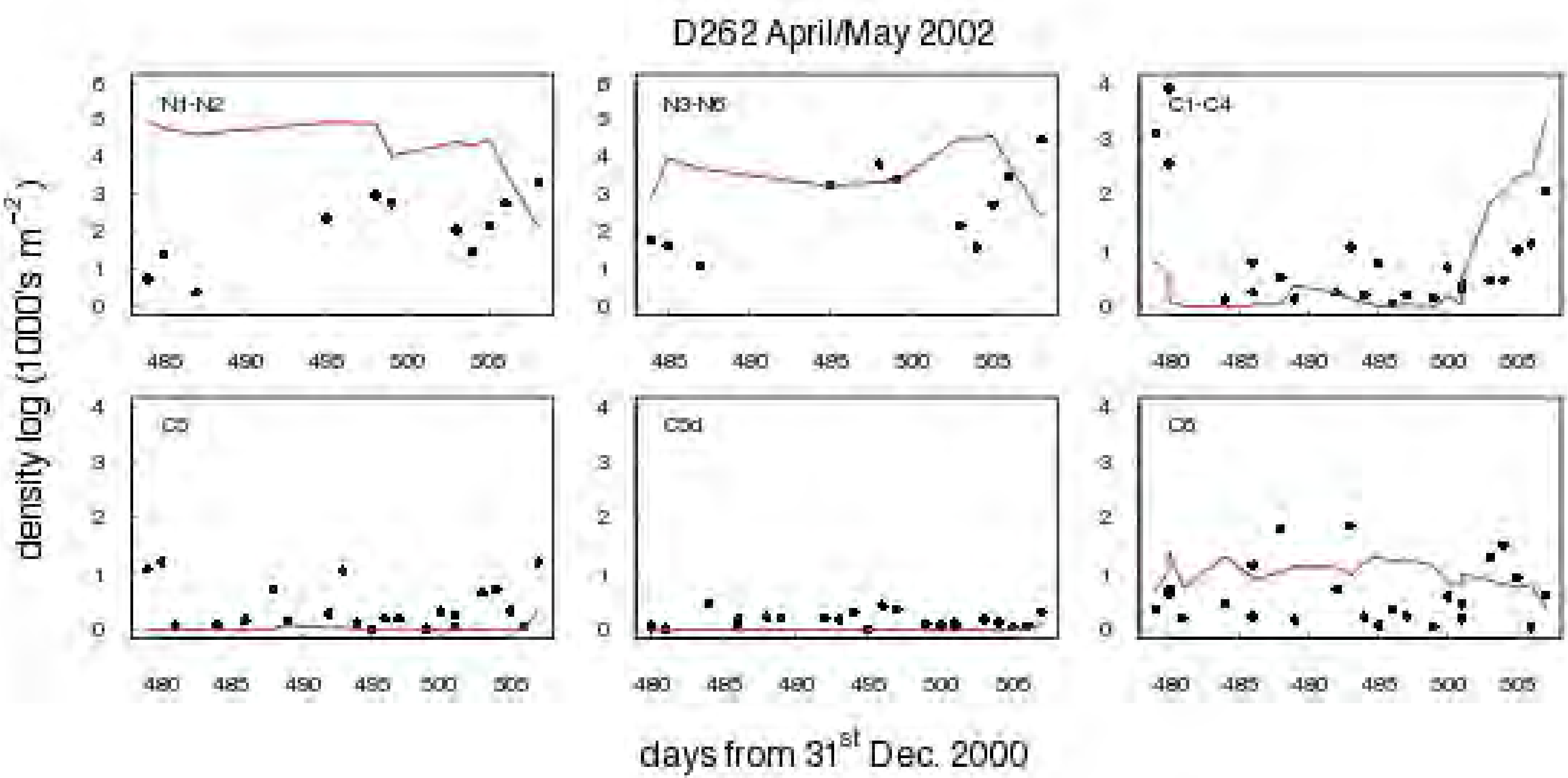
Egg production uncorrelated with Chlorophyll or location

N3-N4 mortality high below 0.6 mg m^{-3} chlorophyll

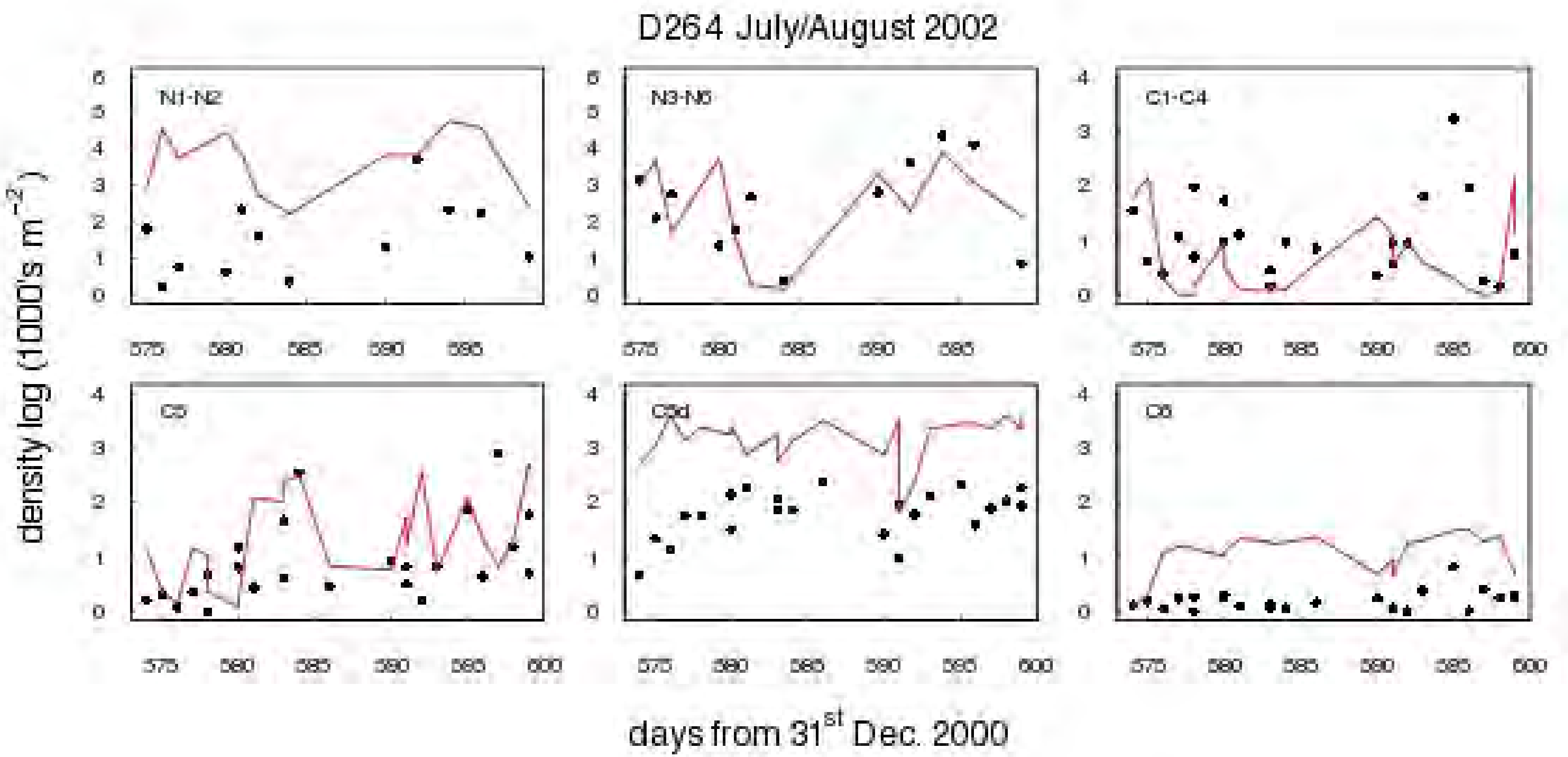
Winter 2001 observed and predicted



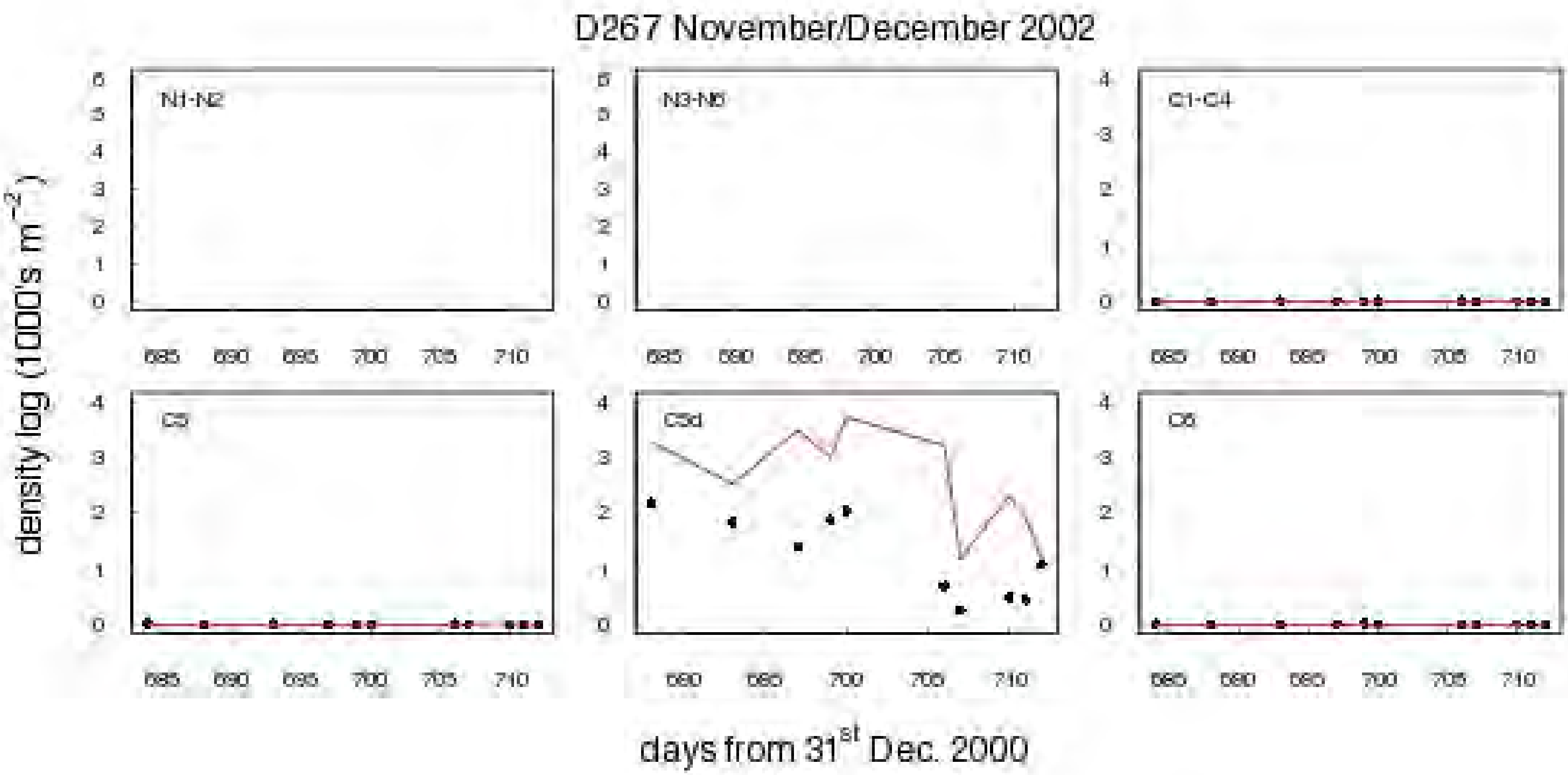
Spring 2002 observed and predicted



Summer 2002 observed and predicted



Winter 2002 observed and predicted



Simulated Annealing

The idea works by analogy with slow cooling (annealing):

Probability *P* of observing state in energy state *E* is proportional to the Boltzmann factor

$$P \propto e^{-E/T}$$

where *T* is the temperature.

If we have 2 energy states E_1 and E_2, then the relative probability is

$$\frac{P(E_1)}{P(E_2)} = \frac{e^{-E_1/T}}{e^{-E_2/T}} = e^{-(E_1 - E_2)/T}$$

and the inverse of the partition function has cancelled out.

The Metropolis Algorithm

1. Starting from a configuration *A*, with known energy E_A, make a change in the configuration to obtain a new (nearby) configuration *B*.

1. Compute E_B (typically as a small change from E_A).

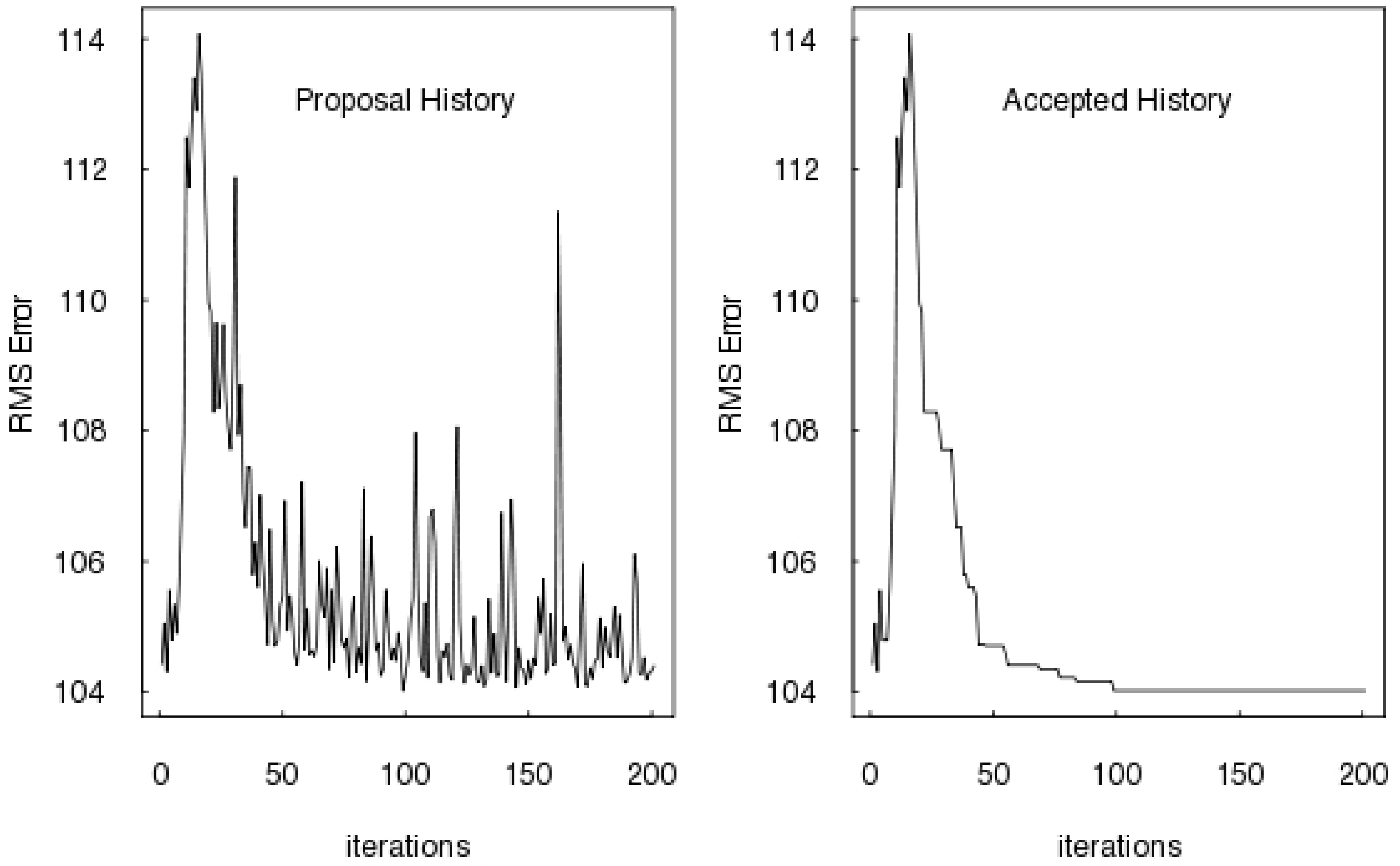
1. If $E_B < E_A$, assume the new configuration, since it has lower energy (a desirable thing, according to the Boltzmann factor).

1. If $E_B > E_A$, accept the new (higher energy) configuration with probability $p = \exp\{-(E_B - E_A)/T\}$. This means that when the temperature is high, we don’t mind taking steps in the “wrong” direction, but as the temperature is lowered, we are forced to settle into the lowest configuration we can find in our neighbourhood.

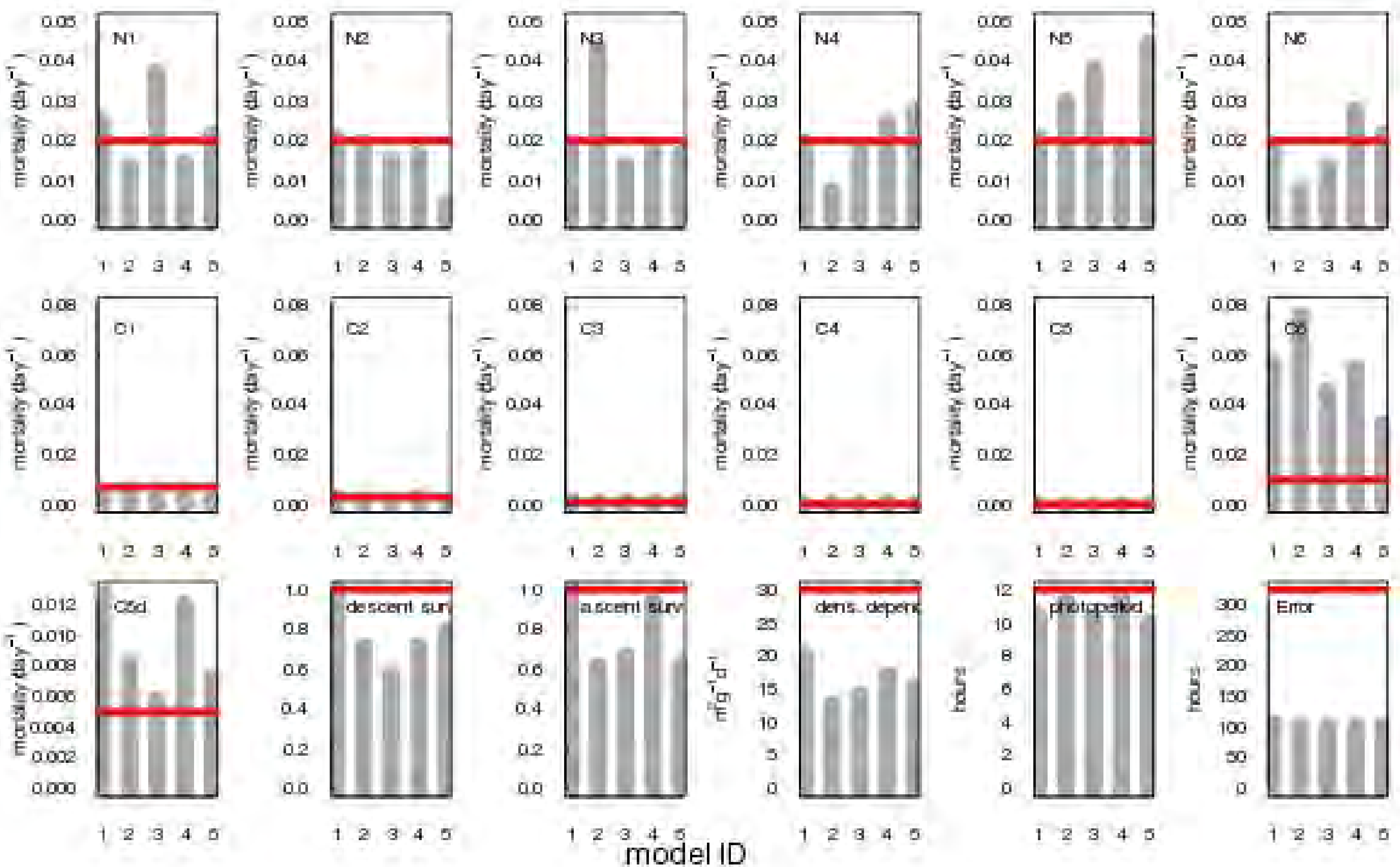
Five fitting senarios

- R1 fit stage-dependent naupliar, surface copepodite, and diapause background mortality rates, density dependent parameter, ascent photoperiod (16 parameters)
- R2 add a survivorship to ascent and descent (18 parameters)
- R3 add temperature dependent mortality parameters to fitting (21 parameters)
- R4 as R3 but turn off transport (21 parameters)
- R5 as R3 but add additional increase to N3-N4 mortality if chlorophyll is below a threshold (22 parameters)

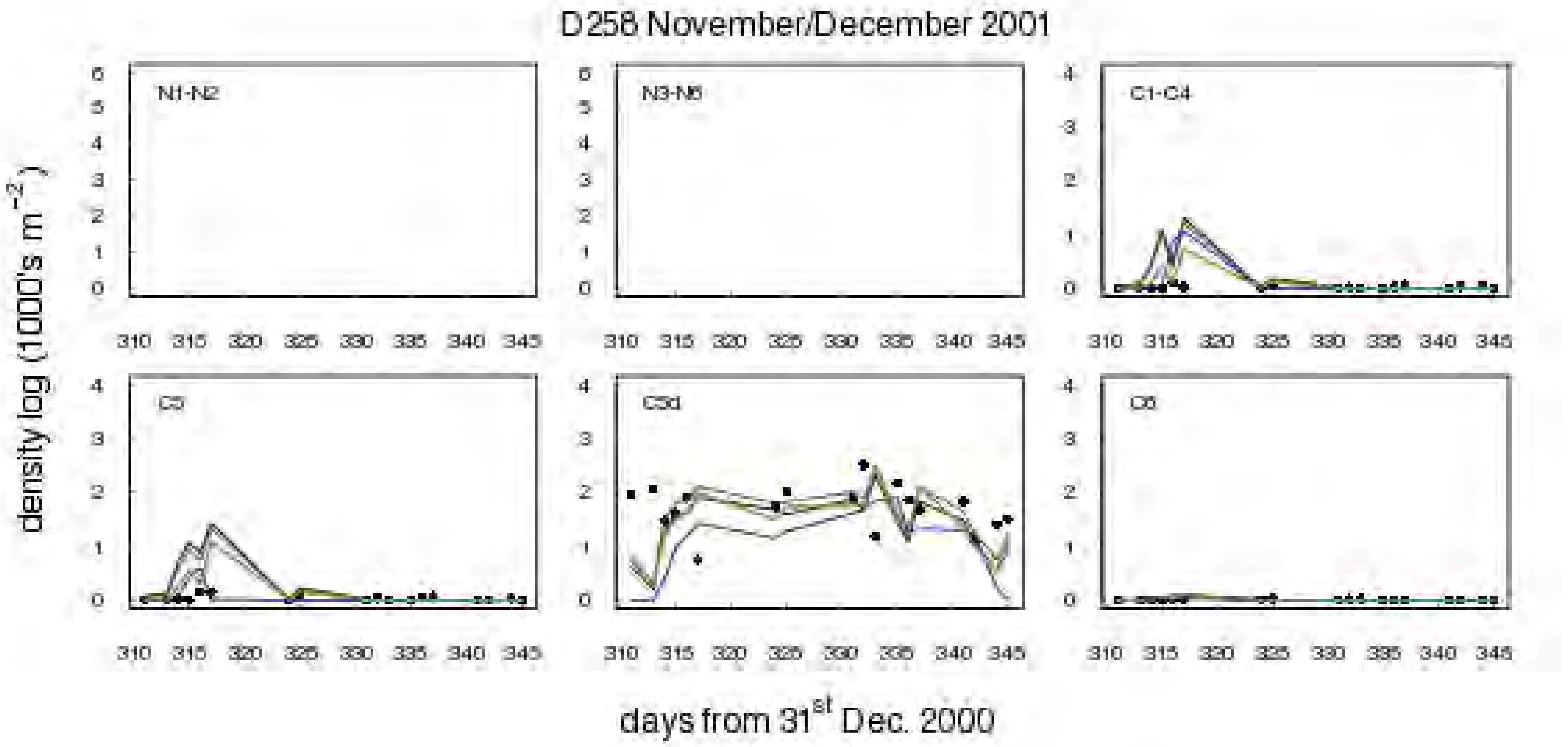
Fitting history



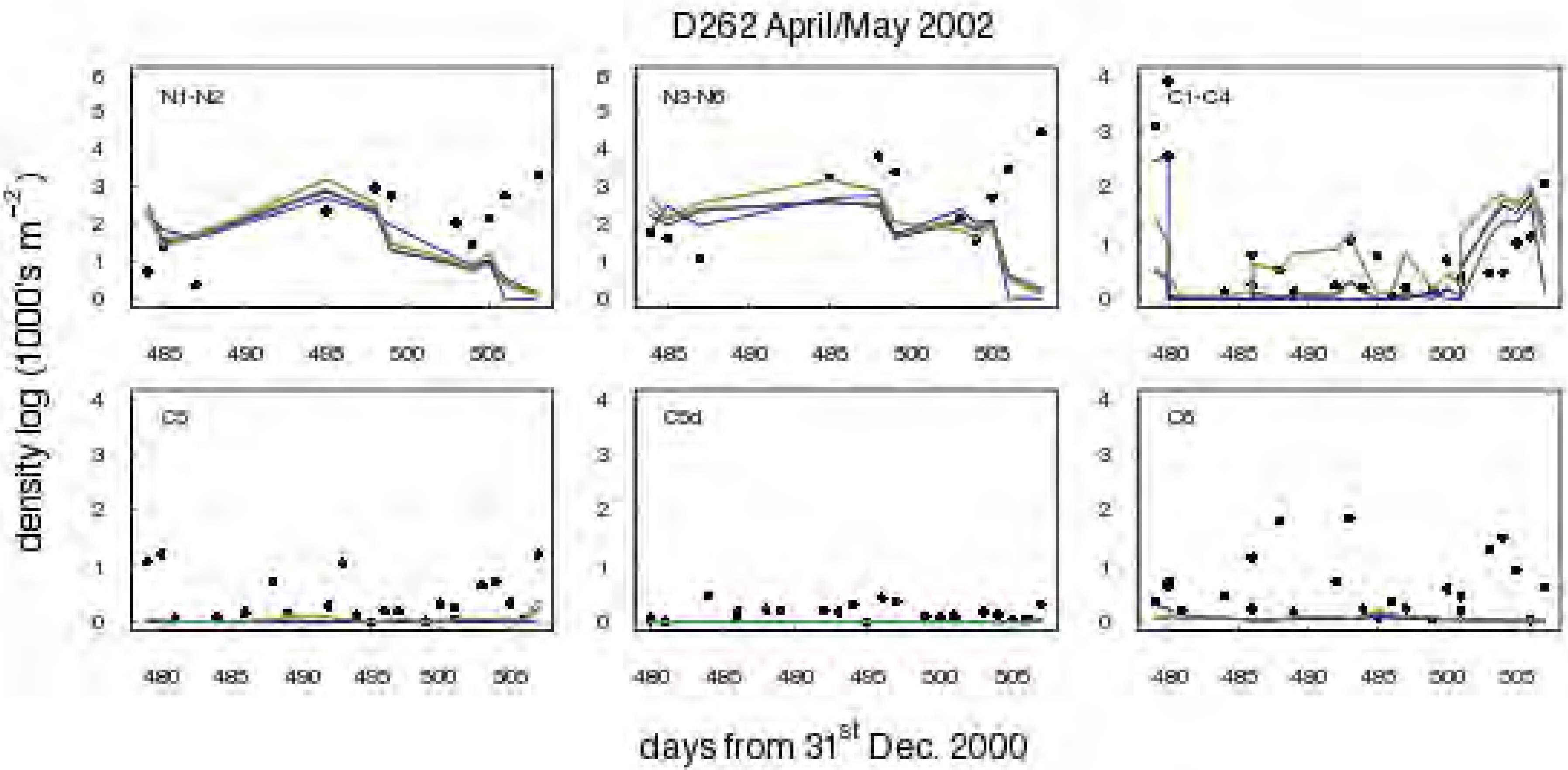
(Provisonal) Best fit parameters



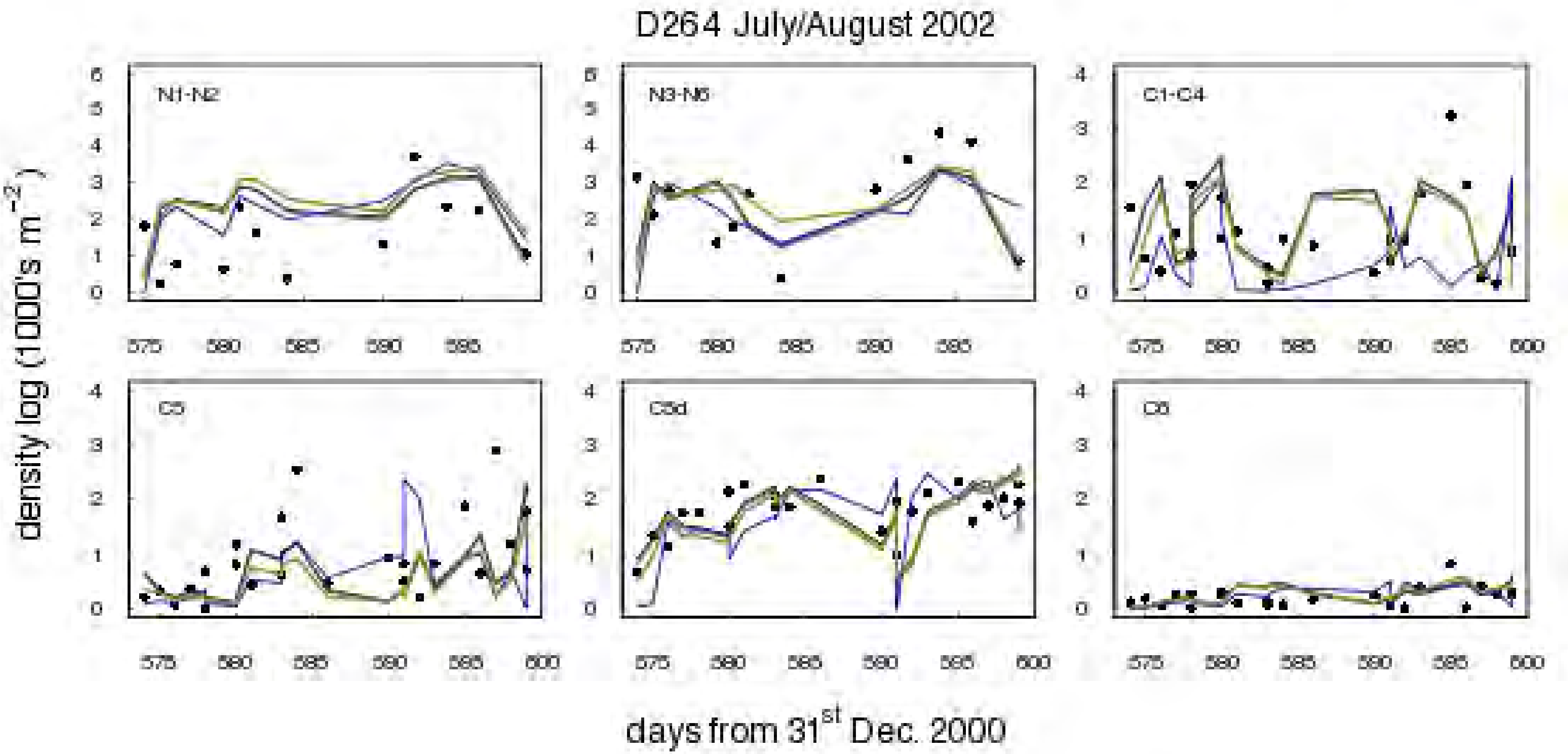
Winter 2001 observed and fitted



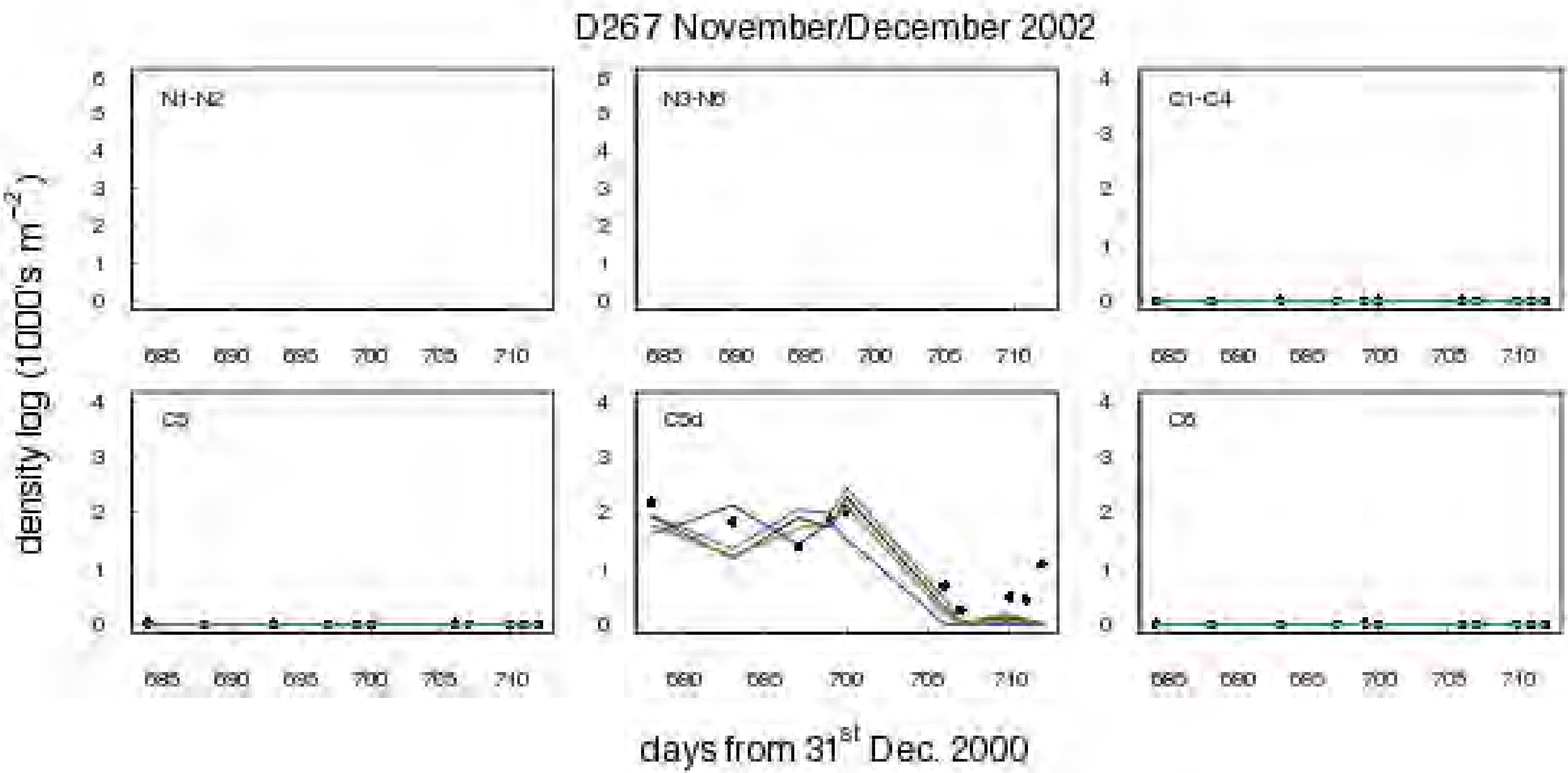
Spring 2002 observed and fitted



Summer 2002 observed and fitted



Winter 2002 observed and fitted



Conclusions

General Remarks

- Models (especially IBM's!) are often parameter rich
- Generally can only be estimated by fitting
- But data can be sparse in space and time
- This can cause problem for parameter estimation
- Simulated annealing is a powerful fitting tool
- Simple to implement and does not get trapped in local minima
- Need to pay attention to computational efficiency

(Very) Provisional Results from the Irminger Sea

- "Out-of-the-box" result was poor fit, most stages hugely over-represented
- Simulated annealing resulted in hugely improved fit
- Quality of fit unexpectedly insensitive to model variants
- Parameter compensation suggests fitting is under-constrained
- Emergence from diapause is about 10 days earlier than NS