

Catch-age Assessments

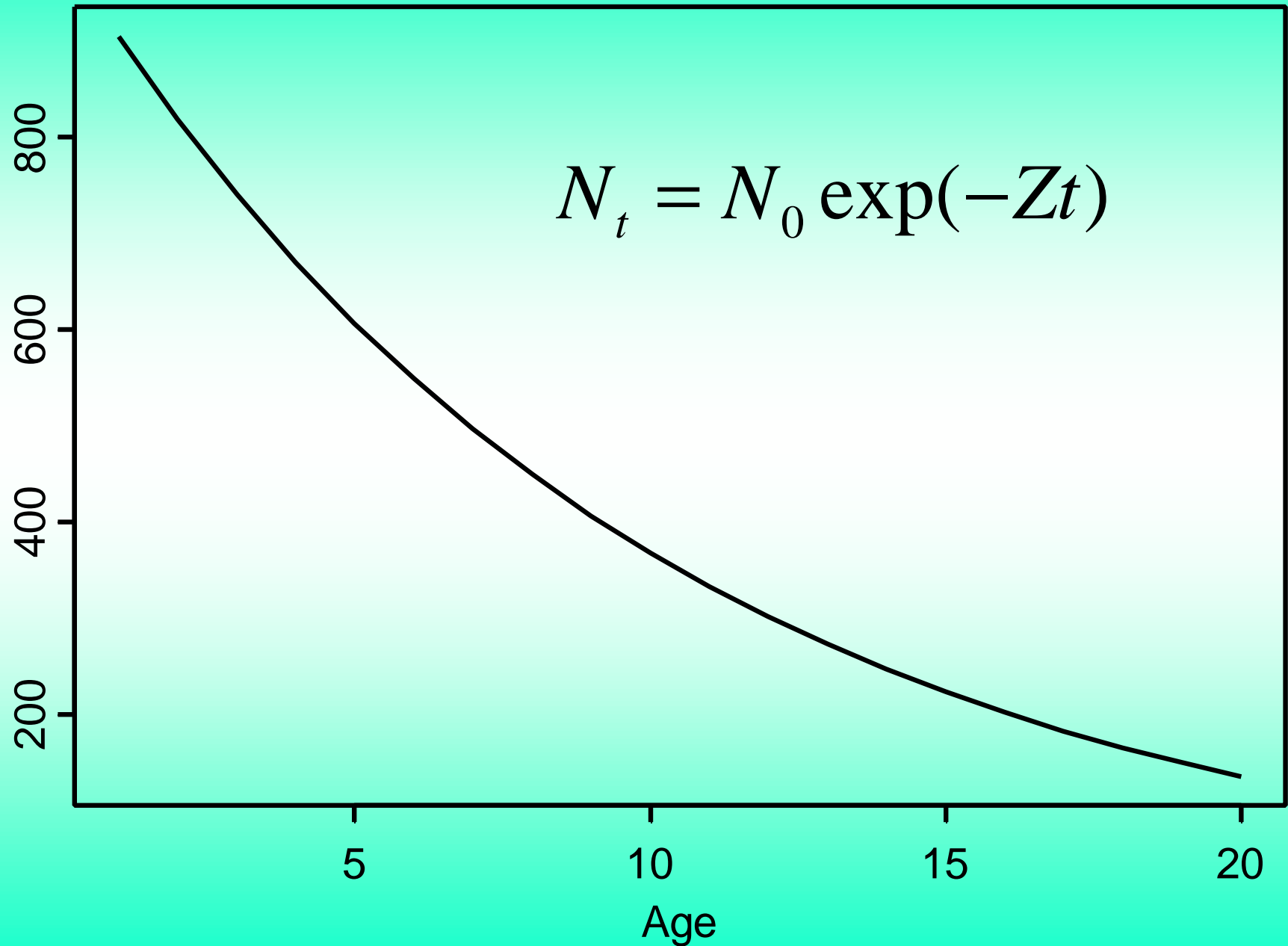
Something Familiar

Something New

Overview

- **Virtual Population Analysis**
- **Cohort Analysis**
- **CAGEAN / ADAPT**
- **Some New Ideas (AD Model Bldr.)**
- **Ref: Quinn and Deriso (1999)**
 - **Quantitative Fish Dynamics**

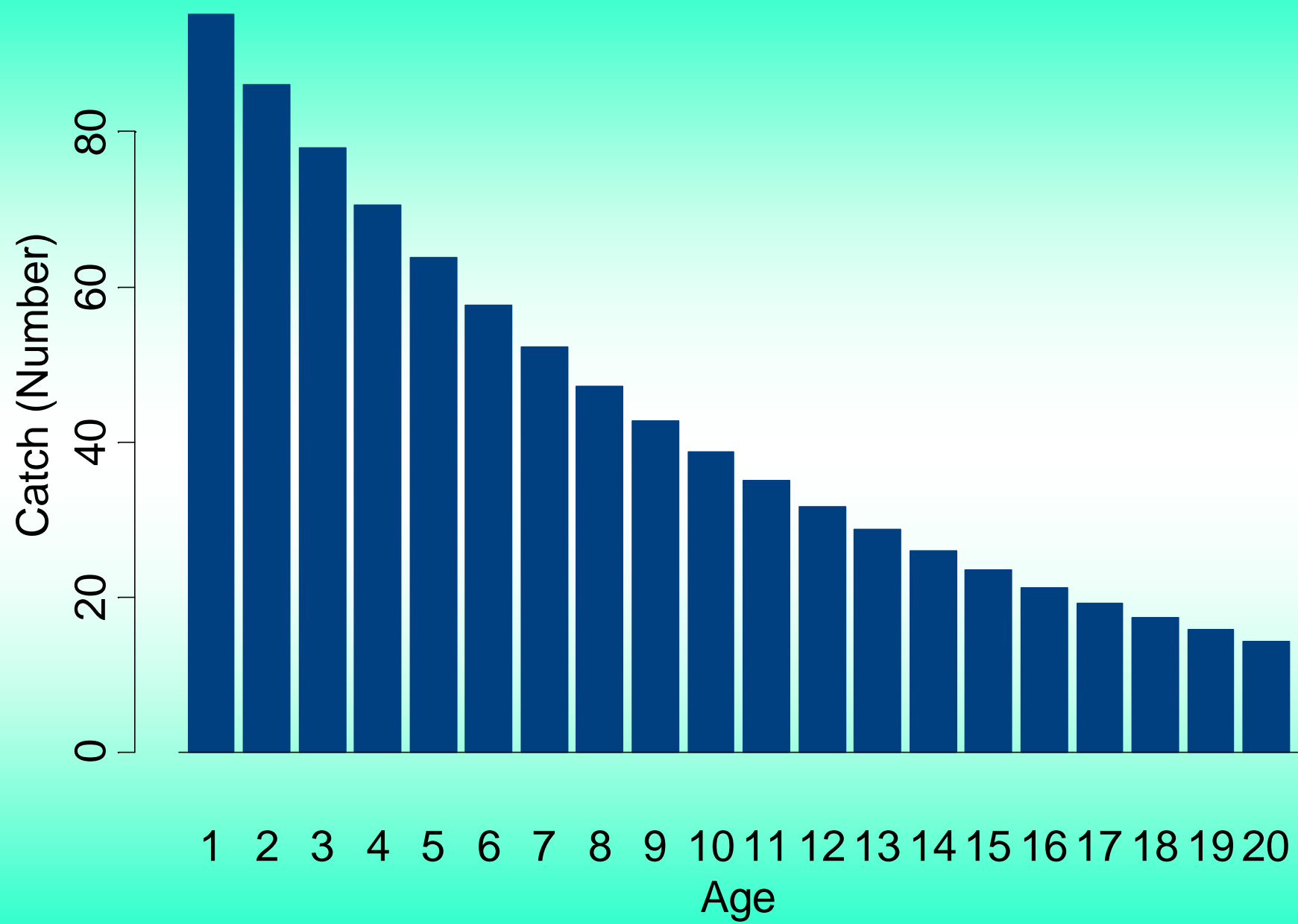
Cohort Numbers at Age



Virtual Population Analysis

$$N_{t+1} = N_t S_t$$

$$C_t = N_t (1 - S_t)$$



History of VPA

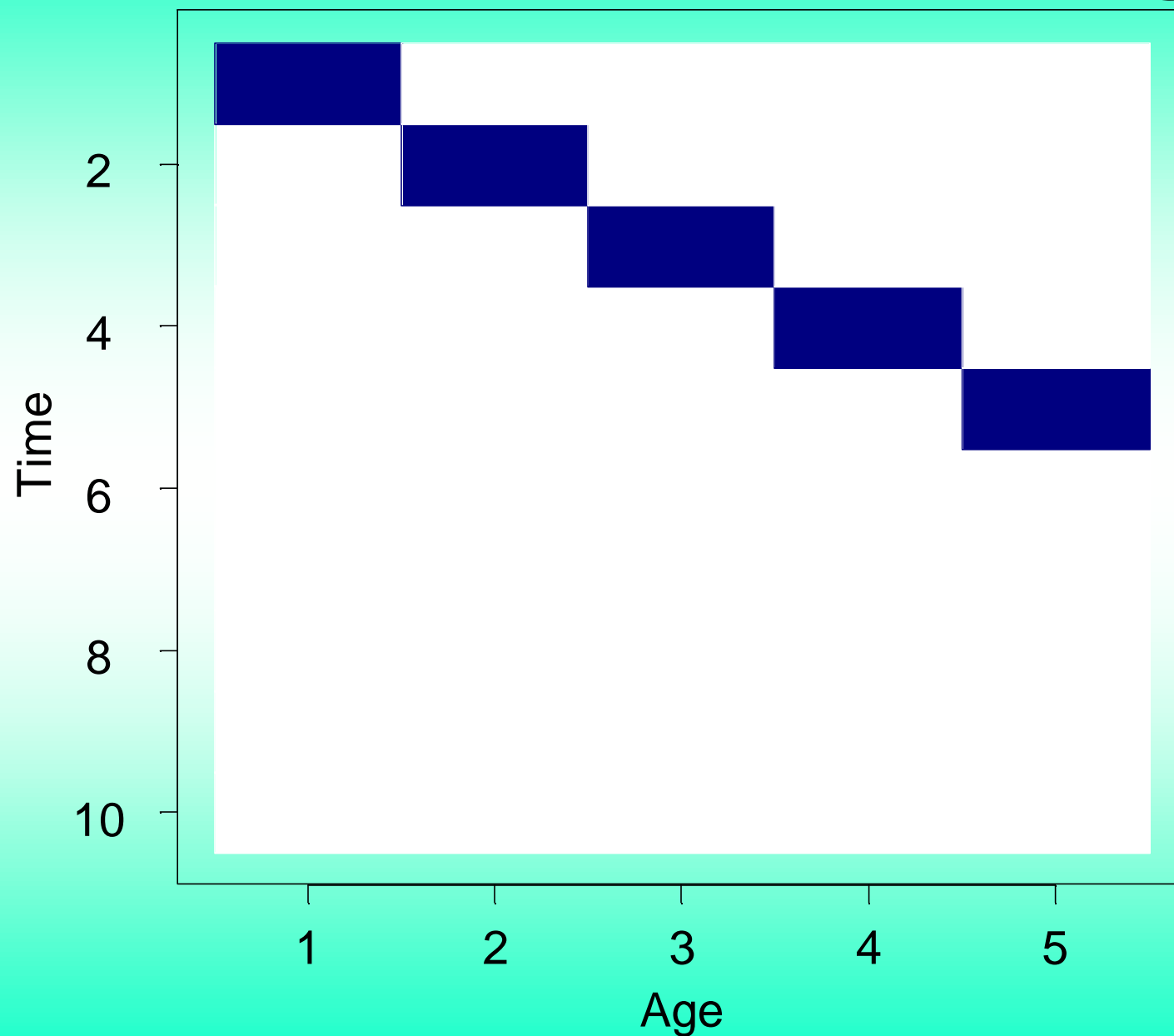
- **Virtual Population Analysis**
 - (Fry 1949)
- **Virtual Population Analysis**
 - (Gulland 1965)
- **Cohort Analysis**
 - (Pope 1972)

Baranov Catch Equation

$$N_{t+1,a+1} = N_{t,a} \exp(-(F_{t,a} + M))$$

$$C_{t,a} = \frac{F_{t,a}}{F_{t,a} + M} (1 - \exp(-(F_{t,a} + M))) N_{t,a}$$

Cohort Numbers at Age

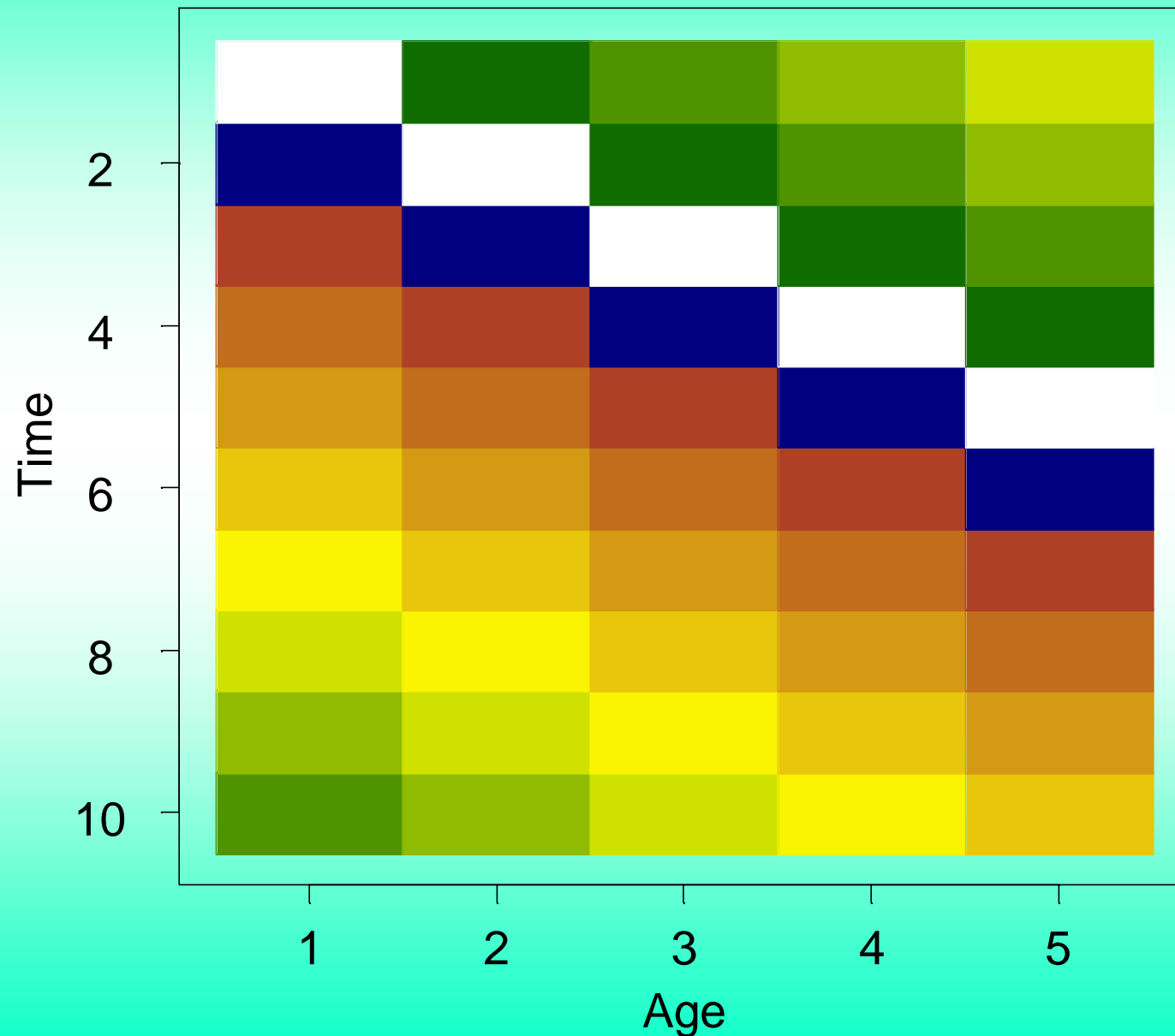


VPA

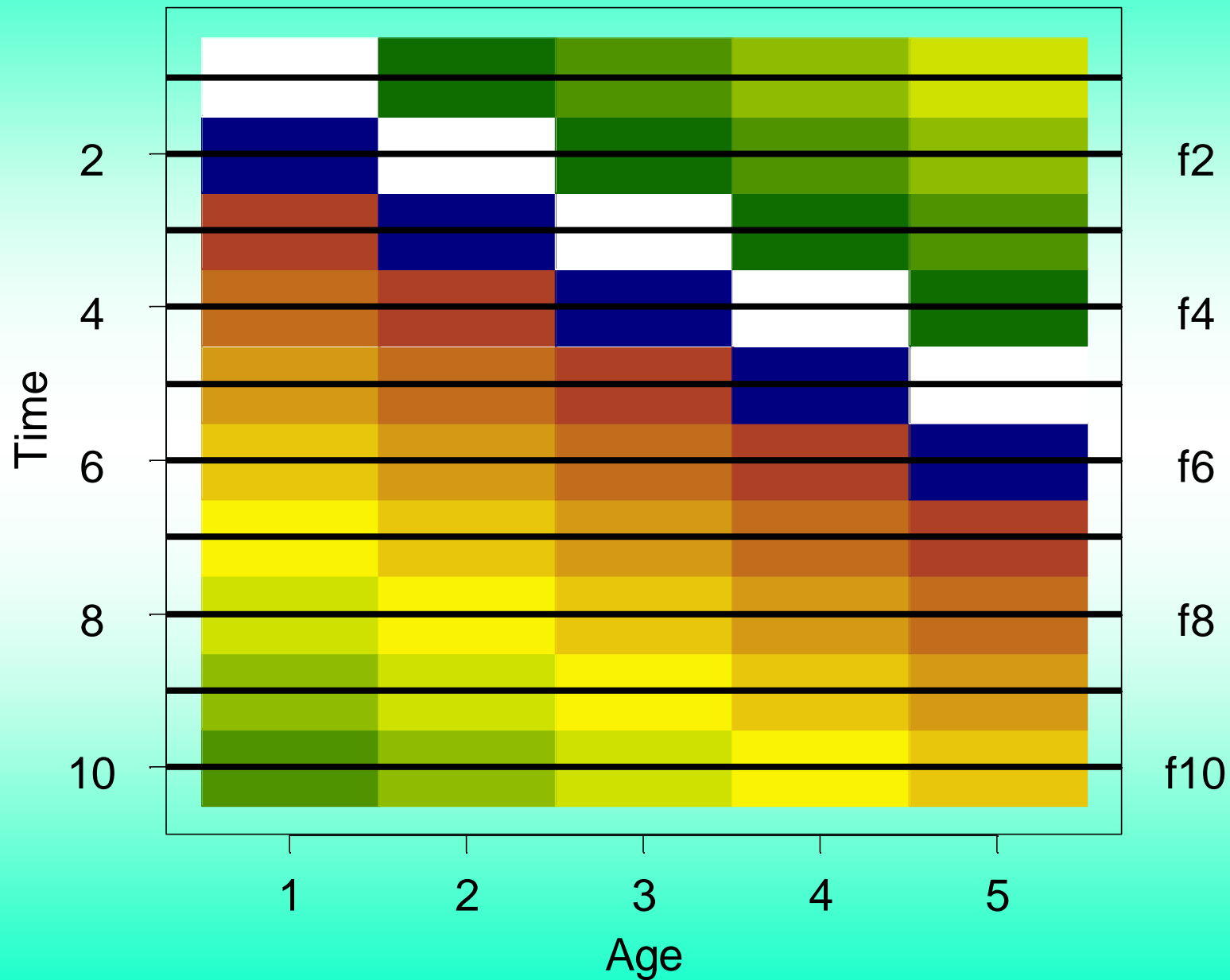
- **Number of Estimates
= Number of Observations - 1**

Statistical Catch-Age Analysis

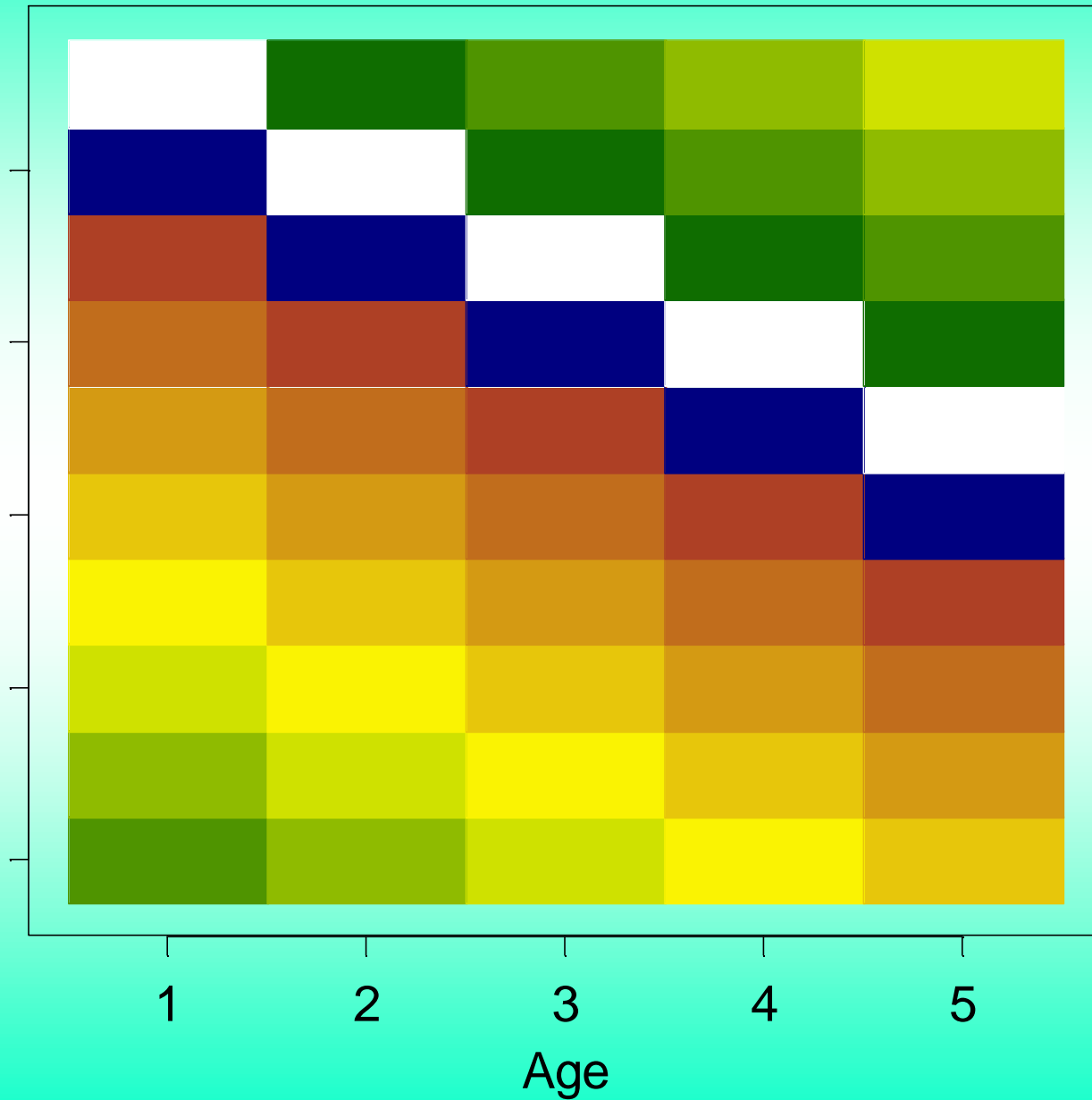
Cohort Numbers at Age



Year Effect



Age Effect

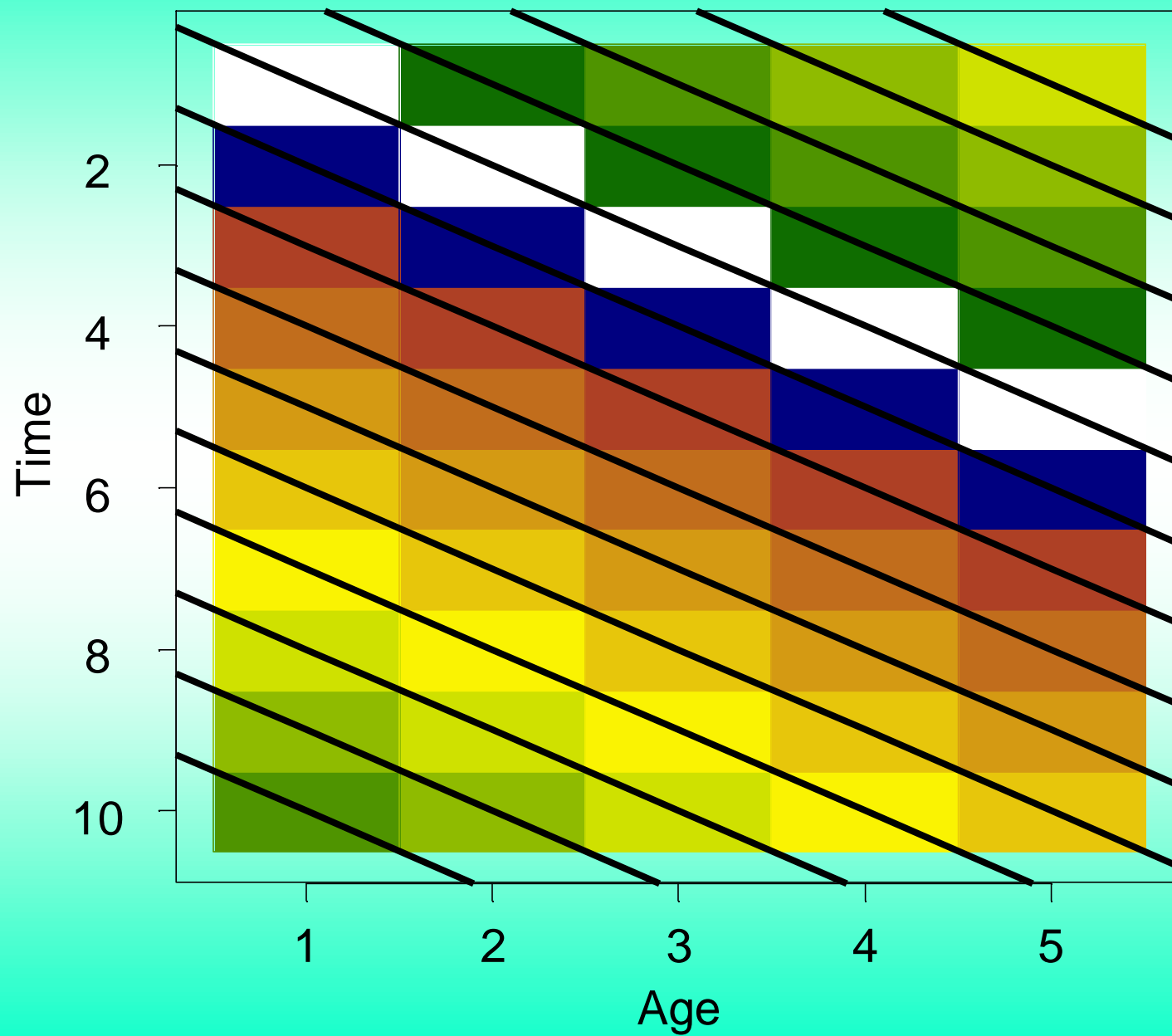


Key Structural Assumptions

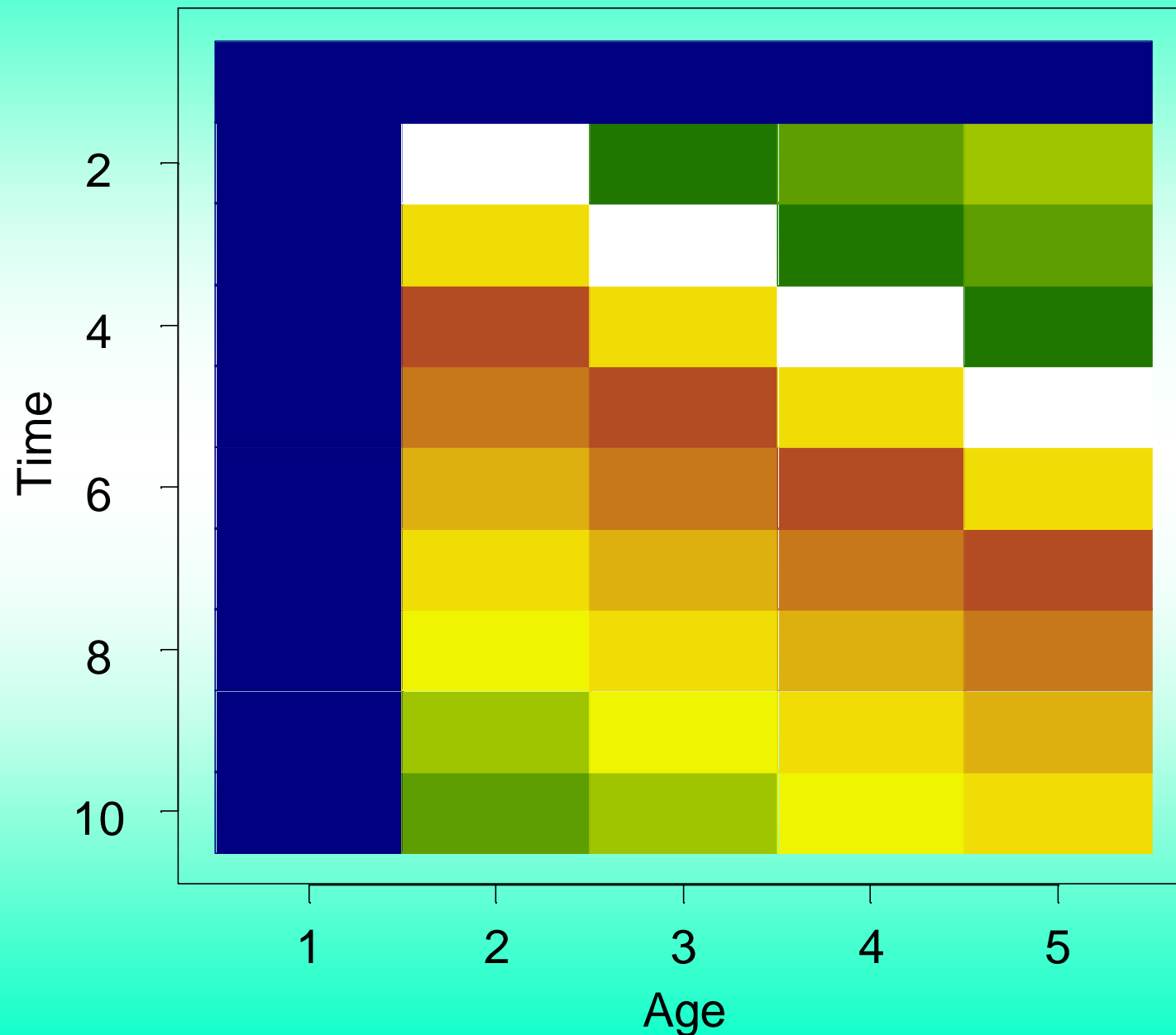
$$F_{t\ a} = f_t s_a$$

$$f_t = qE_t$$

Cohort Effect



Initial Numbers & Recruitment



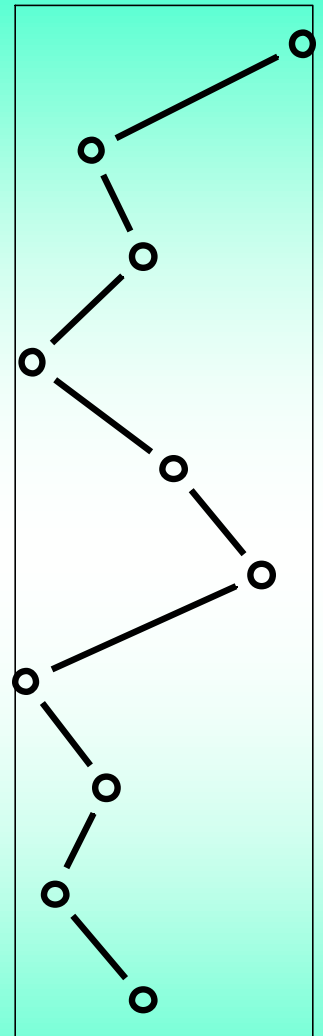
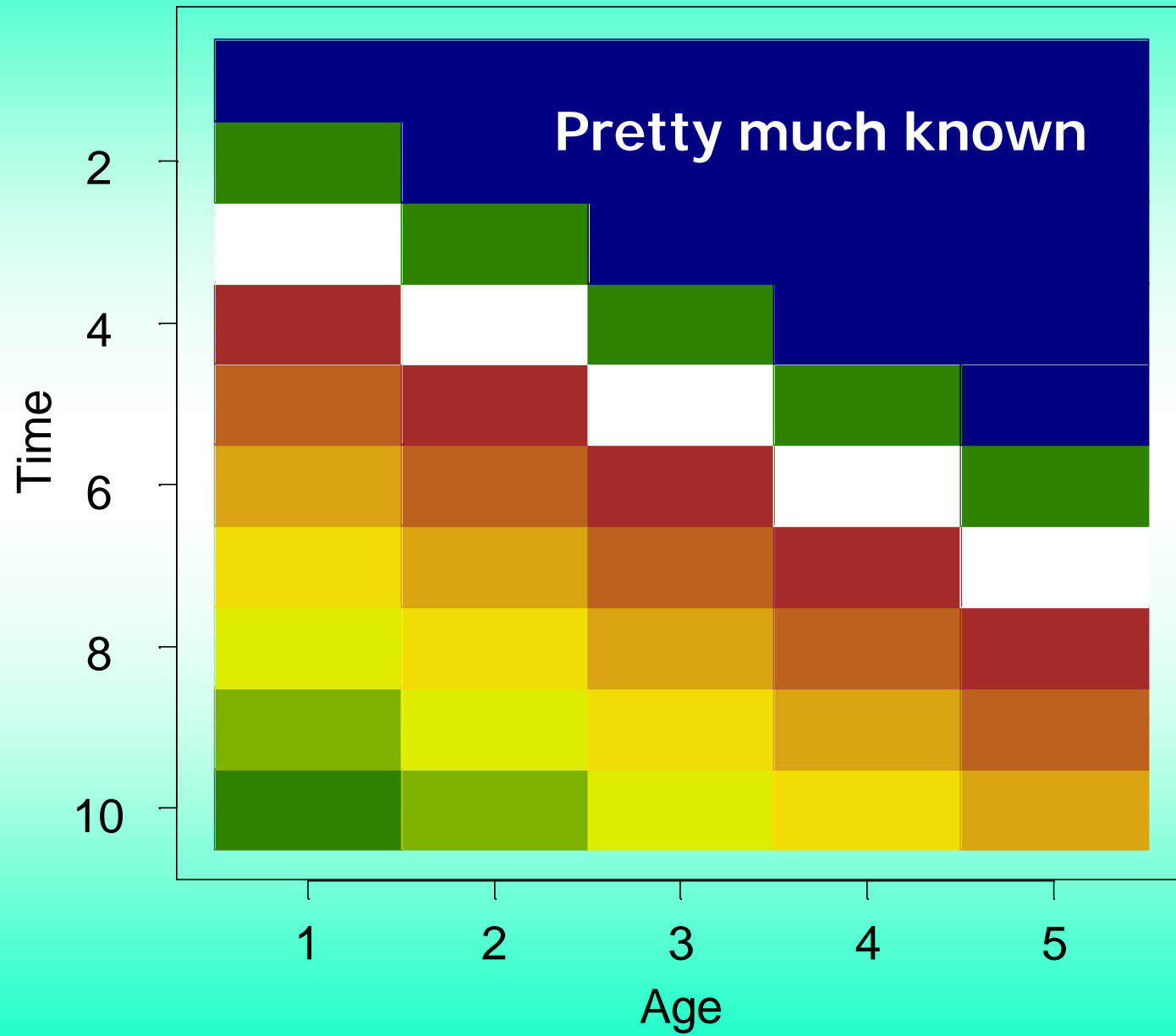
Separable Catch-Age

- **Number of Estimates**
 $= Y + A + 1 + A + Y$
 - year effect
 - age effect
 - catchability
 - initial numbers and recruitment

Catch-age Analysis with Auxiliary Information

- **Paloheimo (1980), Dupont (1983),
Fournier and Archibald (1982),
Deriso, Quinn, and Neal (1985)**

CPUE



Objective Function (Effort)

$$SS_{Catch} = \sum_{t,a} (\log(C_{t,a}) - \log(\hat{C}_{t,a}))^2$$

$$SS_{Effort} = I \sum_t (\log(E_t) - \log(\hat{q}) - \log(\hat{f}_t))^2$$

$$SS_{Total} = SS_{Catch} + SS_{Effort}$$

Objective Function (CPUE)

$$SS_{Catch} = \sum_{t,a} (\log(C_{t,a}) - \log(\hat{C}_{t,a}))^2$$

$$SS_{CPUE} = I \sum_t (\log(CPUE_t) - \log(CPUE\hat{E}_t))^2$$

$$SS_{Total} = SS_{Catch} + SS_{CPUE}$$

Catch-age Programs Using Auxiliary Information

- **CAGEAN (Statistical Catch-age)**
- **ADAPT (VPA)**

**So what the heck is
AD Model Builder?**

AD Model Builder

- **Model builder, not a model**
- **Template to C++**
- **Parameter Estimation via Optimization**
 - Least squares
 - Maximum likelihood
- **Automatic differentiation**

DATA_SECTION

init_int nobs

init_vector Y(1,nobs)

init_vector X(1,nobs)

PARAMETER_SECTION

init_number a

init_number b

vector pred_Y(1,nobs)

objective_function_value SS

PROCEDURE_SECTION

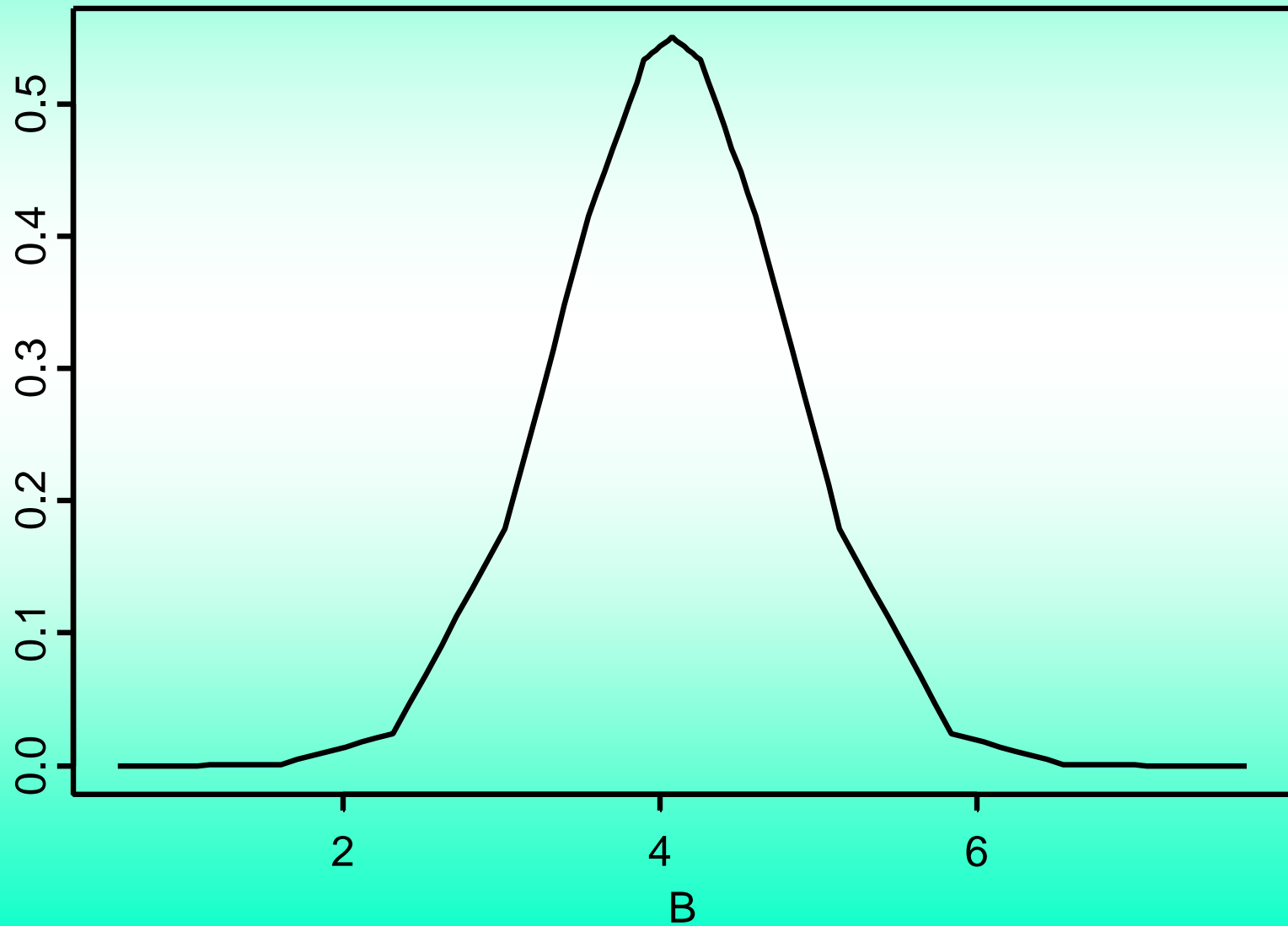
pred_Y=a*X+b;

SS=norm2(pred_Y-Y);

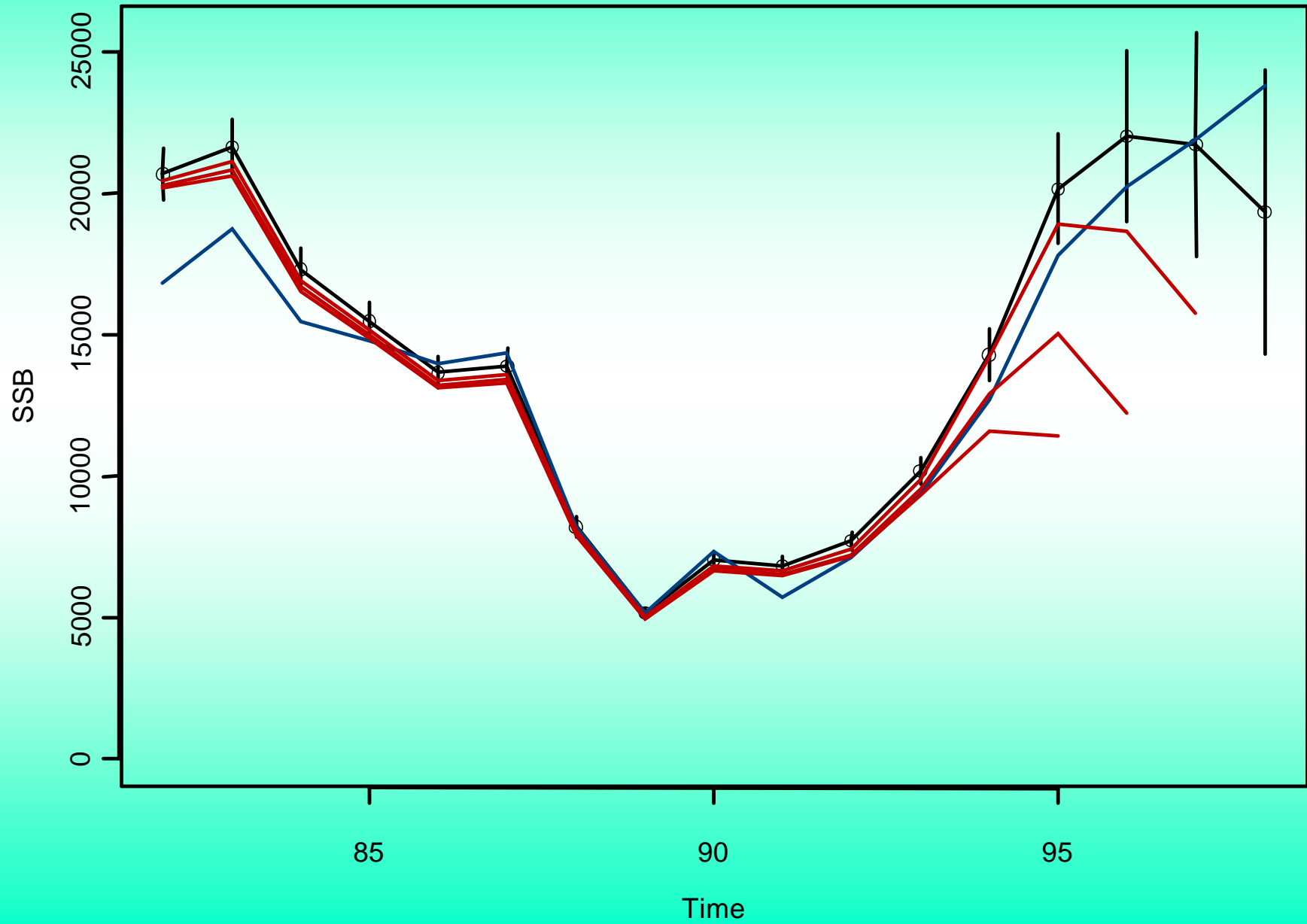
Fournier's Philosophy

- **"Easier" Programming (than C++)**
- **Efficient Optimization**
- **One Step at a Time**
 - **Phases**
 - **Large Scale then Small Scale**
- **Other Features**
 - **Profile Likelihoods**
 - **Linear Approximation of Parameter Standard Deviations**
 - **Markov Chain Monte Carlo**

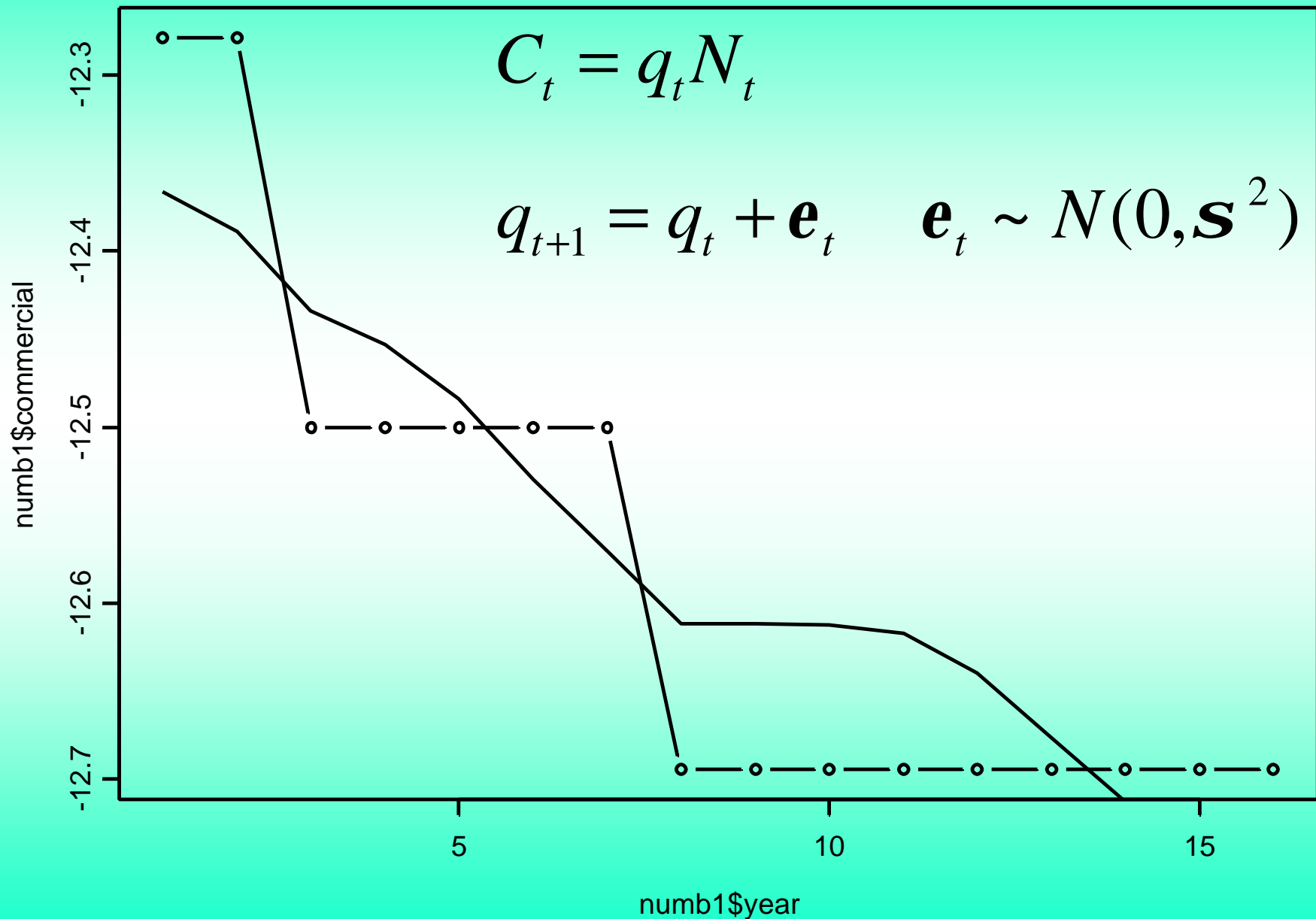
Likelihood Profile



Spawning Stock Biomass



Walleye Catchability



A New Paradigm

- Opening the black box!
- AD Model
 - Template to C++
 - Facilitates model development
- No longer restricted to small class of standard models
- Powerful, but rules of statistics still apply!!!

