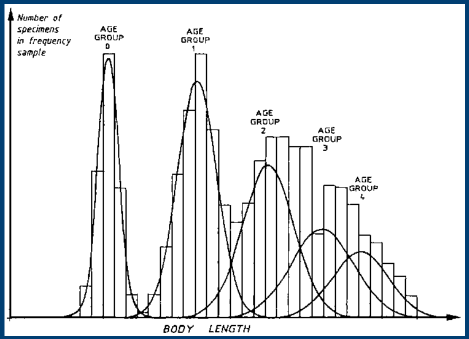
Science, Service, Stewardship



Analysis of Size-Frequency Data

(aka Mean Length Approach)

SEDAR 26

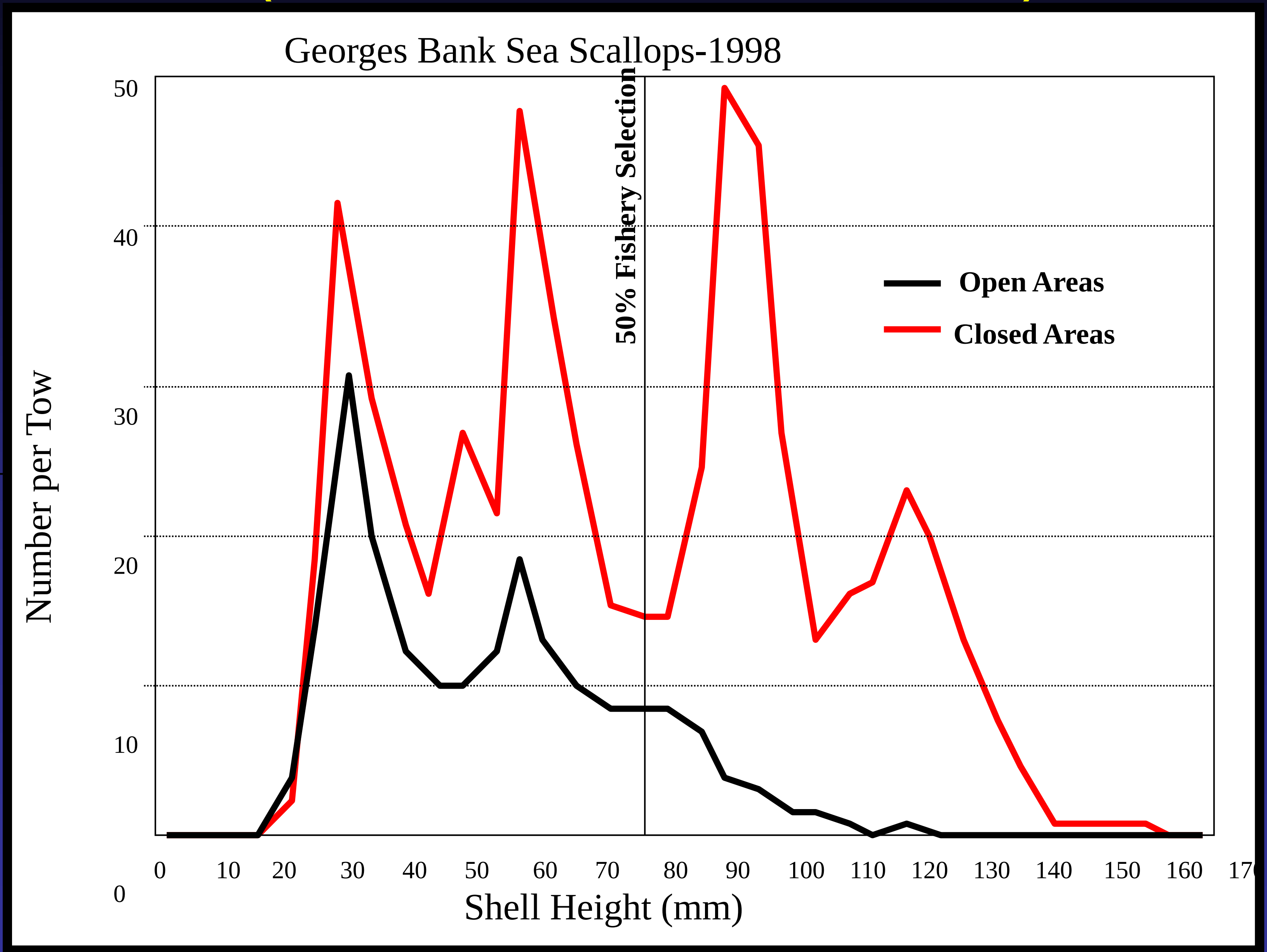
October, 2011

NOAA FISHERIES SERVICE

Todd Gedamke (SEFSC)

Early Use of Length Based Methods–late 1800's

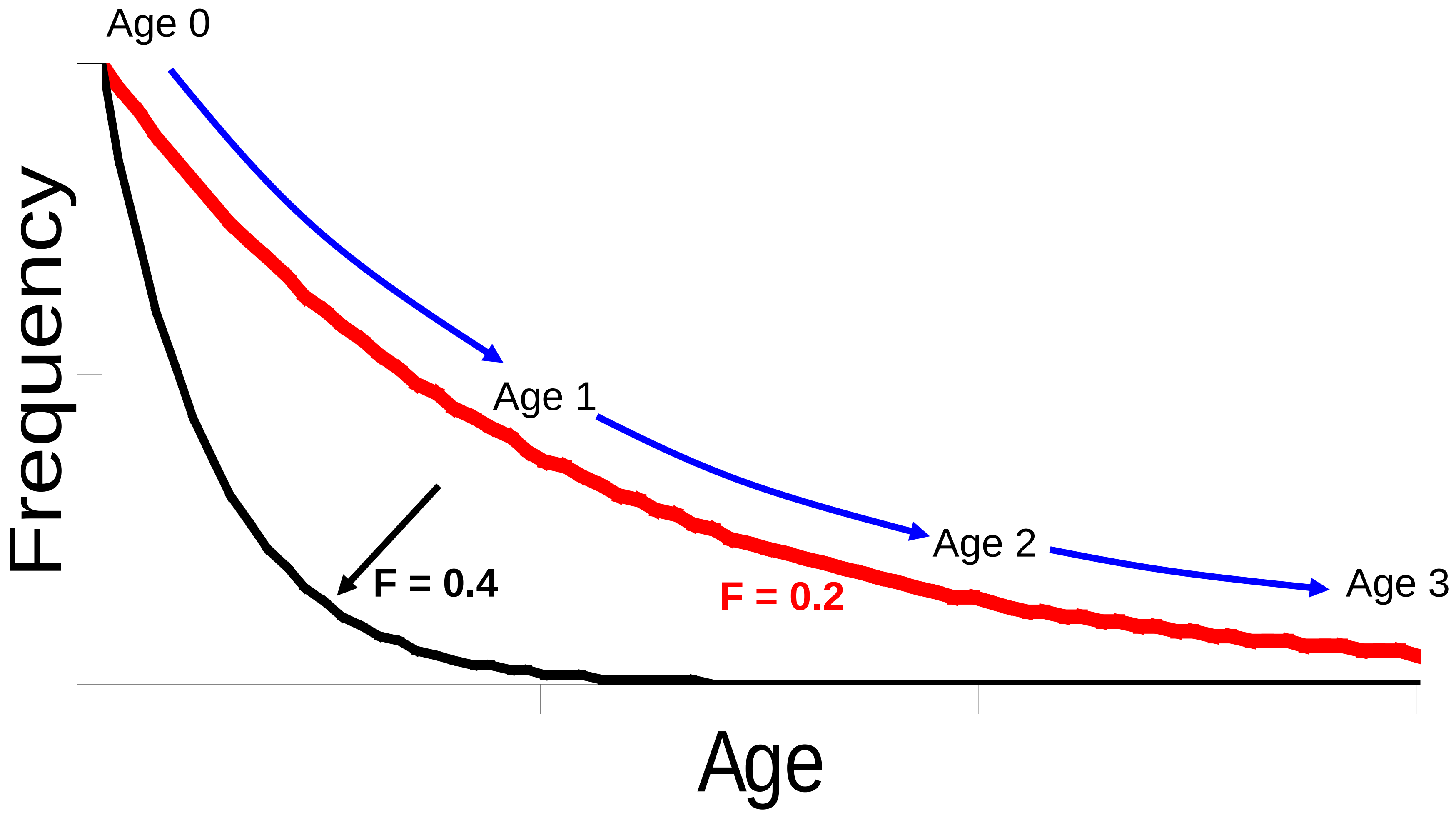
(Petersen, then Fulton, Baranov and others)



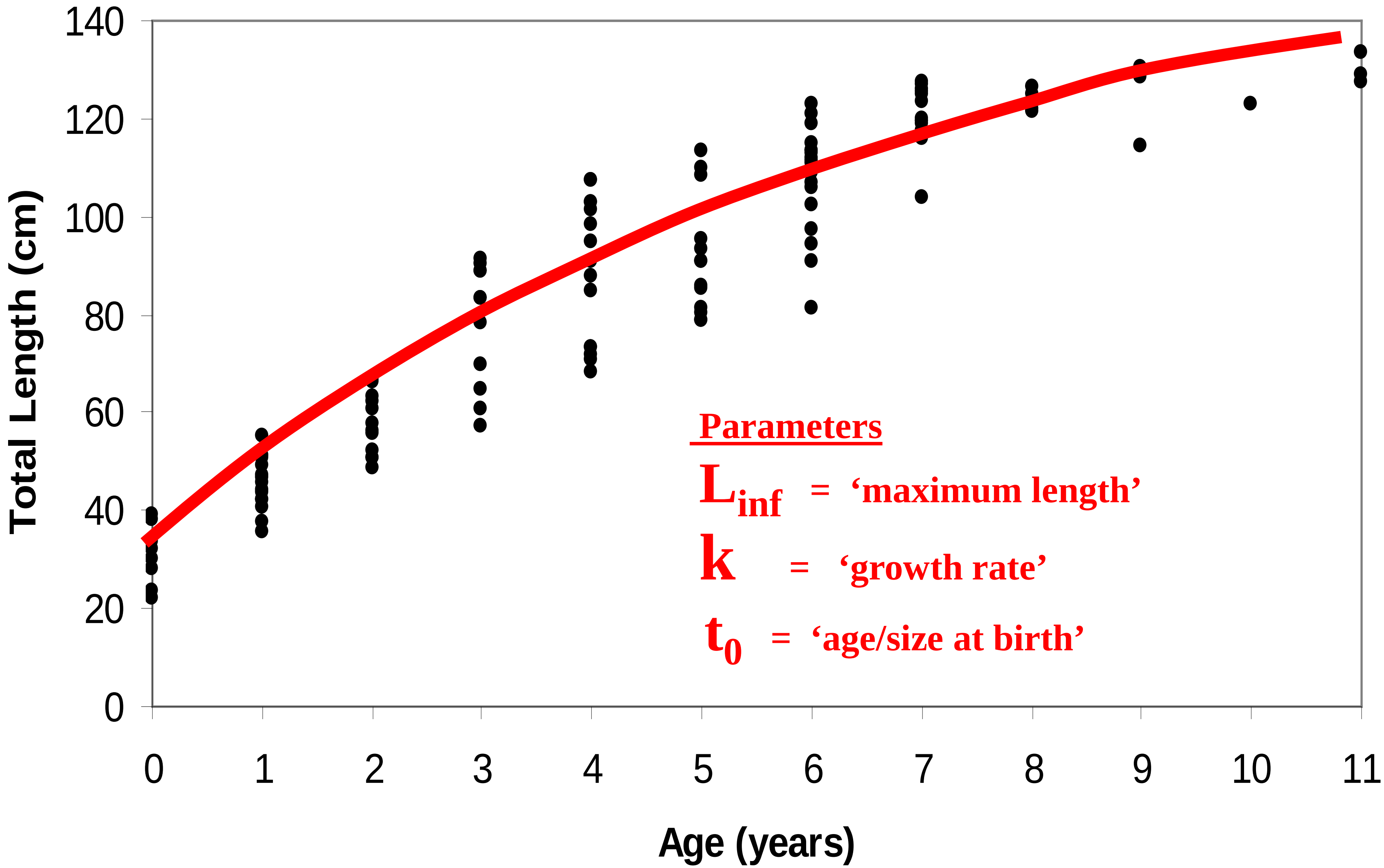
What determines mean length?

$$\bar{L} = \frac{\int_{t_c}^{\infty} N_t L_t \, dt}{\int_{t_c}^{\infty} N_t \, dt} = \frac{\Sigma \text{Number of animals at age t} \times \text{Length at age t}}{\Sigma \text{ Number of animals at age t}}$$

More Fishing → Less Older/Larger Fish



Von Bertalanffy Growth Function



Beverton-Holt mean length mortality estimator

growth rate

maximum length

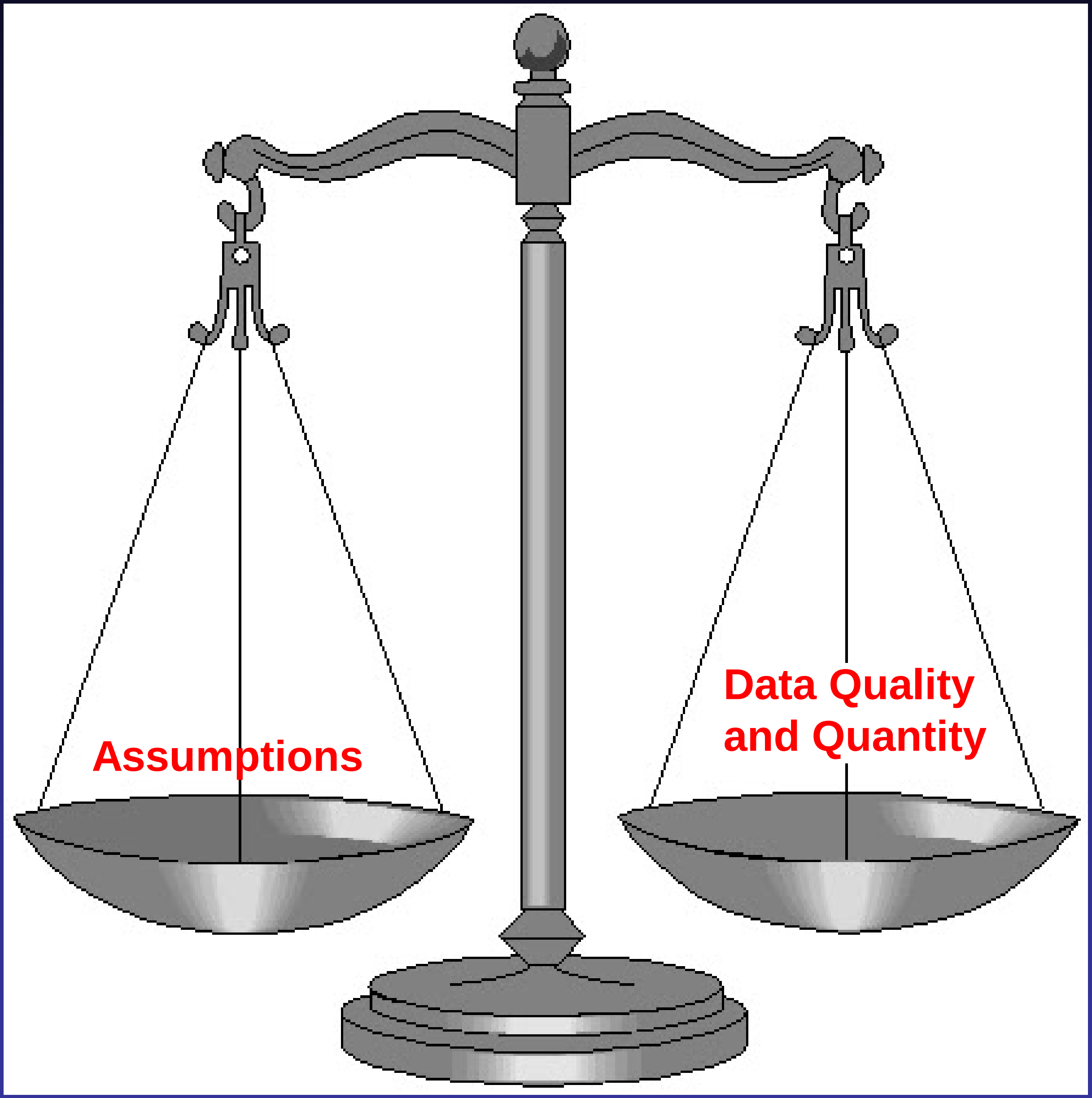
$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

total mortality

mean length

length at which all animals are fully vulnerable to gear

The Trade-off!



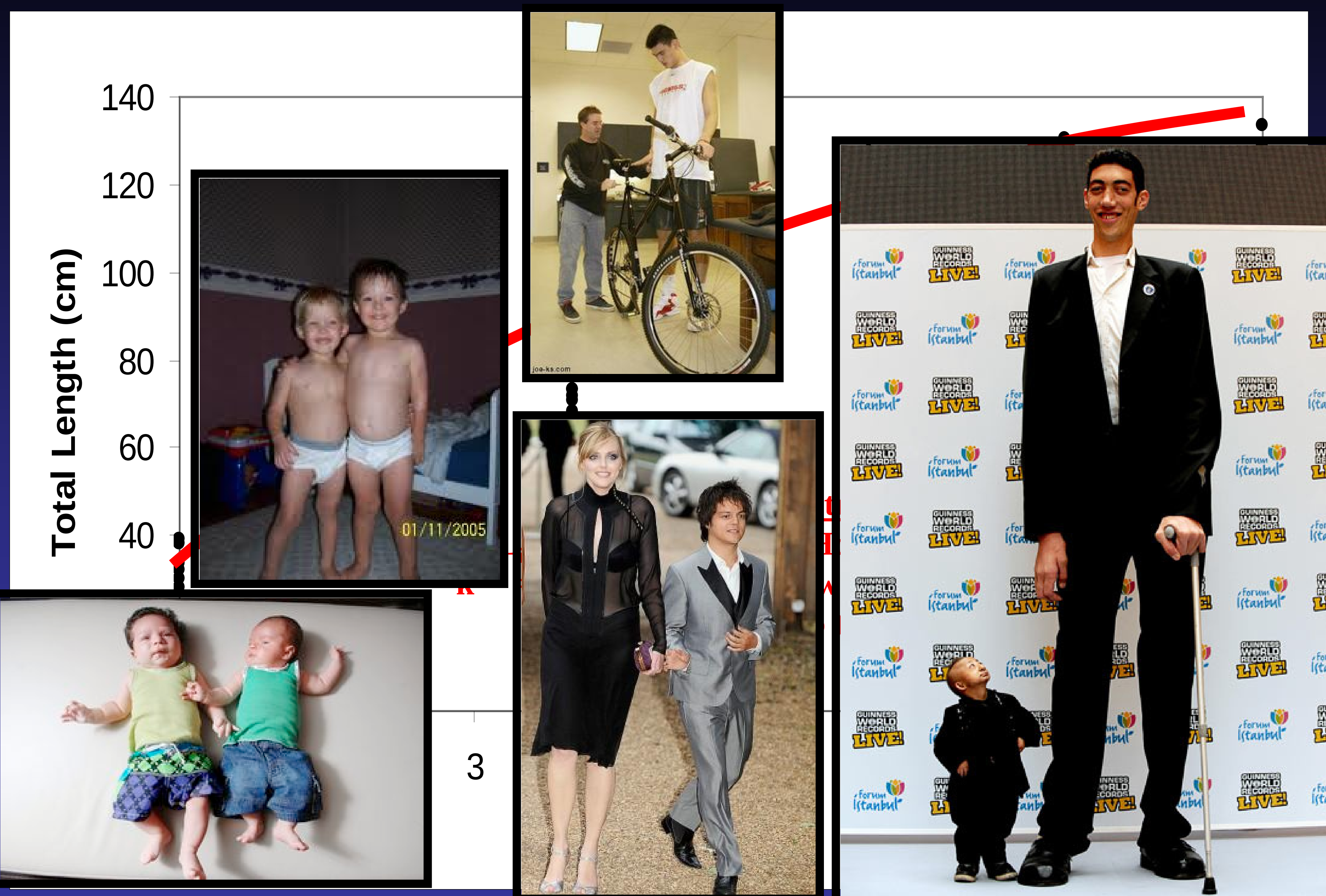
Beverton-Holt mean length mortality estimator

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

5 assumptions:

1. Asymptotic growth, K and L_∞ known & constant over time.
2. No individual variability in growth.
3. 'Constant' & continuous recruitment over time.
4. Mortality constant with age (eg. Selectivity, M).
5. Mortality constant over time → Population in equilibrium (mean length reflects mortality)

Von Bertalanffy Growth Function



Beverton-Holt mean length mortality estimator

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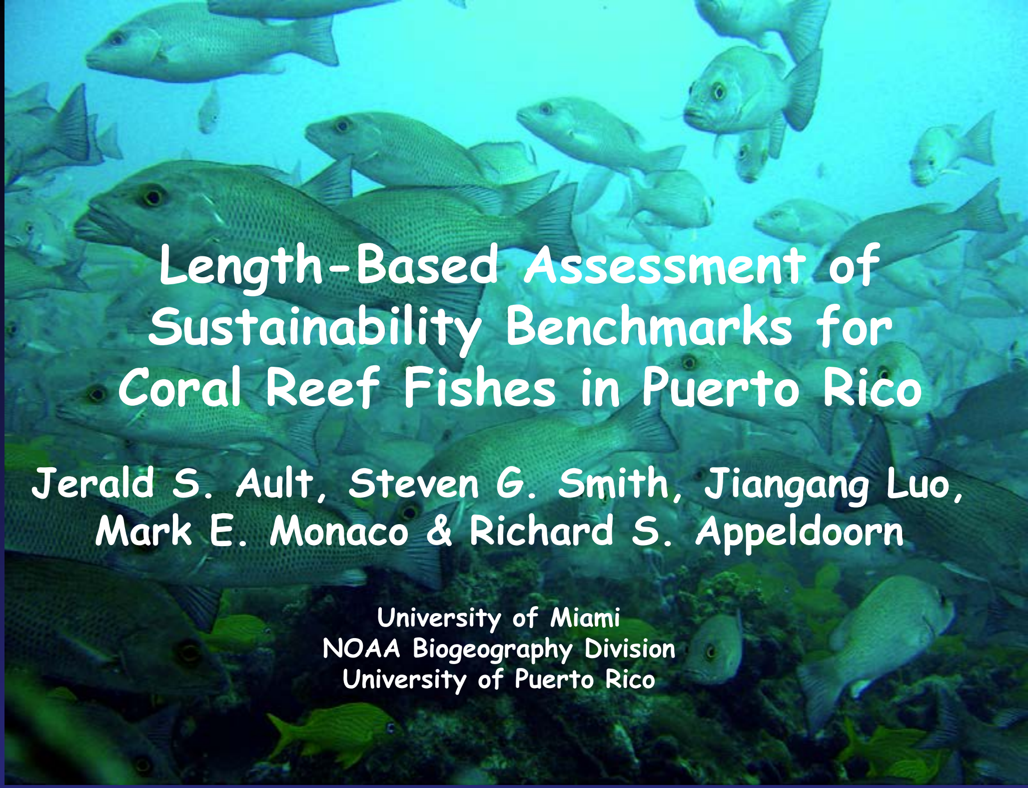
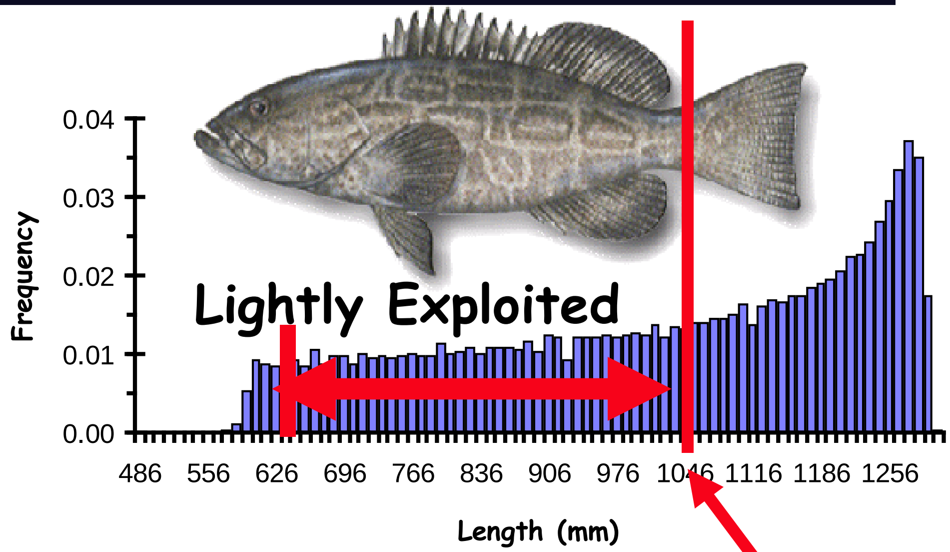
Modifications of the B-H Mortality Estimator

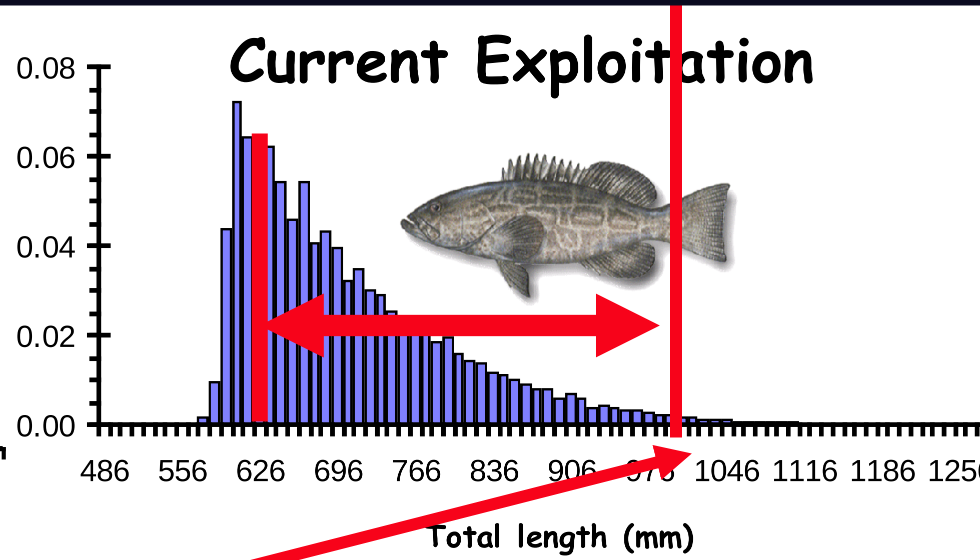


5 assumptions:

1. Asymptotic growth, K and L_∞ known & constant over time.
2. No individual variability in growth.
3. ‘Constant’ & continuous recruitment over time.
4. **Mortality constant with age (eg. Selectivity, M).**
5. Mortality constant over time → Population in equilibrium (mean length reflects mortality)

Ehrhardt-Ault mortality estimators





$$\overline{L}(t) = \frac{F(t)\int_{a_c}^{a_\lambda} N(a,t)\,L(a,t)\,da}{F(t)\int_{a_c}^{a_\lambda} N(a,t)\,da}$$

Estimating Mortality from Mean Lengths in Non-equilibrium Situations

Gedamke and Hoenig (2006)

Beverton-Holt mean length mortality estimator

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

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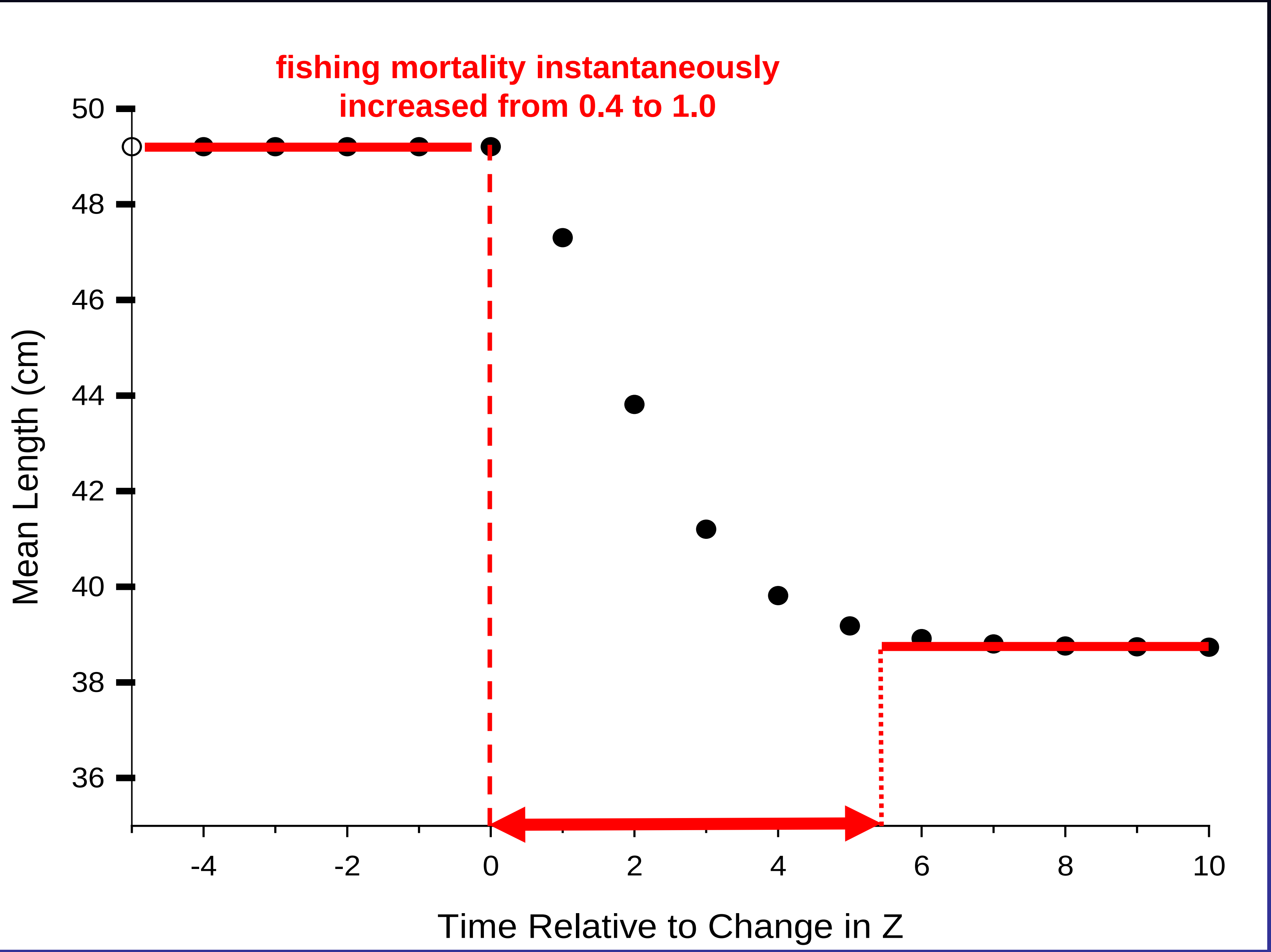

fishing mortality instantaneously
increased from 0.4 to 1.0
Mean Length (cm)
50
48
46
44
42
40
38
36
-4
-2
0
2
4
6
8
10
Time Relative to Change in Z

$$\bar{L} = \frac{\int_{t_c}^{g} N_o \exp(-Z_2(t-t_c))L_t dt + \int_{g}^{\infty} N_o \exp(-Z_2 d\ \ ) \exp(-Z_1(t-g))L_t dt}{\int_{t_c}^{g} N_o \exp(-Z_2(t-t_c))dt + \int_{g}^{\infty} N_o \exp(-Z_2 d\ \ ) \exp(-Z_1(t-g))dt}$$

In English:

Mean Length =

$$\frac{\left[\text{SUM \# of younger animals at each age } (Z_2 \text{ only}) \bullet \text{Length at age}\right] + \left[\text{SUM \# of older animals at each age (both } Z_1 \text{ and } Z_2) \bullet \text{Length at age}\right]}{\text{SUM \# of younger animals at each age } (Z_2 \text{ only}) + \text{SUM \# of older animals at each age (both } Z_1 \text{ and } Z_2)}$$

$$\bar{L} = \frac{\int_{t_c}^{g} N_o \exp(-Z_2(t-t_c)) L_t\,dt + \int_{g}^{\infty} N_o \exp(-Z_2 d\ ) \exp(-Z_1(t-g)) L_t\,dt}{\int_{t_c}^{g} N_o \exp(-Z_2(t-t_c))\,dt + \int_{g}^{\infty} N_o \exp(-Z_2 d\ ) \exp(-Z_1(t-g))\,dt}$$

In English:

Mean Length =

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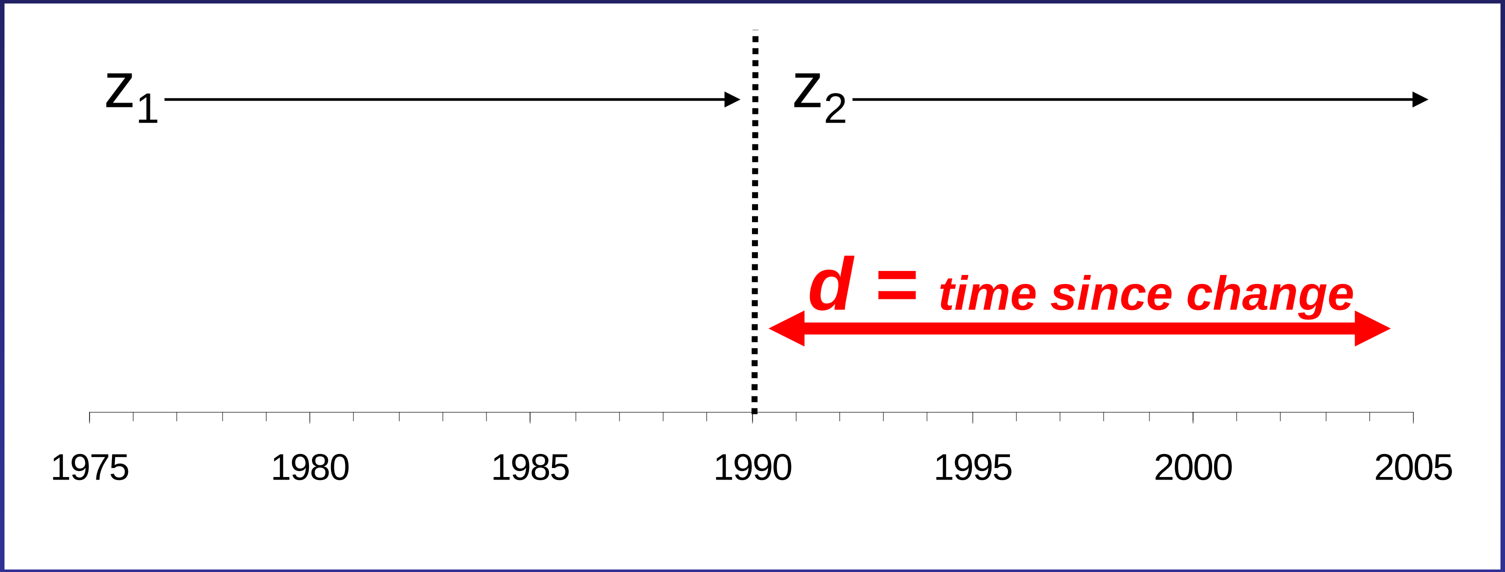
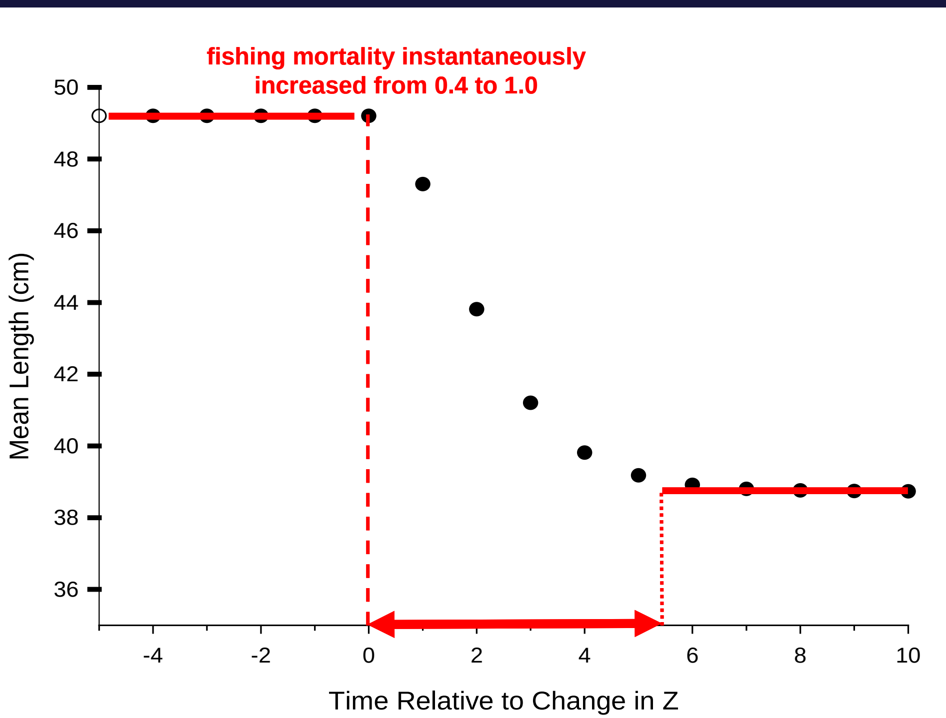
Simplified Equation (at least relatively)

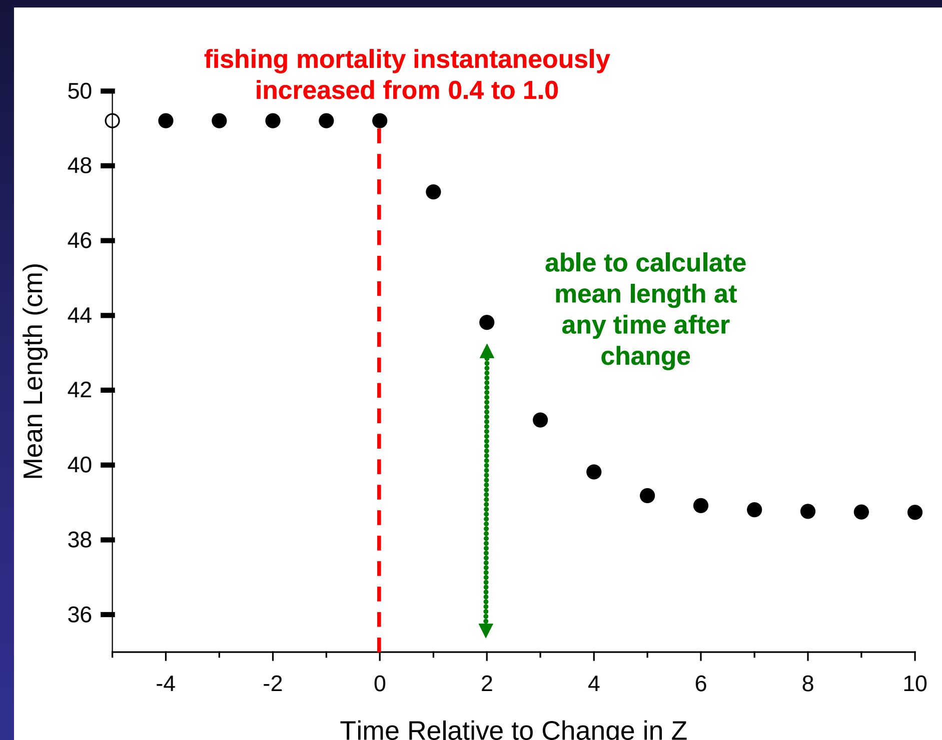
$$\bar{L} = L_\infty - \frac{Z_1 Z_2 (L_\infty - L_c)\{Z_1 + K + (Z_2 - Z_1)\exp(-(Z_2 + K)d)\}}{(Z_1 + K)(Z_2 + K)(Z_1 + (Z_2 - Z_1)\exp(-Z_2 d))}$$



Estimating Mortality from Mean Lengths in Non-equilibrium Situations

Gedamke and Hoenig (2006)





$$\bar{L} = L_\infty - \frac{Z_1 Z_2 (L_\infty - L_c)\{Z_1 + K + (Z_2 - Z_1)\exp(-(Z_2 + K)d)\}}{(Z_1 + K)(Z_2 + K)(Z_1 + (Z_2 - Z_1)\exp(-Z_2 d))}$$

Assumption 5

Population in equilibrium (enough time elapsed after change in mortality that mean length reflects new mortality).

Hard to meet in the real world!

Years to "reach" equilibrium after change in mortality

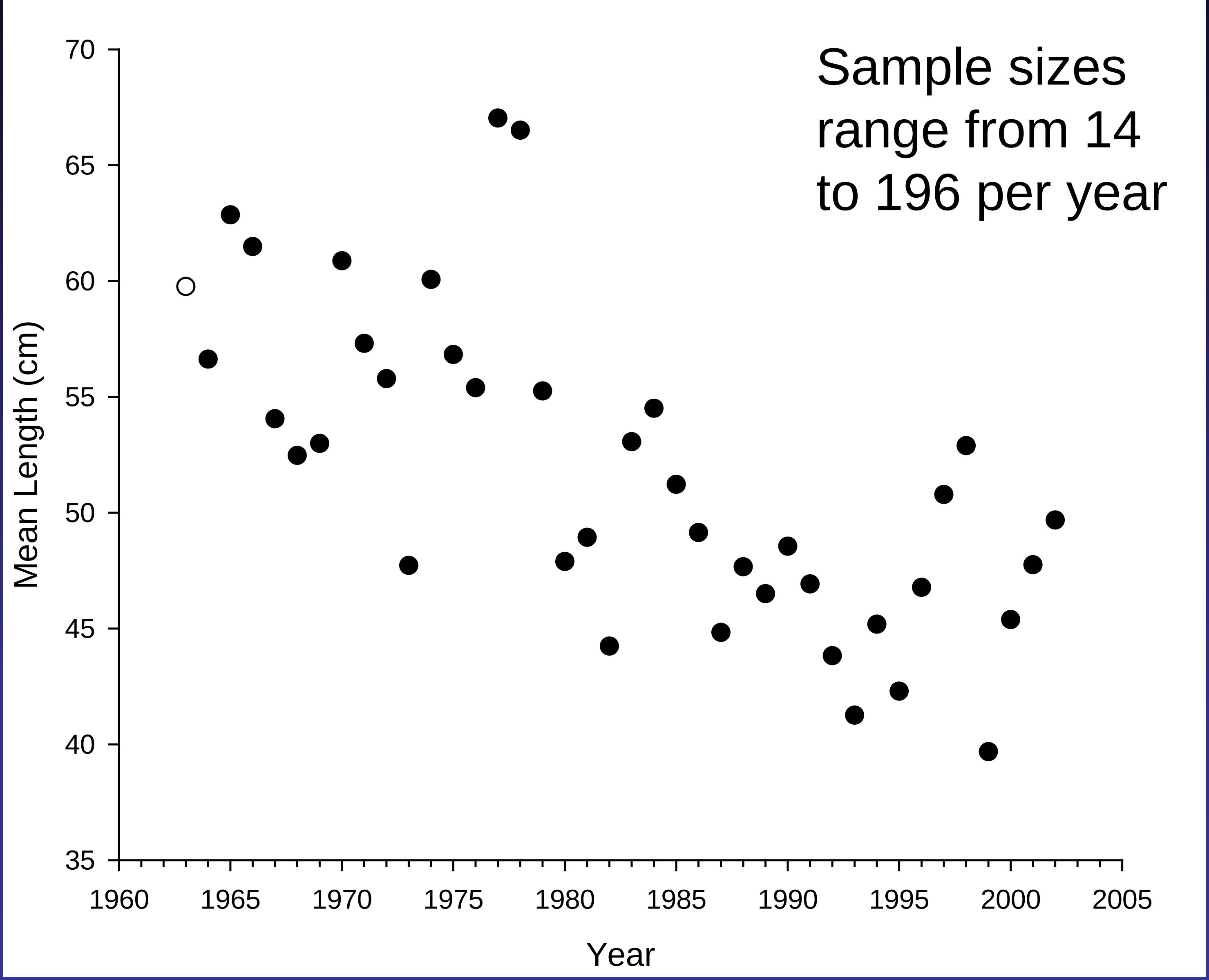
		Z_2				
		0.1	**0.3**	**0.5**	**0.7**	**0.9**
Z_1	**0.1**	-	14	11	9	$\boxed{7}$
	0.3	26	-	6	6	6
	0.5	28	8	-	4	4
	0.7	29	10	5	-	3
	0.9	$\boxed{29}$	10	6	3	-

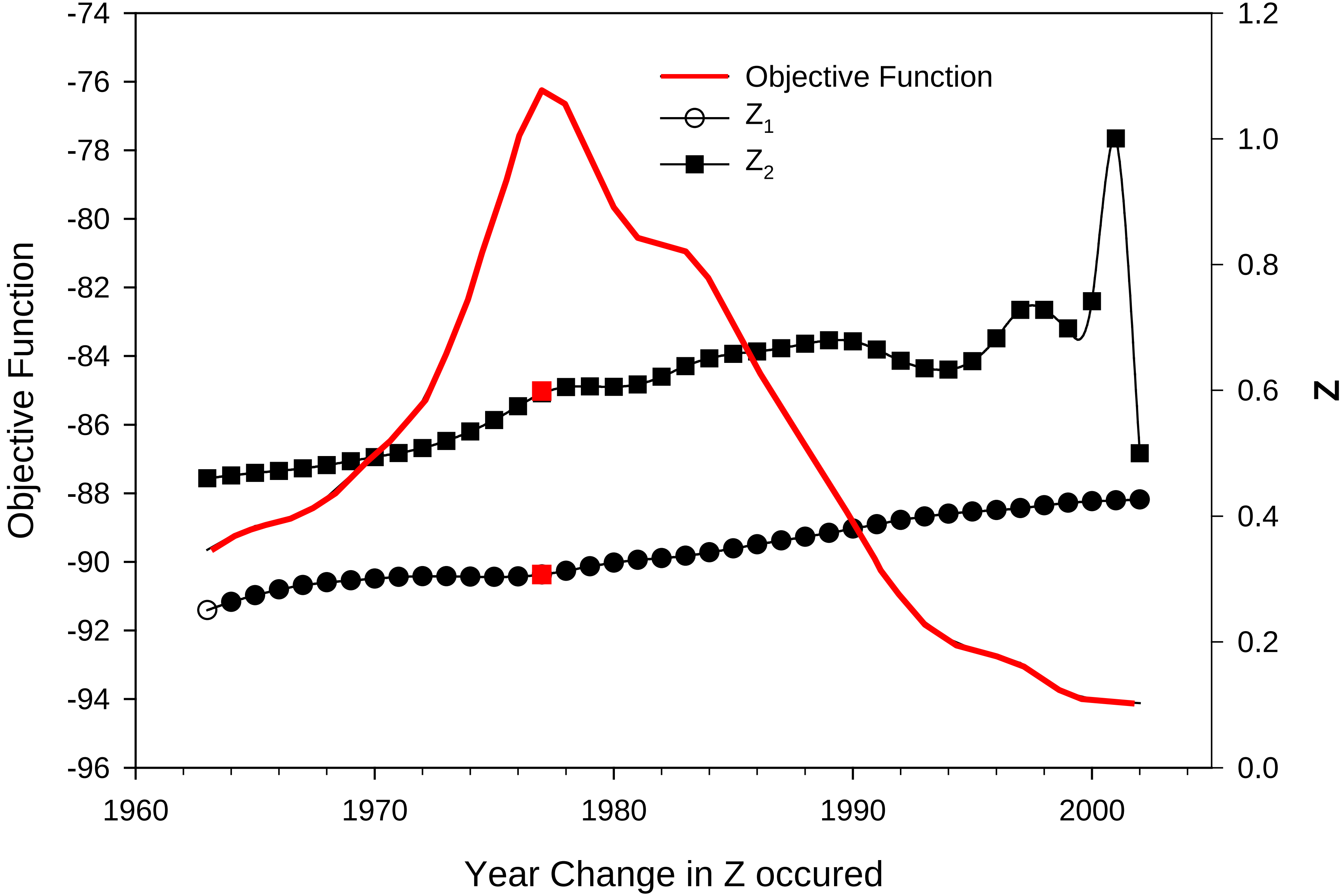
Application to the Assessment of Goosefish (*Lophius americanus*)

data: mean lengths over time, sample sizes

maximum likelihood estimation

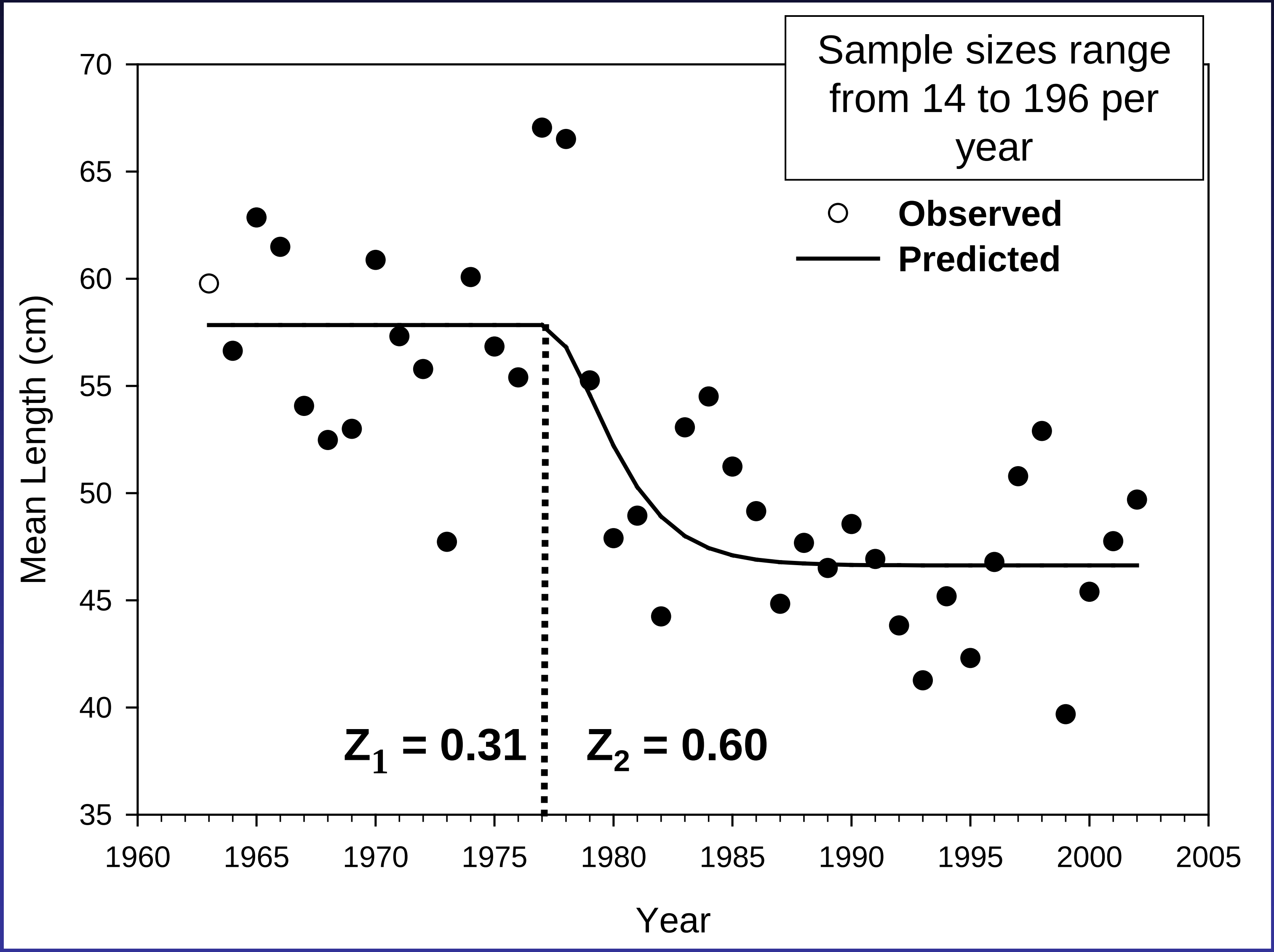
Goosefish Mean Length Data - Southern Management Region - NEFSC Fall Groundfish Survey





Objective Function
Z1
Z2
-74
-76
-78
-80
-82
-84
-86
-88
-90
-92
-94
-96
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Objective Function
Z
Year Change in Z occured

Mortality Estimates for Goosefish - Southern Management Region - NEFSC Fall Groundfish Survey



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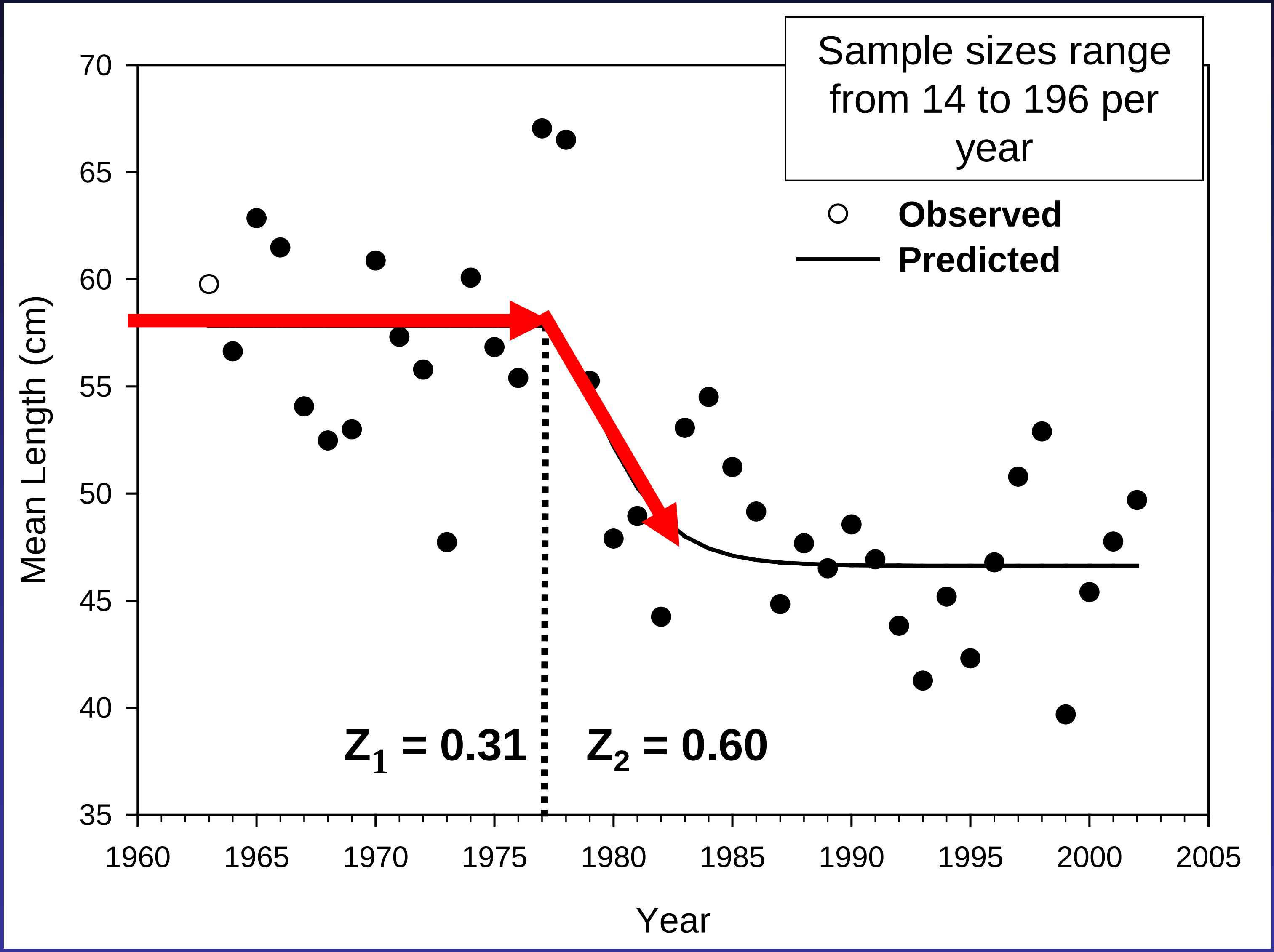
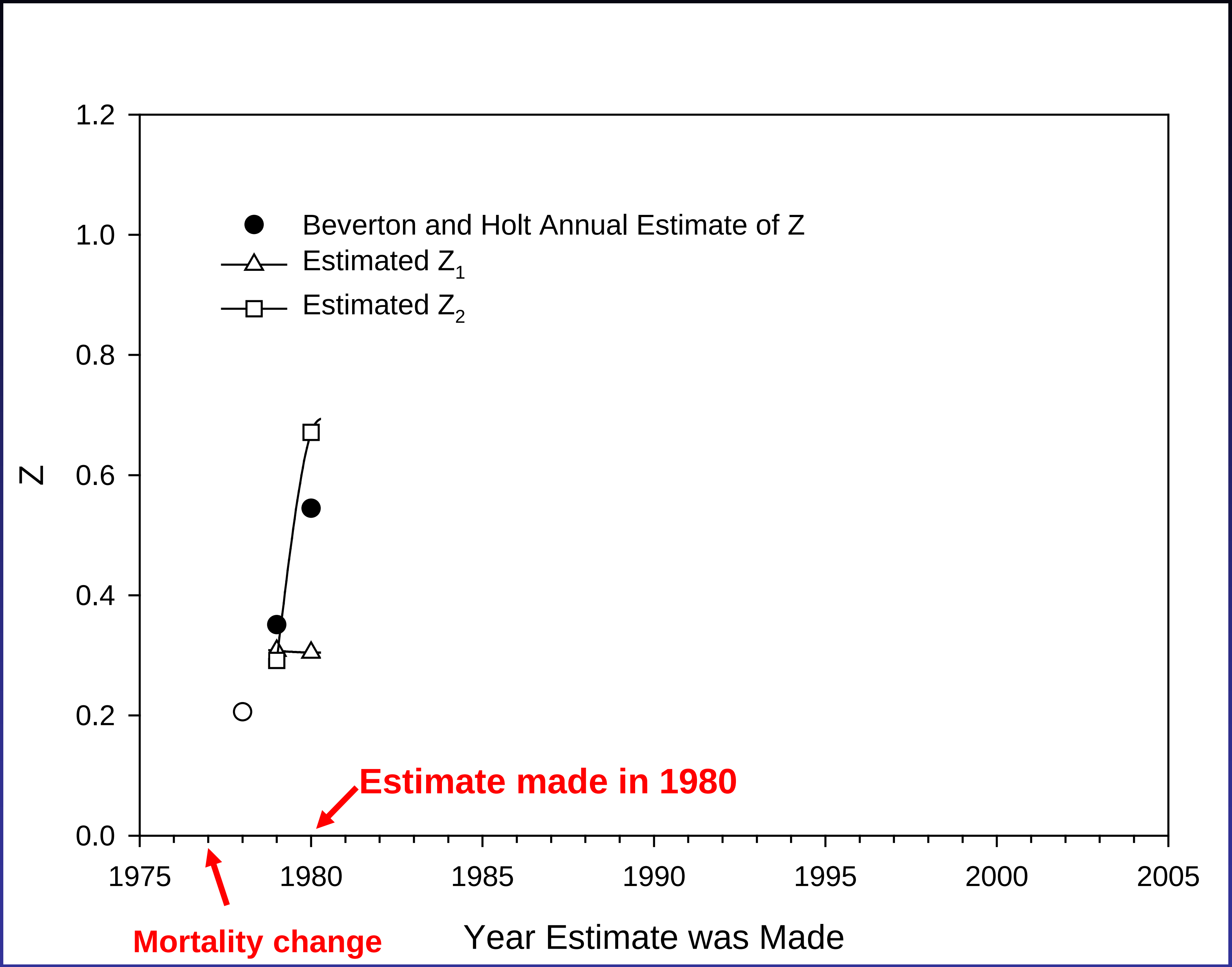
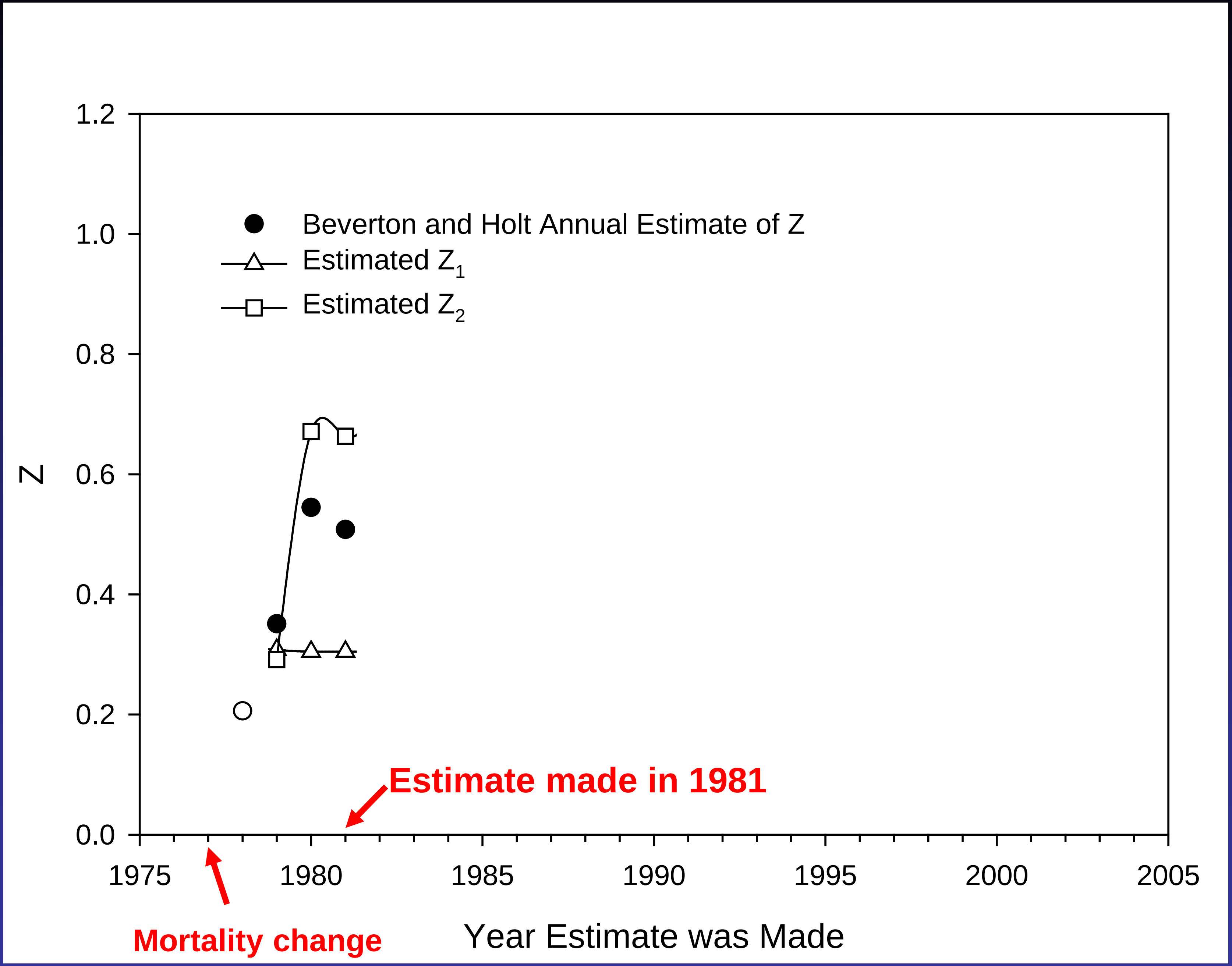
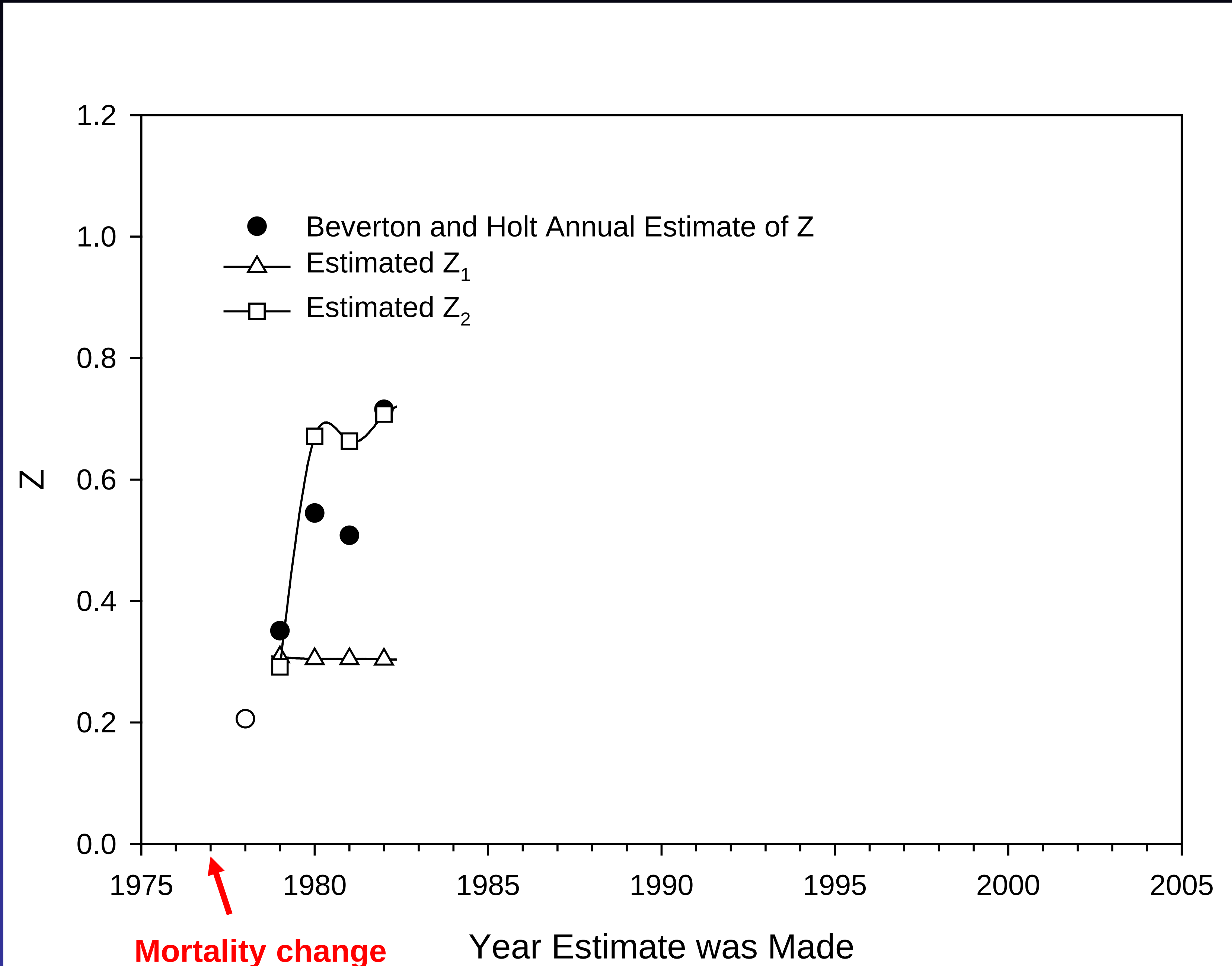




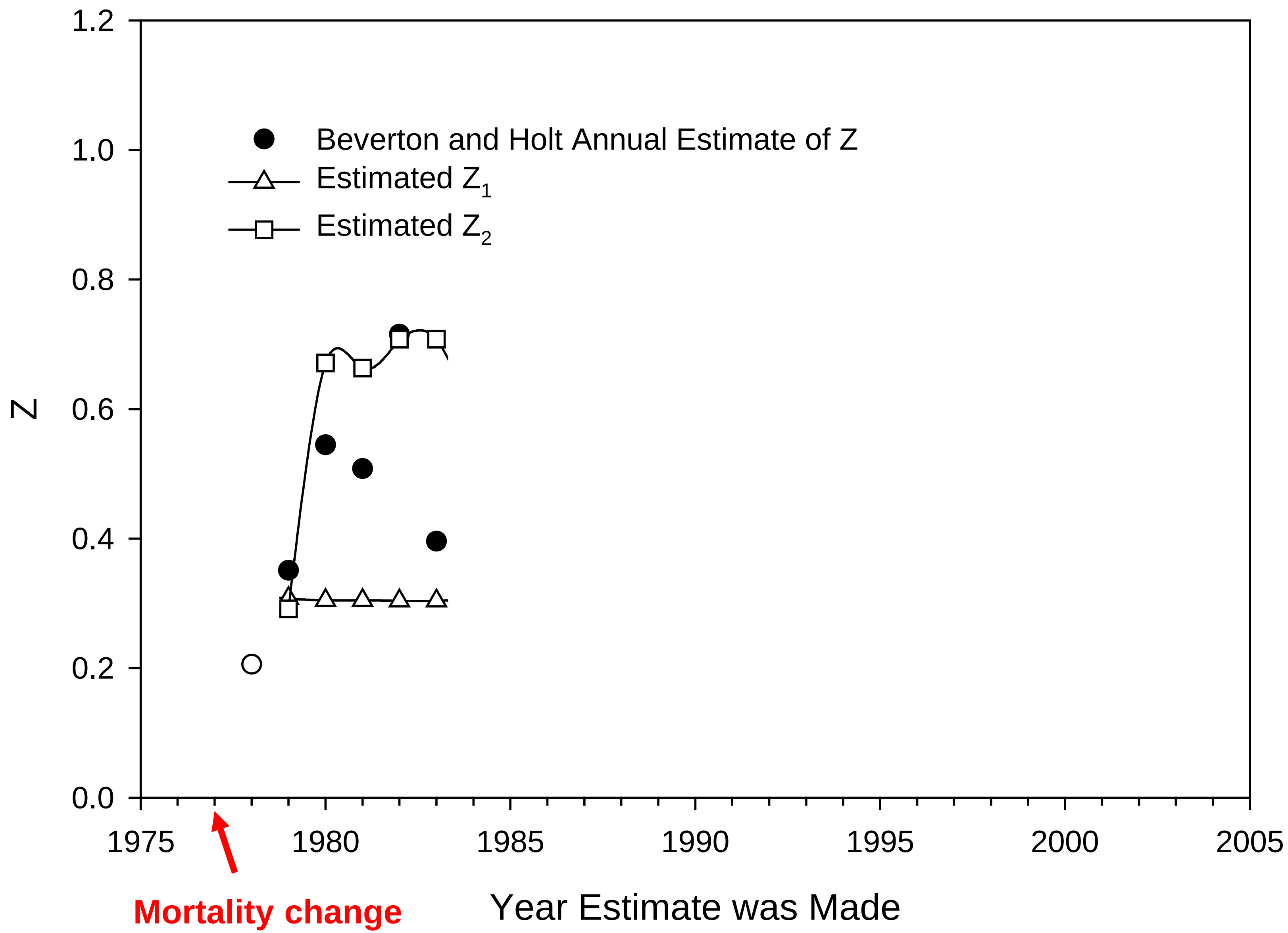
Beverton and Holt Annual Estimate of Z
Estimated Z_1
Estimated Z_2
Z
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1975
1980
1985
1990
1995
2000
2005
Year Estimate was Made
Estimate made in 1980
Mortality change



Beverton and Holt Annual Estimate of Z
Estimated Z1
Estimated Z2
Z
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1975
1980
1985
1990
1995
2000
2005
Estimate made in 1981
Mortality change
Year Estimate was Made



Beverton and Holt Annual Estimate of Z
Estimated Z_1
Estimated Z_2
Z
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1975
1980
1985
1990
1995
2000
2005
Year Estimate was Made
Mortality change



1.2
1.0
0.8
0.6
0.4
0.2
0.0
Z
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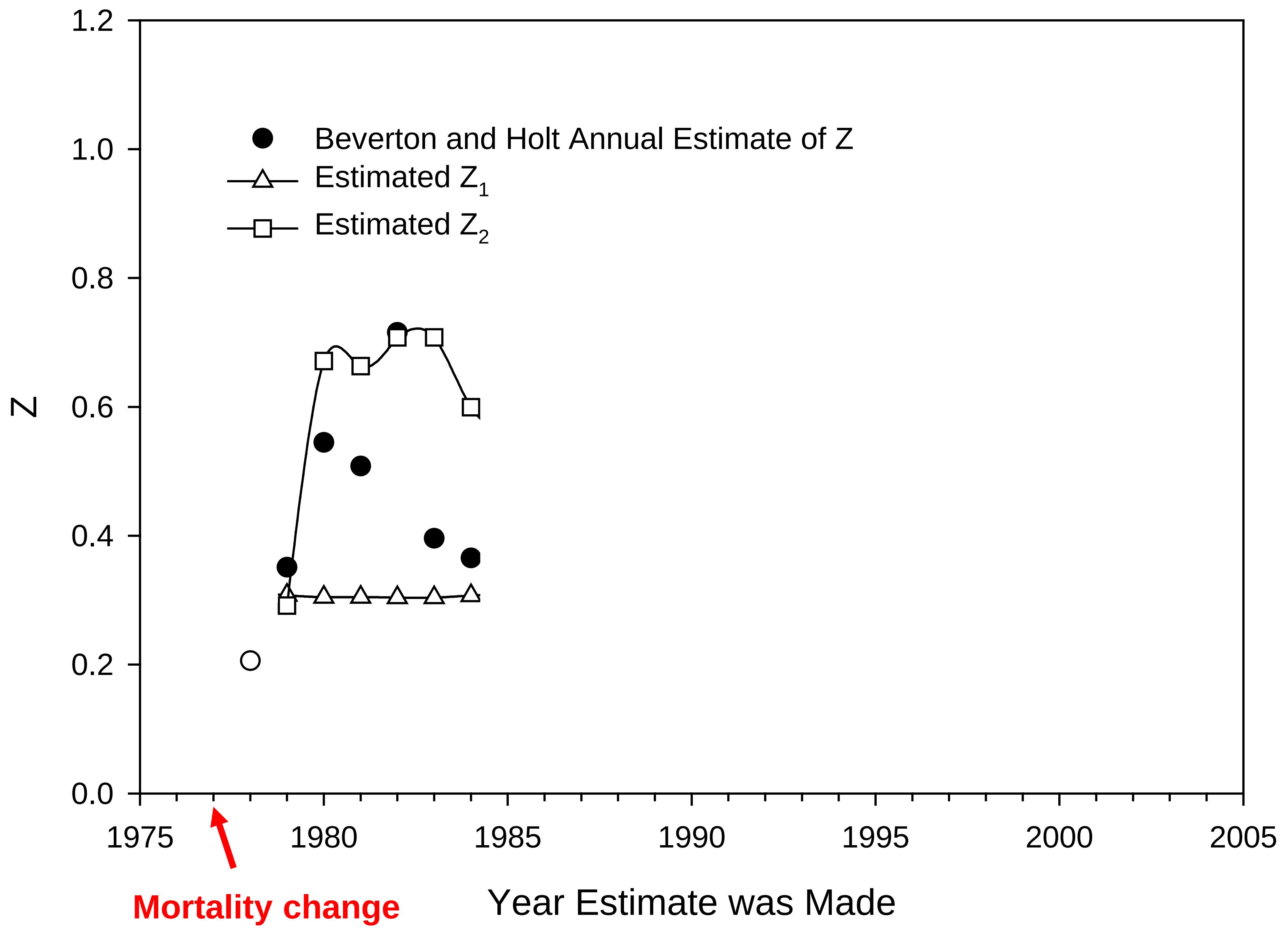
Mortality change



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0.2
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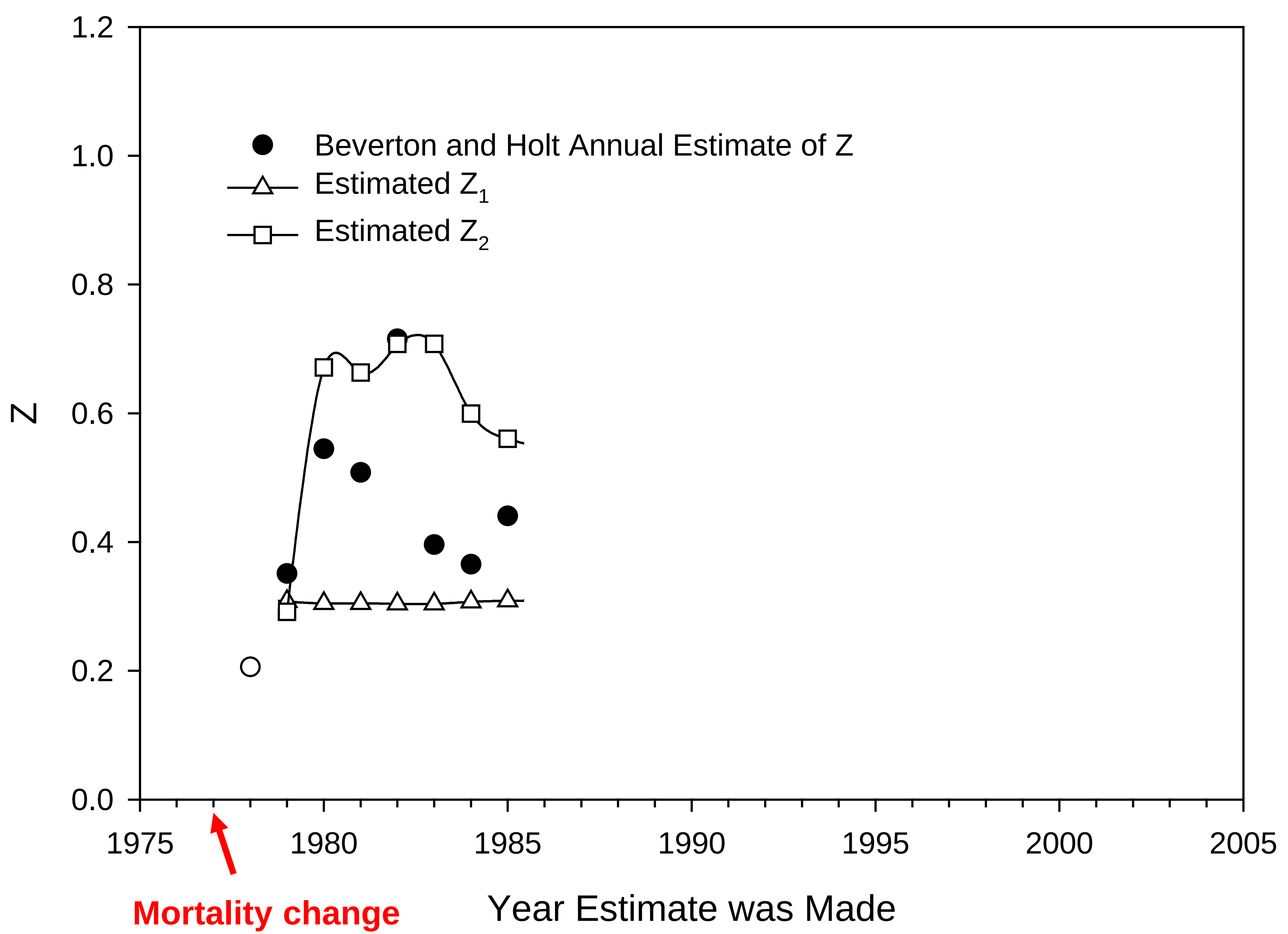
Mortality change


1.2
1.0
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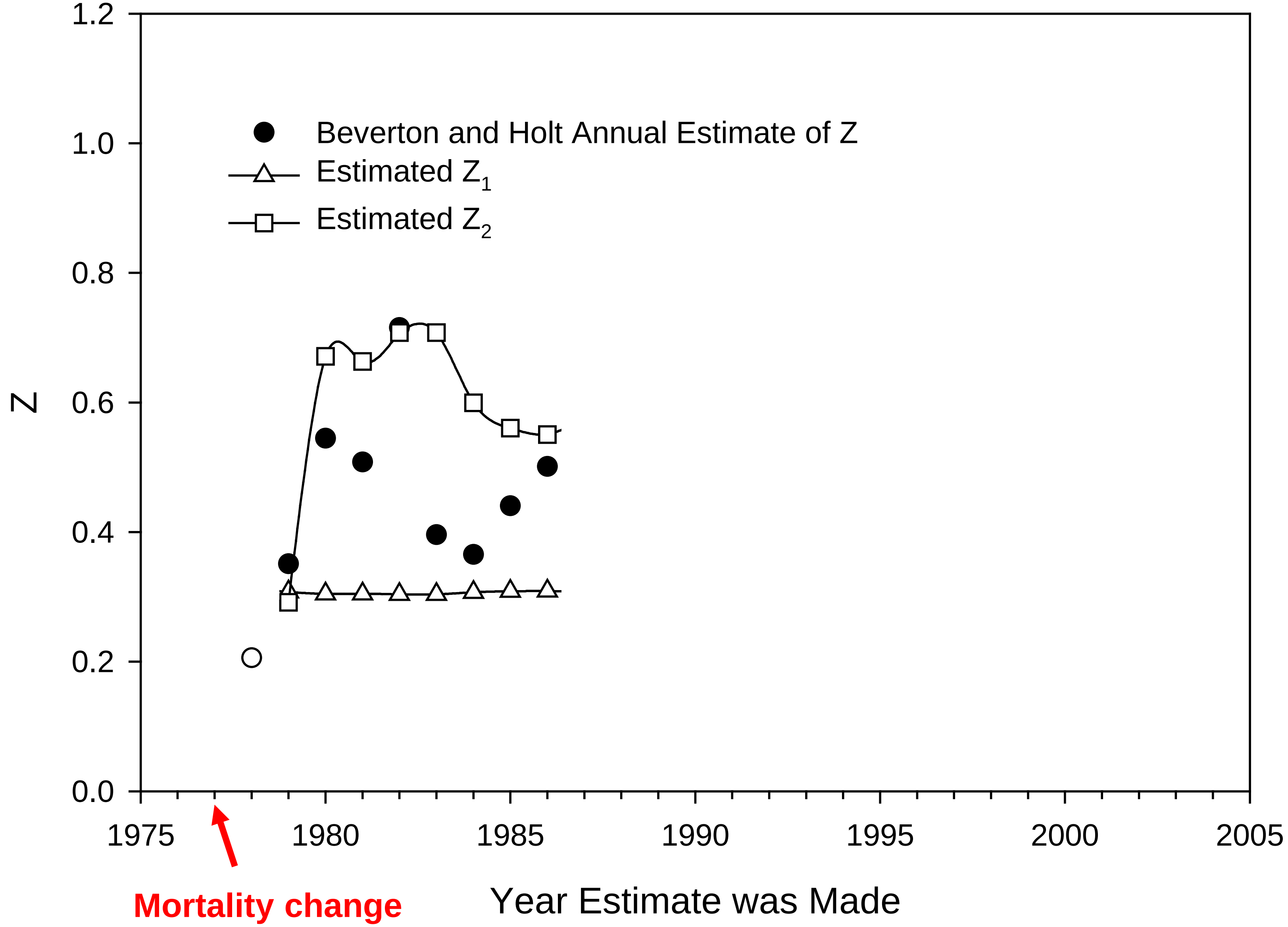
Mortality change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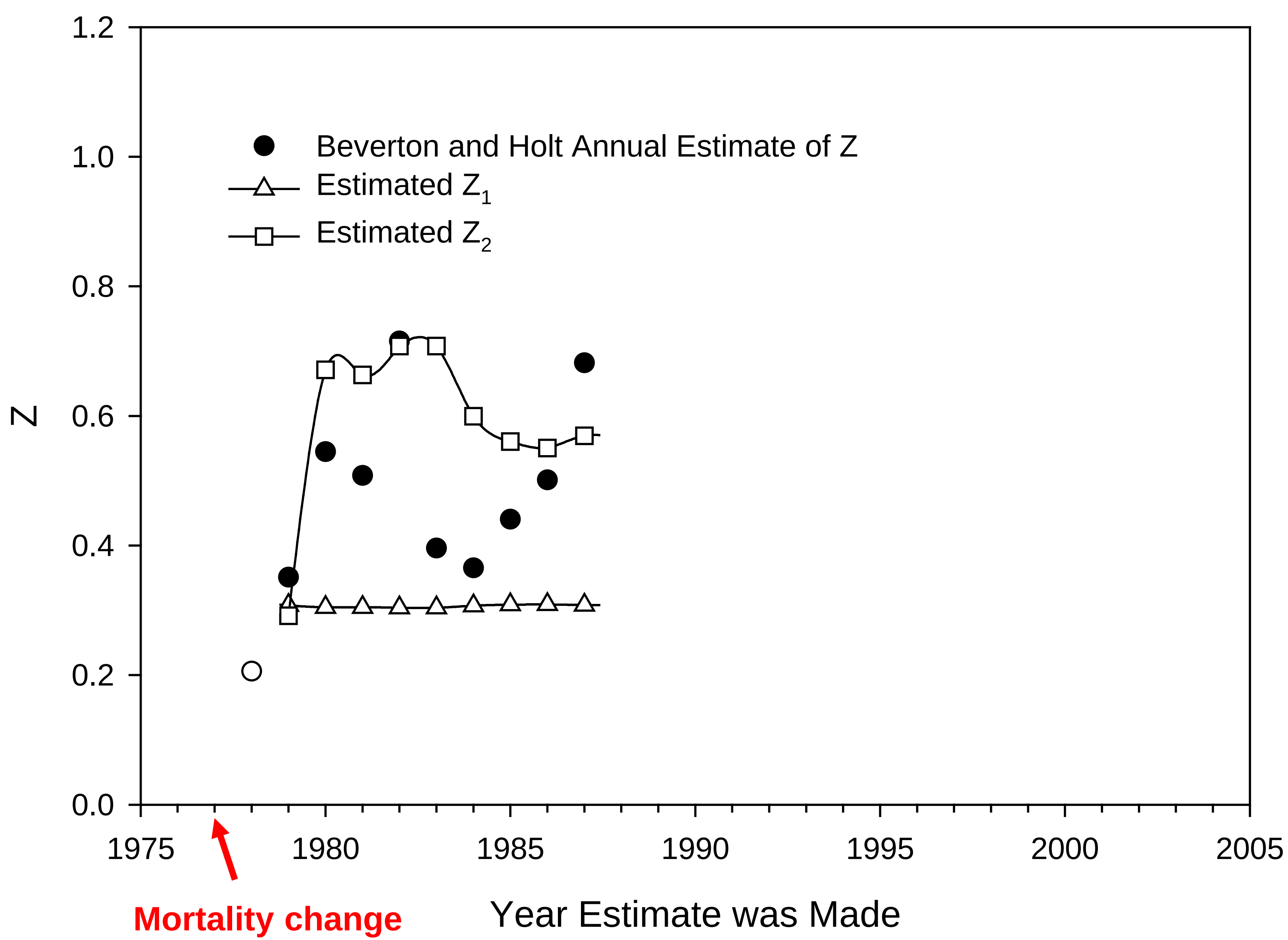

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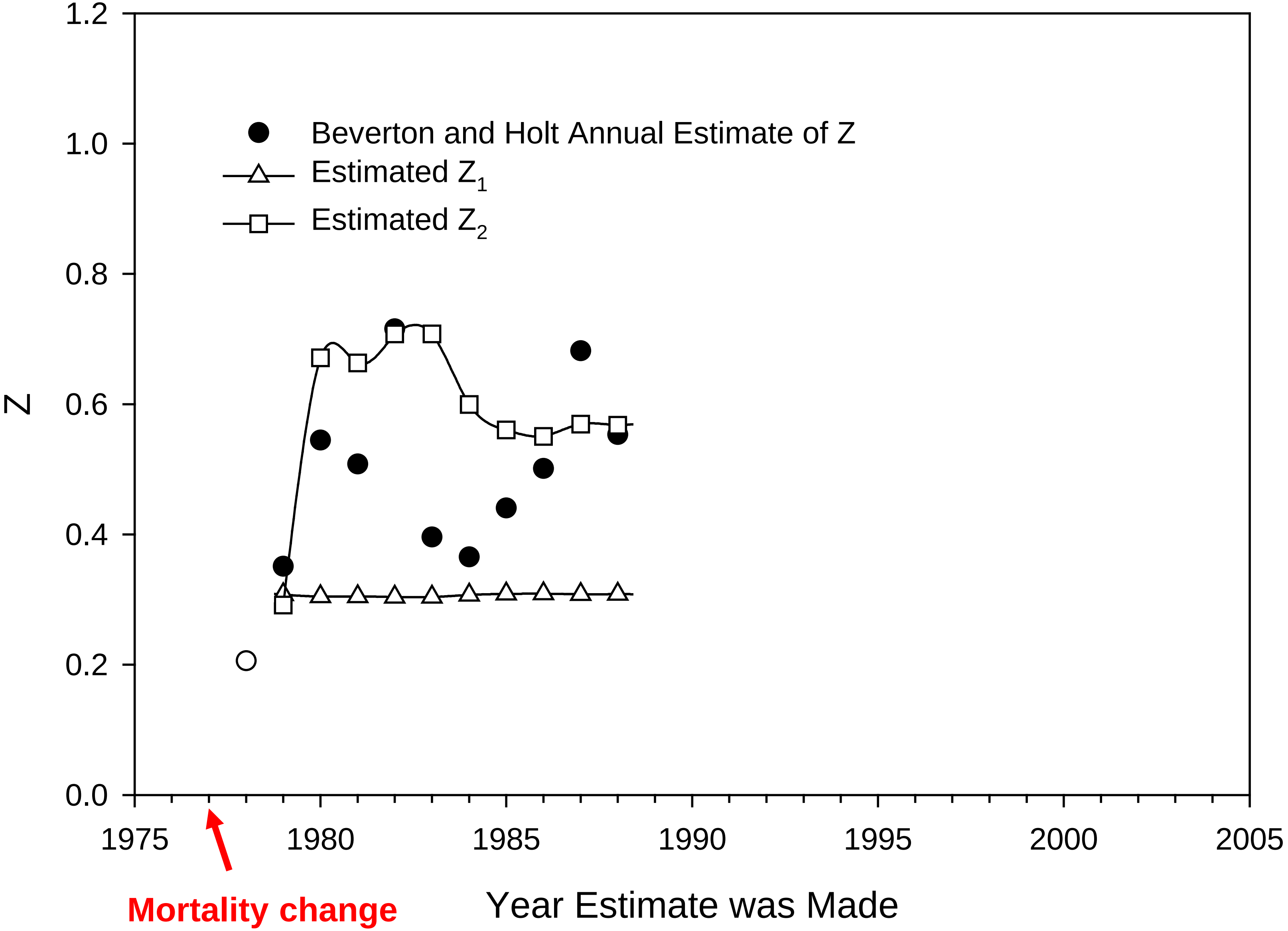

1.2
1.0
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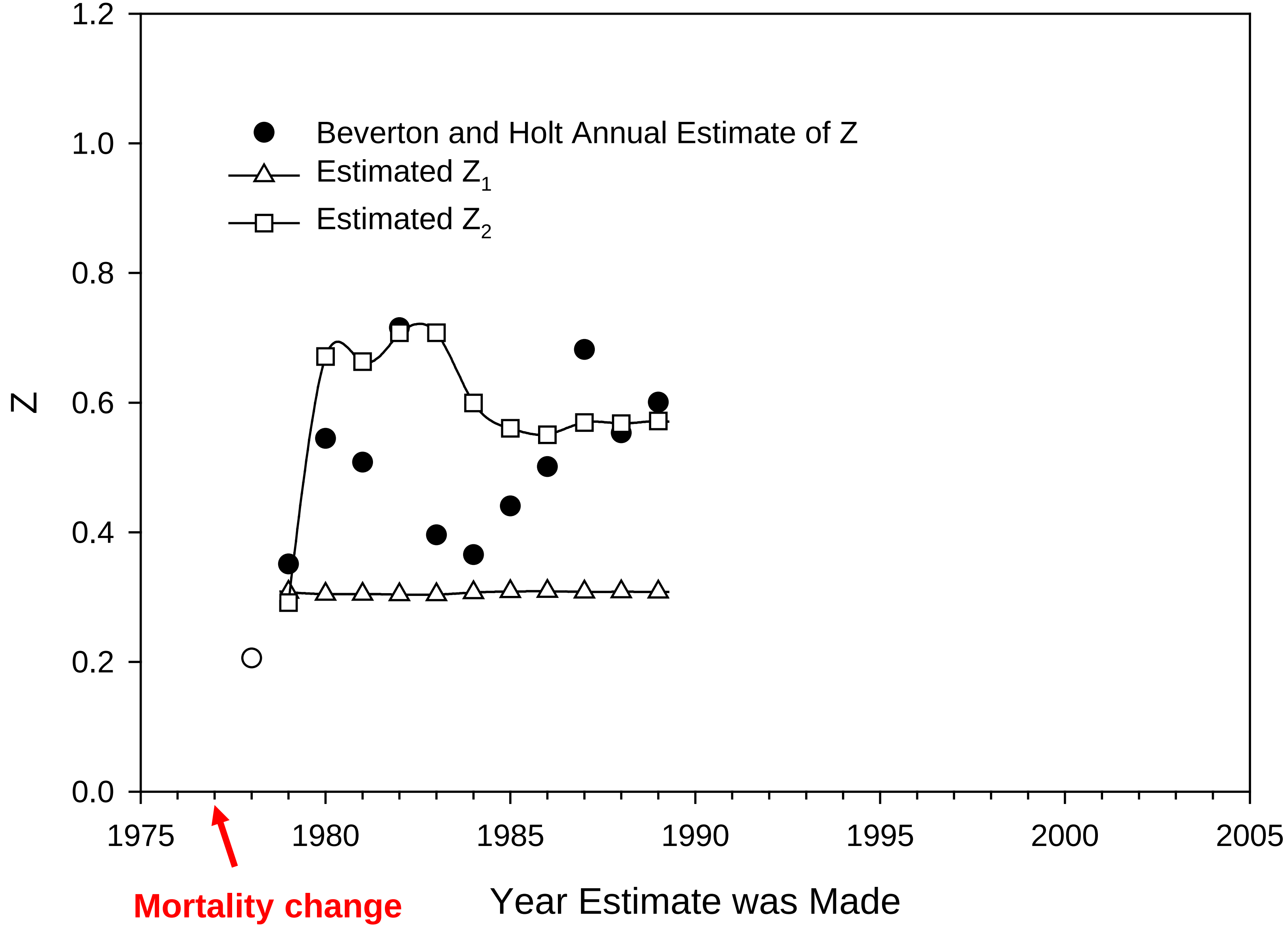

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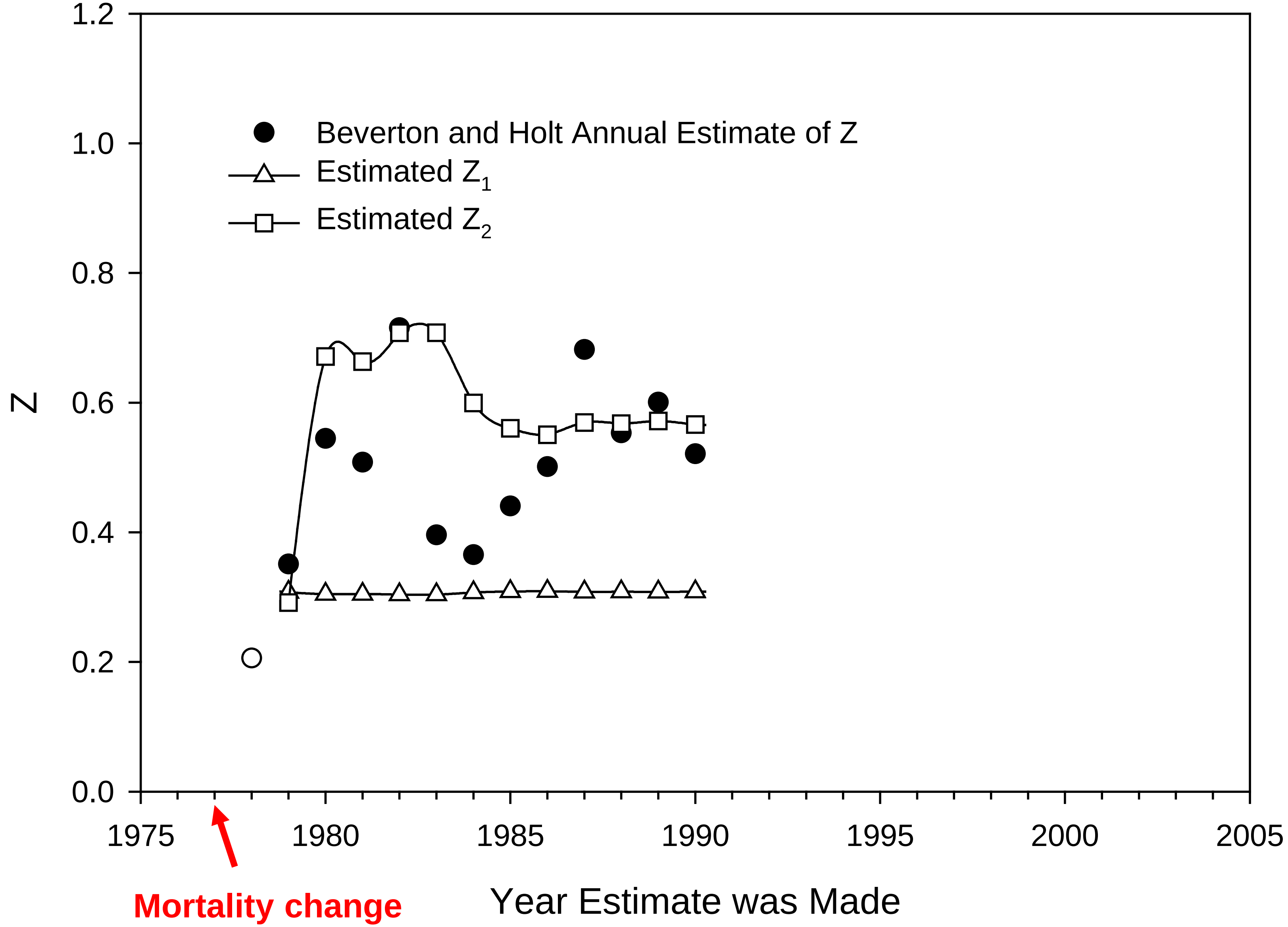

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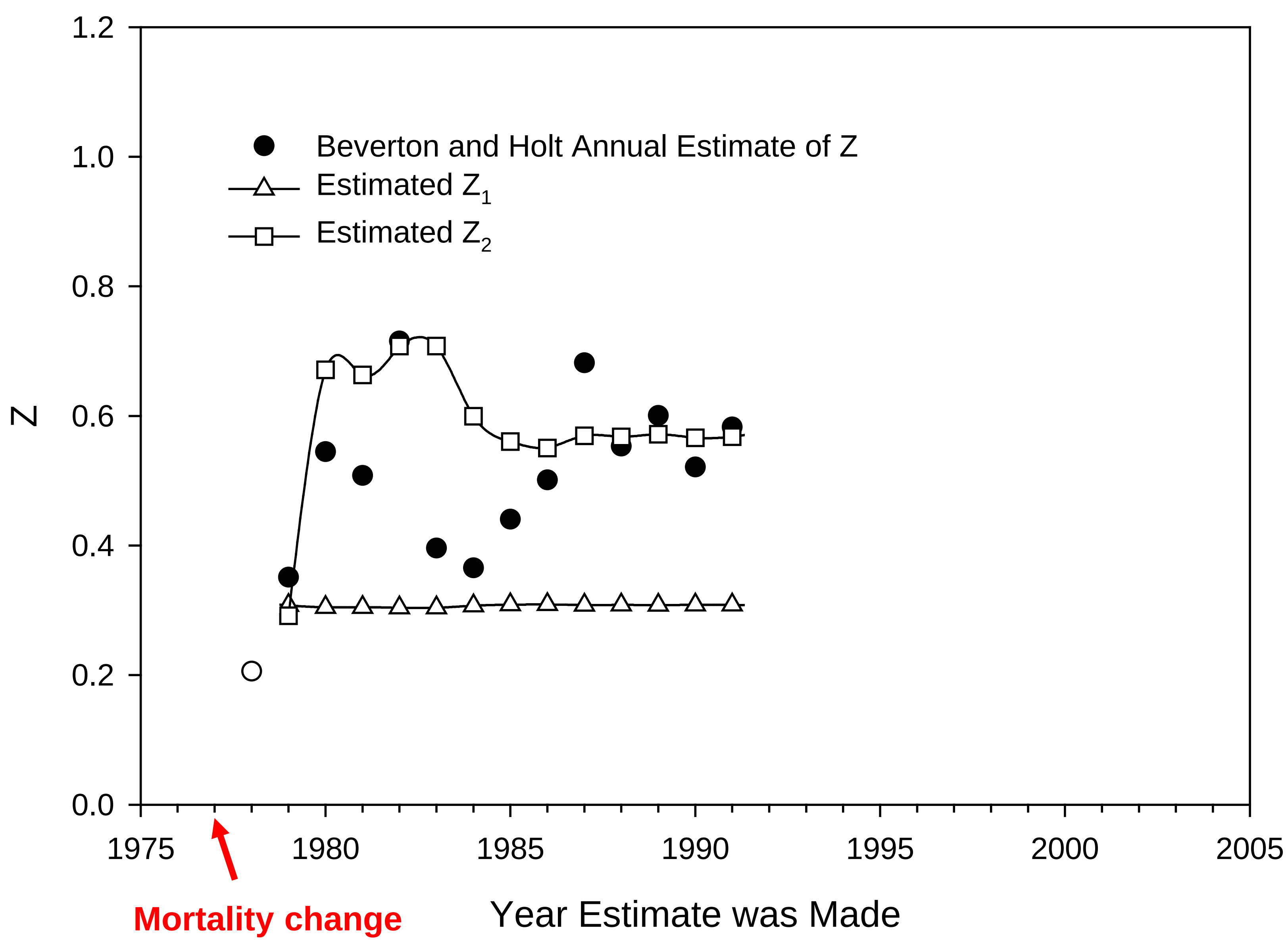

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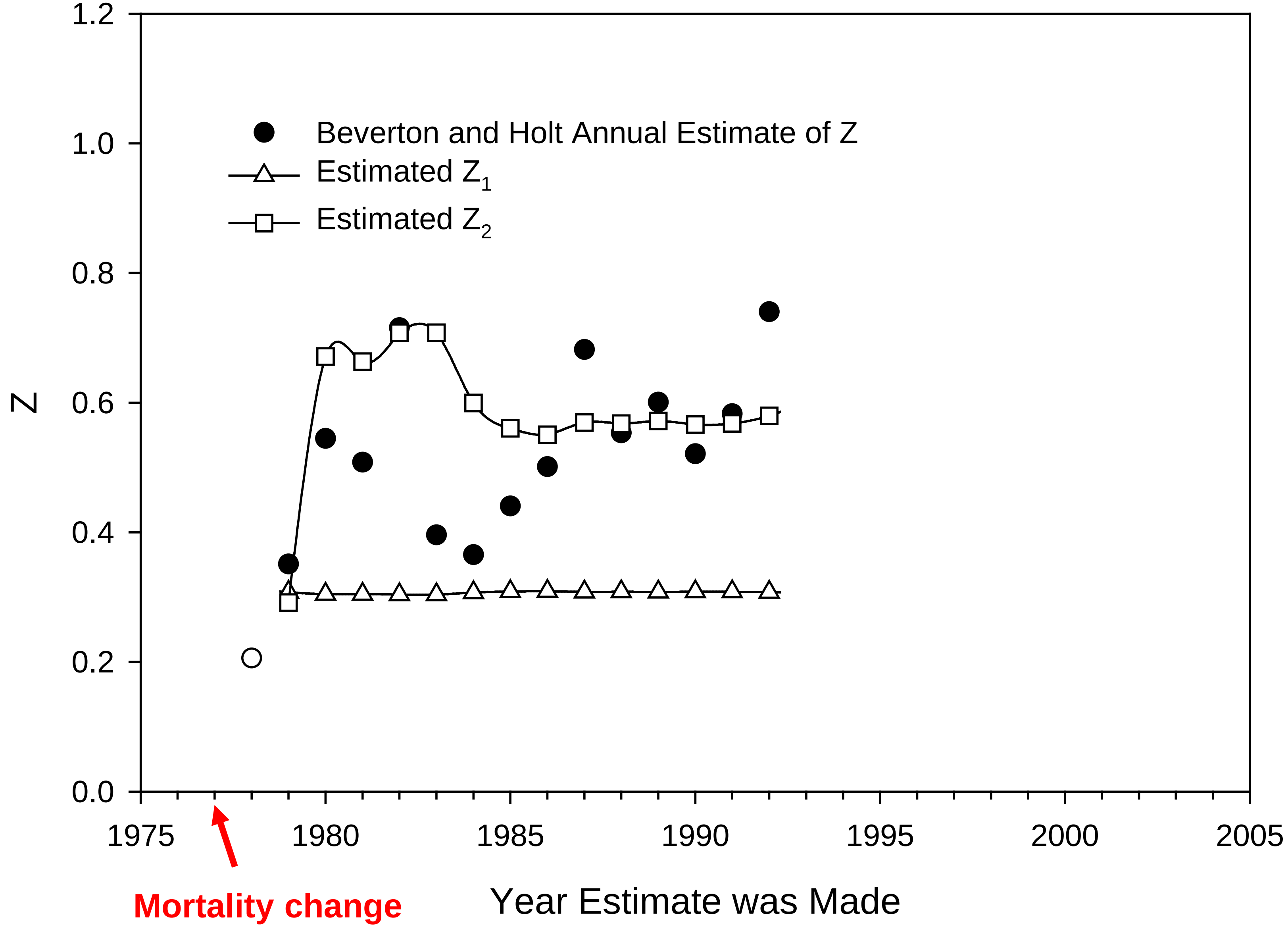
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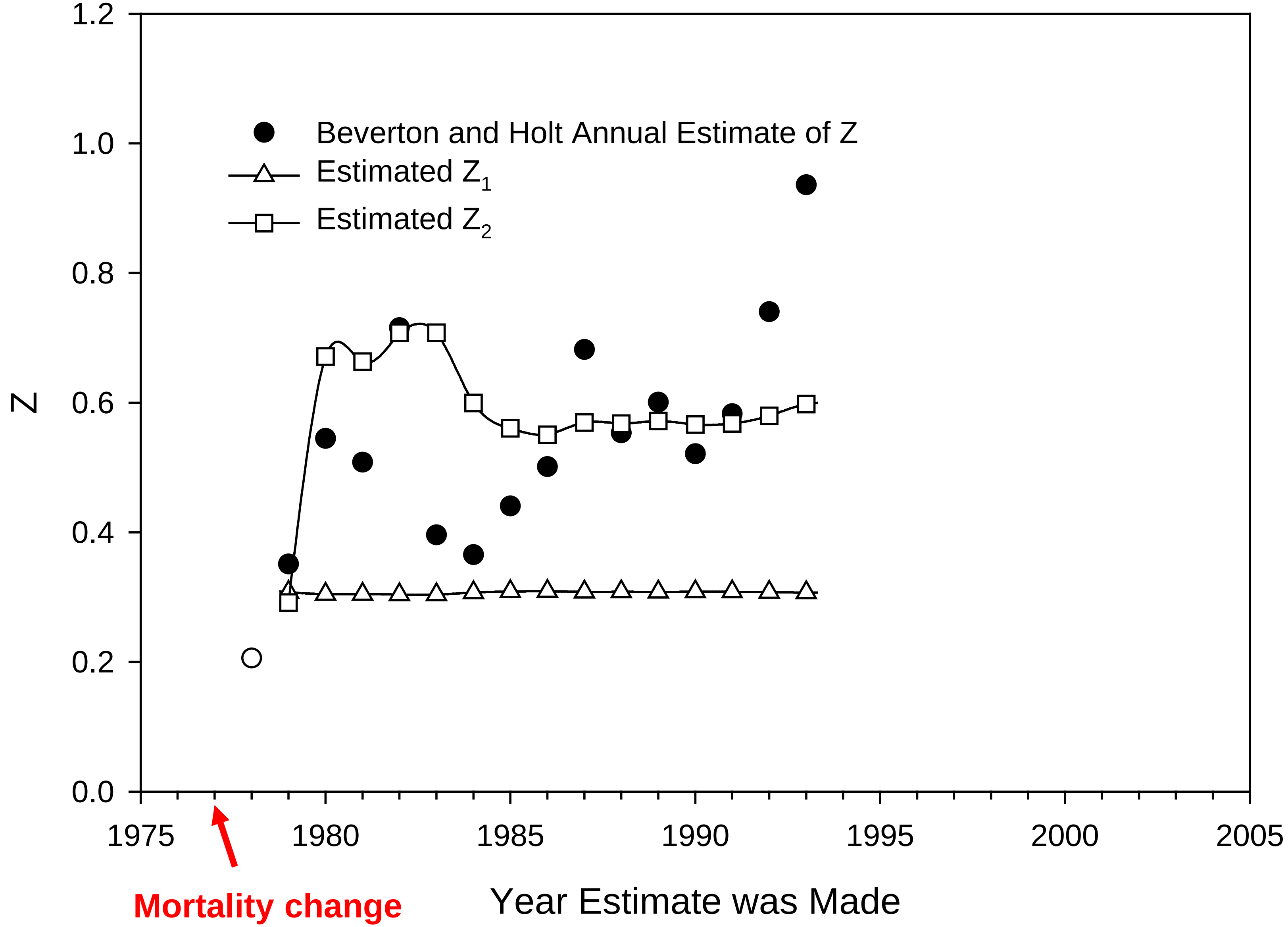

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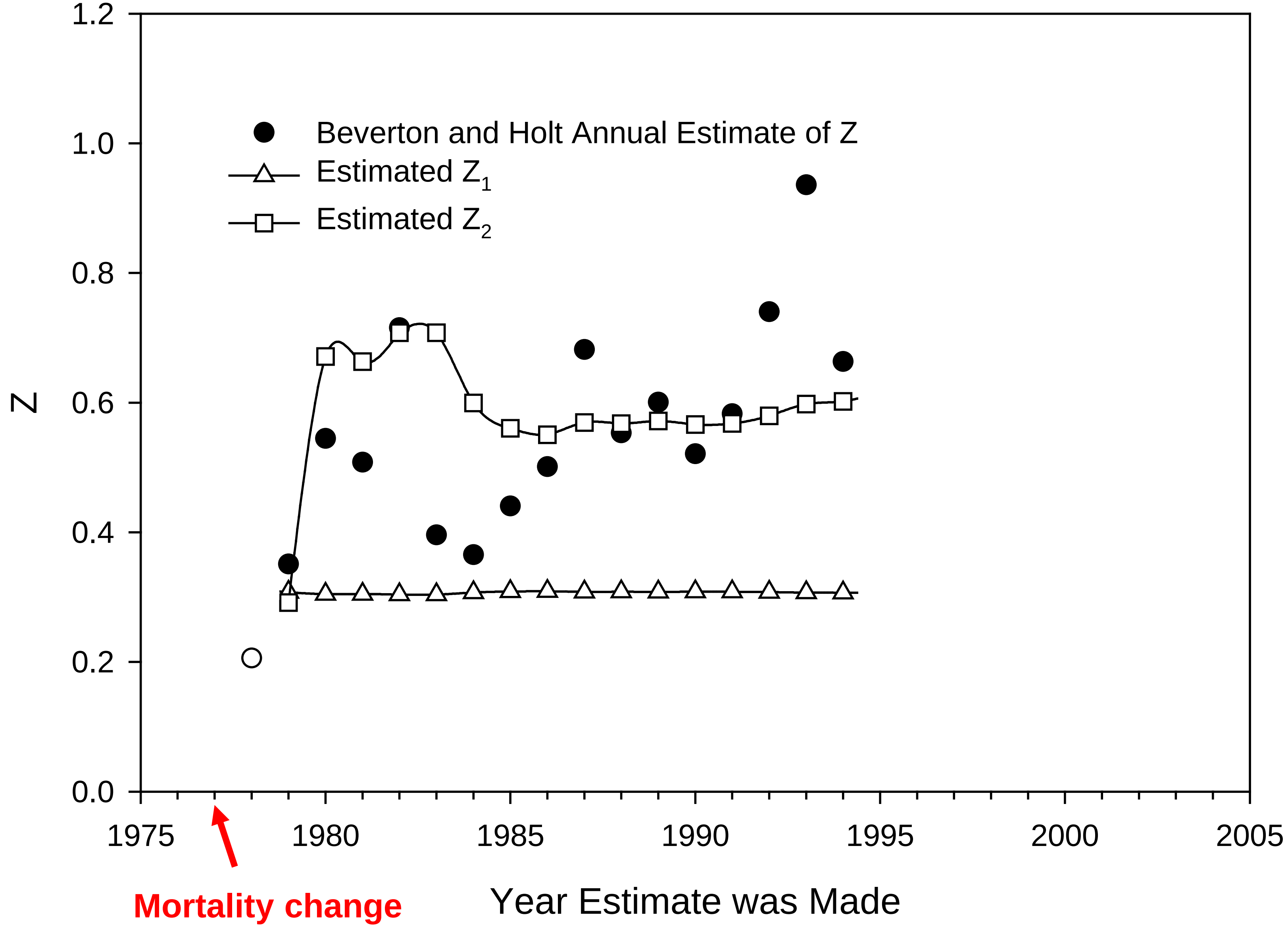

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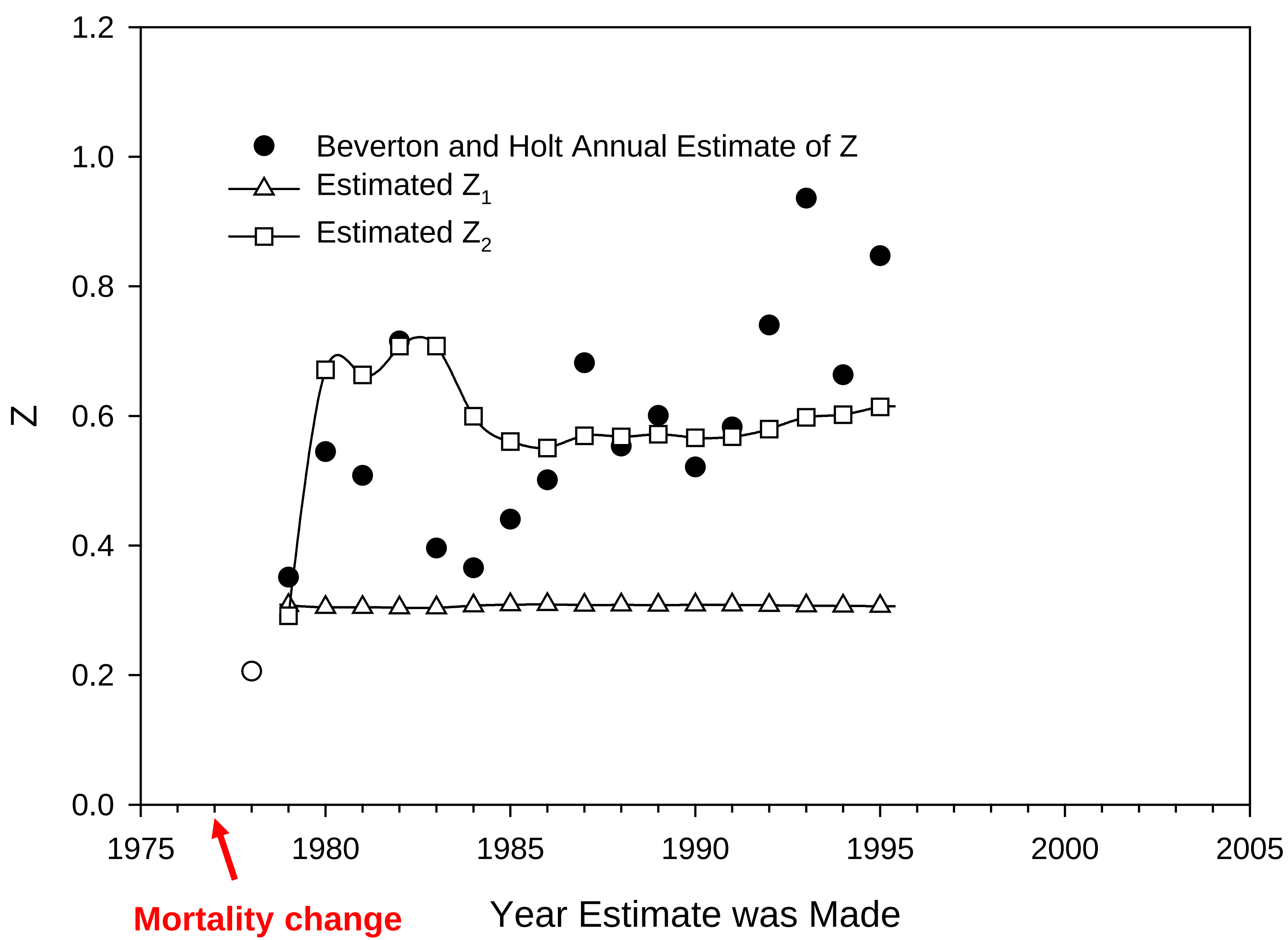

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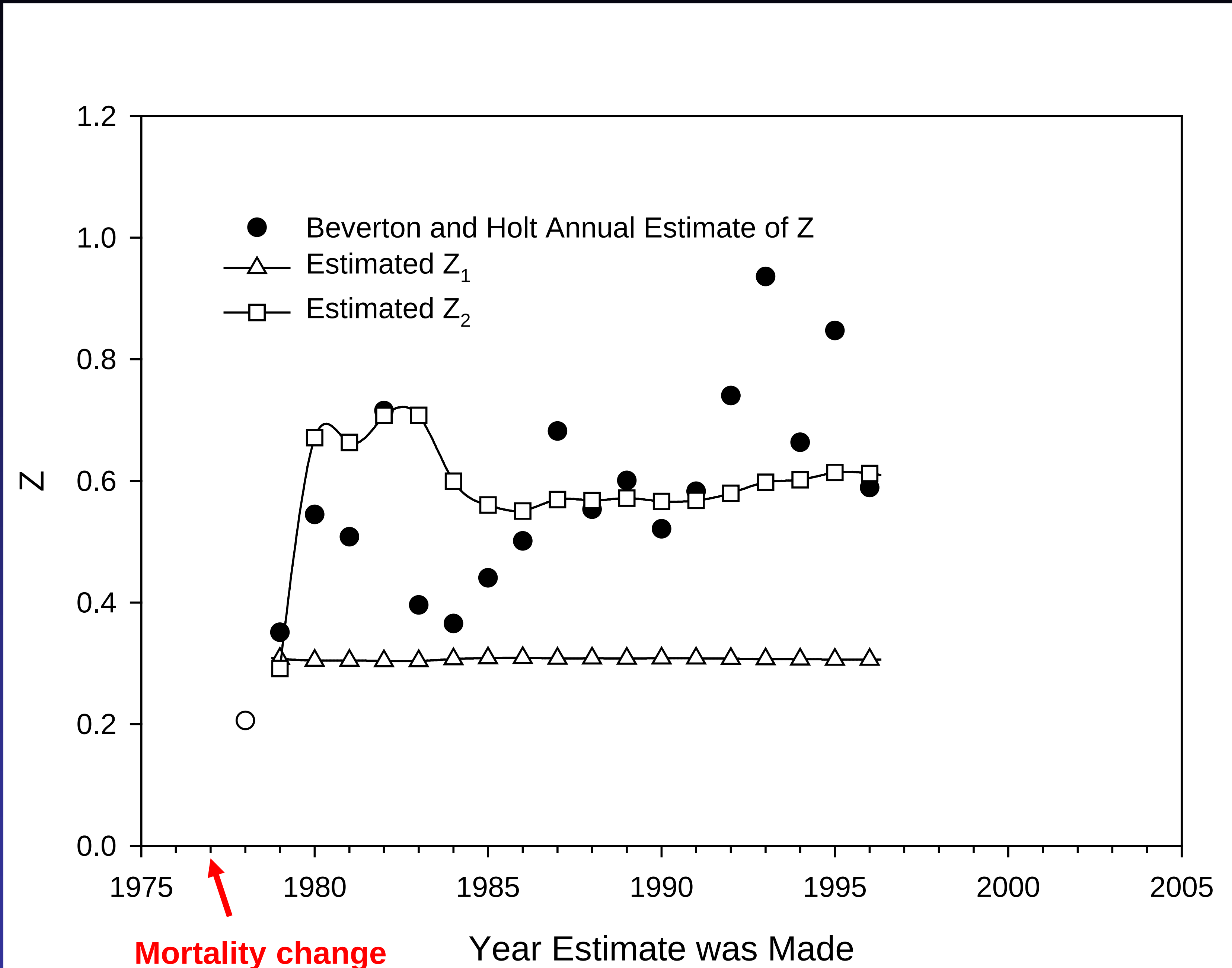

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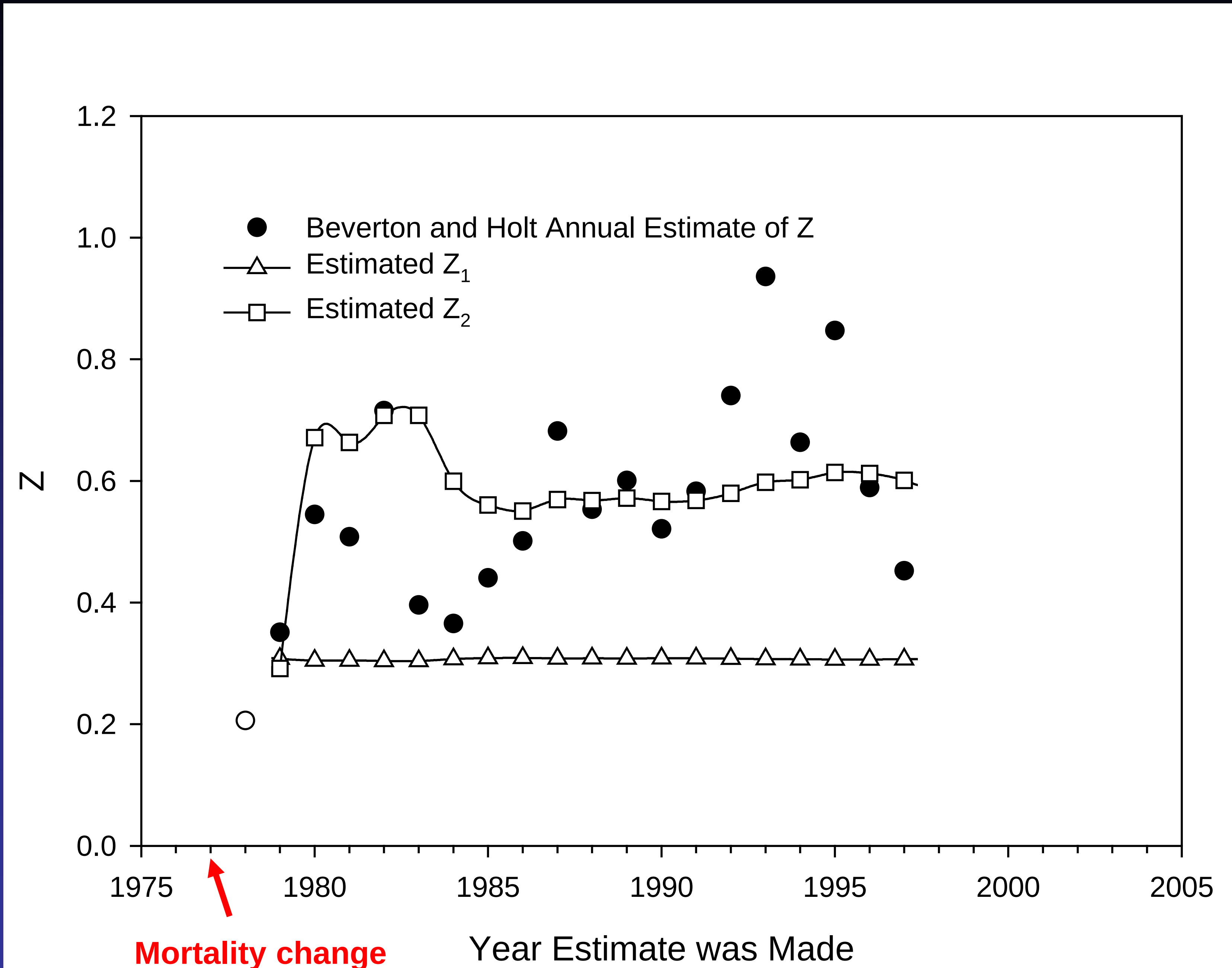
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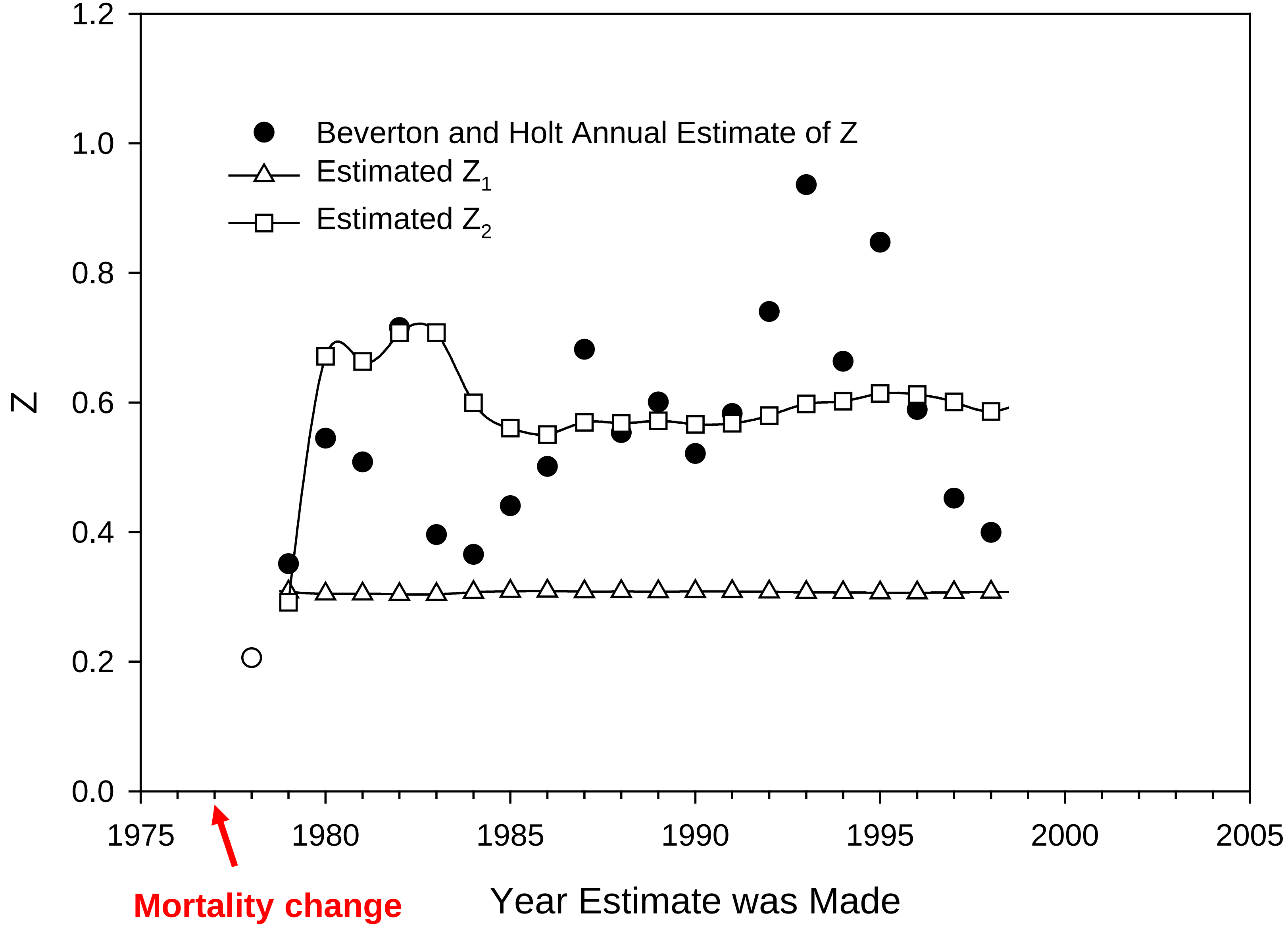
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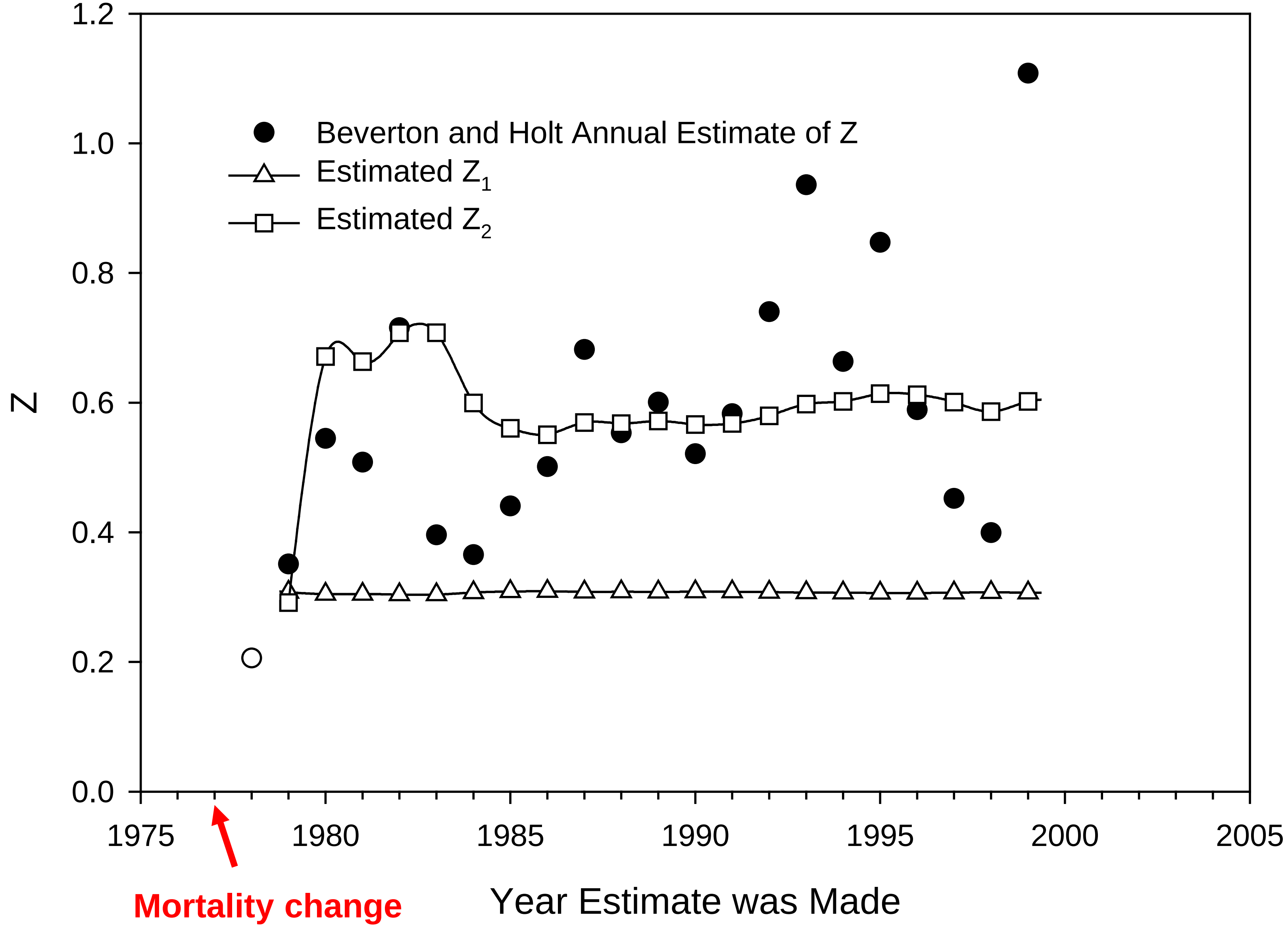
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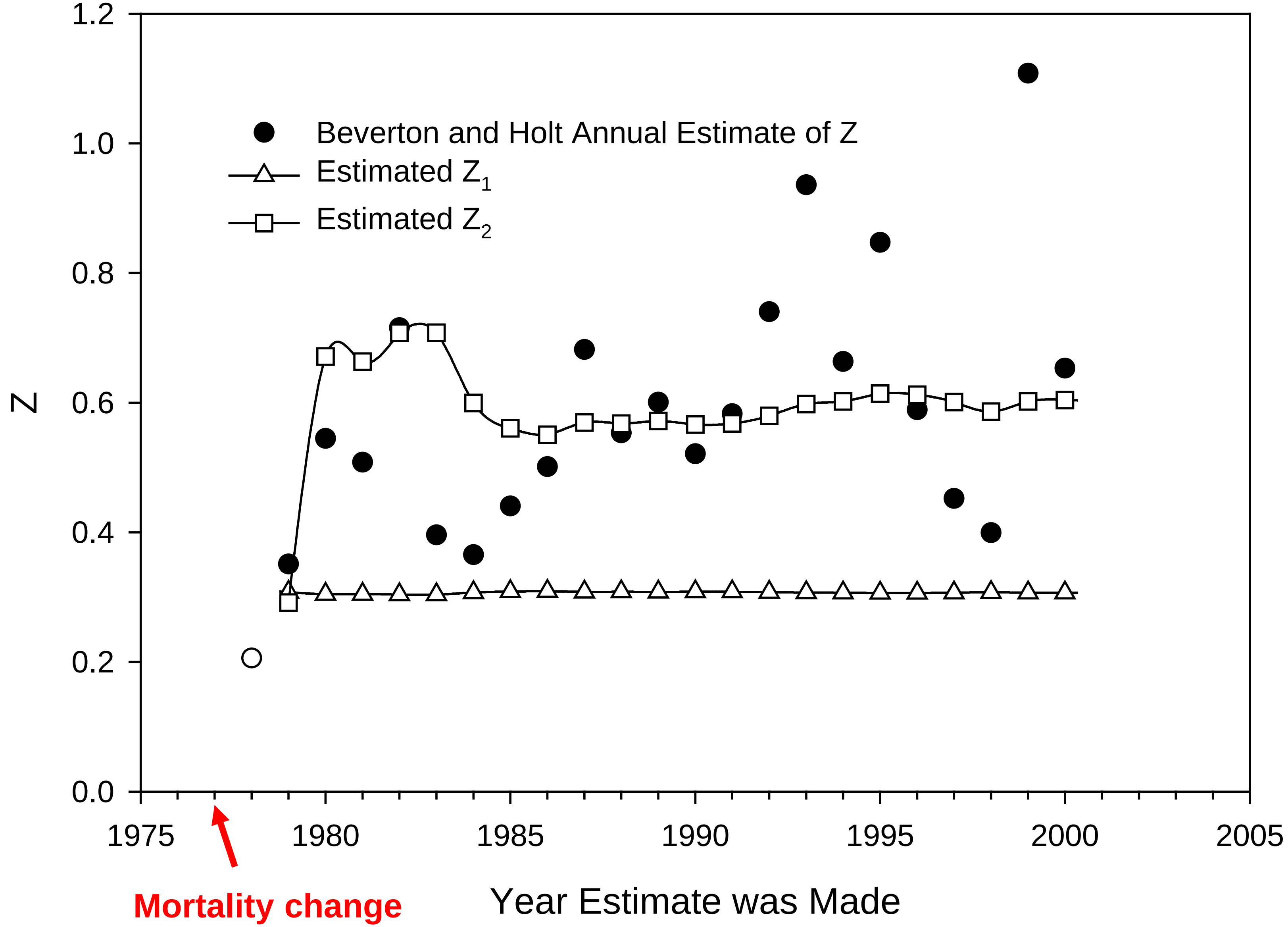

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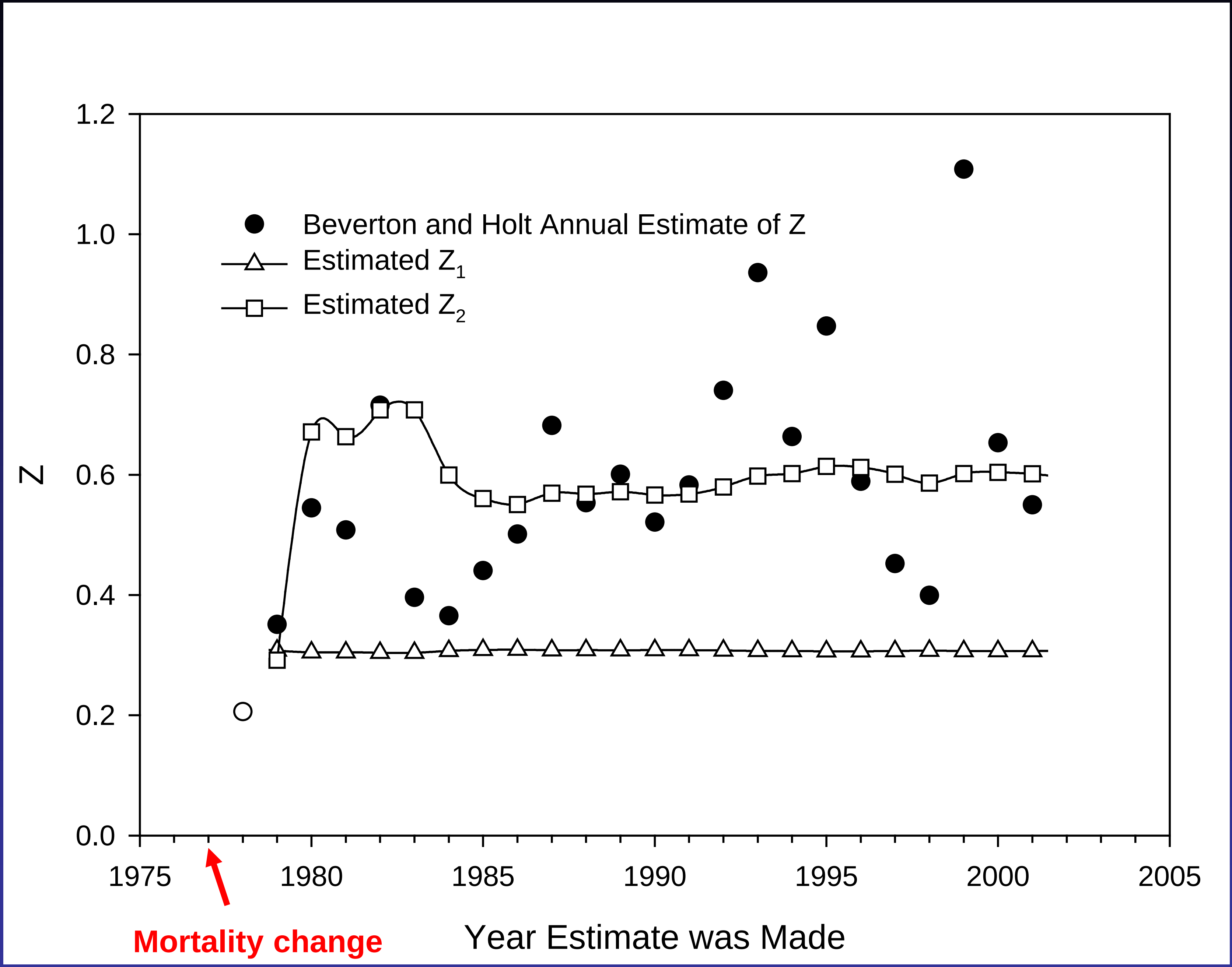
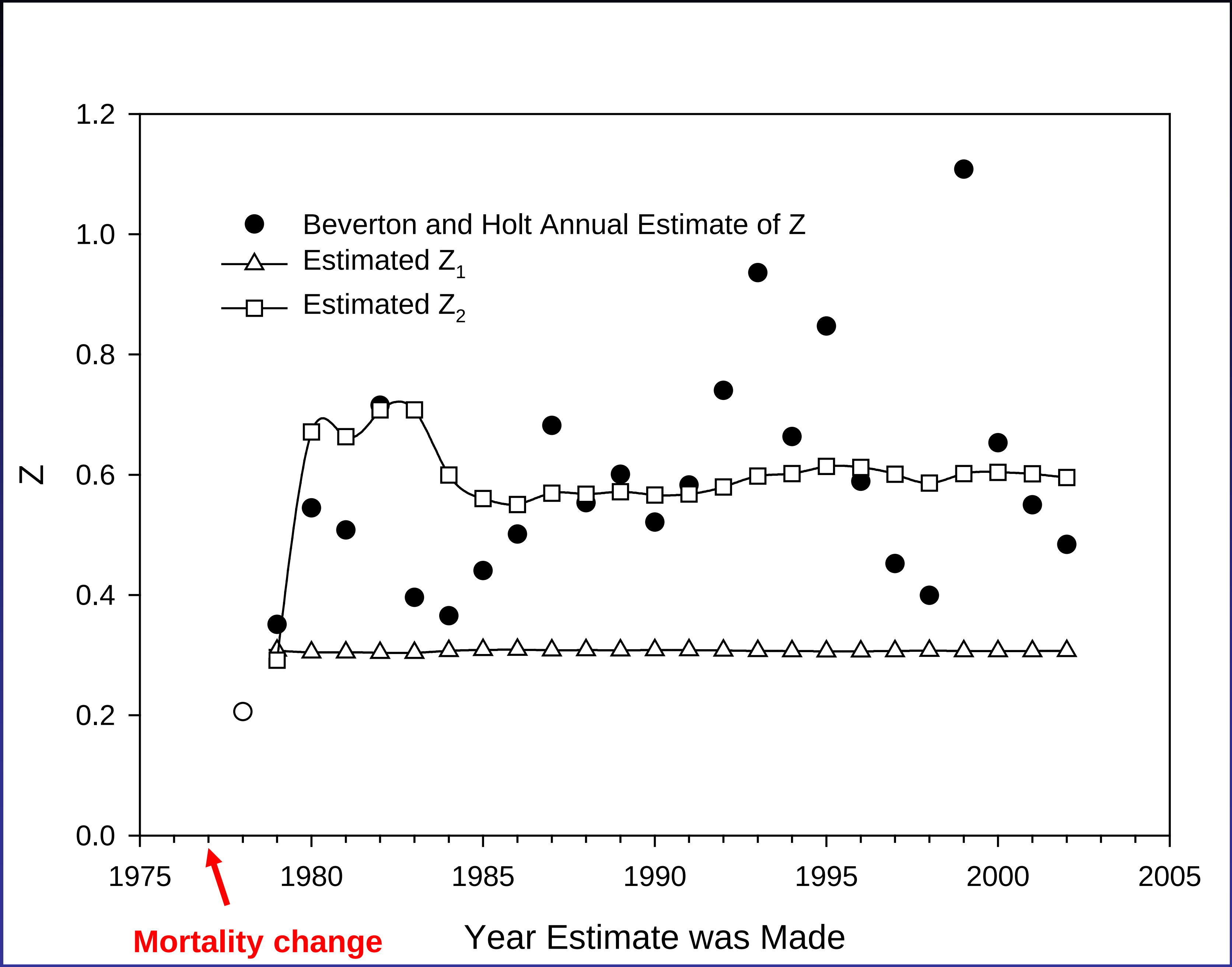
Year Estimate was Made
Mortality change



Beverton and Holt Annual Estimate of Z
Estimated Z_1
Estimated Z_2
Z
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1975
1980
1985
1990
1995
2000
2005
Year Estimate was Made
Mortality change



Beverton and Holt Annual Estimate of Z
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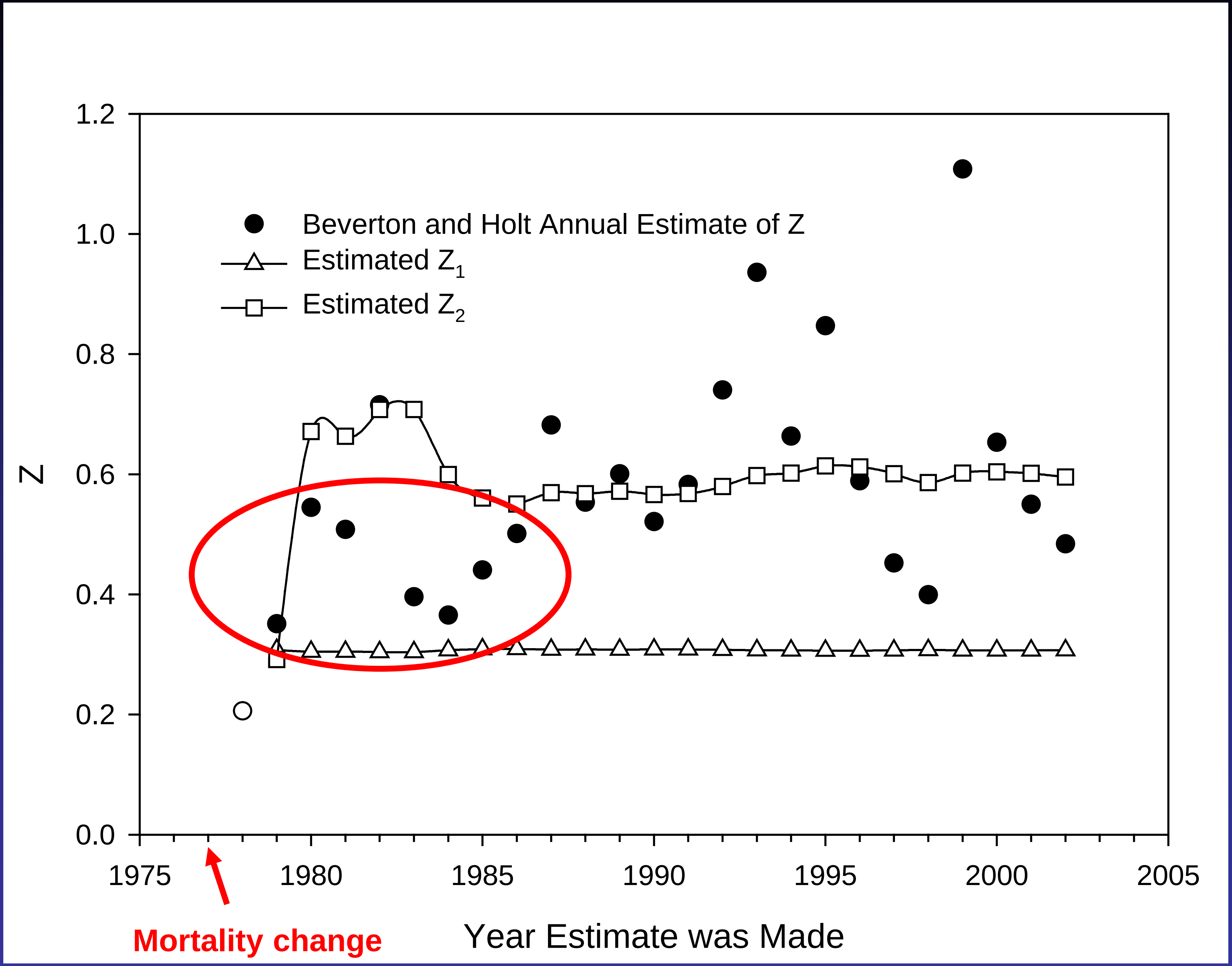
Mortality change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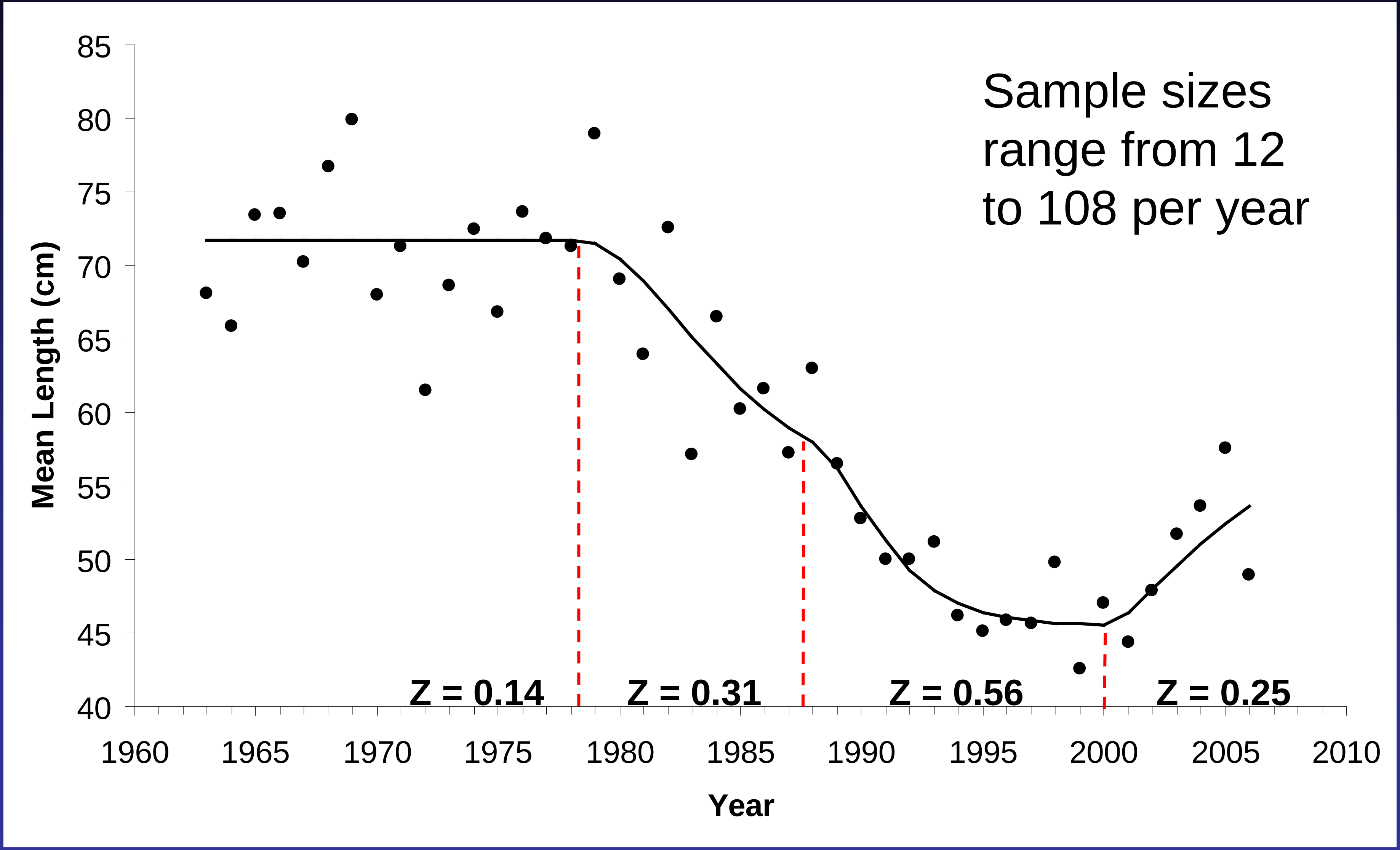
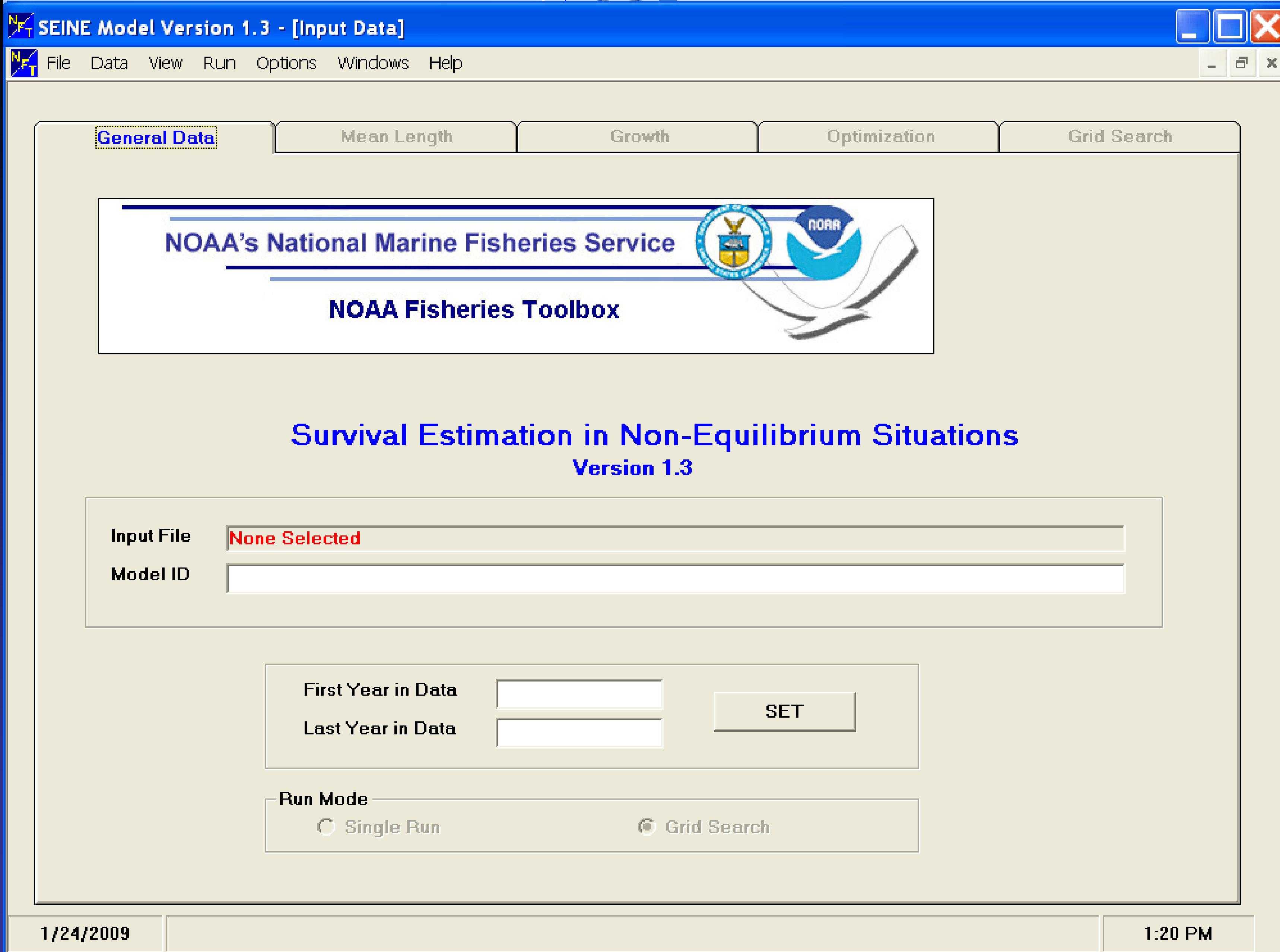
1980
1985
1990
1995
2000
2005
Mortality change
Year Estimate was Made

Goosefish Mortality Estimates--Northern Management Region
NEFSC Fall Groundfish Survey





GUI Programming:
Alan Seaver

Moral Support:
Chris Legault

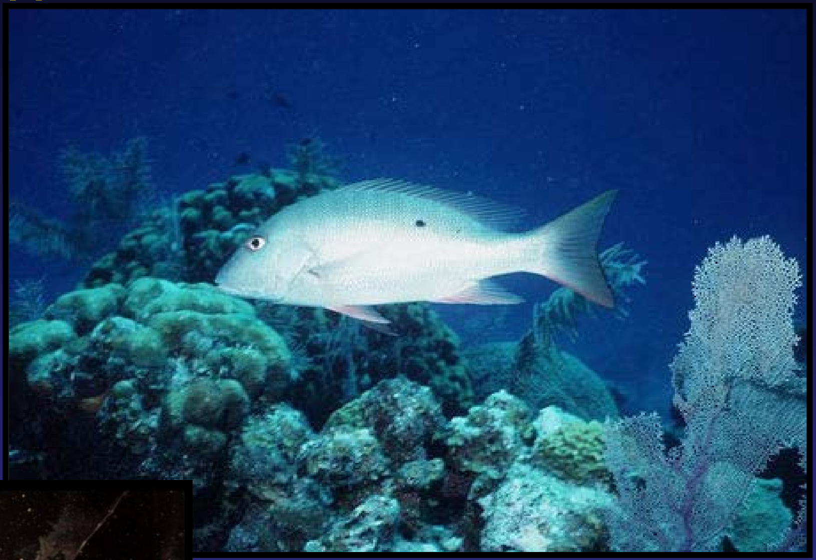
Programming Support:
Brian Linton

Variations of Non-equilibrium formulation

Estimating Mortality from Changes in Mean Lengths <u>and Catch Rates</u> in Non-equilibrium Conditions

Application to the Mutton Snapper Assessment

Lutjanus analis



Lutjanus analis

Lophius americanus

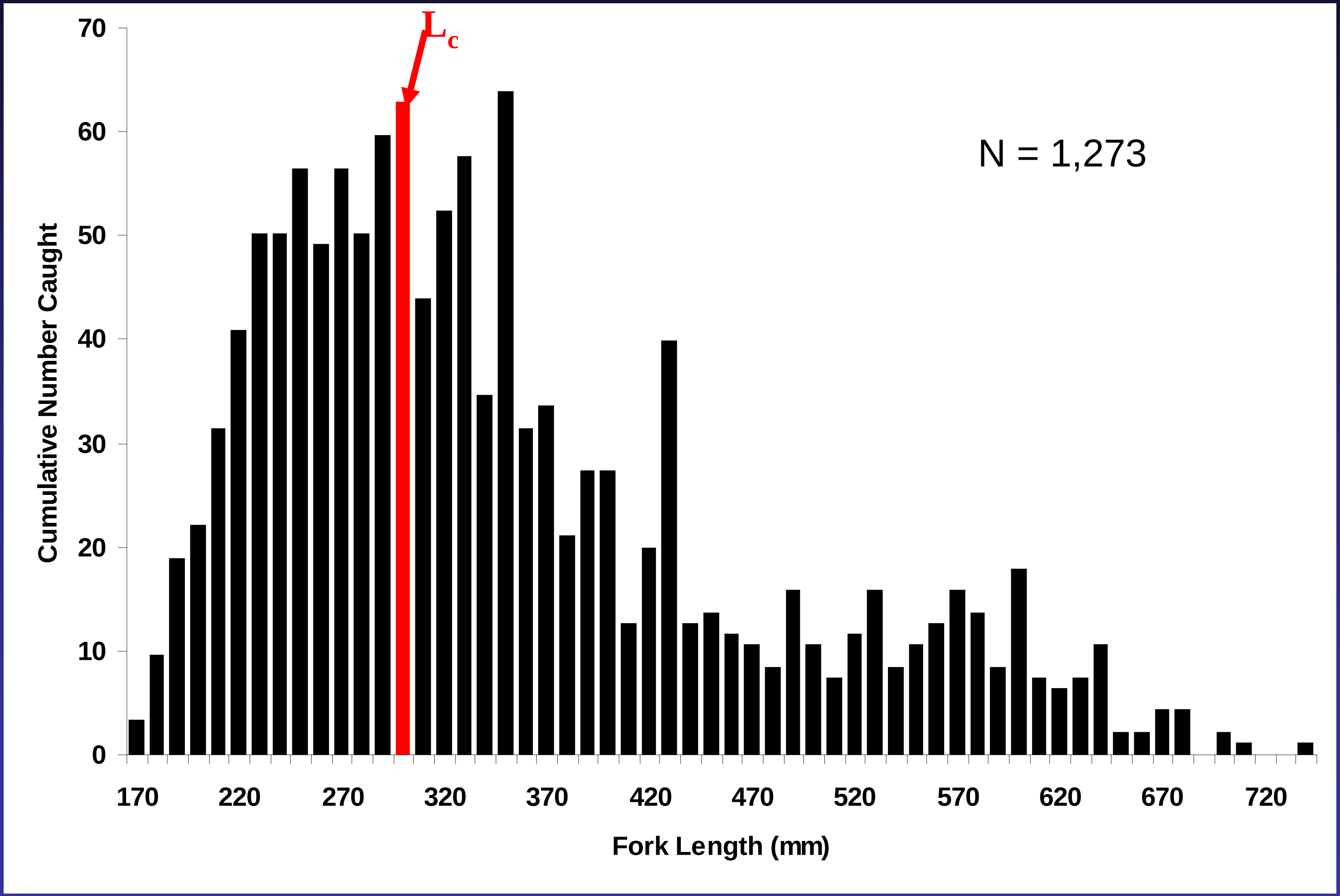
Mutton Snapper Photos reprinted from http://www.flmnh.ufl.edu/fish/gallery/descript/muttonsnapper/muttonsnapper.html.

Todd Gedamke[1], Clay E. Porch[1] and John Hoenig[2]

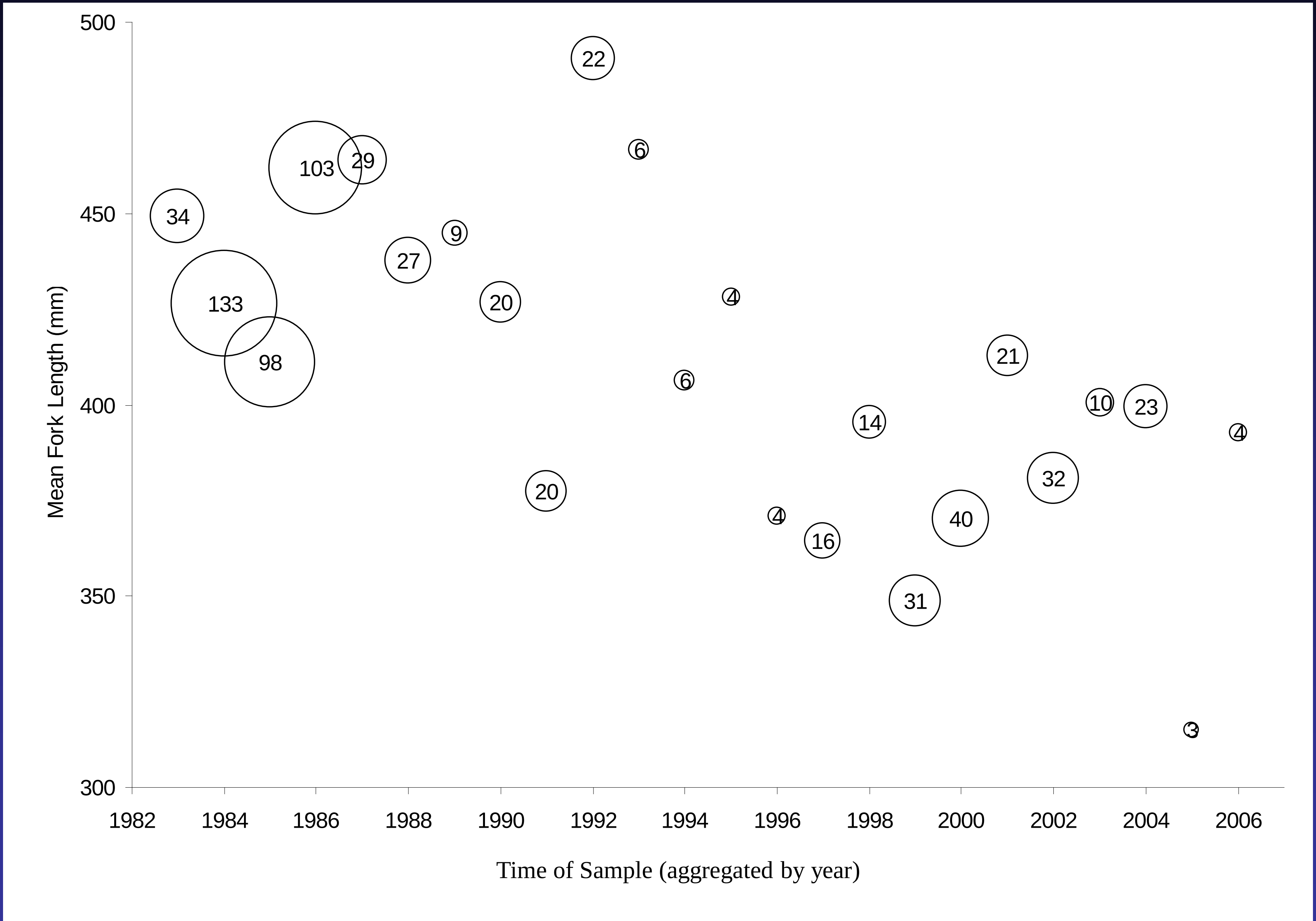
[1]National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida

[2]Virginia Institute of Marine Science, Gloucester Point, Virginia

Cumulative plot of all individuals in the trap fishery of Puerto Rico (1983– 2006).

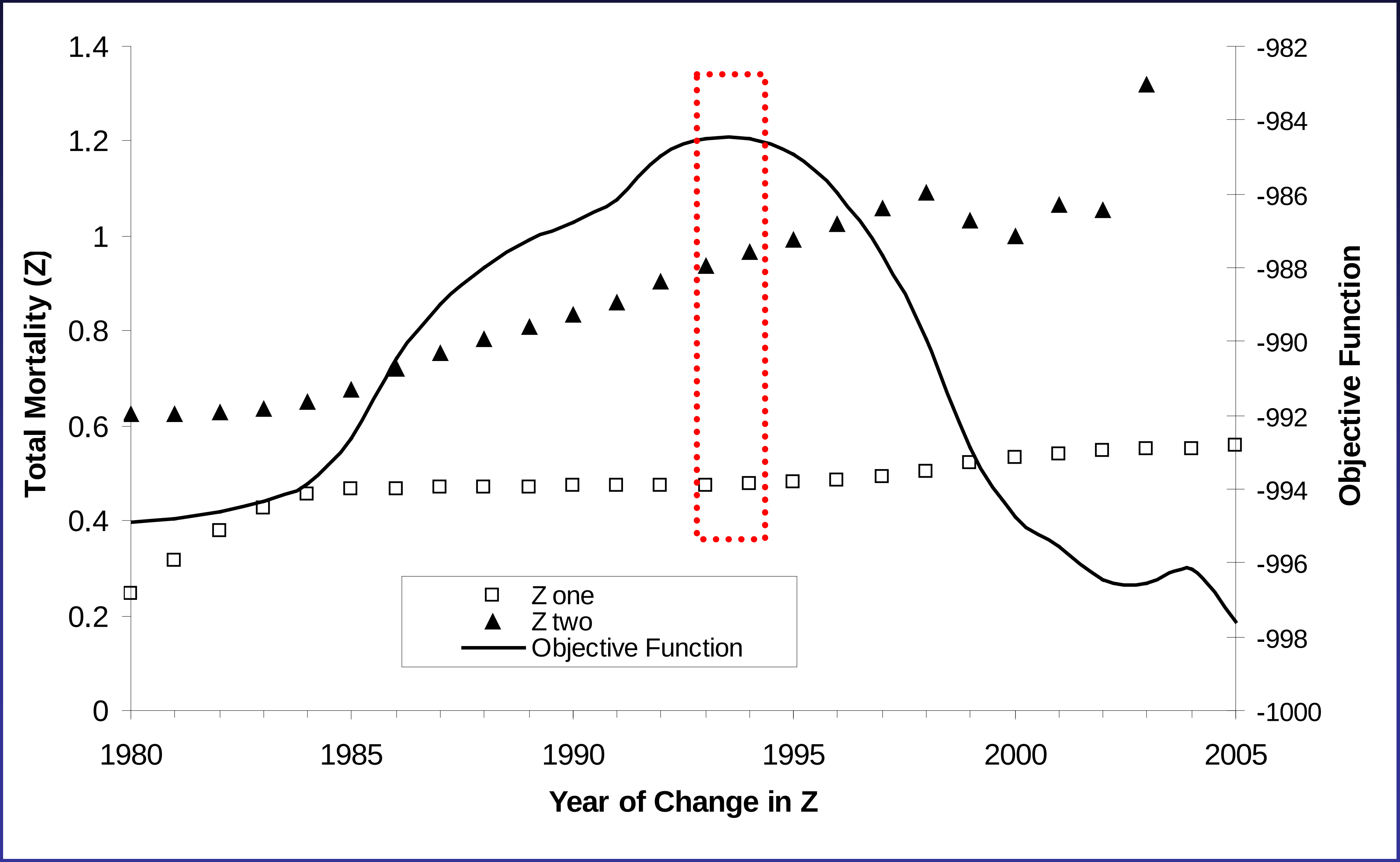


Mean Length calculated by year. Sample numbers for each year have been indicated by both bubble size and number.

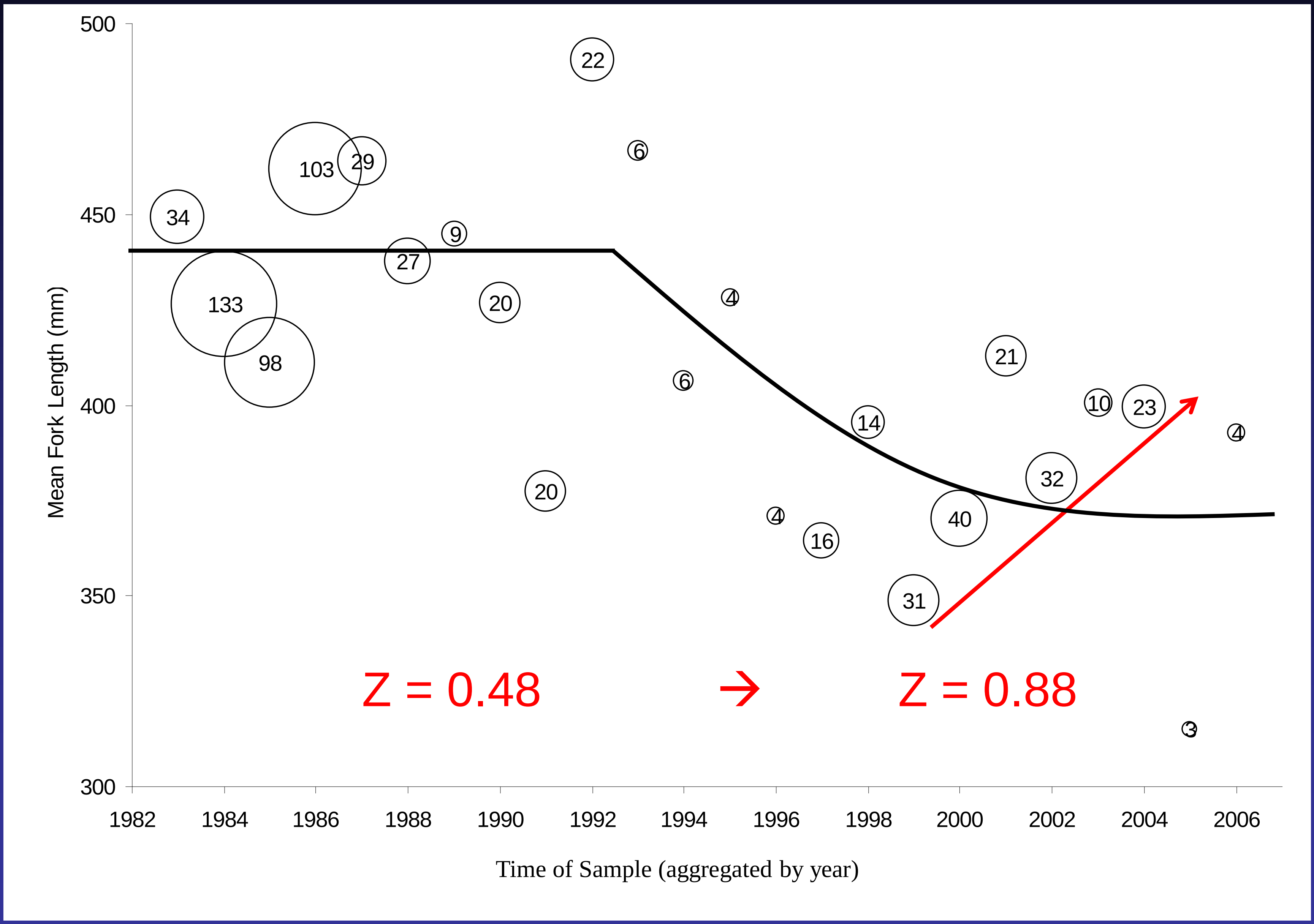


Results of grid search. Likelihood function is weighted by the sample size.

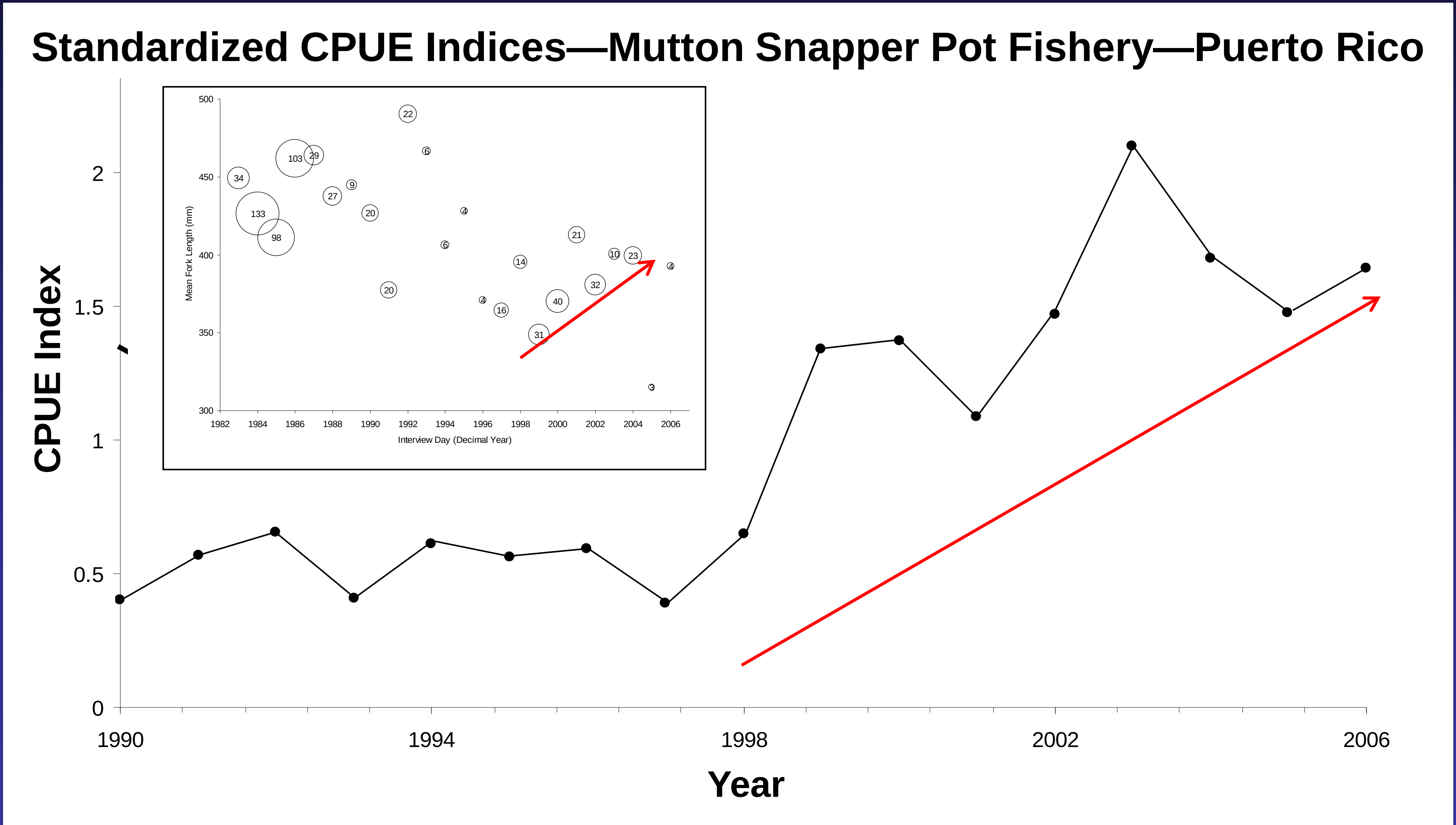
Z_{one} = 0.48 yr^{-1} → Z_{two} = 0.97 yr^{-1} in 1993.



Mean Length calculated by year. Sample numbers for each year have been indicated by both bubble size and number.



Integrating Catch Rates into the Mean Length Analysis



Estimating Mortality from Changes in Mean Lengths and Catch Rates in Non-equilibrium Conditions

Application to the Mutton Snapper Assessment

Final Step of Derivation:

If q* is assumed to be constant,

$$\frac{I_1}{I_2} = \frac{Z_2}{Z_1}$$

Key Point: Only able to get information on relative changes in total mortality rates from catch indices

e.g. $2 * Z = 0.5 * I$

Todd Gedamke[1], Clay E. Porch[1] and John Hoenig[2]
[1]National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida
[2]Virginia Institute of Marine Science, Gloucester Point, Virginia

Multispecies

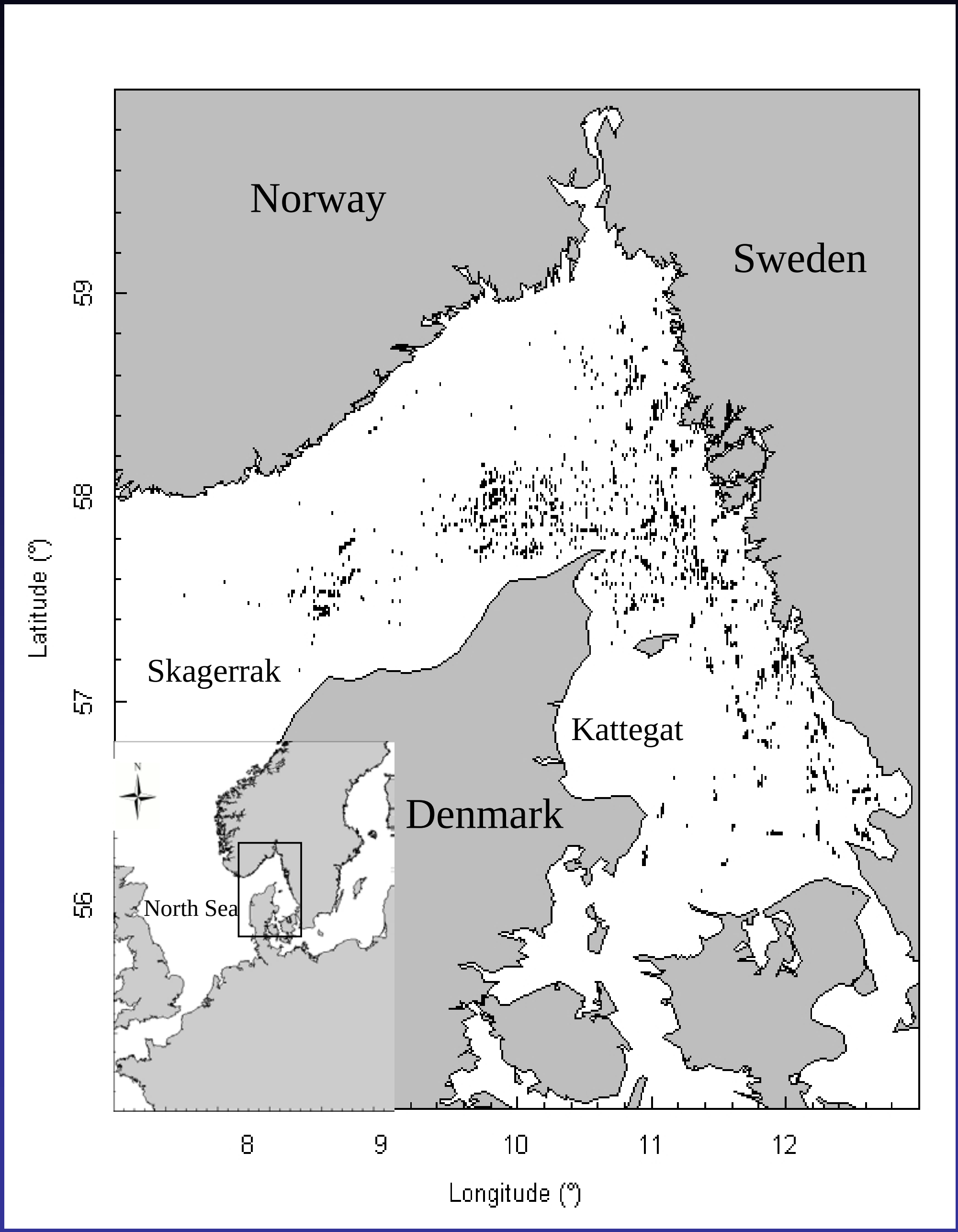
A century of variability of body size in a flatfish community: implications for management

Massimiliano Cardinale*, Andrea Belgrano, Valerio Bartolino, Todd Gedamke, Hans Linderholm

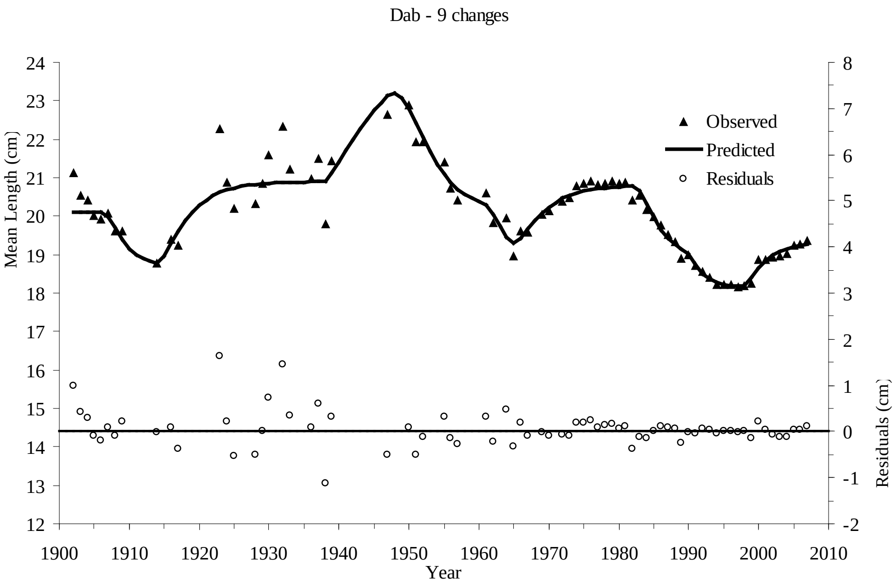
Massimiliano Cardinale, Andrea Belgrano, Valerio Bartolino, Institute of Marine Research, Swedish Board of Fisheries, P.O. Box 4, SE-453 21 Lysekil, Sweden

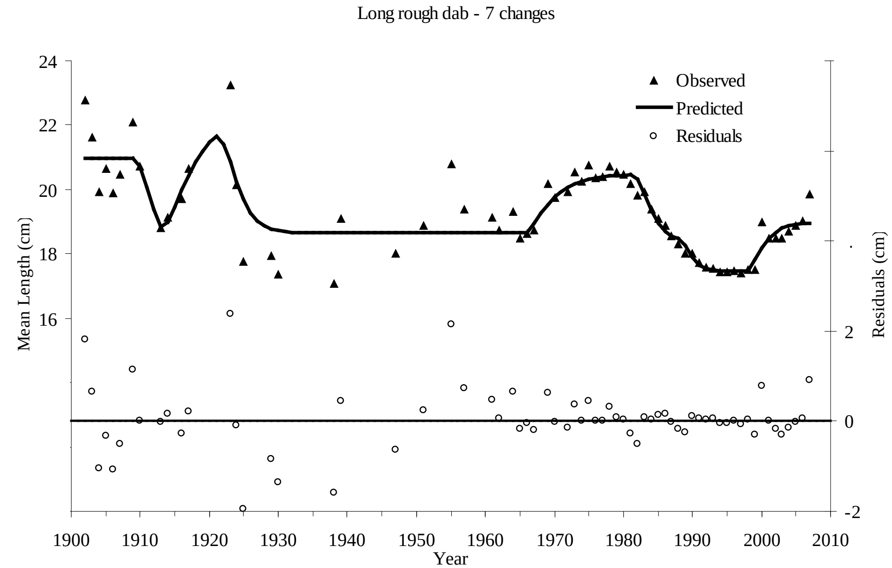
Todd Gedamke, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, Florida, 33149, USA

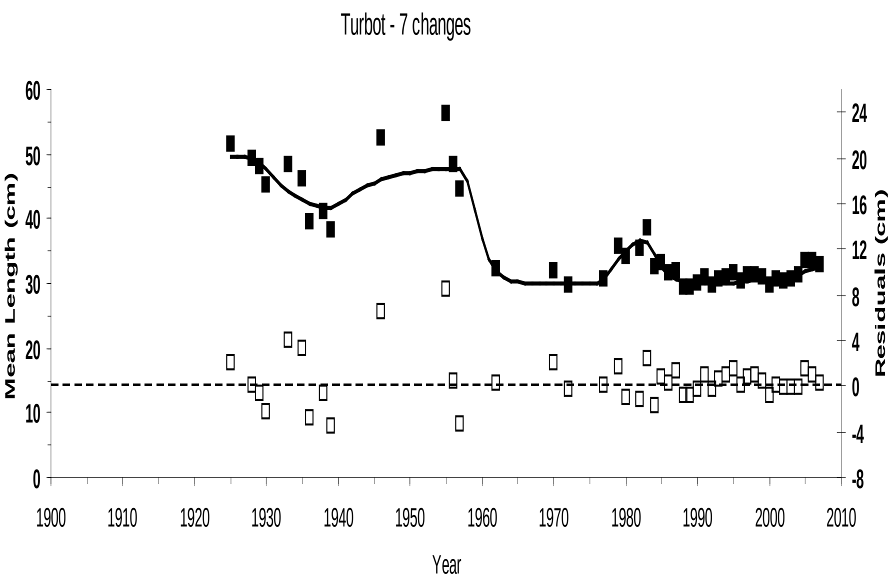
Hans Linderholm, Regional Climate Group, Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden

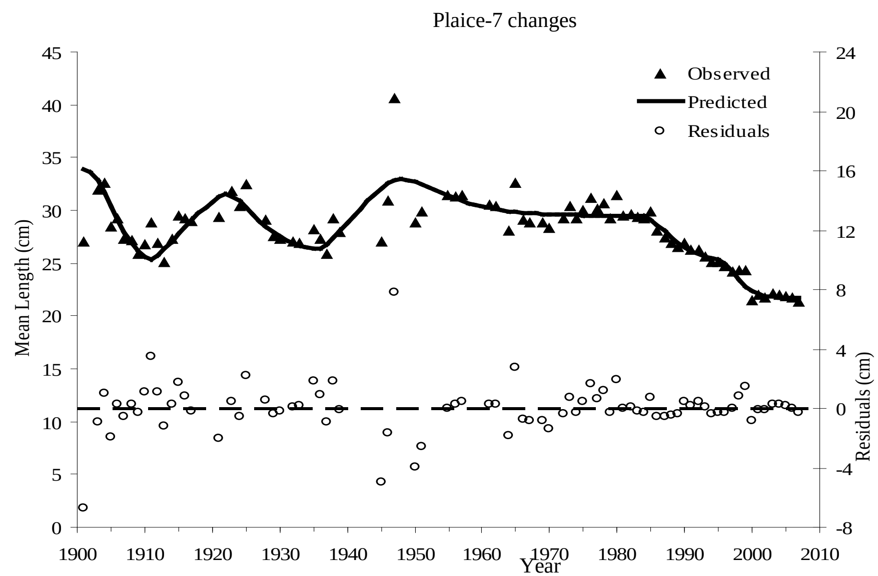


Dab, Long Rough Dab, Turbot, Plaice

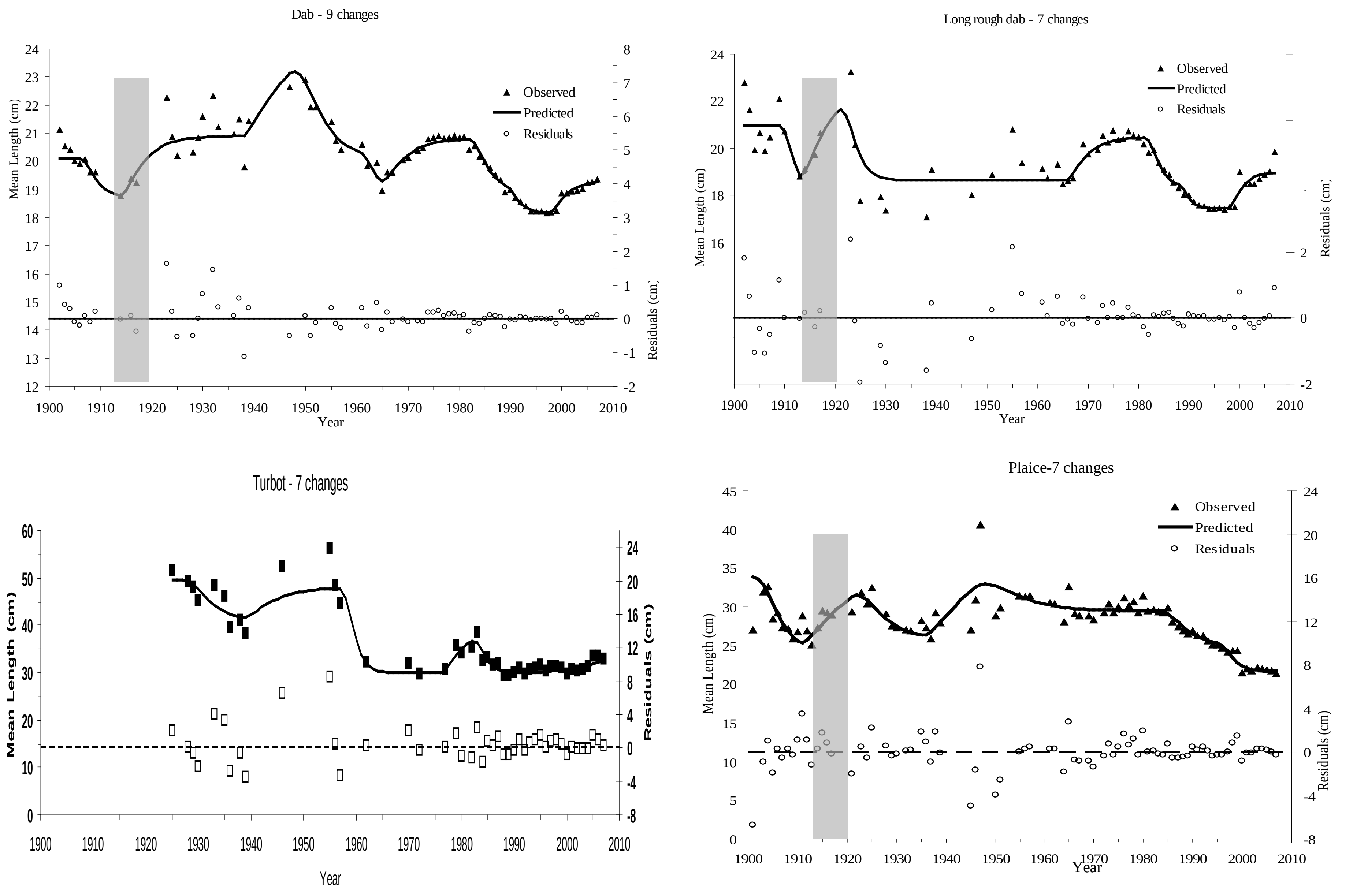




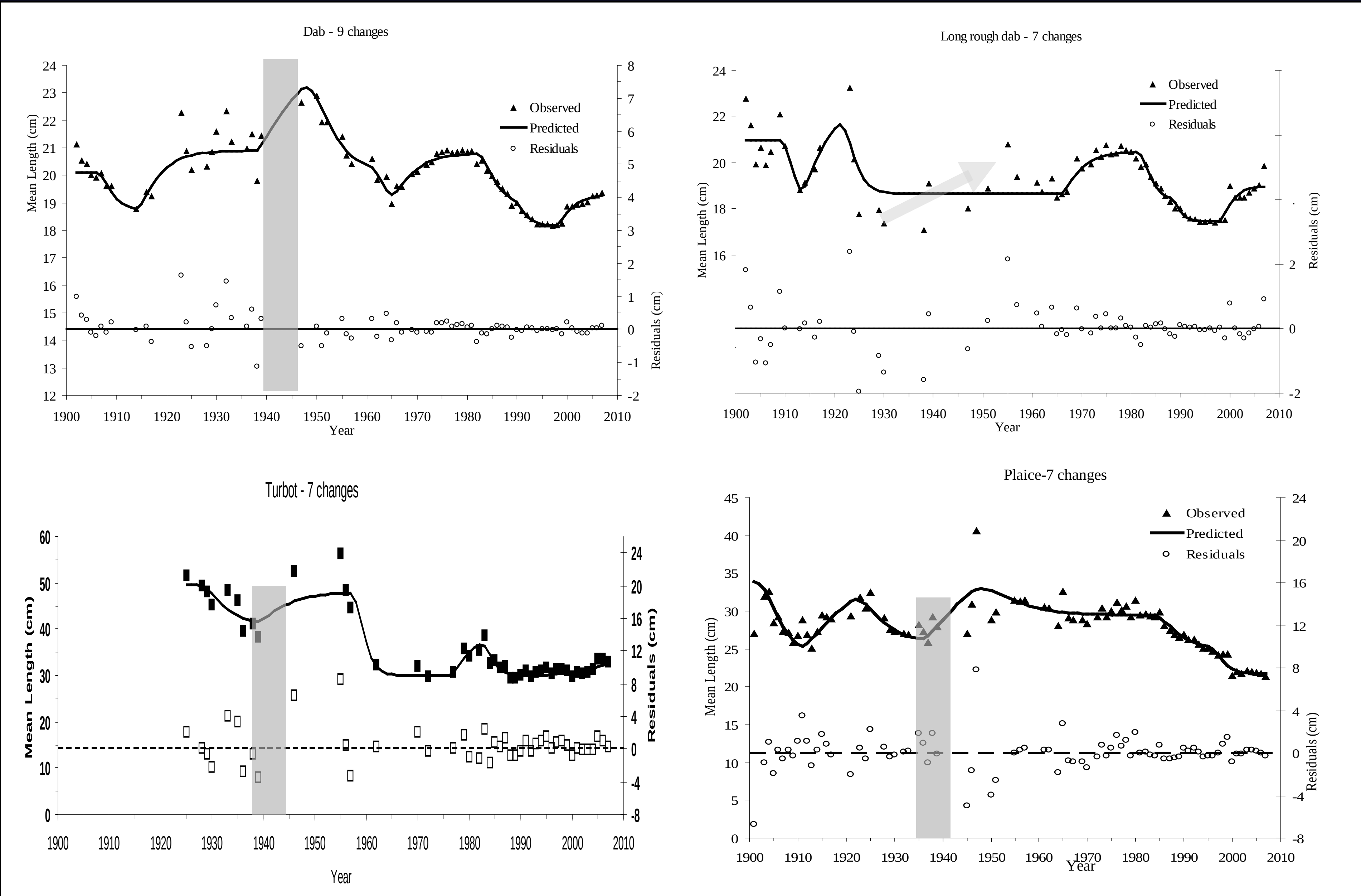




World War I

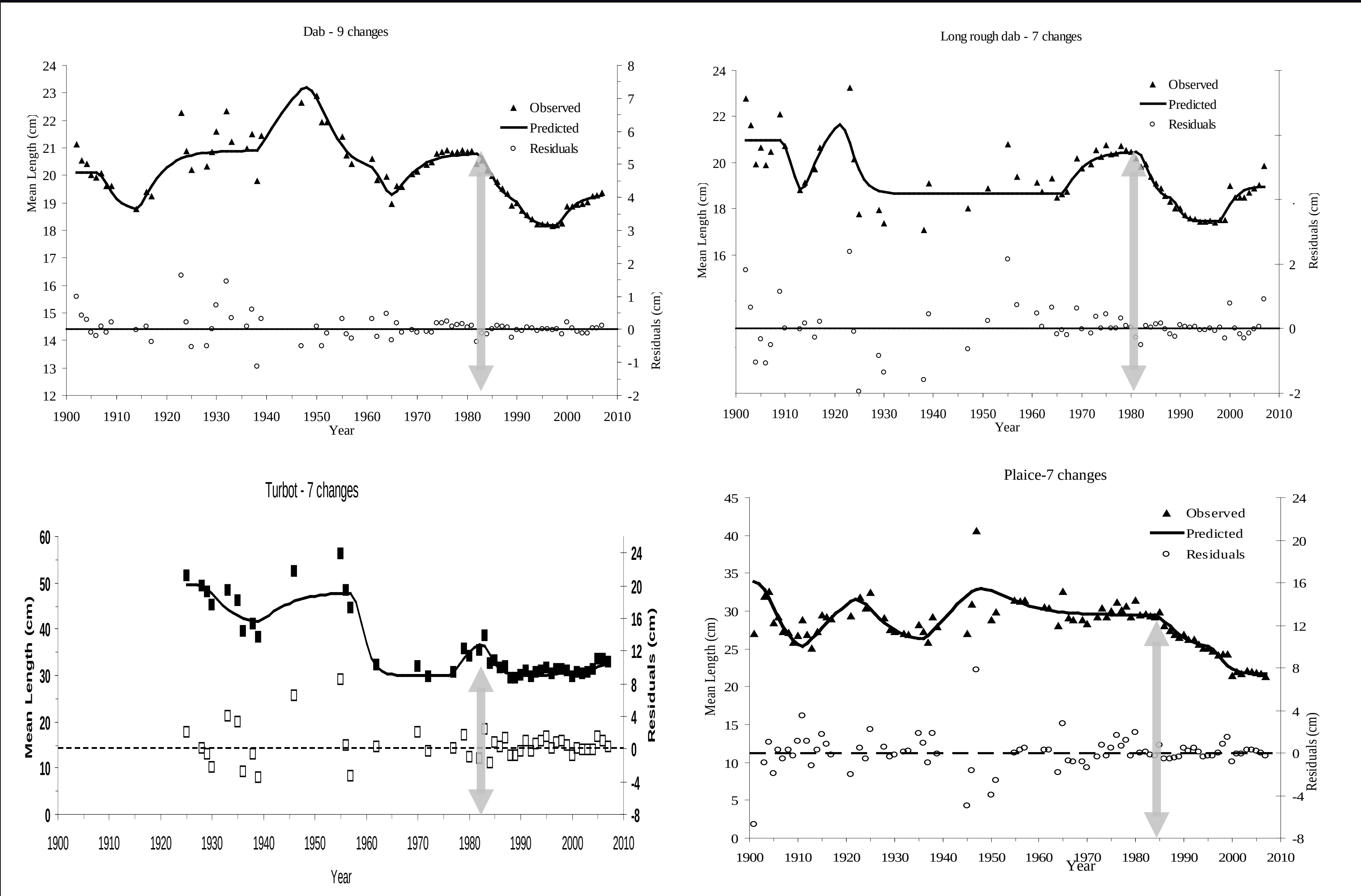

Dab - 9 changes
Mean Length (cm)
Residuals (cm)
Year
Observed
Predicted
Residuals
Long rough dab - 7 changes
Mean Length (cm)
Residuals (cm)
Year
Observed
Predicted
Residuals
Turbot - 7 changes
Mean Length (cm)
Residuals (cm)
Year
Plaice-7 changes
Mean Length (cm)
Residuals (cm)
Year
Observed
Predicted
Residuals

World War II

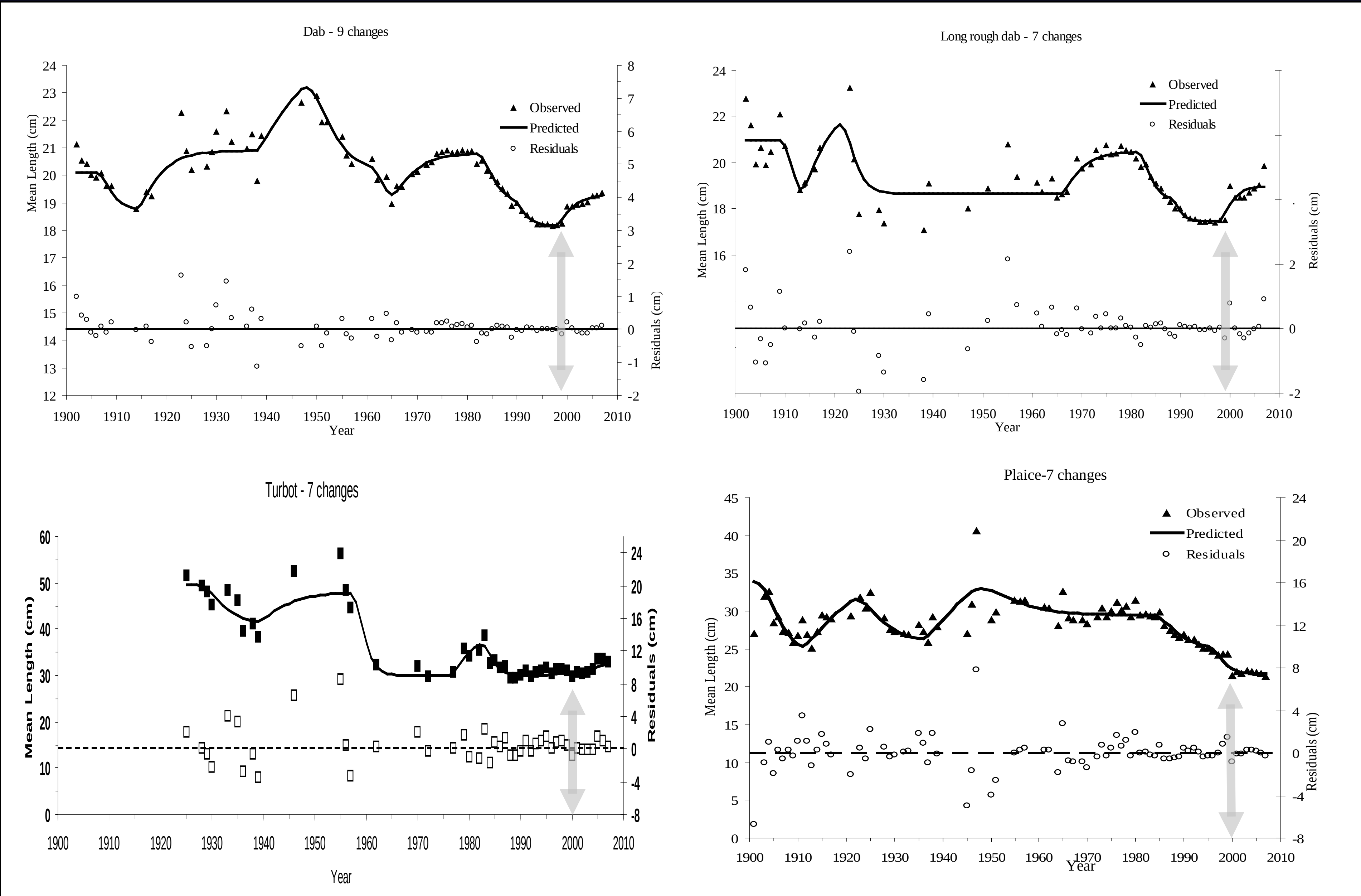


Dab - 9 changes
Long rough dab - 7 changes
Turbot - 7 changes
Plaice-7 changes
Observed
Predicted
Residuals
Mean Length (cm)
Residuals (cm)
Year

Early 1980's – Declining Mean Lengths



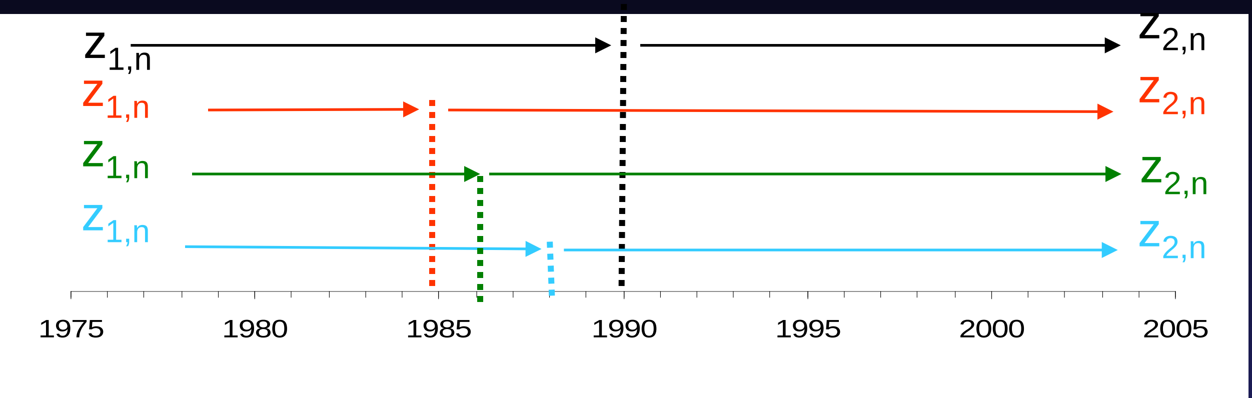
Another Change ~2000 - Management?



MULTI-SPECIES APPROACH

- Similar to single species model with modified assumptions
- Uses information from multiple species to increase sample size
- Assumes that species used from ‘complexes’ are subject to similar patterns of effort

Multi-Species Model Development

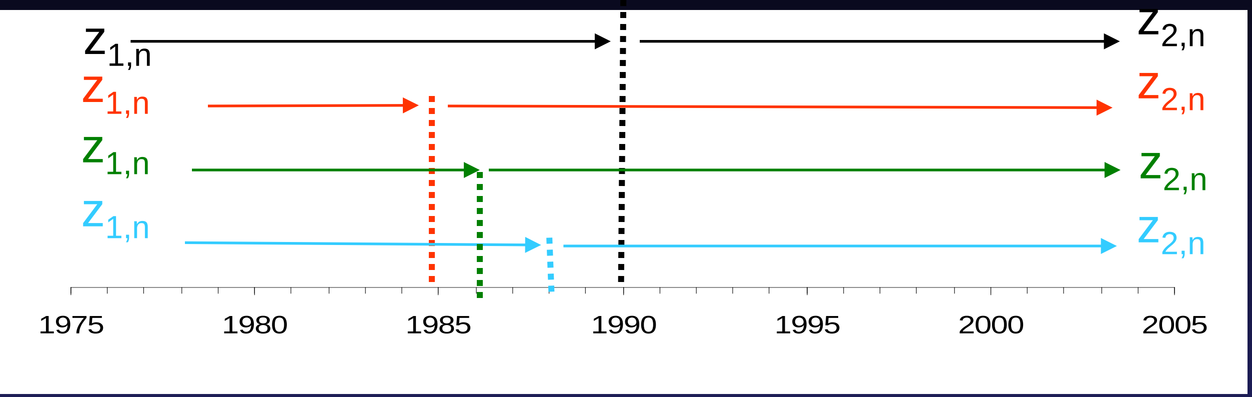


Single Species Model:
4 parameters =
(Z_1, Z_2, ChangeYear, σ)

4 species = 16 parameters

+ 4 parameters for each additional species

Multi-Species Model Development



Single Species Model:
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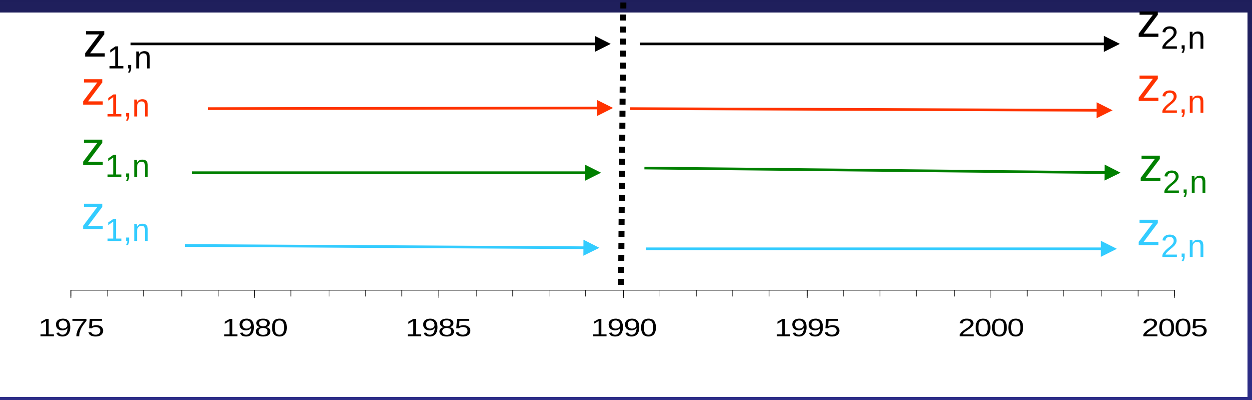
4 species = 16 parameters

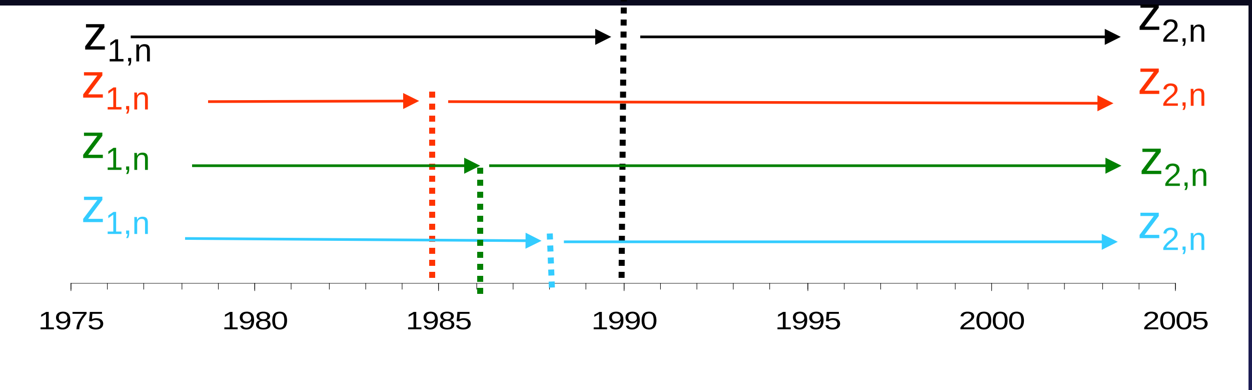


Multi-Species Model 1:
4 parameters =
(Z_1, Z_2, ChangeYear, σ)

Assume common ChangeYear for multiple species → 4 species = 13 parameters

+ 3 parameters for each additional species

Multi-Species Model Development



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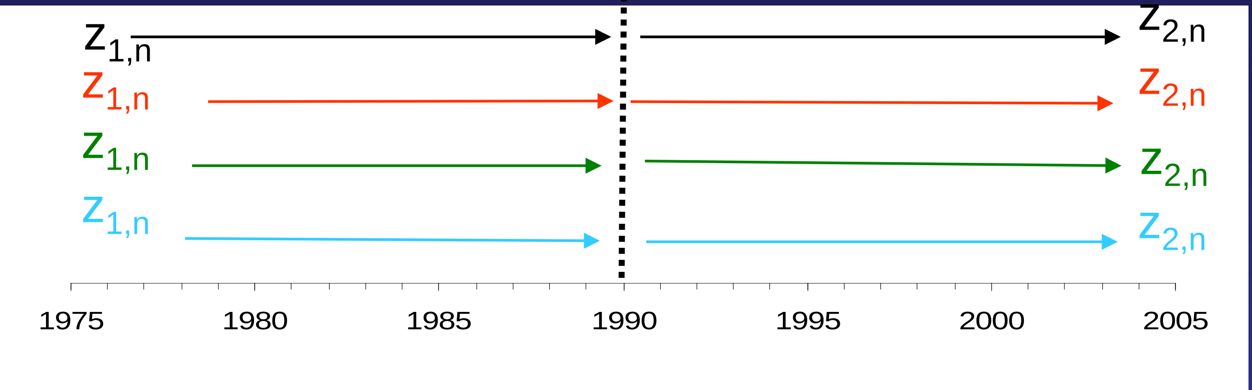

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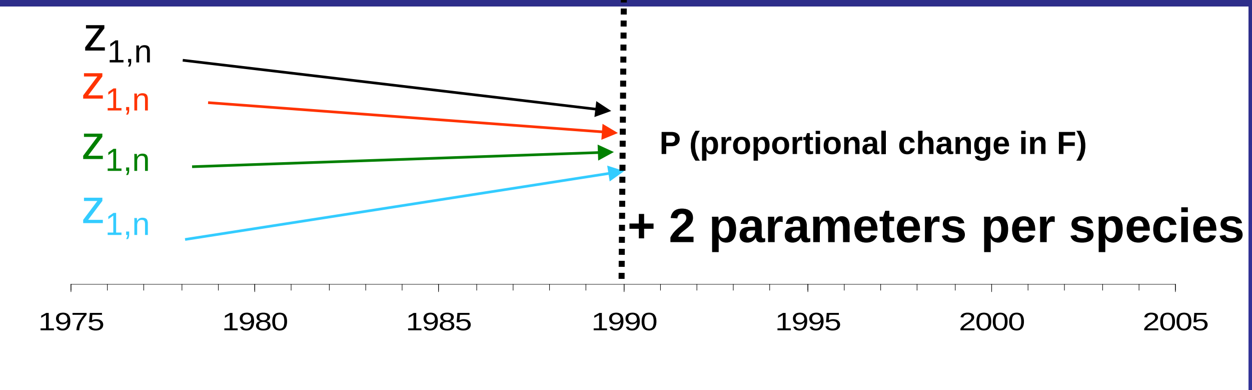
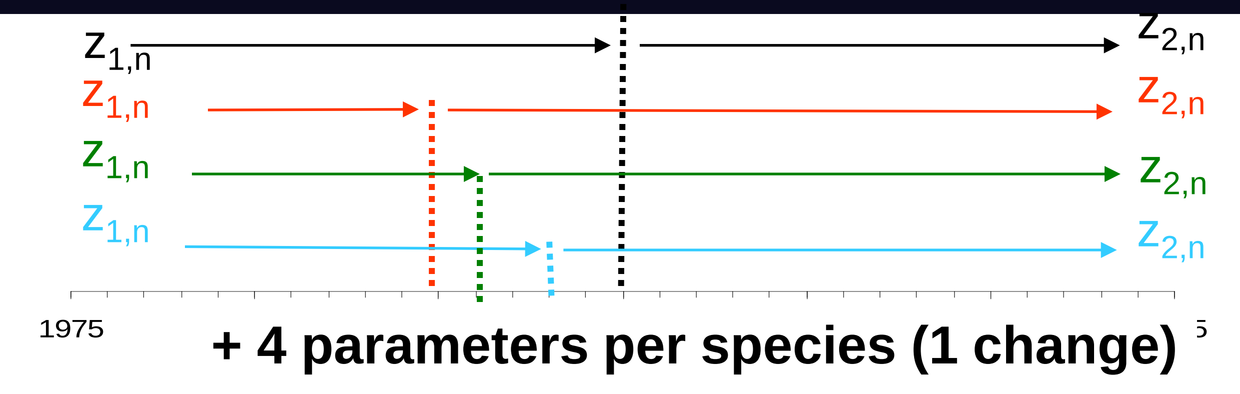


Multi-Species Model 2:
4 parameters =
(Z_1, Z_2, ChangeYear, σ)

Assume common ChangeYear and proportional change in F
→ 4 species = 10 parameters

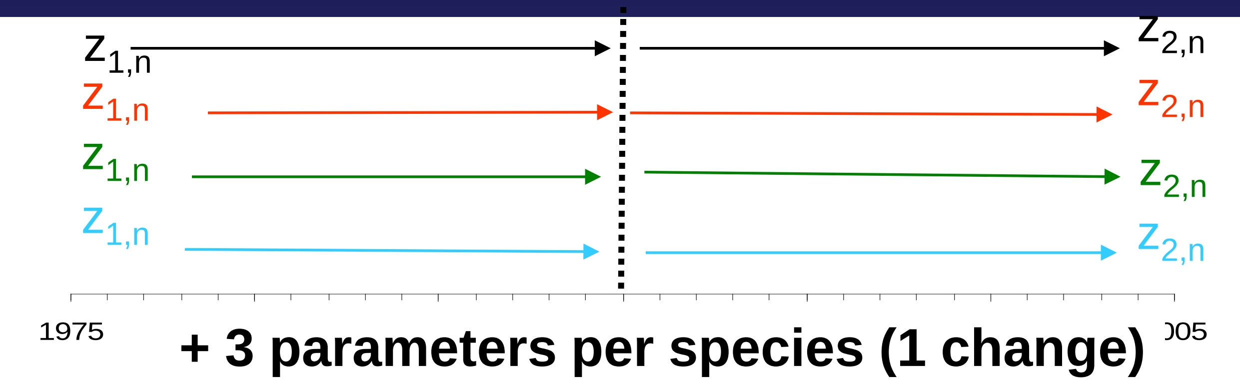
Multi-Species Model Development



+ 4 parameters per species (1 change)

For 3 ChangeYears and 4 species:

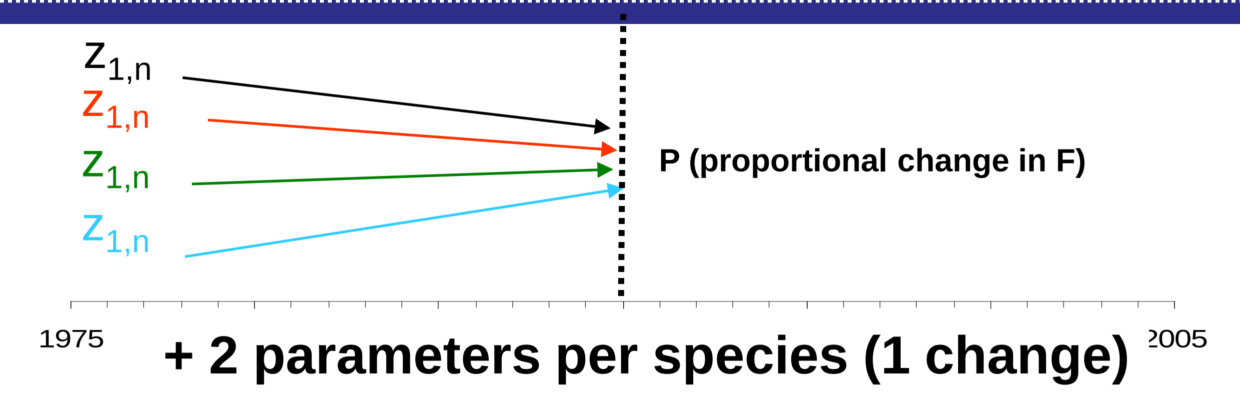
32 Parameters



+ 3 parameters per species (1 change)

Assume common ChangeYear

23 Parameters



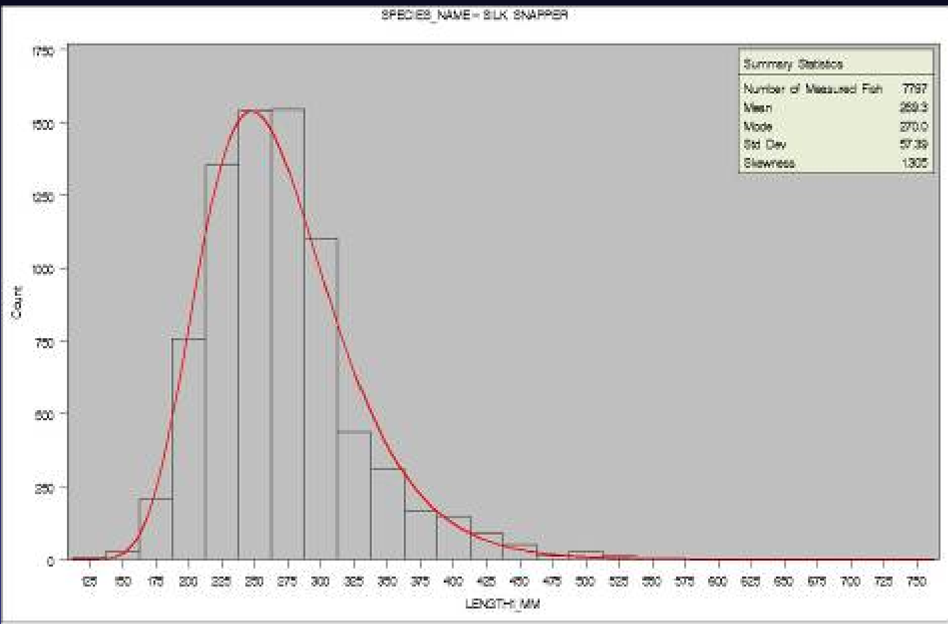
+ 2 parameters per species (1 change)

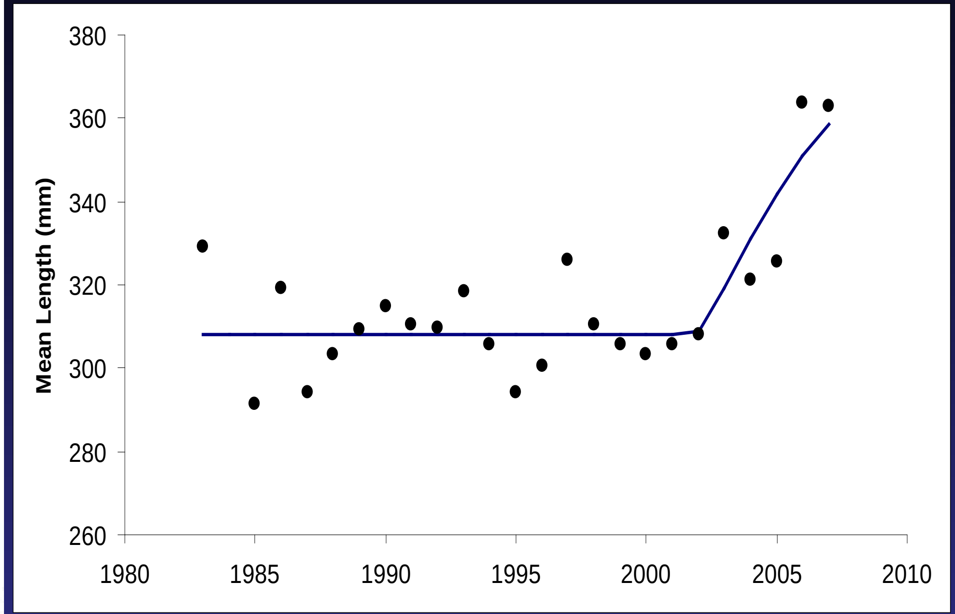
Assume common ChangeYear and proportional change in F

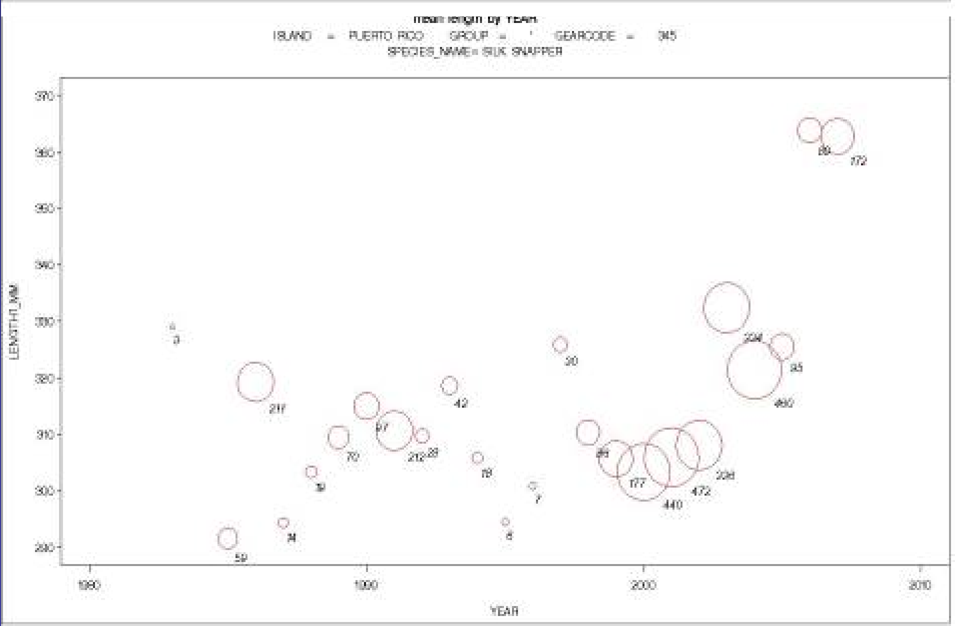
14 Parameters

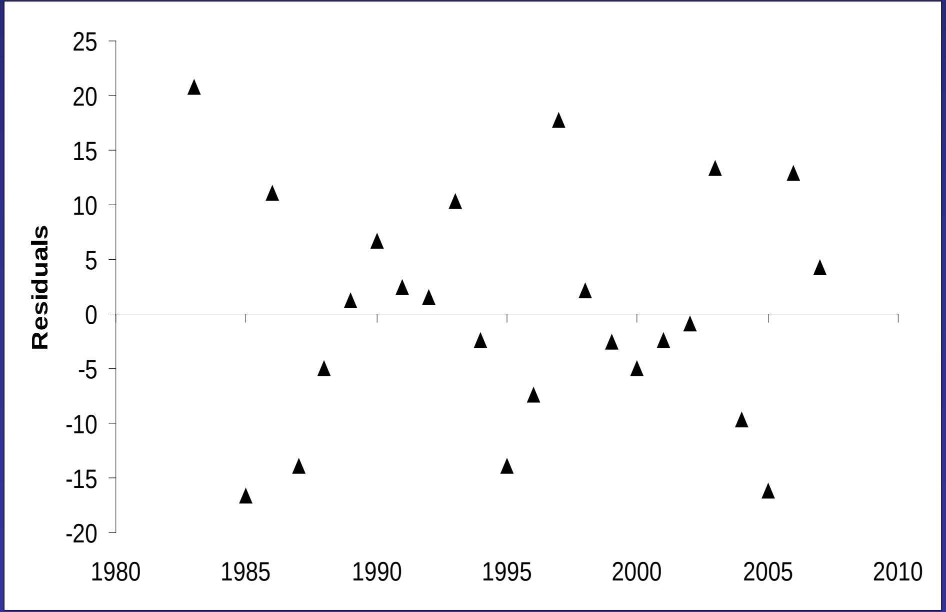
Puerto Rico – Silk Snapper – Traps

Z = 1.12 → 0.31 in 2001.8



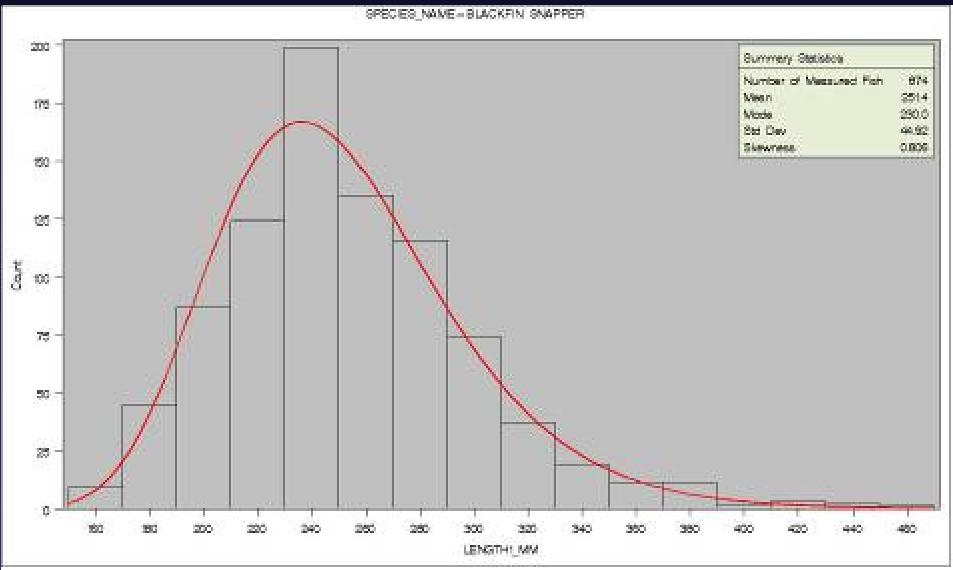


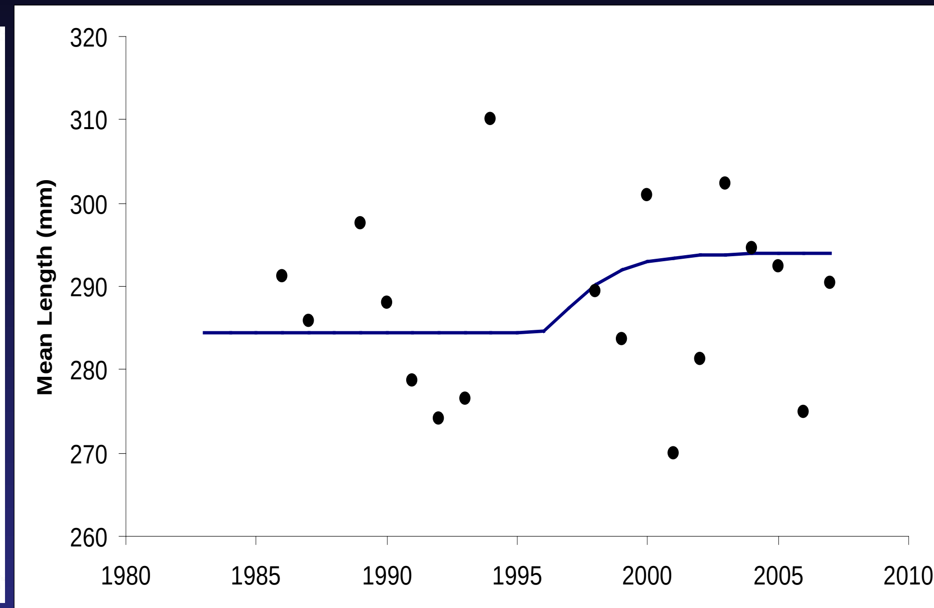


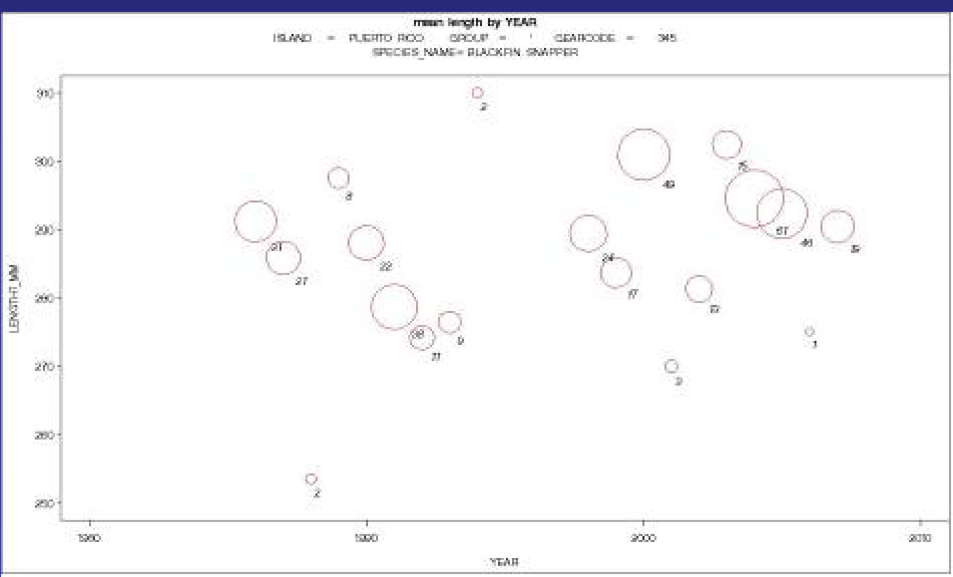


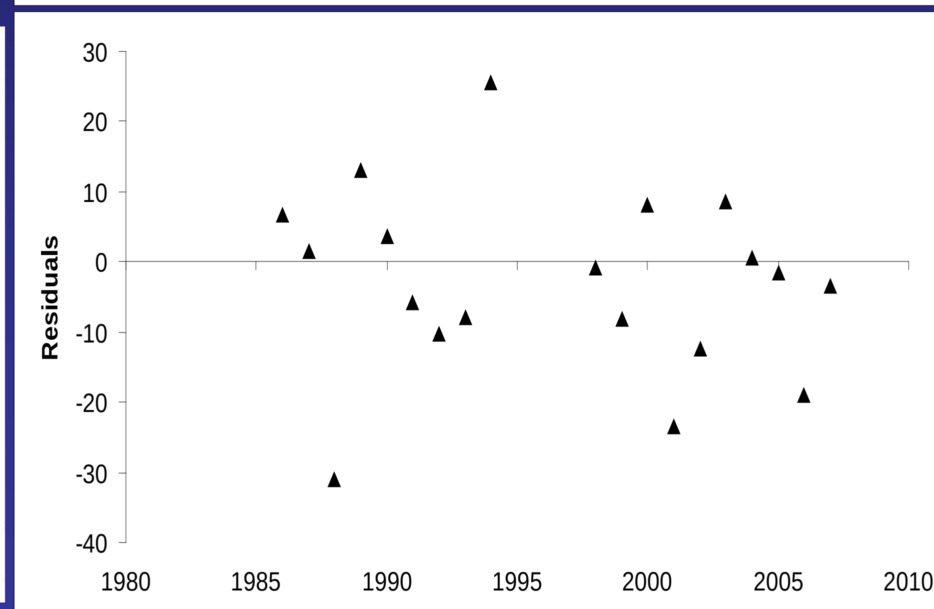
Puerto Rico – Blackfin Snapper – Traps

Z = 1.13 → 0.86 in 1995.8



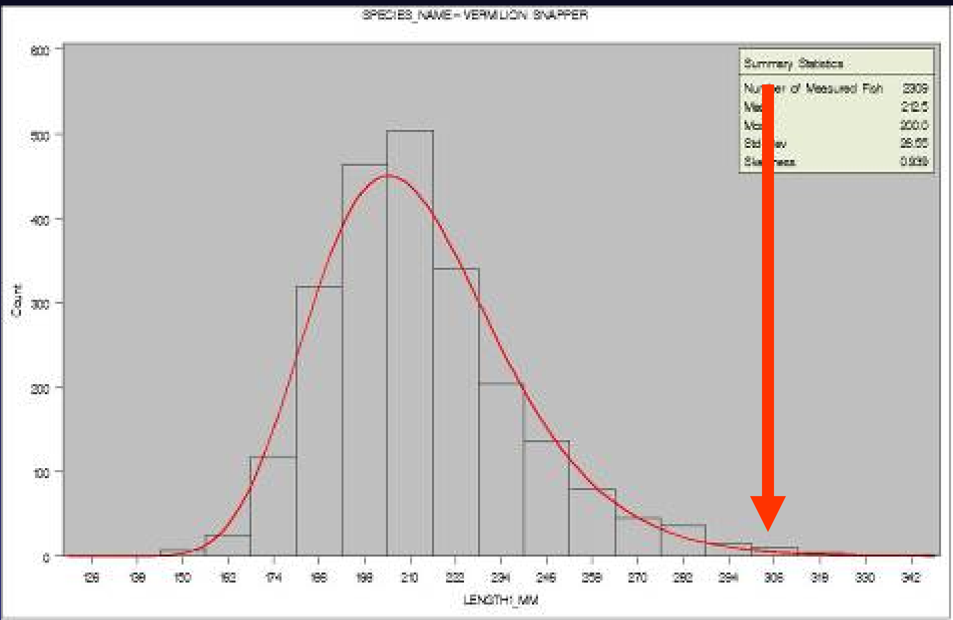


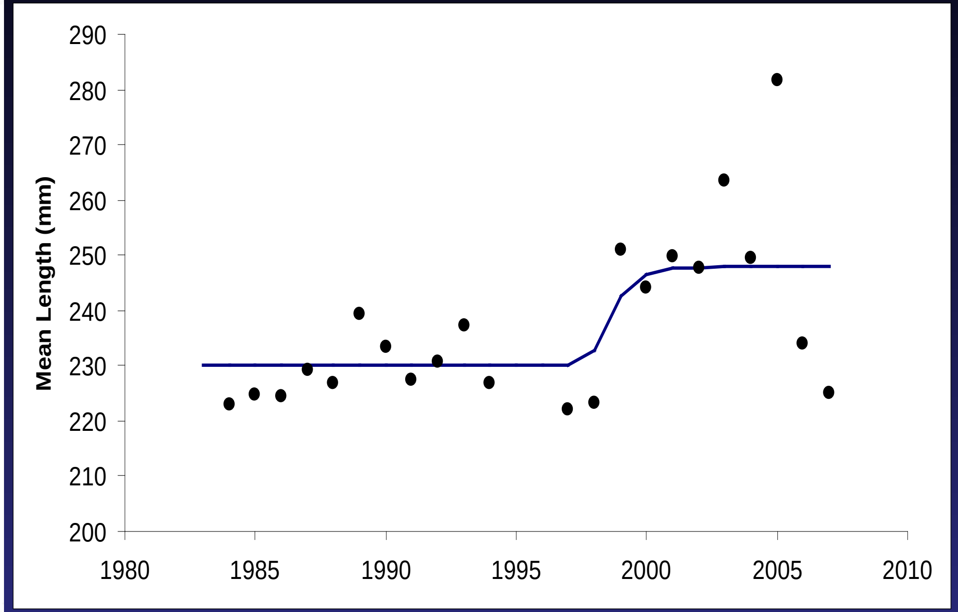


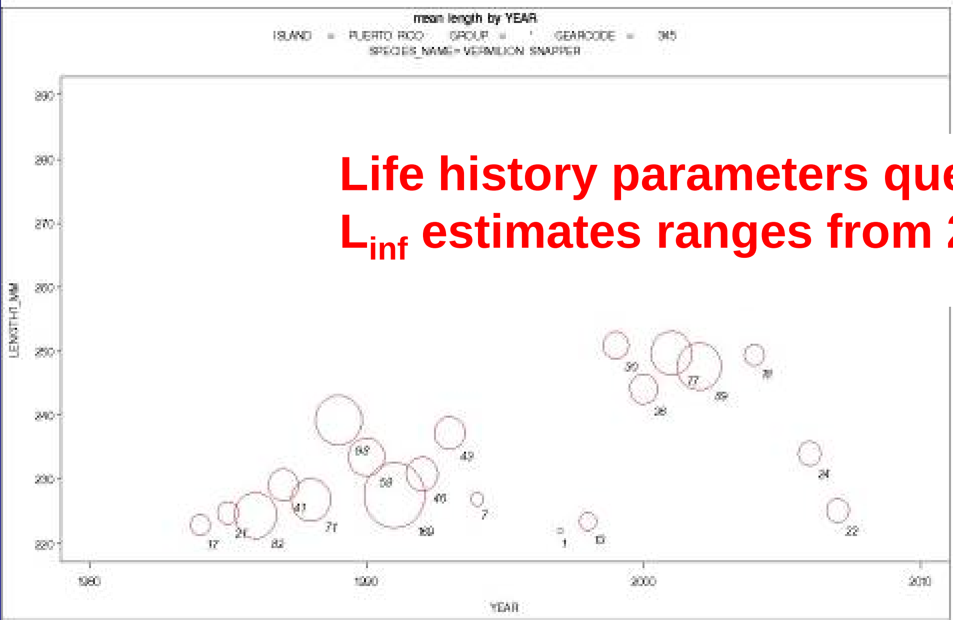


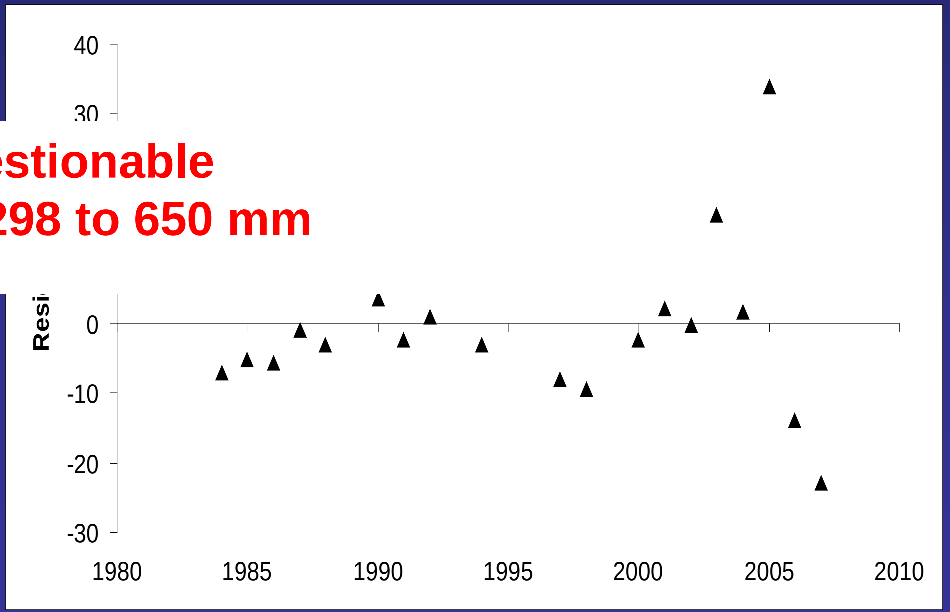
Vermillion Snapper

Z = 3.46 → 1.64 in 1997.7







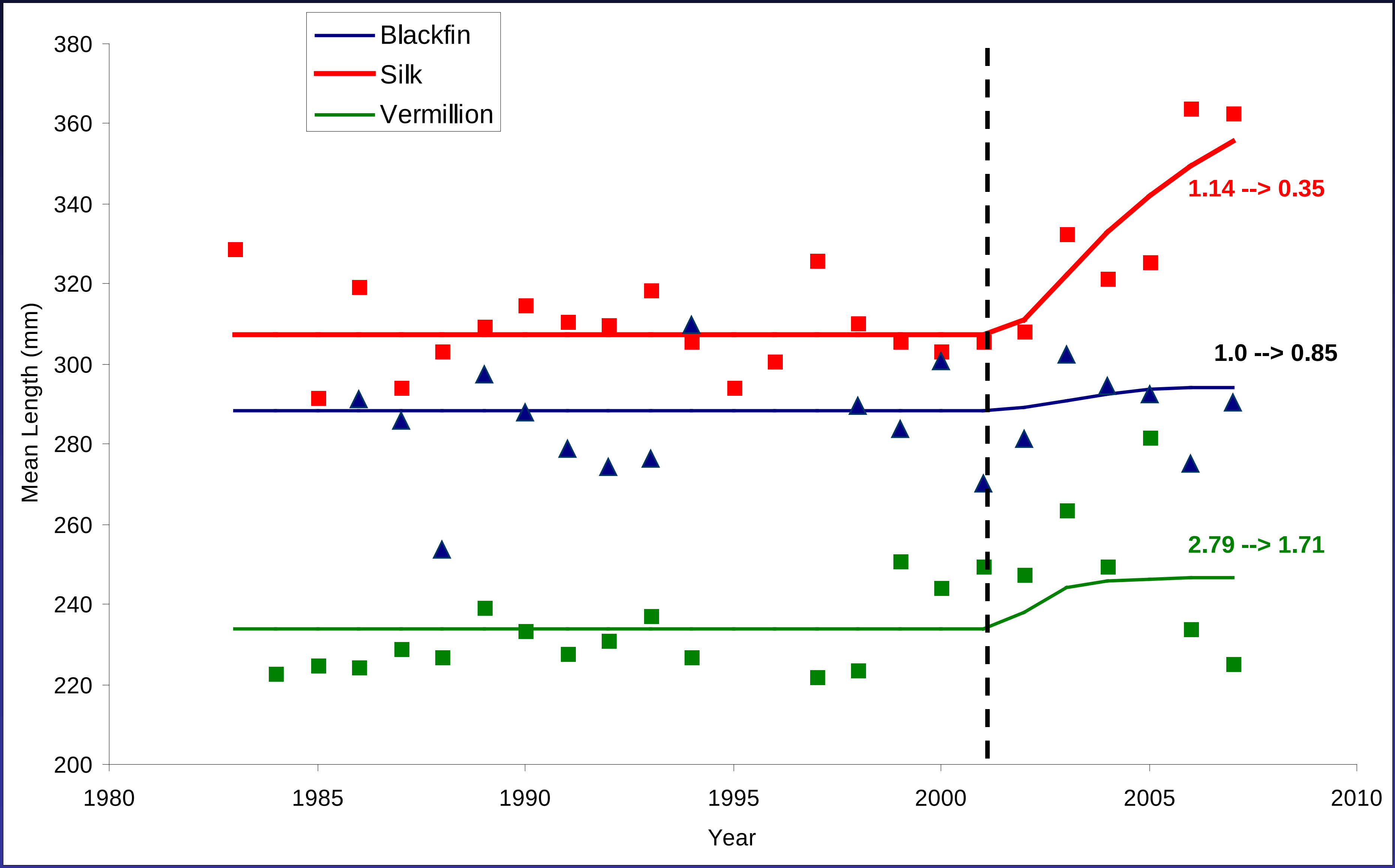


Life history parameters questionable

L_{inf} estimates ranges from 298 to 650 mm

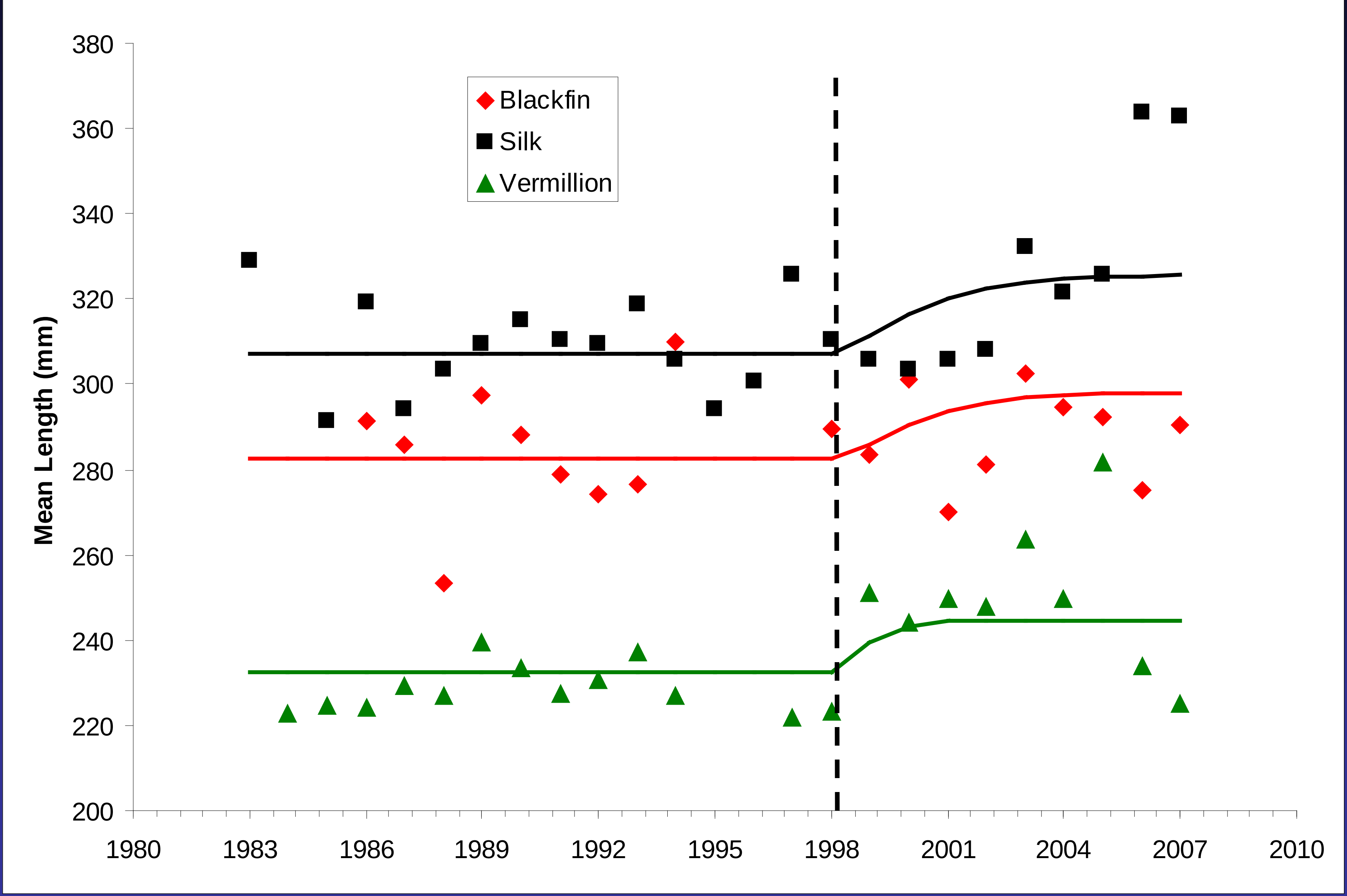
Multispecies - Individual Z's estimated

Estimated Common Year of Change = 2001.4



Multispecies w/ Common Proportional Change in F

Common Year of Change = 1998.03
Common Proportional change in F = 0.57



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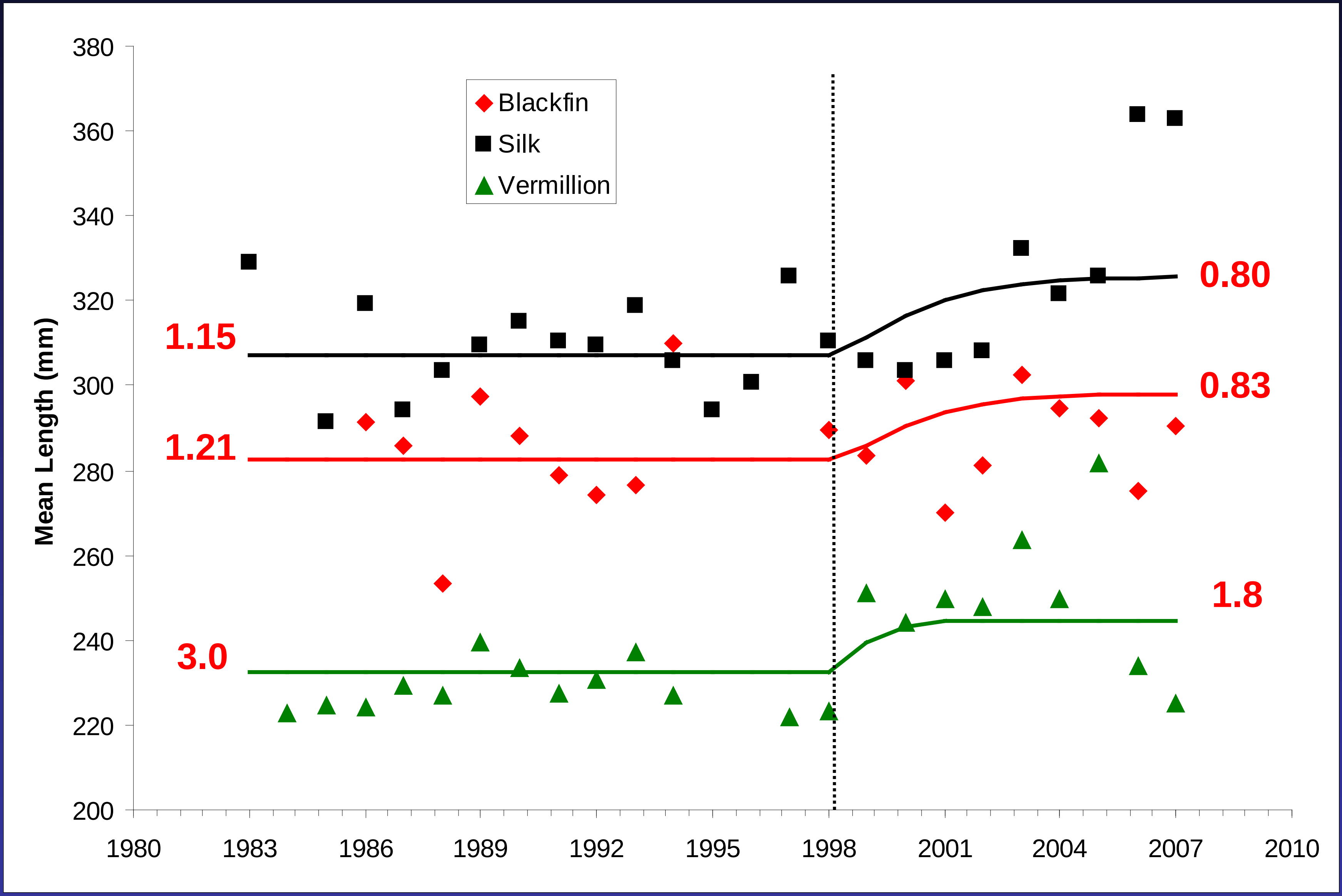

Model Selection

AIC (Akaike's information criterion)

- **Evaluates balance between number of parameters in model and the fit to the data (likelihood value).**
- **Penalty for increased number of parameters**
- **Lower AIC values better → Reduction of ~5 indicates strong support for model**

AICc = AIC + (2*Nparam*(Nparam+1)/(NumObs – Nparam-1)

Model	Gear	Depth	Number of Parameters	Likelihood Value	AIC	AICc
Single species	345/610	<80	12	441.2	906.4	911.4
Multispecies (individual Z's)	345/610	<80	10	432.9	885.7	889.1
Multispecies (proportional change)	345/610	<80	8	445.0	905.9	908.1
Single species	345	All	12	398.1	820.3	825.3
Multispecies (individual Z's)	345	All	10	363.1	746.1	749.6
Multispecies (proportional change)	345	All	8	370.6	757.1	759.3

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