# Introduction to the **COLERAINE** stock assessment model

Arni Magnusson

# Overview

**MODEL**

- generalized equations
- Excel user interface
- Bayesian parameter estimation
- AD Model Builder optimization

**DATA**

- catch by age/length, biomass indices
- stratification by sex and gears
- priors for estimated parameters
- values of fixed parameters

**OUTPUT**

- max likelihood point estimates
- MCMC posterior likelihood profiles
- projections of harvest strategies

**APPLICATION**

- Icelandic cod data

# Background

| | |
|---|---|
| Ray Hilborn<br>Professor, Univ. of Wash. | ***Theory & application*** |
| Mark Maunder<br>Ph.D. student, Univ. of Wash. | ***Programming & application*** |
| Ana Parma<br>Int. Pac. Halibut Comm. | ***Theory*** |
| Billy Ernst<br>Ph.D. student, Univ. of Wash. | ***Programming & application*** |
| John Payne<br>Ph.D. student, Univ. of Wash. | ***User interface*** |
| Paul Starr<br>New Zeal. Seaf. Ind. Council | ***Application*** |

# Generalized model

Coleraine can be used to model a wide variety of stocks. The model may or may not be

- sex-specific
- gear-specific
- fitted to data from commercial landings
  and/or research surveys
  and/or CPUE
- fitted to age and/or length data

# Population dynamics

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

$N$ : population size

$a$ : age

$t$ : year

$M$ : natural mortality rate

$u$ : harvest rate

# Harvest rate and landings

$$u_t = \frac{C_t}{e^{-0.5M} \sum_a s_a N_{a,t} w_{a,t}}$$

$u$ : harvest rate

$t$ : year

$C$ : landings

$M$ : natural mortality rate

$N$ : population size

$s$ : selectivity

$a$ : age

$w$ : weight

# Age distribution in first year

recruits $$N_{1,1} = \omega \; R_0$$

intermediate age classes $$N_{a,1} = N_{1,1} \, e^{-M(a-1)}$$

plus group $$N_{a,1} = \frac{N_{1,1} \, e^{-M(A-1)}}{1 - e^{-M}}$$

$N$ : population size

$\omega$ : initial recruitment fraction

$R_0$ : virgin recruitment

$a$ : age

$M$ : natural mortality rate

$v_{init}$ : initial selectivity

$u_{init}$ : initial harvest rate

$A$ : maximum age

# Population constructed

$N_{1,1} = R_0$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
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# Population constructed

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
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# Population constructed

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | |
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# Population constructed

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

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|---|---|---|---|---|---|---|---|---|---|---|
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| 1991 | | | | | | | | | | |
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# Population constructed

$$N_{1,1} = R_0$$

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$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Population constructed

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

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|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | | | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
| 1993 | | | | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | | | | | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | | | | | | 138 | 77 | 43 | 25 | 41 |
| 1996 | | | | | | | 73 | 40 | 23 | 35 |
| 1997 | | | | | | | | 43 | 24 | 34 |
| 1998 | | | | | | | | | 24 | 32 |
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| 2005 | | | | | | | | | | |

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Recruitment

$$N_{1,t+1} = \frac{S_t}{\alpha + \beta S_t}$$

$N_1$ : recruits

$t$ : years

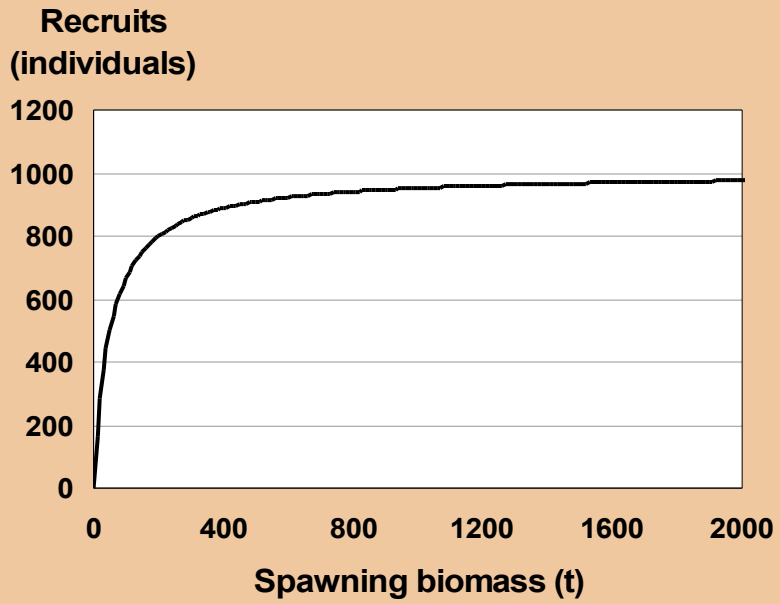
$S$ : spawning biomass

$\alpha$ : shape parameter (1 / initial slope)

$\beta$ : shape parameter (1 / asymptote)

# Beverton-Holt

$$N_{1,t+1} = \frac{S_t}{\alpha + \beta S_t}$$




$N_1$ : recruits

$t$ : years

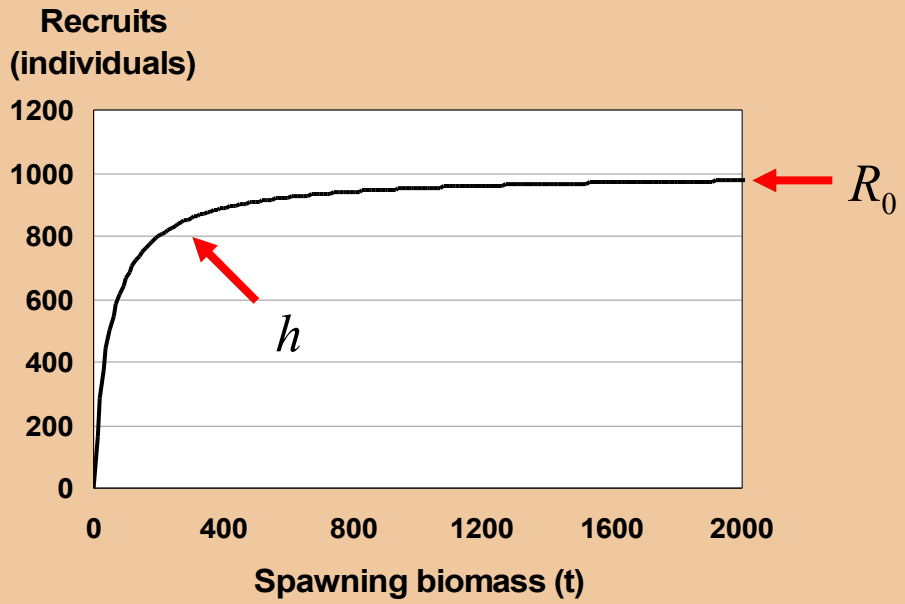
$S$ : spawning biomass

$\alpha$ : shape parameter (1 / initial slope)

$\beta$ : shape parameter (1 / asymptote)

# Reparametrized Beverton-Holt

$$N_{1,t+1} = \frac{S_t}{\alpha + \beta S_t}$$




$$N_{1,t+1} = f(S_t \mid R_0, h)$$

$R_0$ : virgin recruitment

$h$ : slope parameter (by definition $0.2 \leq h \leq 1.0$)

# Spawning biomass

$$S_t = \sum_a N_{a,t} \Phi_a w_{a,t}$$

$S$ : spawning biomass

$N$ : population size

$a$ : age

$t$ : years

$\Phi$ : fraction mature

$w$ : weight

# Population constructed

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
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$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Population constructed

$$N_{1,1} = R_0$$

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$$N_{1,t+1} = f(S_t \mid R_0, h)$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
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| 1993 | 989 | 256 | 154 | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | 723 | 371 | 564 | 117 | 64 | 138 | 77 | 43 | 25 | 41 |
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

Harvest rate

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Harvest rate

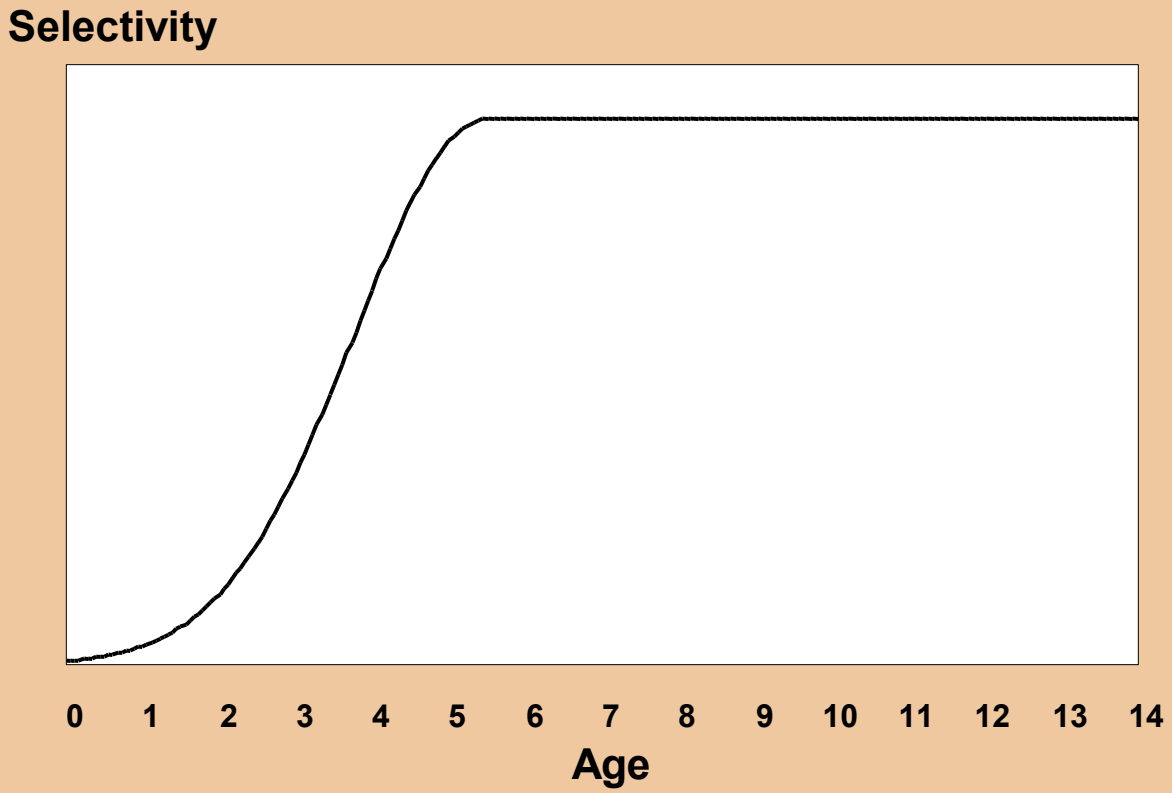
$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

$$u_{a,t} = u_t s_{a,t}$$  selectivity

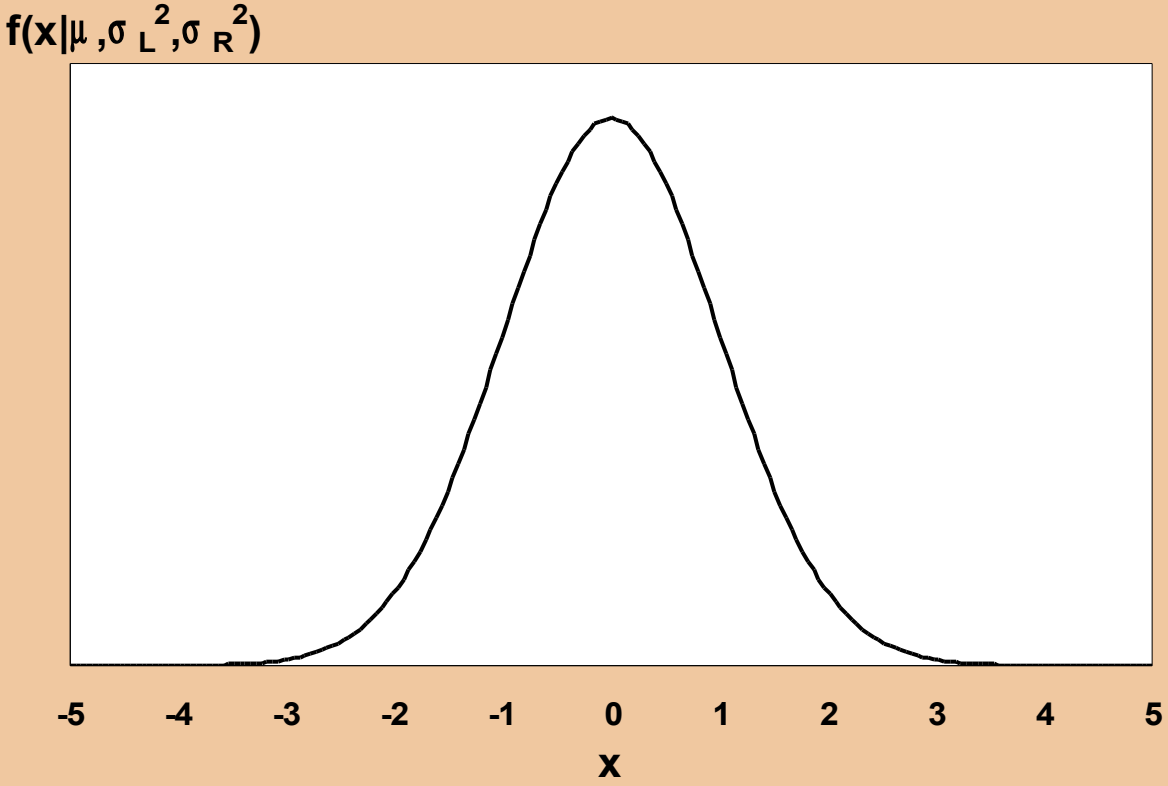
$$u_t = \frac{Y_t}{e^{-0.5M} \sum_a s_{a,t} N_{a,t} w_{a,t}}$$

# Selectivity

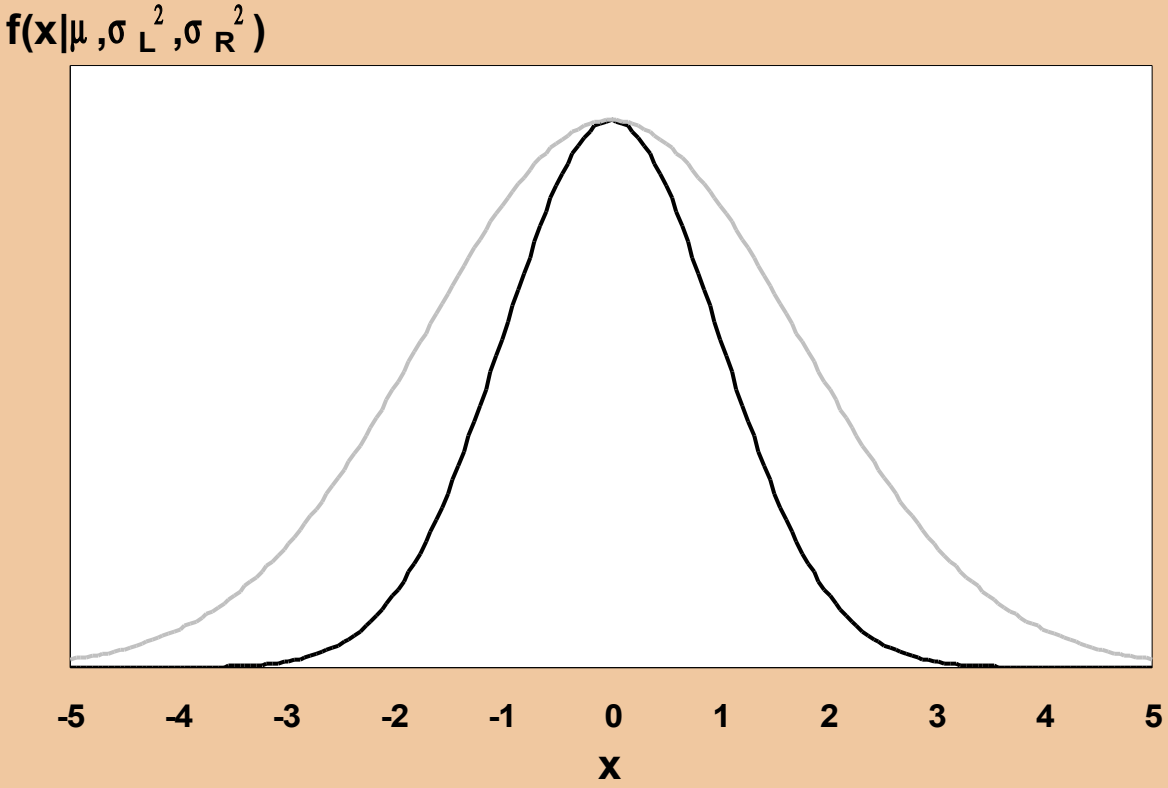
Proportional harvest rate



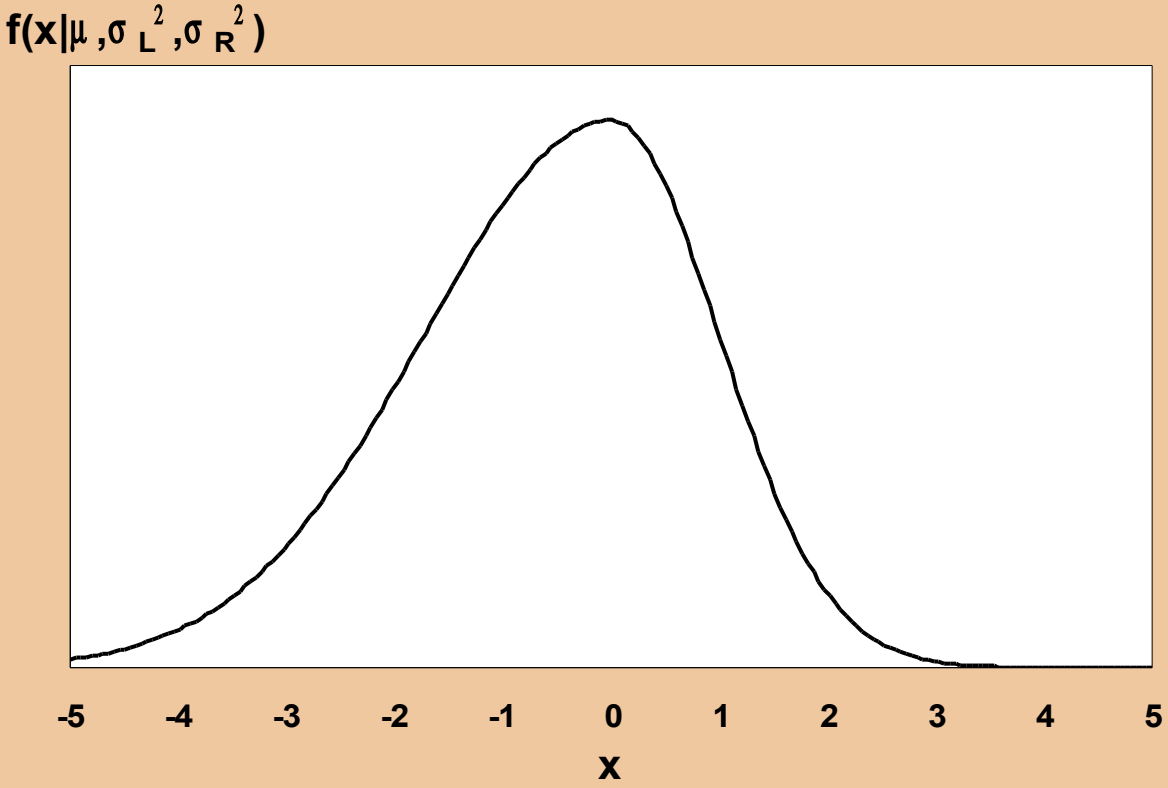
# Normal distribution



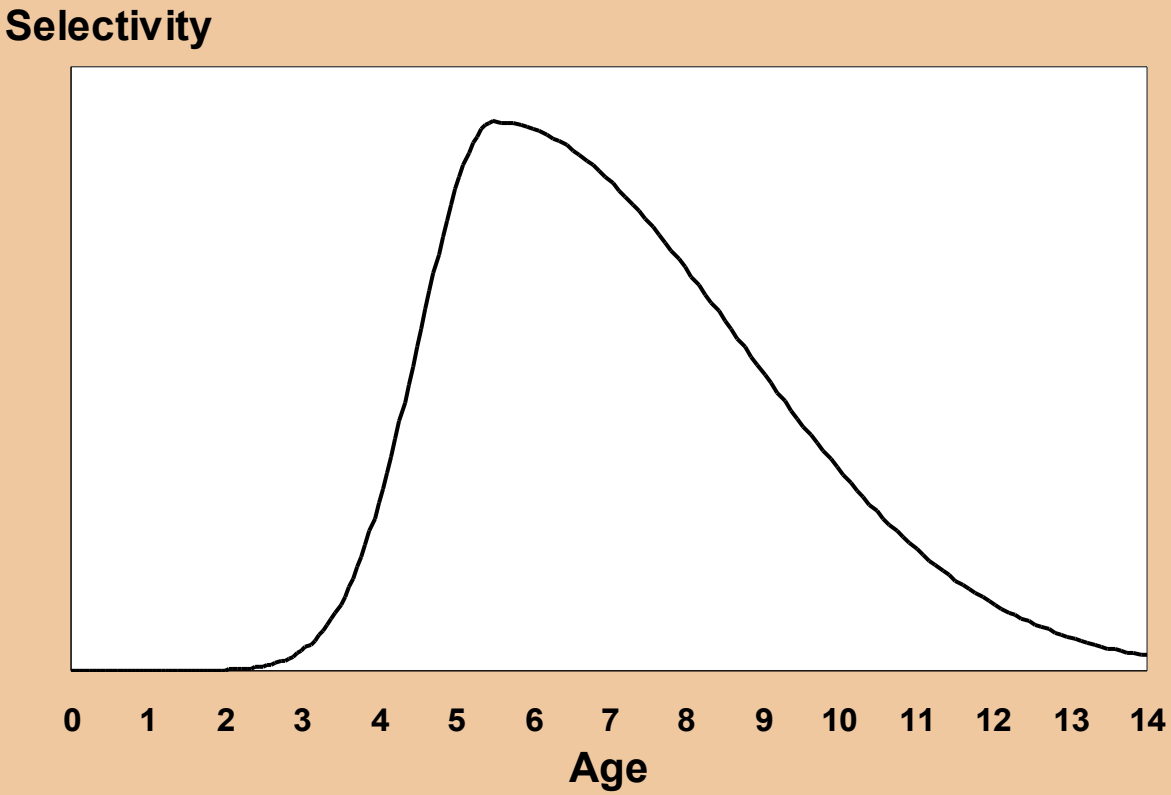
# Different variance



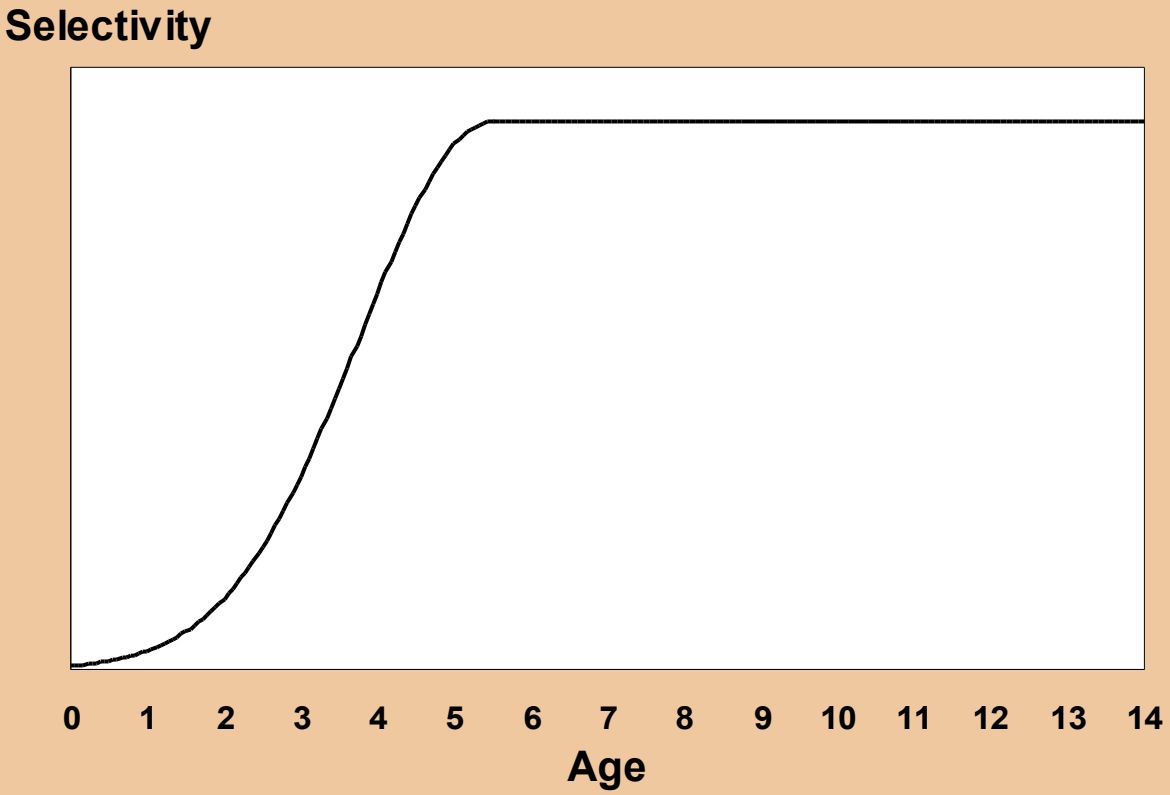
# Asymmetric normal



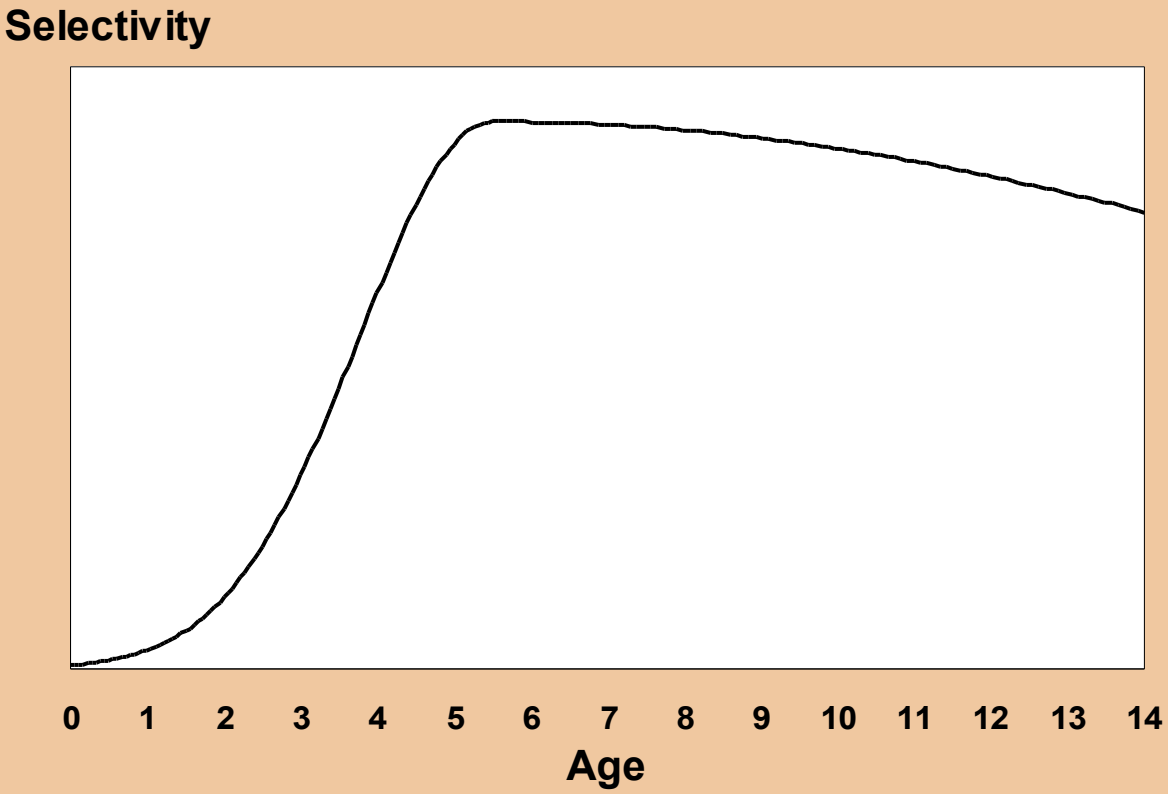
# Gillnet



# Bottom trawl



# Bottom trawl



# Estimated parameters

Virgin recruitment

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

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| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

Selectivity parameters: Sleft, Sfull, Sright

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t}) \qquad u_{a,t} = u_t s_{a,t}$$

# User interface

## Excel

Maincode.xls

Template.xls

Graph.xls

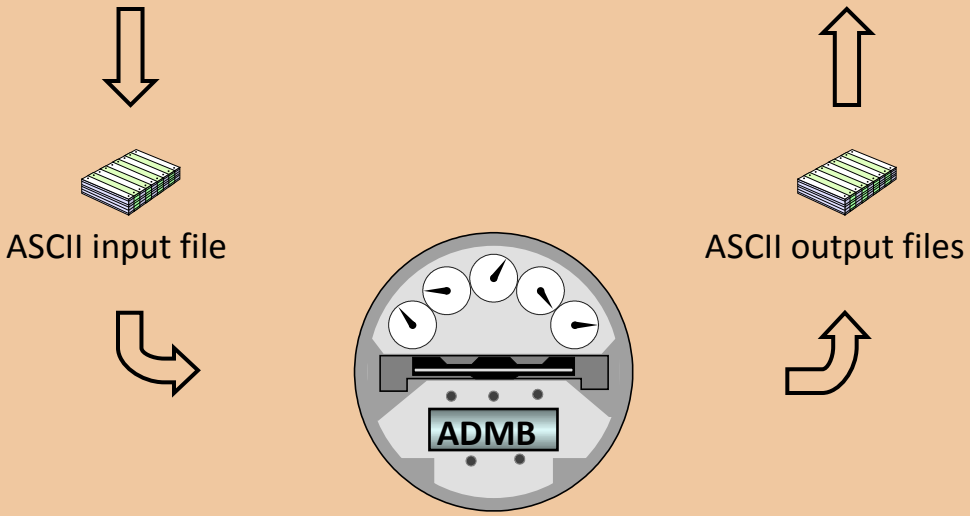
Tracker.xls

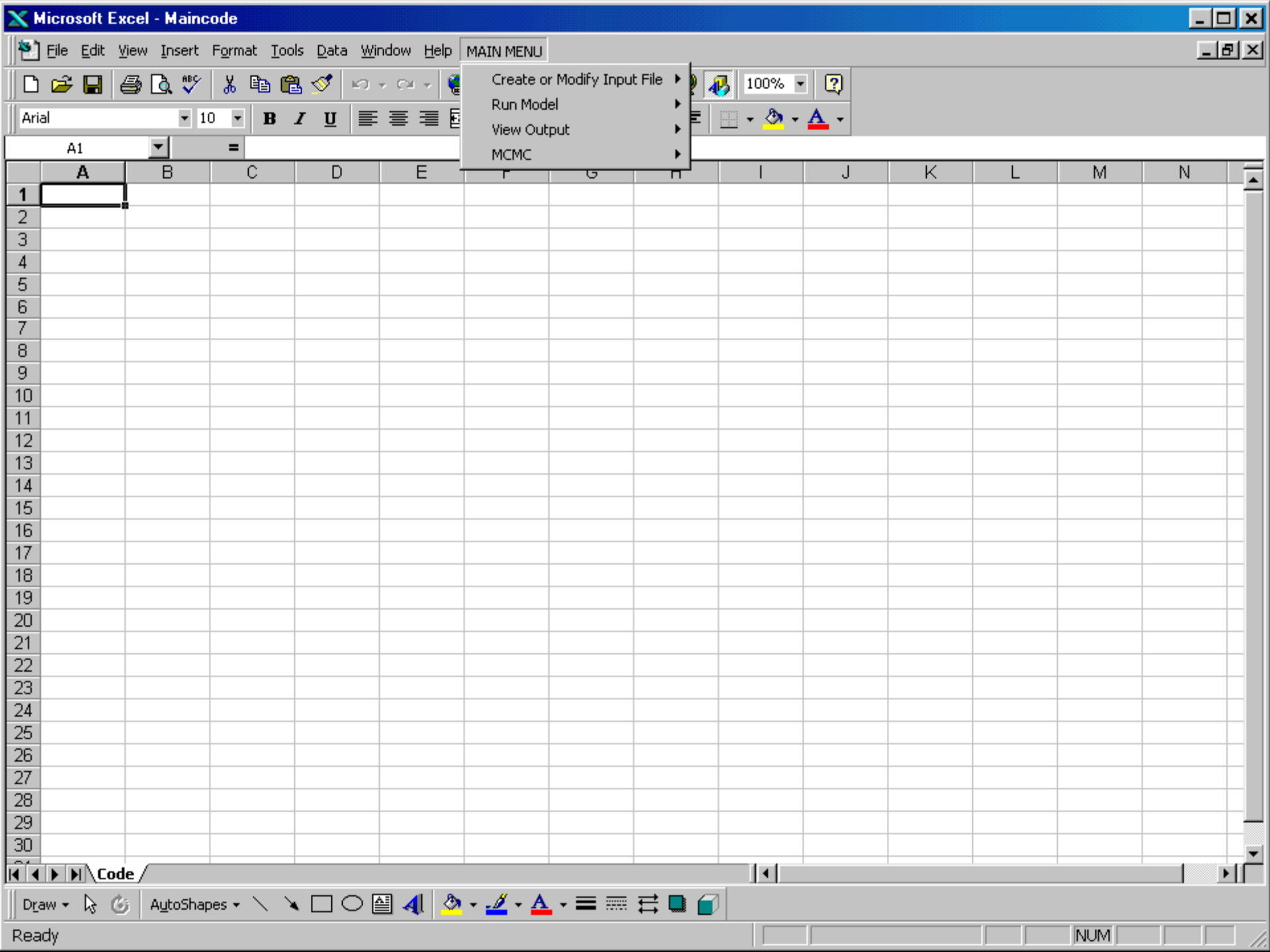
**DATA INPUT**

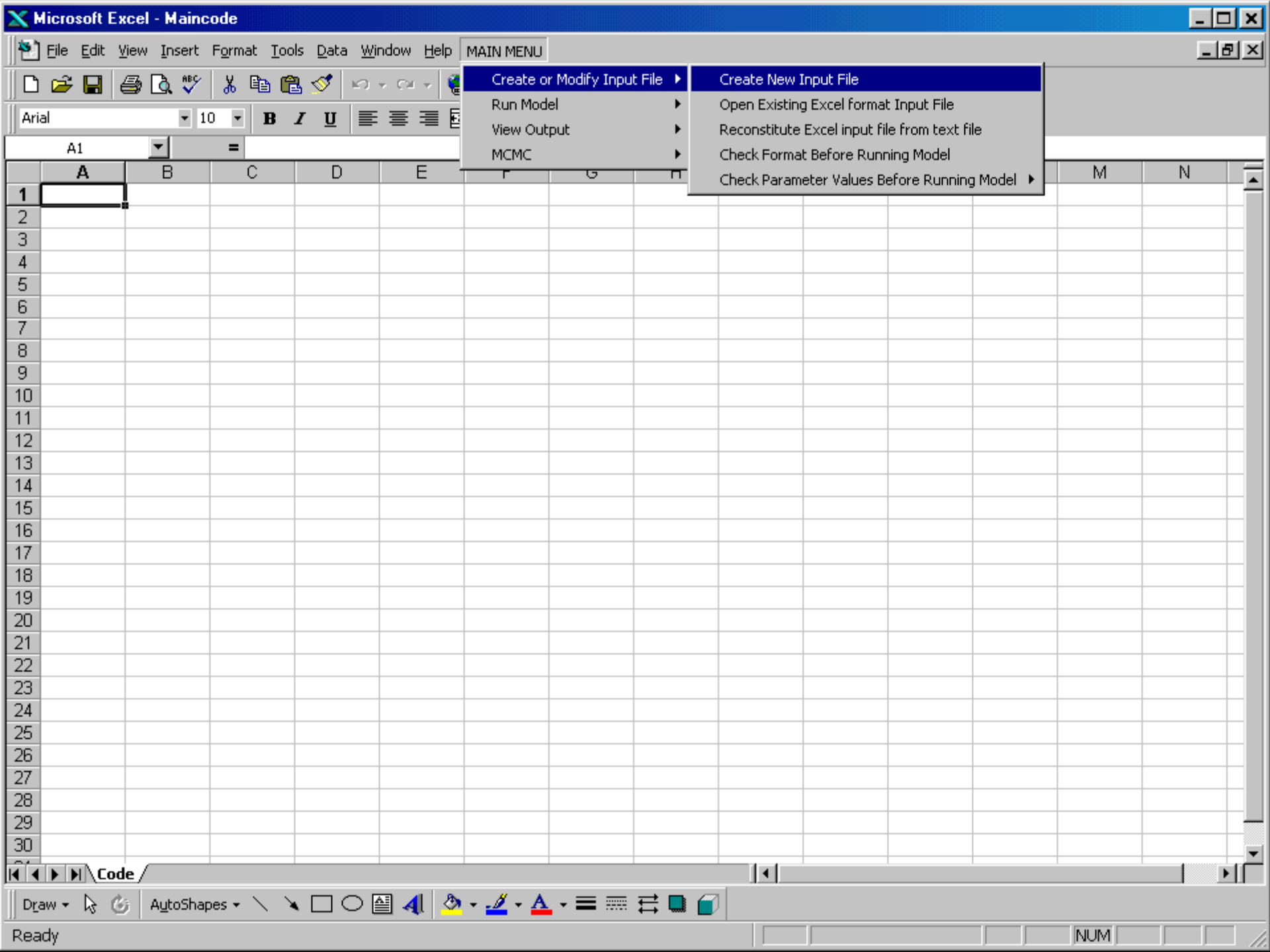
*Model specifications*
*Priors for estimated parameters*
*Values of fixed parameters*

**MODEL OUTPUT**

*Parameter estimates*
*Derived statistics*
*Diagnostic graphs*




Microsoft Excel - Maincode
File Edit View Insert Format Tools Data Window Help
MAIN MENU
Create or Modify Input File
Run Model
View Output
MCMC
100%
Arial
10
A1
Code
Draw
AutoShapes
Ready
NUM


Microsoft Excel - Maincode
File Edit View Insert Format Tools Data Window Help
MAIN MENU
Create or Modify Input File
Run Model
View Output
MCMC
Create New Input File
Open Existing Excel format Input File
Reconstitute Excel input file from text file
Check Format Before Running Model
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Code
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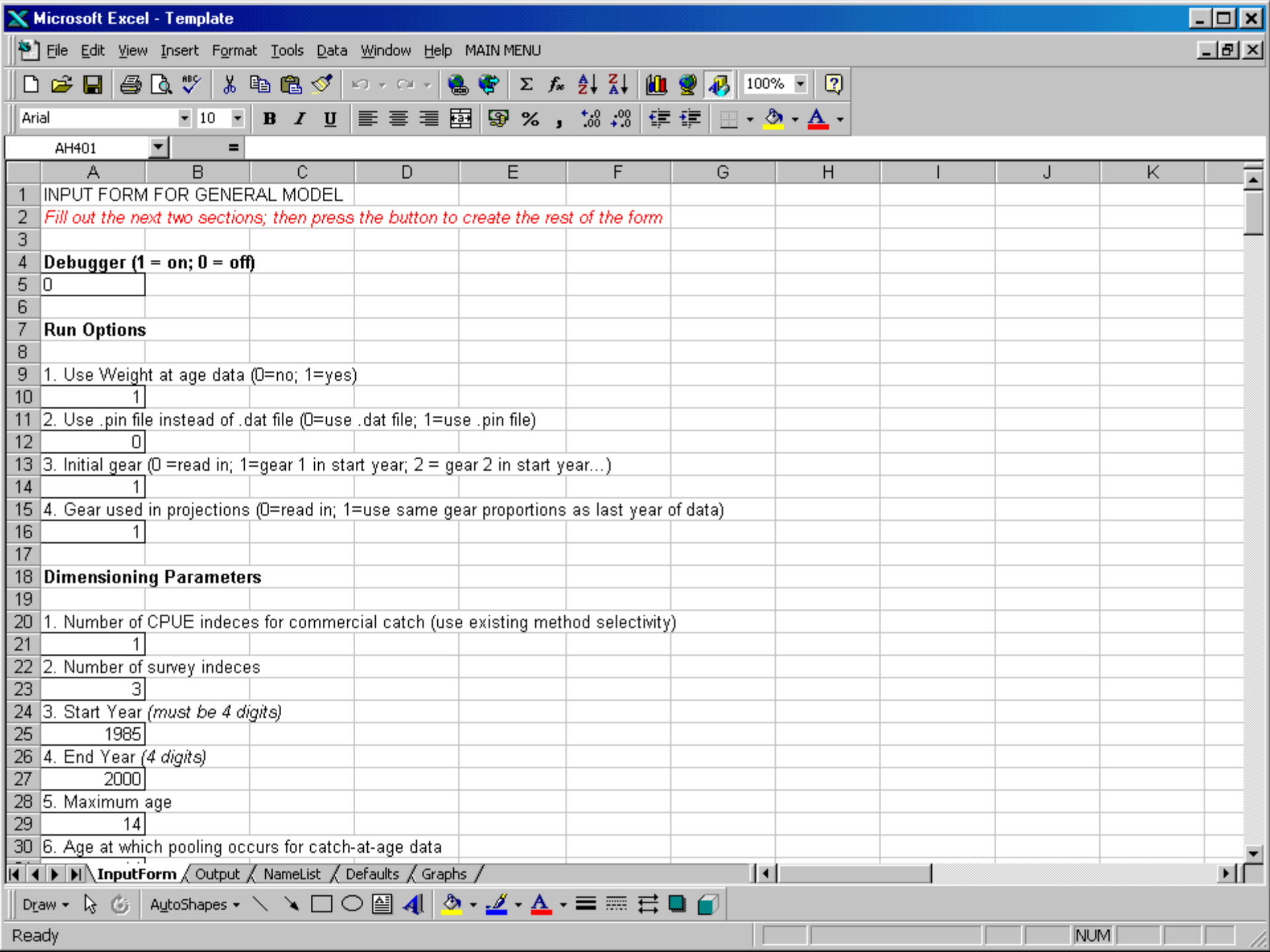
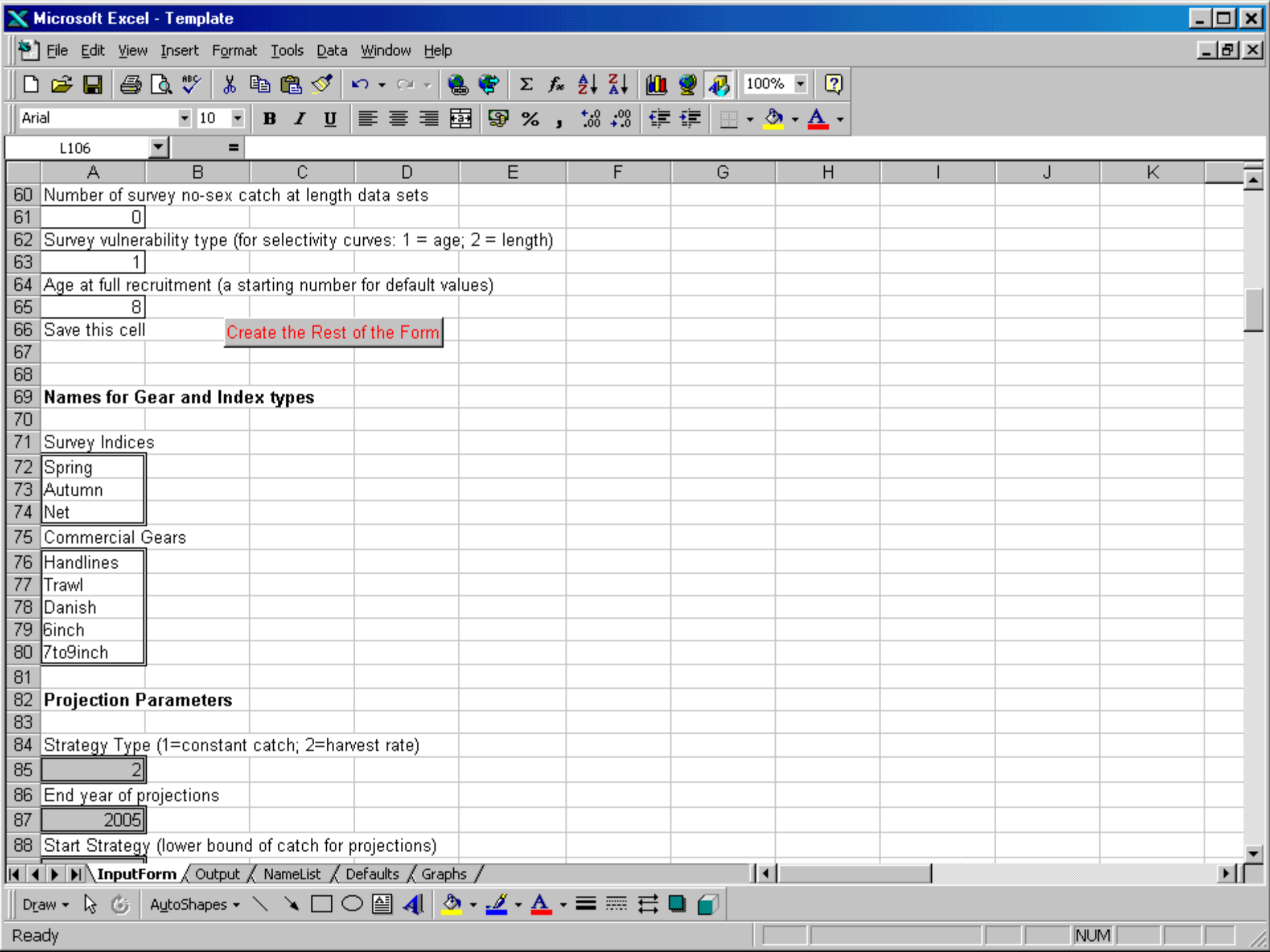
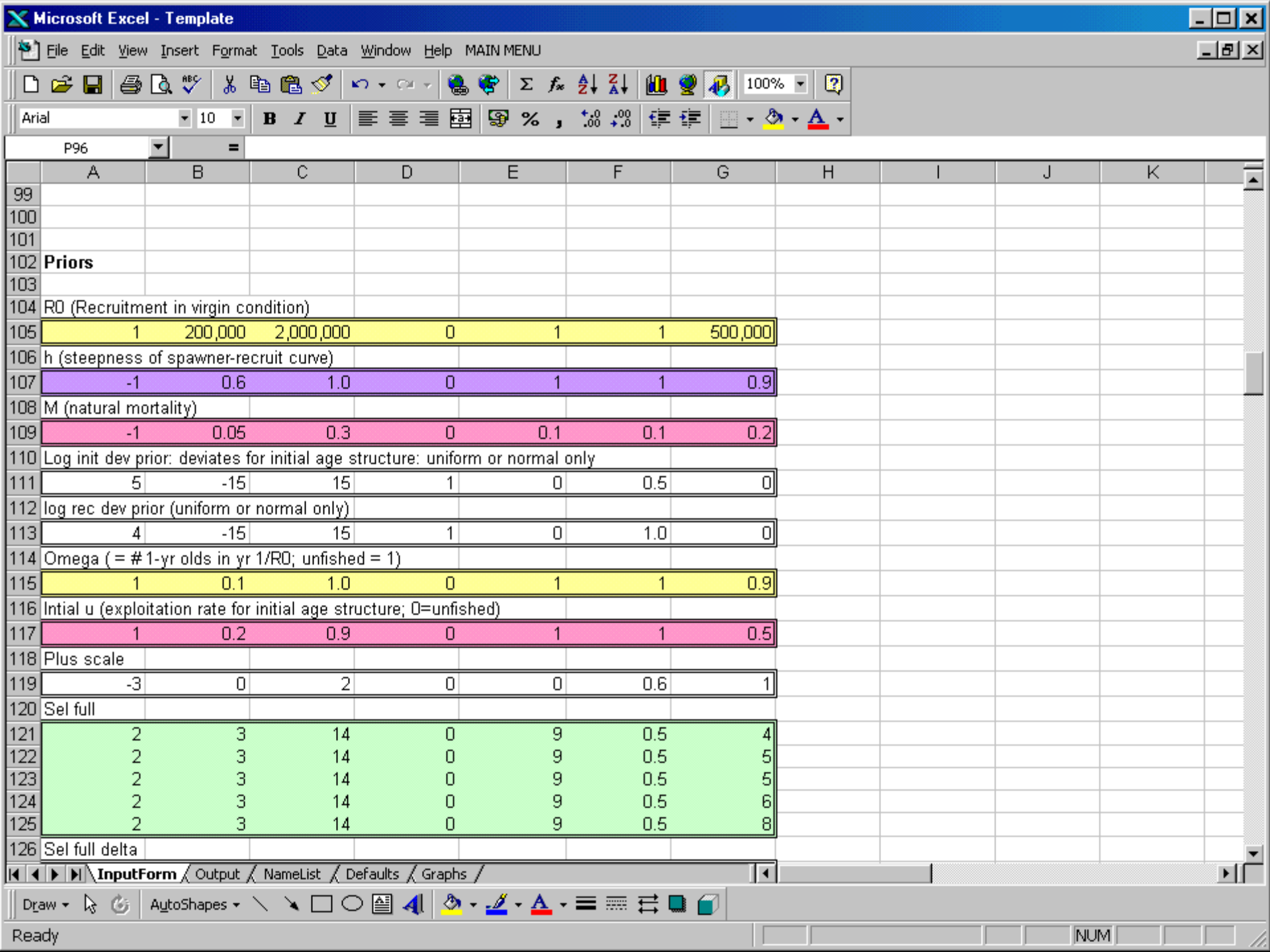
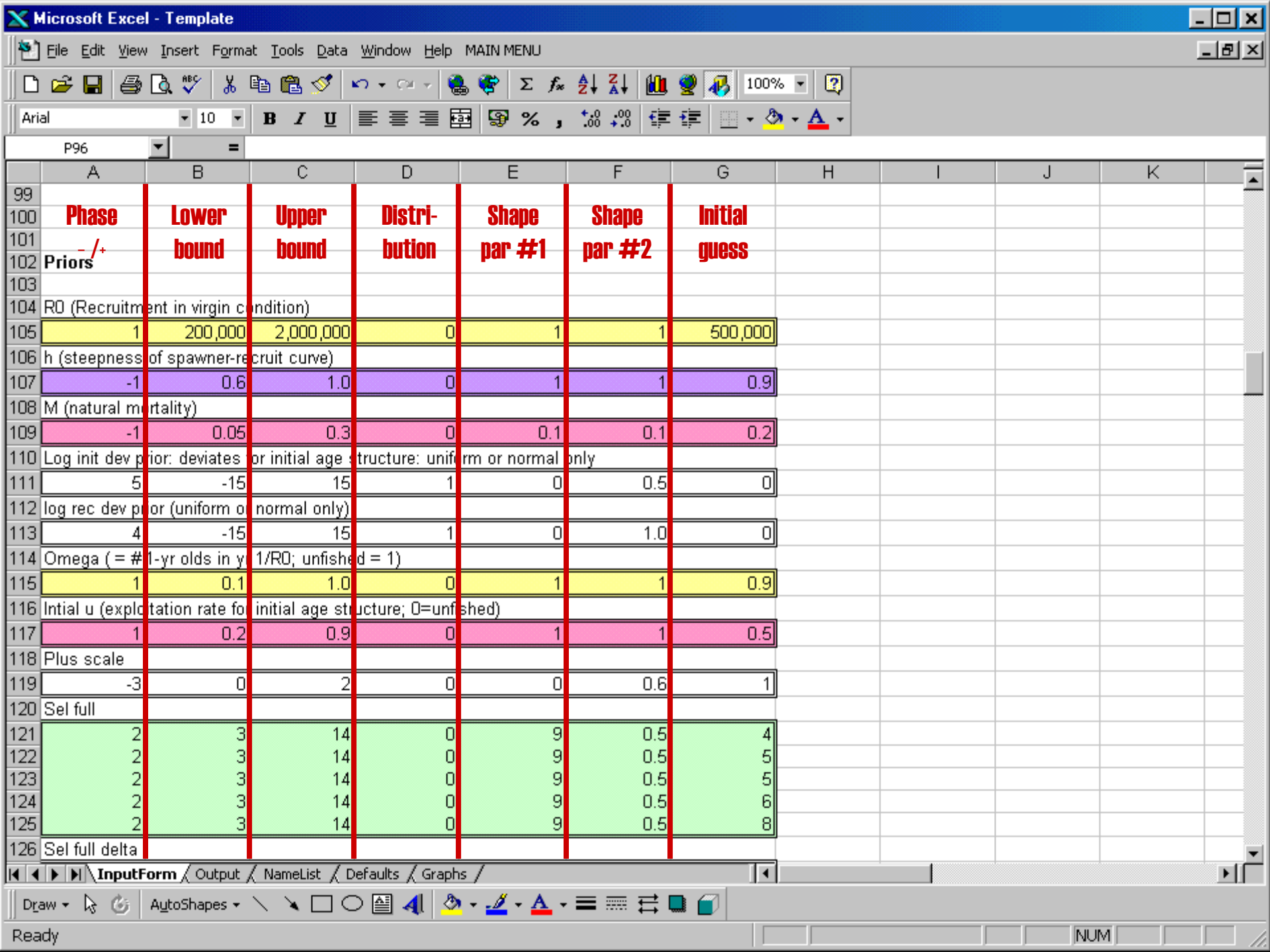
NUM


Microsoft Excel - Template
File Edit View Insert Format Tools Data Window Help MAIN MENU
Arial 10
AH401
INPUT FORM FOR GENERAL MODEL
Fill out the next two sections; then press the button to create the rest of the form
Debugger (1 = on; 0 = off)
0
Run Options
1. Use Weight at age data (0=no; 1=yes)
1
2. Use .pin file instead of .dat file (0=use .dat file; 1=use .pin file)
0
3. Initial gear (0 =read in; 1=gear 1 in start year; 2 = gear 2 in start year...)
1
4. Gear used in projections (0=read in; 1=use same gear proportions as last year of data)
1
Dimensioning Parameters
1. Number of CPUE indeces for commercial catch (use existing method selectivity)
1
2. Number of survey indeces
3
3. Start Year (must be 4 digits)
1985
4. End Year (4 digits)
2000
5. Maximum age
14
6. Age at which pooling occurs for catch-at-age data
InputForm Output NameList Defaults Graphs
Draw AutoShapes
Ready
NUM


Microsoft Excel - Template
File Edit View Insert Format Tools Data Window Help
Arial 10
L106
Number of survey no-sex catch at length data sets
0
Survey vulnerability type (for selectivity curves: 1 = age; 2 = length)
1
Age at full recruitment (a starting number for default values)
8
Save this cell
Create the Rest of the Form
Names for Gear and Index types
Survey Indices
Spring
Autumn
Net
Commercial Gears
Handlines
Trawl
Danish
6inch
7to9inch
Projection Parameters
Strategy Type (1=constant catch; 2=harvest rate)
2
End year of projections
2005
Start Strategy (lower bound of catch for projections)
InputForm Output NameList Defaults Graphs
Draw AutoShapes
Ready
NUM


Microsoft Excel - Template
File Edit View Insert Format Tools Data Window Help MAIN MENU
Arial 10
P96 =
Priors
R0 (Recruitment in virgin condition)
1 200,000 2,000,000 0 1 1 500,000
h (steepness of spawner-recruit curve)
-1 0.6 1.0 0 1 1 0.9
M (natural mortality)
-1 0.05 0.3 0 0.1 0.1 0.2
Log init dev prior: deviates for initial age structure: uniform or normal only
5 -15 15 1 0 0.5 0
log rec dev prior (uniform or normal only)
4 -15 15 1 0 1.0 0
Omega ( = # 1-yr olds in yr 1/R0; unfished = 1)
1 0.1 1.0 0 1 1 0.9
Intial u (exploitation rate for initial age structure; 0=unfished)
1 0.2 0.9 0 1 1 0.5
Plus scale
-3 0 2 0 0 0.6 1
Sel full
2 3 14 0 9 0.5 4
2 3 14 0 9 0.5 5
2 3 14 0 9 0.5 5
2 3 14 0 9 0.5 6
2 3 14 0 9 0.5 8
Sel full delta
InputForm Output NameList Defaults Graphs
Draw AutoShapes
Ready
NUM


Microsoft Excel - Template
File Edit View Insert Format Tools Data Window Help MAIN MENU
Arial 10
P96
Phase -/+
Lower bound
Upper bound
Distri-bution
Shape par #1
Shape par #2
Initial guess
Priors
R0 (Recruitment in virgin condition)
1 200,000 2,000,000 0 1 1 500,000
h (steepness of spawner-recruit curve)
-1 0.6 1.0 0 1 1 0.9
M (natural mortality)
-1 0.05 0.3 0 0.1 0.1 0.2
Log init dev prior: deviates for initial age structure: uniform or normal only
5 -15 15 1 0 0.5 0
log rec dev prior (uniform or normal only)
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Omega ( = #1-yr olds in y 1/R0; unfished = 1)
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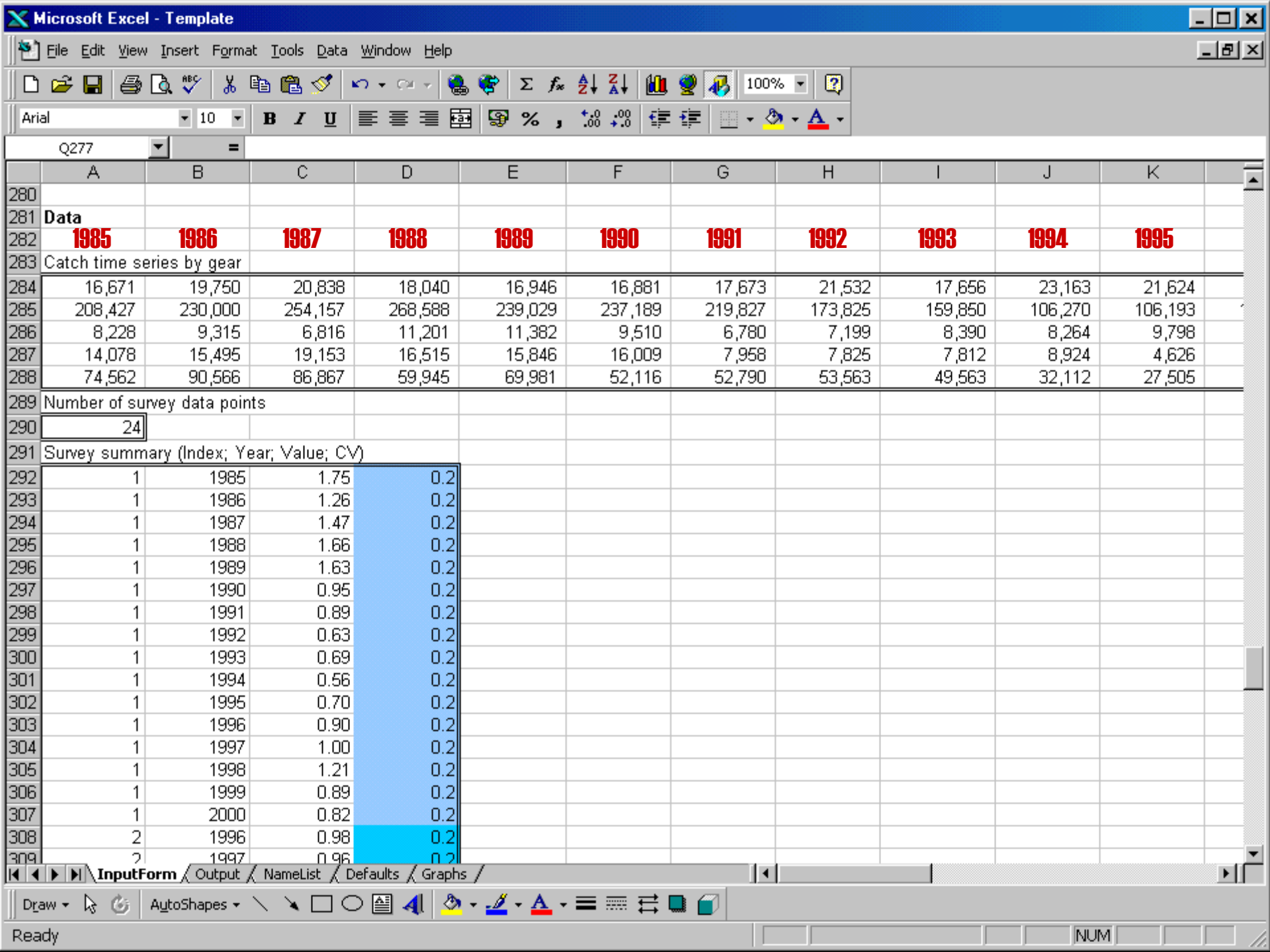
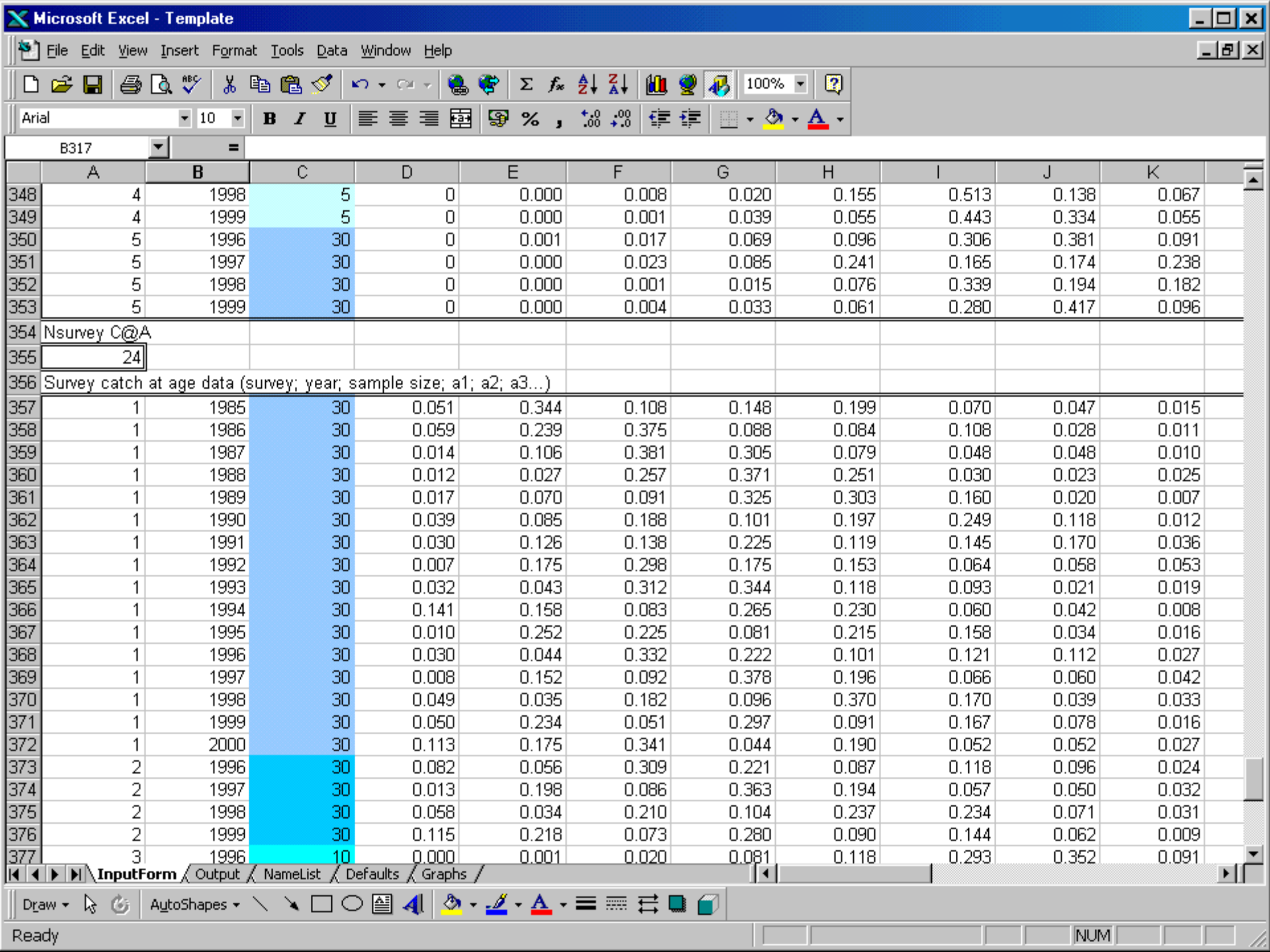
Intial u (exploitation rate for initial age structure; 0=unfished)
1 0.2 0.9 0 1 1 0.5
Plus scale
-3 0 2 0 0 0.6 1
Sel full
2 3 14 0 9 0.5 4
2 3 14 0 9 0.5 5
2 3 14 0 9 0.5 5
2 3 14 0 9 0.5 6
2 3 14 0 9 0.5 8
Sel full delta
InputForm Output NameList Defaults Graphs
Draw AutoShapes
Ready
NUM


Microsoft Excel - Template
File Edit View Insert Format Tools Data Window Help
Arial 10
Q277
Data
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
Catch time series by gear
16,671 19,750 20,838 18,040 16,946 16,881 17,673 21,532 17,656 23,163 21,624
208,427 230,000 254,157 268,588 239,029 237,189 219,827 173,825 159,850 106,270 106,193
8,228 9,315 6,816 11,201 11,382 9,510 6,780 7,199 8,390 8,264 9,798
14,078 15,495 19,153 16,515 15,846 16,009 7,958 7,825 7,812 8,924 4,626
74,562 90,566 86,867 59,945 69,981 52,116 52,790 53,563 49,563 32,112 27,505
Number of survey data points
24
Survey summary (Index; Year; Value; CV)
1 1985 1.75 0.2
1 1986 1.26 0.2
1 1987 1.47 0.2
1 1988 1.66 0.2
1 1989 1.63 0.2
1 1990 0.95 0.2
1 1991 0.89 0.2
1 1992 0.63 0.2
1 1993 0.69 0.2
1 1994 0.56 0.2
1 1995 0.70 0.2
1 1996 0.90 0.2
1 1997 1.00 0.2
1 1998 1.21 0.2
1 1999 0.89 0.2
1 2000 0.82 0.2
2 1996 0.98 0.2
InputForm Output NameList Defaults Graphs
Draw AutoShapes
Ready
NUM




| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 348 | 4 | 1998 | 5 | 0 | 0.000 | 0.008 | 0.020 | 0.155 | 0.513 | 0.138 | 0.067 |
| 349 | 4 | 1999 | 5 | 0 | 0.000 | 0.001 | 0.039 | 0.055 | 0.443 | 0.334 | 0.055 |
| 350 | 5 | 1996 | 30 | 0 | 0.001 | 0.017 | 0.069 | 0.096 | 0.306 | 0.381 | 0.091 |
| 351 | 5 | 1997 | 30 | 0 | 0.000 | 0.023 | 0.085 | 0.241 | 0.165 | 0.174 | 0.238 |
| 352 | 5 | 1998 | 30 | 0 | 0.000 | 0.001 | 0.015 | 0.076 | 0.339 | 0.194 | 0.182 |
| 353 | 5 | 1999 | 30 | 0 | 0.000 | 0.004 | 0.033 | 0.061 | 0.280 | 0.417 | 0.096 |
| 354 | Nsurvey C@A | | | | | | | | | | |
| 355 | 24 | | | | | | | | | | |
| 356 | Survey catch at age data (survey; year; sample size; a1; a2; a3...) | | | | | | | | | | |
| 357 | 1 | 1985 | 30 | 0.051 | 0.344 | 0.108 | 0.148 | 0.199 | 0.070 | 0.047 | 0.015 |
| 358 | 1 | 1986 | 30 | 0.059 | 0.239 | 0.375 | 0.088 | 0.084 | 0.108 | 0.028 | 0.011 |
| 359 | 1 | 1987 | 30 | 0.014 | 0.106 | 0.381 | 0.305 | 0.079 | 0.048 | 0.048 | 0.010 |
| 360 | 1 | 1988 | 30 | 0.012 | 0.027 | 0.257 | 0.371 | 0.251 | 0.030 | 0.023 | 0.025 |
| 361 | 1 | 1989 | 30 | 0.017 | 0.070 | 0.091 | 0.325 | 0.303 | 0.160 | 0.020 | 0.007 |
| 362 | 1 | 1990 | 30 | 0.039 | 0.085 | 0.188 | 0.101 | 0.197 | 0.249 | 0.118 | 0.012 |
| 363 | 1 | 1991 | 30 | 0.030 | 0.126 | 0.138 | 0.225 | 0.119 | 0.145 | 0.170 | 0.036 |
| 364 | 1 | 1992 | 30 | 0.007 | 0.175 | 0.298 | 0.175 | 0.153 | 0.064 | 0.058 | 0.053 |
| 365 | 1 | 1993 | 30 | 0.032 | 0.043 | 0.312 | 0.344 | 0.118 | 0.093 | 0.021 | 0.019 |
| 366 | 1 | 1994 | 30 | 0.141 | 0.158 | 0.083 | 0.265 | 0.230 | 0.060 | 0.042 | 0.008 |
| 367 | 1 | 1995 | 30 | 0.010 | 0.252 | 0.225 | 0.081 | 0.215 | 0.158 | 0.034 | 0.016 |
| 368 | 1 | 1996 | 30 | 0.030 | 0.044 | 0.332 | 0.222 | 0.101 | 0.121 | 0.112 | 0.027 |
| 369 | 1 | 1997 | 30 | 0.008 | 0.152 | 0.092 | 0.378 | 0.196 | 0.066 | 0.060 | 0.042 |
| 370 | 1 | 1998 | 30 | 0.049 | 0.035 | 0.182 | 0.096 | 0.370 | 0.170 | 0.039 | 0.033 |
| 371 | 1 | 1999 | 30 | 0.050 | 0.234 | 0.051 | 0.297 | 0.091 | 0.167 | 0.078 | 0.016 |
| 372 | 1 | 2000 | 30 | 0.113 | 0.175 | 0.341 | 0.044 | 0.190 | 0.052 | 0.052 | 0.027 |
| 373 | 2 | 1996 | 30 | 0.082 | 0.056 | 0.309 | 0.221 | 0.087 | 0.118 | 0.096 | 0.024 |
| 374 | 2 | 1997 | 30 | 0.013 | 0.198 | 0.086 | 0.363 | 0.194 | 0.057 | 0.050 | 0.032 |
| 375 | 2 | 1998 | 30 | 0.058 | 0.034 | 0.210 | 0.104 | 0.237 | 0.234 | 0.071 | 0.031 |
| 376 | 2 | 1999 | 30 | 0.115 | 0.218 | 0.073 | 0.280 | 0.090 | 0.144 | 0.062 | 0.009 |
| 377 | 3 | 1996 | 10 | 0.000 | 0.001 | 0.020 | 0.081 | 0.118 | 0.293 | 0.352 | 0.091 |

Microsoft Excel - GearGraphSurv

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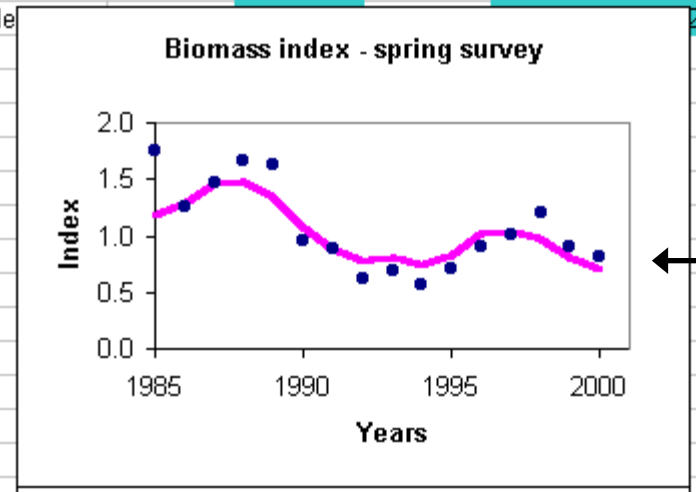
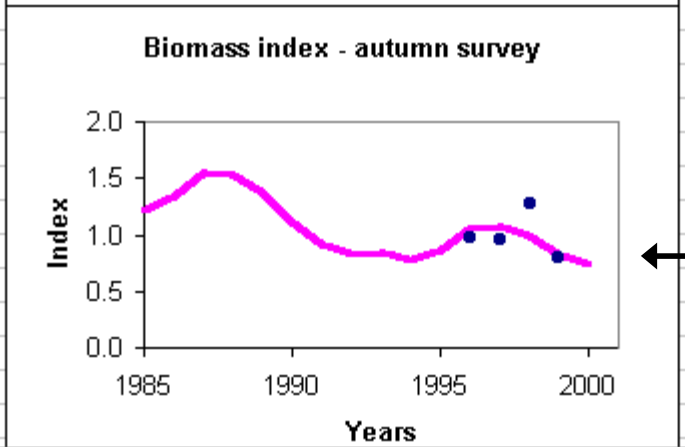
Arial 10 B I U

S6 =

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 11 | Gear | Year | Female | Male | From | To | Major | Minor |
| 12 | Spring | | Y | N/A | 1985 | 2001 | 5 | 0 |
| 13 | Autumn | | Y | N/A | 1985 | 2001 | 5 | 0 |
| 14 | Ne | | | | | 2001 | 5 | 0 |




$q_1$




$q_2$

General SurvNoSexCL SurvC@L ComC@L SurvC@A ComC@A Surveys SurvSel ComSel CPUE Master Graphmaster Nhat

Draw AutoShapes

Ready NUM

# Estimated parameters

Virgin recruitment

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
| 1993 | 989 | 256 | 154 | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | 723 | 371 | 564 | 117 | 64 | 138 | 77 | 43 | 25 | 41 |
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

$$\hat{I}_t = q\hat{B}_t$$

Survey/CPUE catchability

Selectivity parameters: Sleft, Sfull, Sright

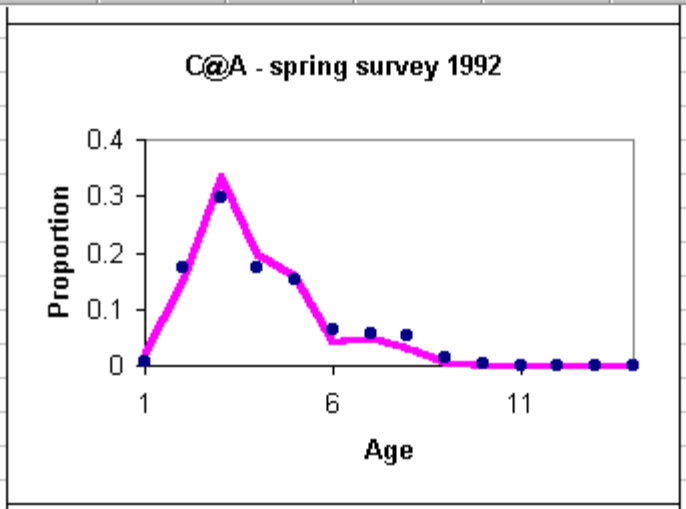
$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t}) \qquad u_{a,t} = u_t s_{a,t}$$

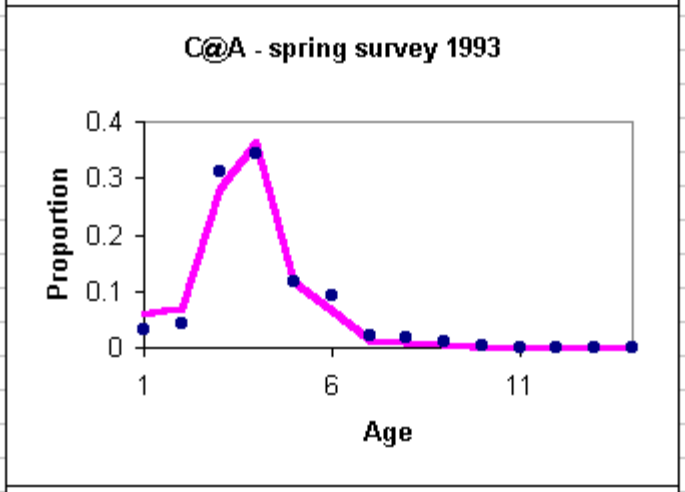
Microsoft Excel - GearGraphSurv

File Edit View Insert Format Tools Data Window Help

Arial 10 B I U

R98 =




C@A - spring survey 1994

General SurvNoSexCL SurvC@L ComC@L SurvC@A ComC@A Surveys SurvSel ComSel CPUE Master Graphmaster Nhat

Draw AutoShapes

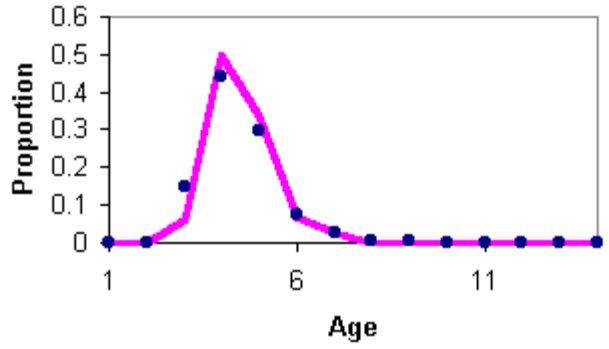
Ready NUM

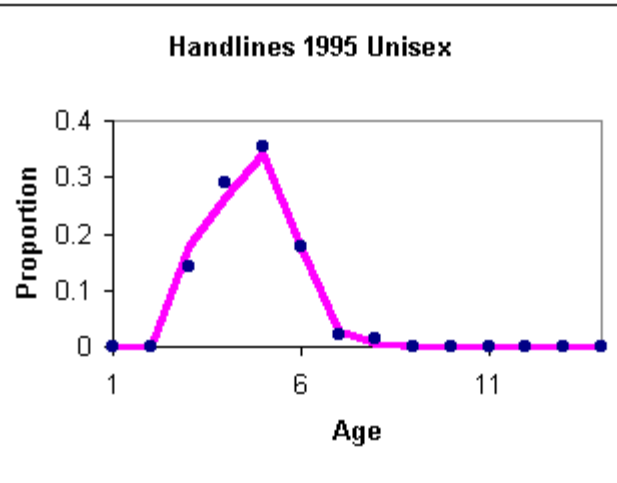
Microsoft Excel - GearGraphFleet

File Edit View Insert Format Tools Data Window Help

Arial 10 B I U

S48 =




Handlines 1996 Unisex

General SurvNoSexCL SurvC@L ComC@L SurvC@A ComC@A Surveys SurvSel ComSel CPUE Master Graphmaster Nhat

Draw AutoShapes

Ready NUM

# Catch-at-age likelihood

$$\log L_C^g = -0.5 \sum_{t=1}^{Nyears} \sum_{a=1}^{A} \log\left[\left(P_{a,t}^g(1-P_{a,t}^g)+0.1/A\right)\right]$$
$$+ \sum_{t=1}^{Nyears} \sum_{a=1}^{A} \log\left[\exp\left\{\frac{-(\tilde{P}_{a,t}^g - P_{a,t}^g)^2}{2(P_{a,t}^g(1-P_{a,t}^g)+0.1/A)\tau^g}\right\}+0.01\right]$$

$L_C$ : catch-at-age likelihood

$g$ : gear

$a$ : age

$t$ : years

$T$ : number of years

$a$ : age

$A$ : number of age groups

$P$ : proportional catch at age

$\tau$ : 1 / catch sample size

# Biomass index likelihood

$$\log L_I^g = \sum_t \log\left[\exp\left(-0.5\frac{{}_{I^g}\varepsilon_t^2}{{}_{I^g}\sigma_t^2}\right) + 0.01\right]$$

$L_I$ : biomass index likelihood

$g$ : gear

$I$ : biomass index

$t$ : years

$\varepsilon$ : log-normal error term

$\sigma$ : survey variance

# Total likelihood

$$\log L = \sum_g \log L_I^g + \sum_g \log L_{\mathrm{C}}^g + \sum_g \log L_{\mathrm{S}}^g$$

$L$ : total likelihood

$g$ : gear

$L_I$ : biomass index likelihood

$L_C$ : commercial catch-at-age likelihood

$L_S$ : survey catch-at-age likelihood

# Penalties

$$Pen_p = 0.5 \frac{\varepsilon_p^2}{\sigma_p^2}$$

For example,
recruitment deviates
or time-varying selectivity

$Pen$ : penalty for deviation

$p$ : parameter

$\varepsilon$ : residual from prior $\mu$

$\sigma$ : variance of prior distribution

# Objective function

$$f = \log L - \sum_{p} Pen_{p}$$

$L$ : total likelihood

$Pen$ : penalty sum of square

$p$ : parameter

# Initial population and recruitment

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

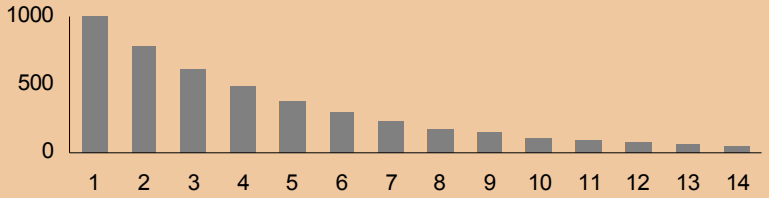
$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
| 1993 | 989 | 256 | 154 | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | 723 | 371 | 564 | 117 | 64 | 138 | 77 | 43 | 25 | 41 |
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Initial population and recruitment




$$N_{1,1} = R_0$$

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
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| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
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| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
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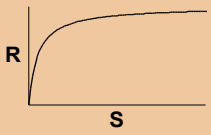
$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Initial population and recruitment

$$N_{1,1} = R_0$$

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$




| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
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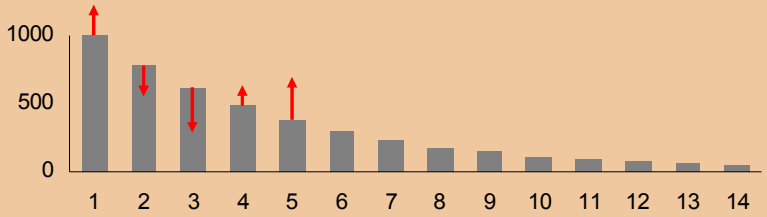
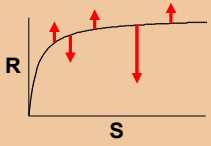
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

# Initial population and recruitment




$$N_{1,1} = R_0$$




| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
| 1993 | 989 | 256 | 154 | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | 723 | 371 | 564 | 117 | 64 | 138 | 77 | 43 | 25 | 41 |
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t})$$

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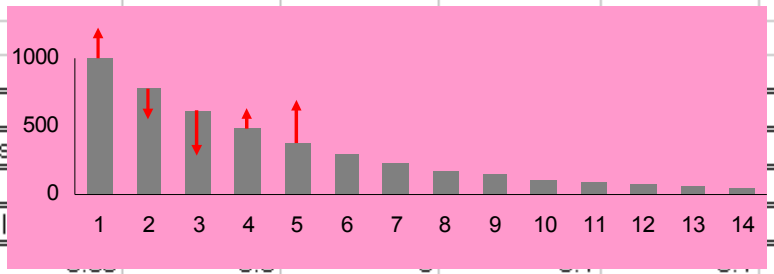
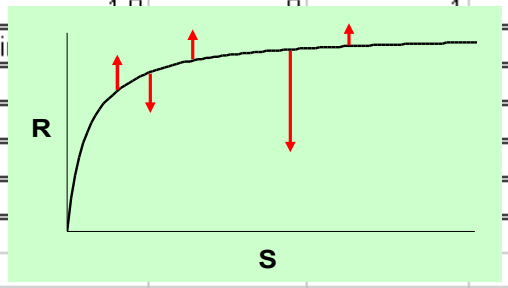
Arial 10 B I U 100%

M95 =

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | | | | | | | | | | | |
| 101 | | | | | | | | | | | |
| 102 | **Priors** | | | | | | | | | | |
| 103 | | | | | | | | | | | |
| 104 | R0 (Recruitment | | | | | | | | | | |
| 105 | 1 | | | | | | 500,000 | | | | |
| 106 | h (steepness of s | | | | | | | | | | |
| 107 | -1 | | | | | | 0.9 | | | | |
| 108 | M (natural mortal | | | | | | | | | | |
| 109 | -1 | | | | | | 0.2 | | | | |
| 110 | Log init dev prior: deviates for initial age structure: uniform or normal only | | | | | | | | | | |
| 111 | 5 | -15 | 15 | 1 | 0 | 0.5 | 0 | | | | |
| 112 | log rec dev prior (uniform or normal only) | | | | | | | | | | |
| 113 | 4 | -15 | 15 | 1 | 0 | 1.0 | 0 | | | | |
| 114 | Omega ( = # 1-yr olds in yr 1/R0; unfished = 1) | | | | | | | | | | |
| 115 | 1 | 0.1 | | | | 1 | 0.9 | | | | |
| 116 | Intial u (exploitation rate for i | | | | | | | | | | |
| 117 | 1 | 0.2 | | | | 1 | 0.5 | | | | |
| 118 | Plus scale | | | | | | | | | | |
| 119 | -3 | 0 | | | | 0.6 | 1 | | | | |
| 120 | Sel full | | | | | | | | | | |
| 121 | 2 | 3 | | | | 0.5 | 4 | | | | |
| 122 | 2 | 3 | | | | 0.5 | 5 | | | | |
| 123 | 2 | 3 | 14 | 0 | 9 | 0.5 | 5 | | | | |
| 124 | 2 | 3 | 14 | 0 | 9 | 0.5 | 6 | | | | |
| 125 | 2 | 3 | 14 | 0 | 9 | 0.5 | 8 | | | | |
| 126 | Sel full delta | | | | | | | | | | |
| 127 | -1 | -3 | 3 | 0 | 0 | 0.6 | 0 | | | | |




InputForm | Output | NameList | Defaults | Graphs

Draw AutoShapes

Ready NUM

# Estimated parameters

Virgin recruitment

$$N_{1,1} = R_0$$

$$\times \exp(Dev_a)$$

Initial deviates

$$N_{a,1} = N_{1,1} e^{-M(a-1)} \prod_{i=1}^{a-1} (1 - u_{i,1})$$

$$N_{A,1} = \frac{N_{1,1} e^{-M(A-1)} \prod_{i=1}^{A-1} u_{i,1}}{1 - e^{-M} \prod_{i=1}^{A-1} u_{i,1}}$$

| | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1000 | 793 | 553 | 329 | 196 | 116 | 69 | 41 | 24 | 80 |
| 1991 | 273 | 783 | 520 | 291 | 173 | 103 | 61 | 36 | 22 | 55 |
| 1992 | 321 | 215 | 536 | 297 | 166 | 99 | 59 | 35 | 21 | 44 |
| 1993 | 989 | 256 | 154 | 334 | 185 | 103 | 62 | 37 | 22 | 40 |
| 1994 | 466 | 793 | 189 | 103 | 223 | 124 | 69 | 41 | 24 | 41 |
| 1995 | 723 | 371 | 564 | 117 | 64 | 138 | 77 | 43 | 25 | 41 |
| 1996 | 1860 | 566 | 244 | 298 | 62 | 34 | 73 | 40 | 23 | 35 |
| 1997 | 459 | 1475 | 395 | 145 | 177 | 37 | 20 | 43 | 24 | 34 |
| 1998 | 501 | 362 | 997 | 220 | 81 | 99 | 20 | 11 | 24 | 32 |
| 1999 | 292 | 393 | 239 | 530 | 117 | 43 | 52 | 11 | 6 | 30 |
| 2000 | 433 | 231 | 269 | 137 | 304 | 67 | 25 | 30 | 6 | 21 |
| 2001 | 726 | 339 | 152 | 143 | 73 | 161 | 36 | 13 | 16 | 14 |
| 2002 | 592 | 572 | 229 | 84 | 79 | 40 | 89 | 20 | 7 | 17 |
| 2003 | 760 | 475 | 423 | 153 | 56 | 53 | 27 | 60 | 13 | 16 |
| 2004 | 1222 | 599 | 321 | 236 | 85 | 31 | 29 | 15 | 33 | 16 |
| 2005 | 324 | 959 | 397 | 172 | 127 | 46 | 17 | 16 | 8 | 27 |

$$N_{1,t+1} = f(S_t \mid R_0, h)$$

$$\times \exp(Dev_t)$$

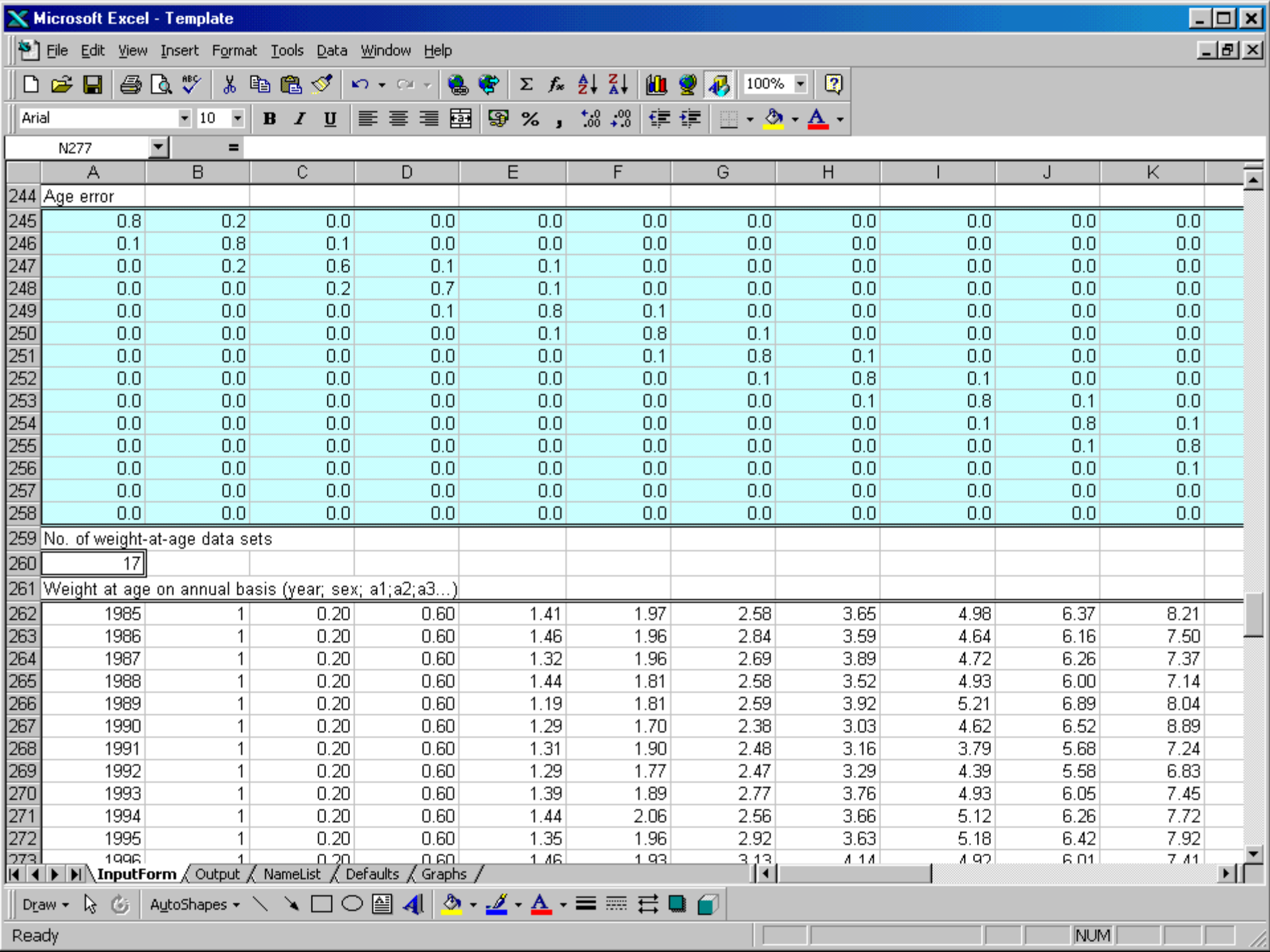
Recruitment deviates

$$\hat{I}_t = q\hat{B}_t$$

Survey/CPUE catchability

Selectivity parameters: Sleft, Sfull, Sright

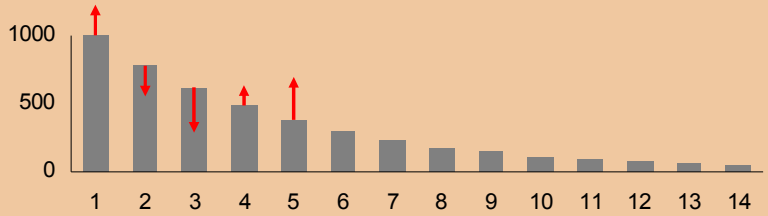
$$N_{a+1,t+1} = N_{a,t} e^{-M} (1 - u_{a,t}) \qquad u_{a,t} = u_t s_{a,t}$$



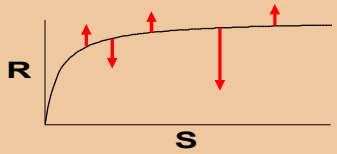

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 244 | Age error | | | | | | | | | | |
| 245 | 0.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 246 | 0.1 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 247 | 0.0 | 0.2 | 0.6 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 248 | 0.0 | 0.0 | 0.2 | 0.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 249 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 250 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 251 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 |
| 252 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 | 0.0 | 0.0 |
| 253 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 | 0.0 |
| 254 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 | 0.1 |
| 255 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.8 |
| 256 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| 257 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 258 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 259 | No. of weight-at-age data sets | | | | | | | | | | |
| 260 | 17 | | | | | | | | | | |
| 261 | Weight at age on annual basis (year; sex; a1;a2;a3...) | | | | | | | | | | |
| 262 | 1985 | 1 | 0.20 | 0.60 | 1.41 | 1.97 | 2.58 | 3.65 | 4.98 | 6.37 | 8.21 |
| 263 | 1986 | 1 | 0.20 | 0.60 | 1.46 | 1.96 | 2.84 | 3.59 | 4.64 | 6.16 | 7.50 |
| 264 | 1987 | 1 | 0.20 | 0.60 | 1.32 | 1.96 | 2.69 | 3.89 | 4.72 | 6.26 | 7.37 |
| 265 | 1988 | 1 | 0.20 | 0.60 | 1.44 | 1.81 | 2.58 | 3.52 | 4.93 | 6.00 | 7.14 |
| 266 | 1989 | 1 | 0.20 | 0.60 | 1.19 | 1.81 | 2.59 | 3.92 | 5.21 | 6.89 | 8.04 |
| 267 | 1990 | 1 | 0.20 | 0.60 | 1.29 | 1.70 | 2.38 | 3.03 | 4.62 | 6.52 | 8.89 |
| 268 | 1991 | 1 | 0.20 | 0.60 | 1.31 | 1.90 | 2.48 | 3.16 | 3.79 | 5.68 | 7.24 |
| 269 | 1992 | 1 | 0.20 | 0.60 | 1.29 | 1.77 | 2.47 | 3.29 | 4.39 | 5.58 | 6.83 |
| 270 | 1993 | 1 | 0.20 | 0.60 | 1.39 | 1.89 | 2.77 | 3.76 | 4.93 | 6.05 | 7.45 |
| 271 | 1994 | 1 | 0.20 | 0.60 | 1.44 | 2.06 | 2.56 | 3.66 | 5.12 | 6.26 | 7.72 |
| 272 | 1995 | 1 | 0.20 | 0.60 | 1.35 | 1.96 | 2.92 | 3.63 | 5.18 | 6.42 | 7.92 |
| 273 | 1996 | 1 | 0.20 | 0.60 | 1.46 | 1.93 | 3.13 | 4.14 | 4.92 | 6.01 | 7.41 |

# Confronting uncertainty

Initial process error




Recruitment process error




Ageing observation error

| | | | |
|---|---|---|---|
| 0.8 | 0.2 | 0.0 | 0.0 |
| 0.1 | 0.8 | 0.1 | 0.0 |
| 0.0 | 0.2 | 0.6 | 0.1 |
| 0.0 | 0.0 | 0.2 | 0.7 |
| 0.0 | 0.0 | 0.0 | 0.1 |
| 0.0 | 0.0 | 0.0 | 0.0 |

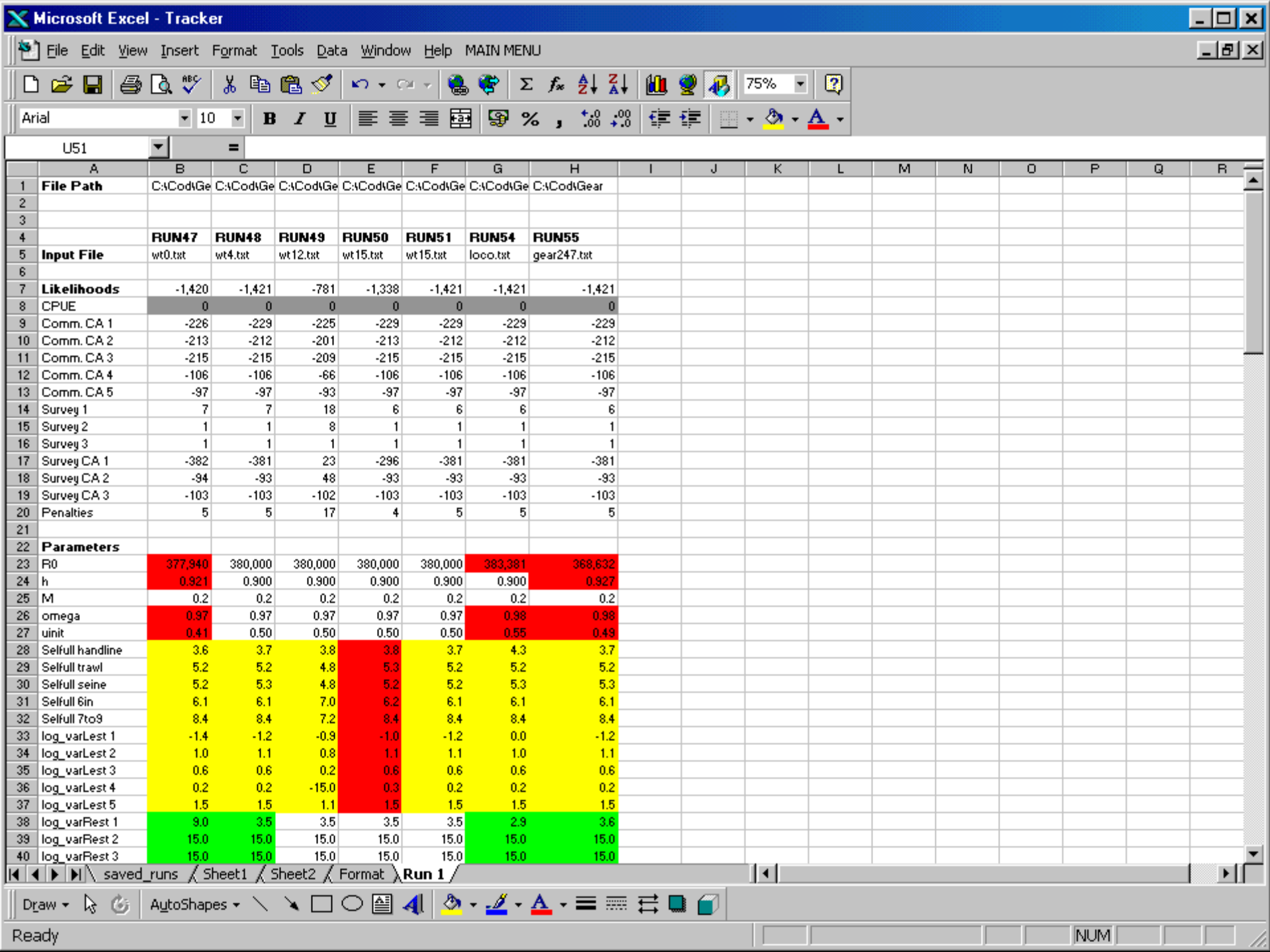
Likelihood function with log-normal error structure

$$\ln L_I^g = \sum_t \ln\left[\exp\left(-0.5\frac{{}^{Ig}\varepsilon_t^2}{{}^{Ig}\sigma_t^2}\right)+0.01\right]$$

# Model output

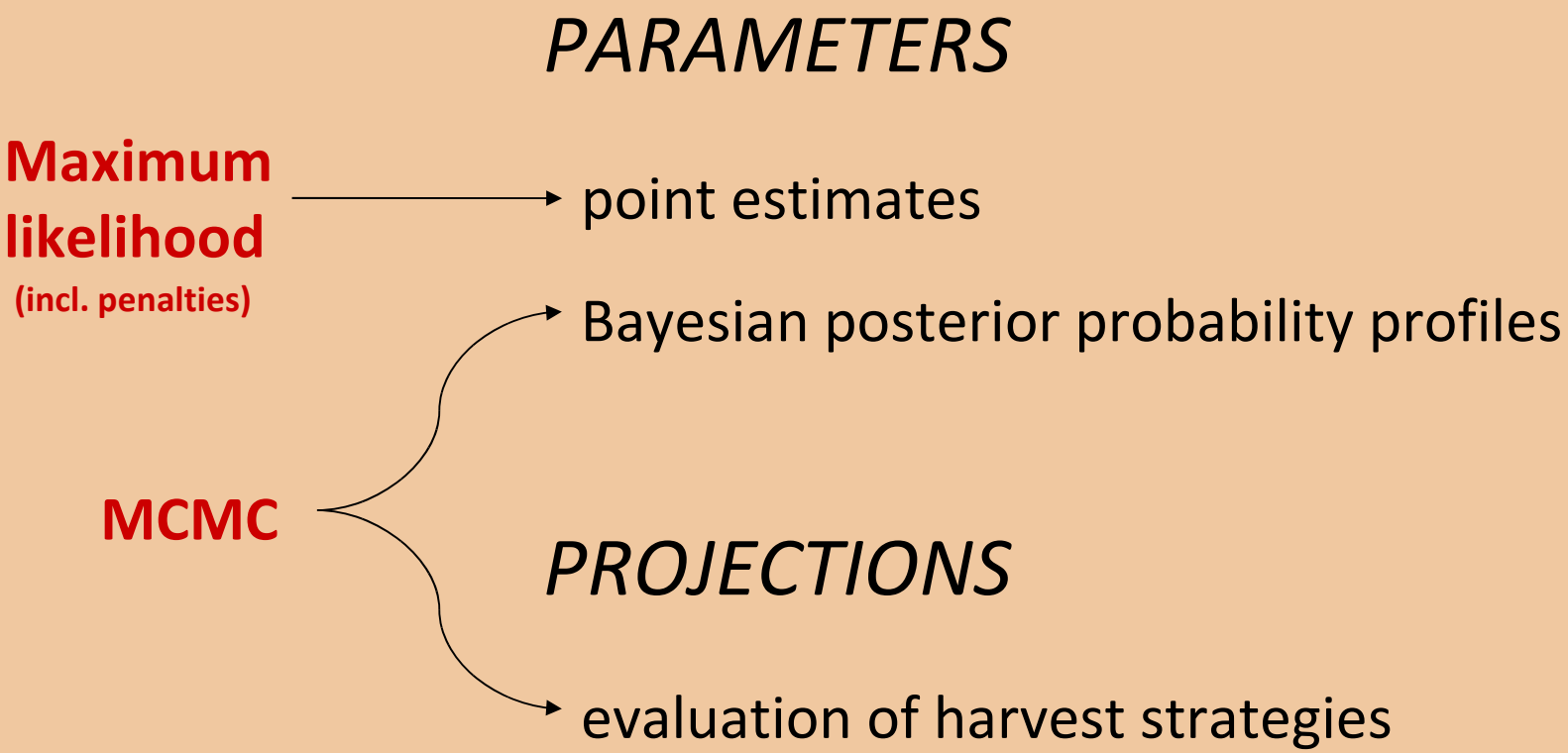
*PARAMETERS*

point estimates




| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **File Path** | C:\Cod\Ge | C:\Cod\Ge | C:\Cod\Ge | C:\Cod\Ge | C:\Cod\Ge | C:\Cod\Ge | C:\Cod\Gear |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | **RUN47** | **RUN48** | **RUN49** | **RUN50** | **RUN51** | **RUN54** | **RUN55** |
| 5 | **Input File** | wt0.txt | wt4.txt | wt12.txt | wt15.txt | wt15.txt | loco.txt | gear247.txt |
| 6 | | | | | | | | |
| 7 | **Likelihoods** | -1,420 | -1,421 | -781 | -1,338 | -1,421 | -1,421 | -1,421 |
| 8 | CPUE | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Comm. CA 1 | -226 | -229 | -225 | -229 | -229 | -229 | -229 |
| 10 | Comm. CA 2 | -213 | -212 | -201 | -213 | -212 | -212 | -212 |
| 11 | Comm. CA 3 | -215 | -215 | -209 | -215 | -215 | -215 | -215 |
| 12 | Comm. CA 4 | -106 | -106 | -66 | -106 | -106 | -106 | -106 |
| 13 | Comm. CA 5 | -97 | -97 | -93 | -97 | -97 | -97 | -97 |
| 14 | Survey 1 | 7 | 7 | 18 | 6 | 6 | 6 | 6 |
| 15 | Survey 2 | 1 | 1 | 8 | 1 | 1 | 1 | 1 |
| 16 | Survey 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | Survey CA 1 | -382 | -381 | 23 | -296 | -381 | -381 | -381 |
| 18 | Survey CA 2 | -94 | -93 | 48 | -93 | -93 | -93 | -93 |
| 19 | Survey CA 3 | -103 | -103 | -102 | -103 | -103 | -103 | -103 |
| 20 | Penalties | 5 | 5 | 17 | 4 | 5 | 5 | 5 |
| 21 | | | | | | | | |
| 22 | **Parameters** | | | | | | | |
| 23 | R0 | 377,940 | 380,000 | 380,000 | 380,000 | 380,000 | 383,381 | 368,632 |
| 24 | h | 0.921 | 0.900 | 0.900 | 0.900 | 0.900 | 0.900 | 0.927 |
| 25 | M | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 26 | omega | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.98 | 0.98 |
| 27 | uinit | 0.41 | 0.50 | 0.50 | 0.50 | 0.50 | 0.55 | 0.49 |
| 28 | Selfull handline | 3.6 | 3.7 | 3.8 | 3.8 | 3.7 | 4.3 | 3.7 |
| 29 | Selfull trawl | 5.2 | 5.2 | 4.8 | 5.3 | 5.2 | 5.2 | 5.2 |
| 30 | Selfull seine | 5.2 | 5.3 | 4.8 | 5.2 | 5.2 | 5.3 | 5.3 |
| 31 | Selfull 6in | 6.1 | 6.1 | 7.0 | 6.2 | 6.1 | 6.1 | 6.1 |
| 32 | Selfull 7to9 | 8.4 | 8.4 | 7.2 | 8.4 | 8.4 | 8.4 | 8.4 |
| 33 | log_varLest 1 | -1.4 | -1.2 | -0.9 | -1.0 | -1.2 | 0.0 | -1.2 |
| 34 | log_varLest 2 | 1.0 | 1.1 | 0.8 | 1.1 | 1.1 | 1.0 | 1.1 |
| 35 | log_varLest 3 | 0.6 | 0.6 | 0.2 | 0.6 | 0.6 | 0.6 | 0.6 |
| 36 | log_varLest 4 | 0.2 | 0.2 | -15.0 | 0.3 | 0.2 | 0.2 | 0.2 |
| 37 | log_varLest 5 | 1.5 | 1.5 | 1.1 | 1.5 | 1.5 | 1.5 | 1.5 |
| 38 | log_varRest 1 | 9.0 | 3.5 | 3.5 | 3.5 | 3.5 | 2.9 | 3.6 |
| 39 | log_varRest 2 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| 40 | log_varRest 3 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |

# Model output



Microsoft Excel - GearGraphFront

File Edit View Insert Format Tools Data Window Help MAIN MENU

- Create or Modify Input File
- Run Model
- View Output
- MCMC
  - Run MCMC
  - Run mc_eval
  - MCMC to CODA

Arial 10 B I U

P33 =

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Titles ("None" to leave blank) | | | Size (in.) | | | Spacing (in.) betw | | | | g Position - 1st chart | | | |
| 2 | X axis | None | | Width | 3.5 | | Left | | | | 0.2 | | | |
| 3 | Y axis | | | Height | 2.5 | | Top | 0 | | | Top 2.4 | | | |
| 4 | Series 1 | Default | | | | | | | | | | | | |
| 5 | Series 2 | Default | | | | | | | | | | | | |
| 6 | | | | | Name of sheet where graphs will go: | | | | | | | | | |
| 7 | | | | | General | | | | | | | | | |
| 8 | | | | | | | | | | | | | | |
| 9 | | | Graph (Y or N) | | | | | | | | | | | |
| 10 | Index or | | Unisex or | | X axis range | | Tick marks | | | | | | | |
| 11 | Gear | Year | Female | Male | From | To | Major | Minor | | | | | | |
| 12 | Handlines | | | | 1985 | 2001 | 5 | 0 | | | | | | |
| 13 | Trawl | | | | 1985 | 2001 | 5 | 0 | | | | | | |
| 14 | Da | | | | | | | | | | | | | |
| 15 | 6in | | | | | | | | | | | | | |
| 16 | 7to | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
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| 24 | | | | | | | | | | | | | | |
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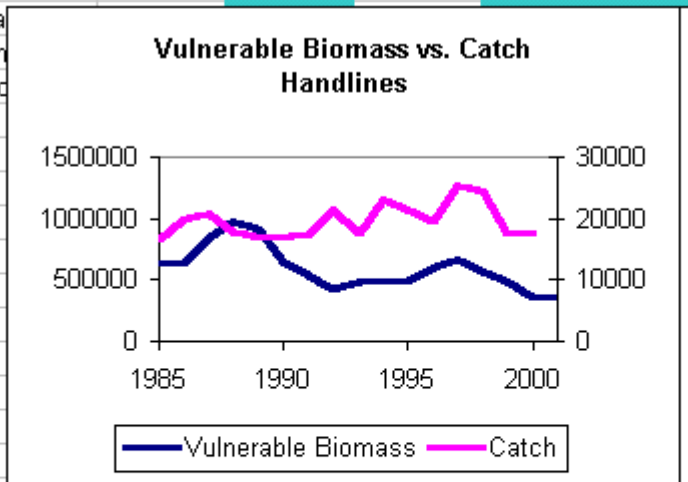
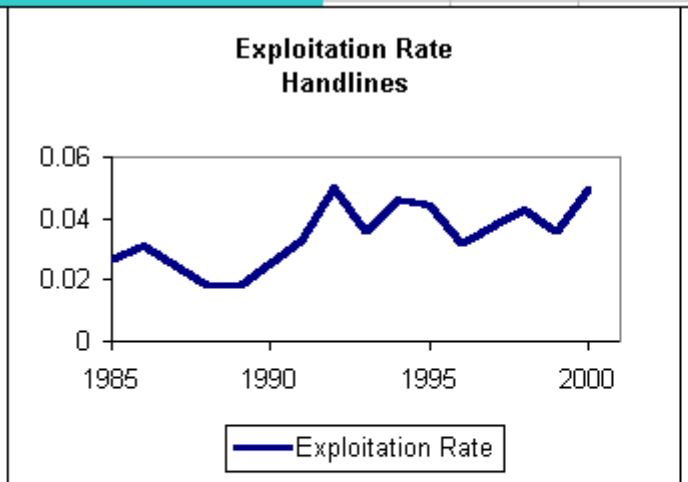
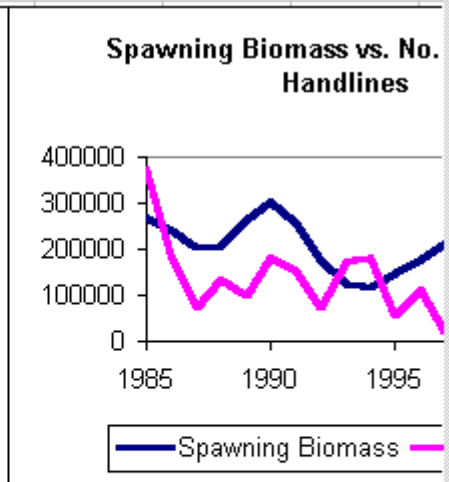
| 28 | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | |

MAKE Charts

DELETE Charts




Vulnerable Biomass vs. Catch
Trawl

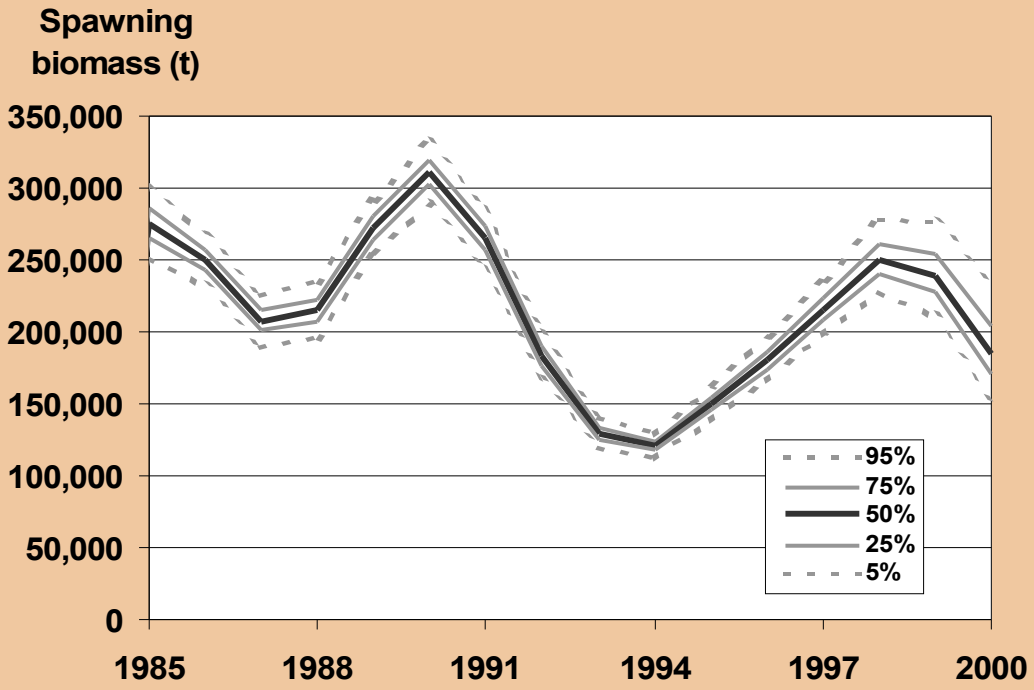
Exploitation Rate
Trawl

General SurvNoSexCL SurvC@L ComC@L SurvC@A ComC@A Surveys SurvSel ComSel CPUE Master Graphmaster Nhat

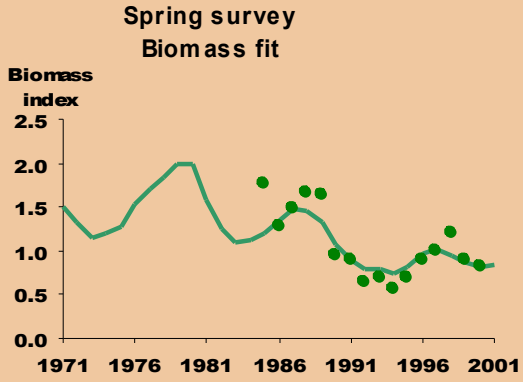
Draw AutoShapes

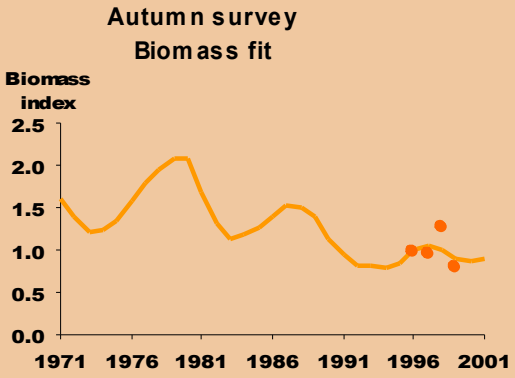
Ready NUM

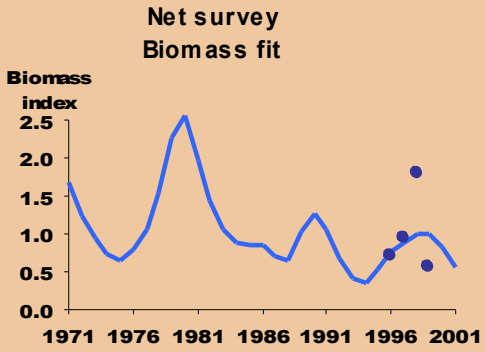
# Icelandic cod



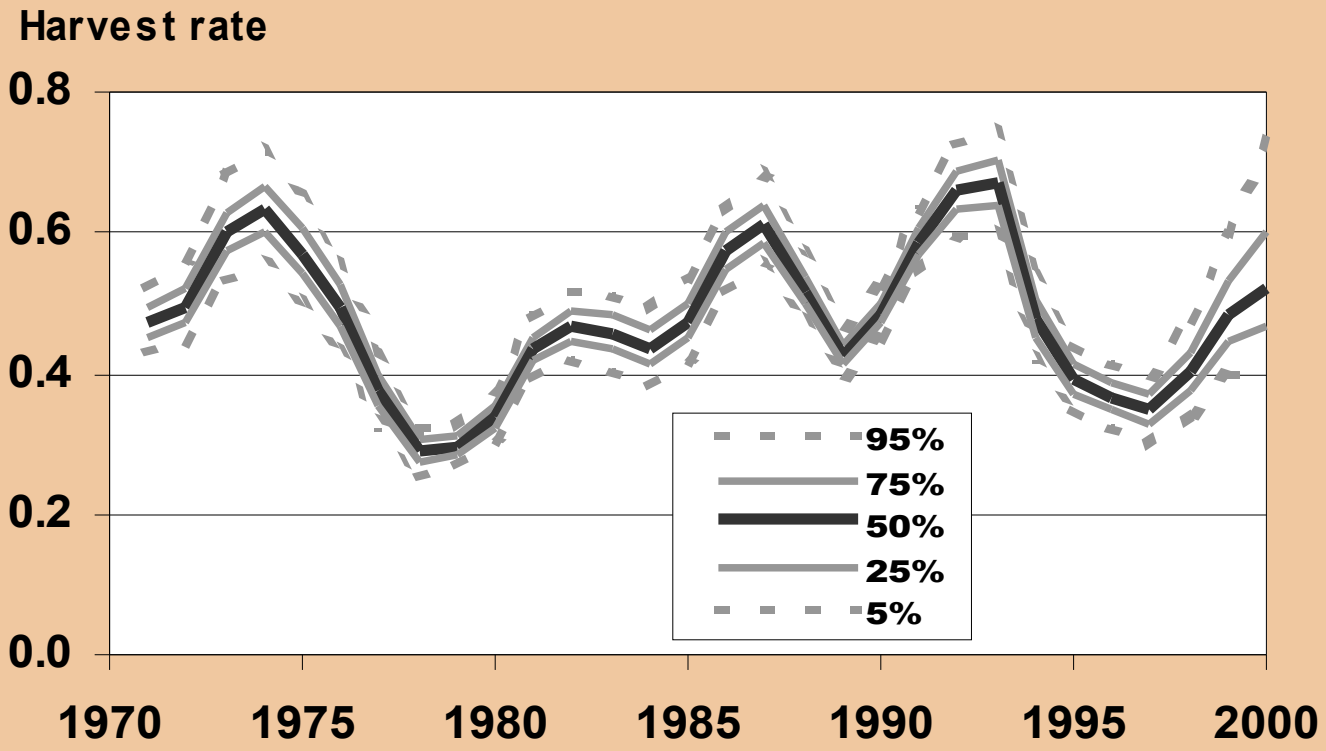
# Icelandic cod



# Icelandic cod



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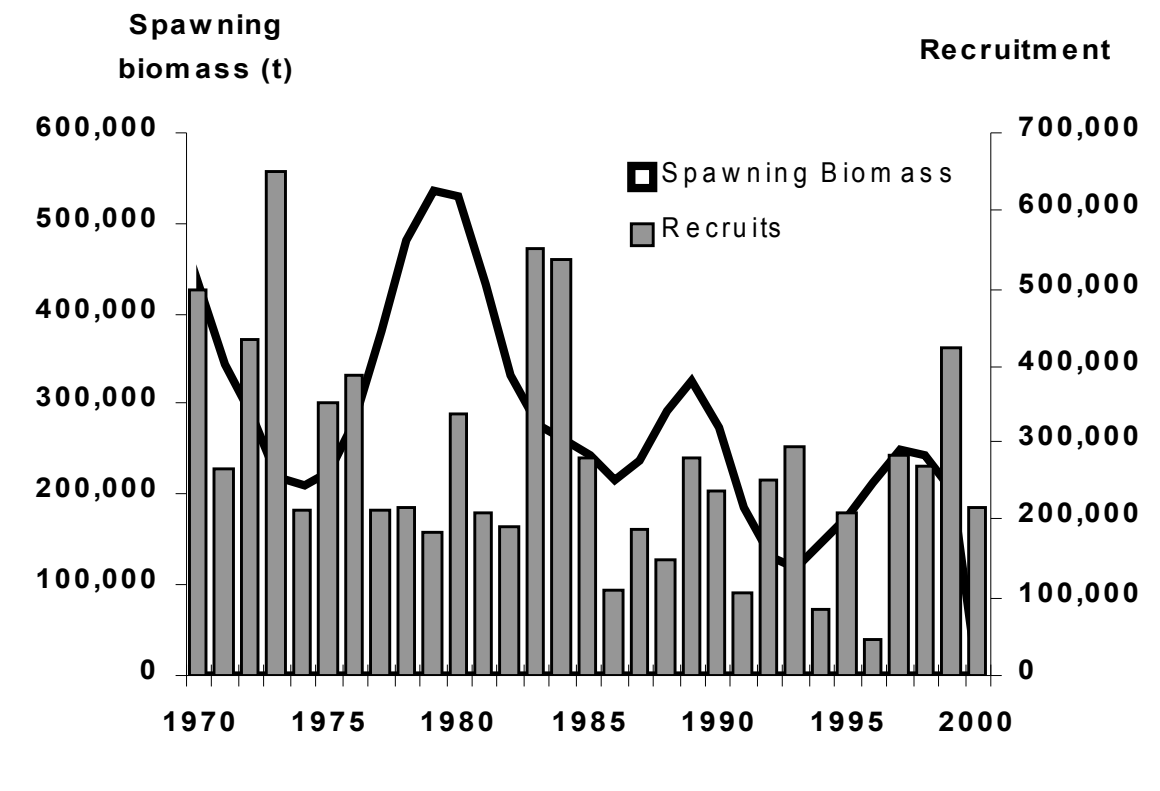
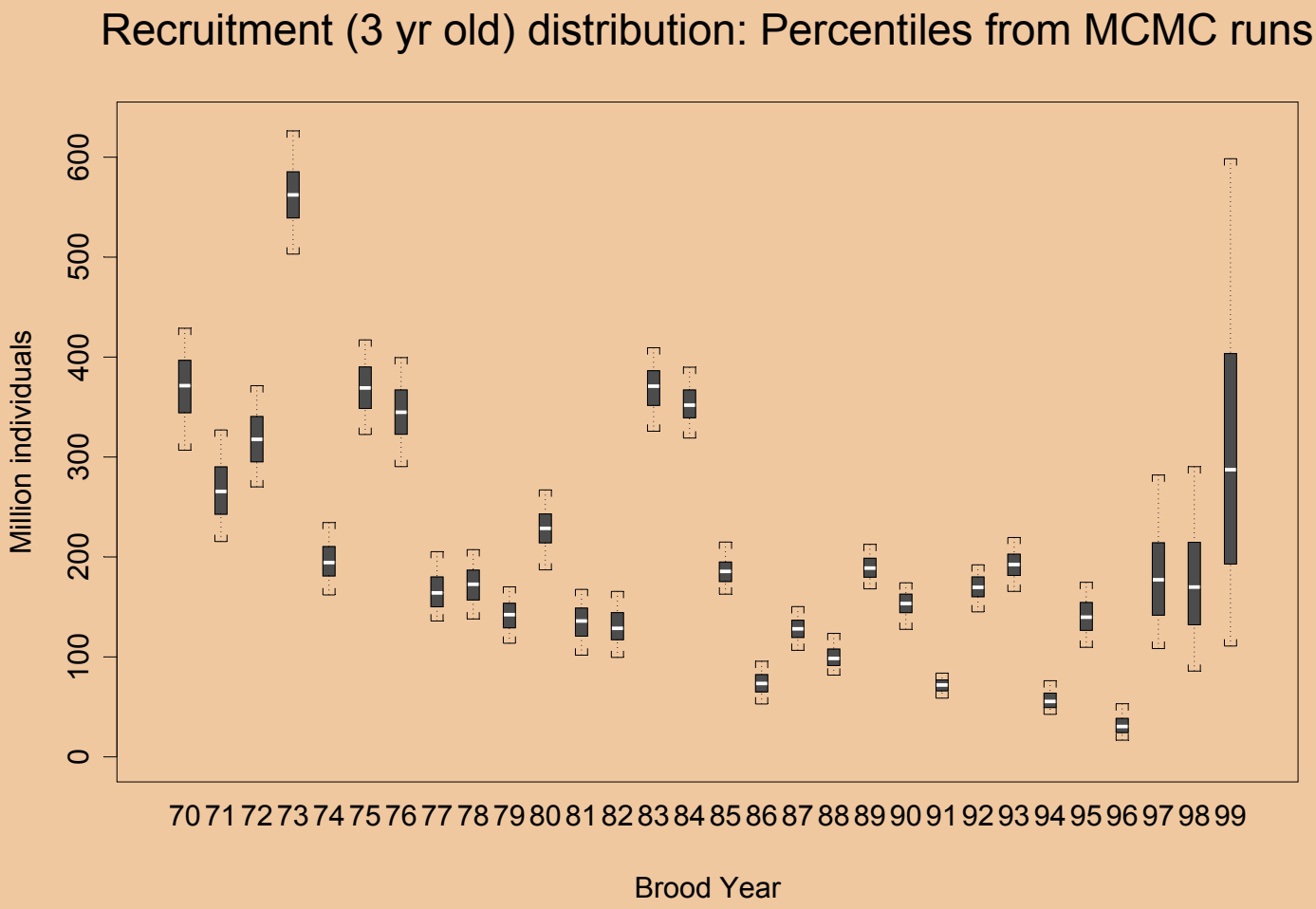
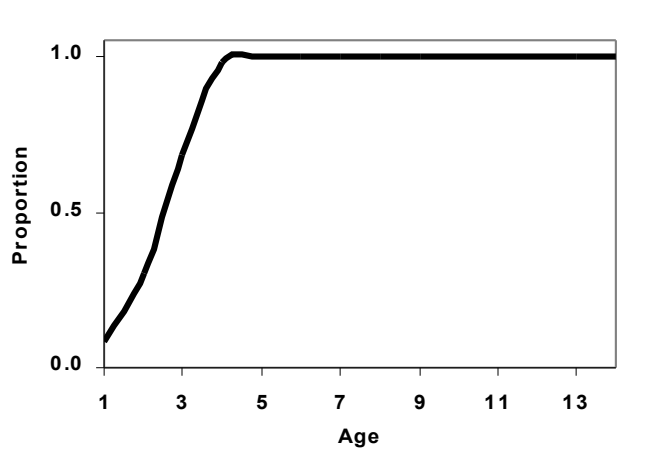


# Icelandic cod

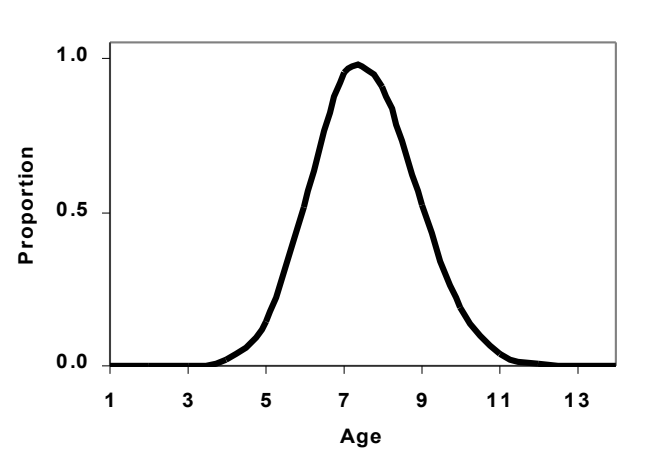


# Icelandic cod

spring survey selectivity




net survey selectivity



# Coleraine

Homepage

**http://www.fish.washington.edu/research/coleraine**

User manual

**http://www.fish.washington.edu/Publications/pdfs/0116.pdf**

(Hilborn et al. 2001, UW School Aquat. Fish. Sci. Rep.)