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Estimation of the Intrinsic Rate of Increase for Georges Bank Yellowtail Flounder

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Canada

Introduction

- Estimate reproductive potential of GB yellowtail flounder using life-table analysis.

- Methodology based on the Euler-Lotka equation (Caswell 1989)

- Apply recently derived GB YT fecundity relationship that includes condition (WP 33)

- Analysis provides :
  - Intrinsic rate of increase → r and instantaneous growth rate $\lambda = \exp(r)$
  - Net Reproductive rate / reproductive potential → R_o

Input Data:

- Time series : 1973-2013
- Population number at age (N); (2013 VPA ,Legault 2013)
- Recruitment (R) = age 1 N
- Sex ratio (X); assume 50/50
- Maturity at age (M); times series average (2013 VPA ,Legault 2013)
- Mean length at age = L_a
    - Use NEFSC spring research bottom trawl survey : Closest to spawning time
    - Missing mean length for age 1 for most years, used a 10 year mean for missing years
    - Some missing age 6 or 7 , use average of adjacent years
    - Regression fit to observed mean length, fitted mean length applied in life-table

Input Data:

- Condition
  - Individual weight only available since 1992.
  - Fulton's Condition at length (l) = $K_{l} =$ [Wt (g) / Length (mm)^3] *100000
  - K assumed = 1 for earlier years
  - Mean K at age = $K_a = \Sigma (K_l / n)$
- Potential Annual Fecundity (F) : combined 2010-2013 (WP 33 McElroy)
  - $\ln(PAF)_a = \beta_0 + \beta_1 \ln L_a (mm) + \beta_2 \text{Oocyte diam} + \beta_3 K_a$
  - oocyte diameter = 450 um (near spawning size)

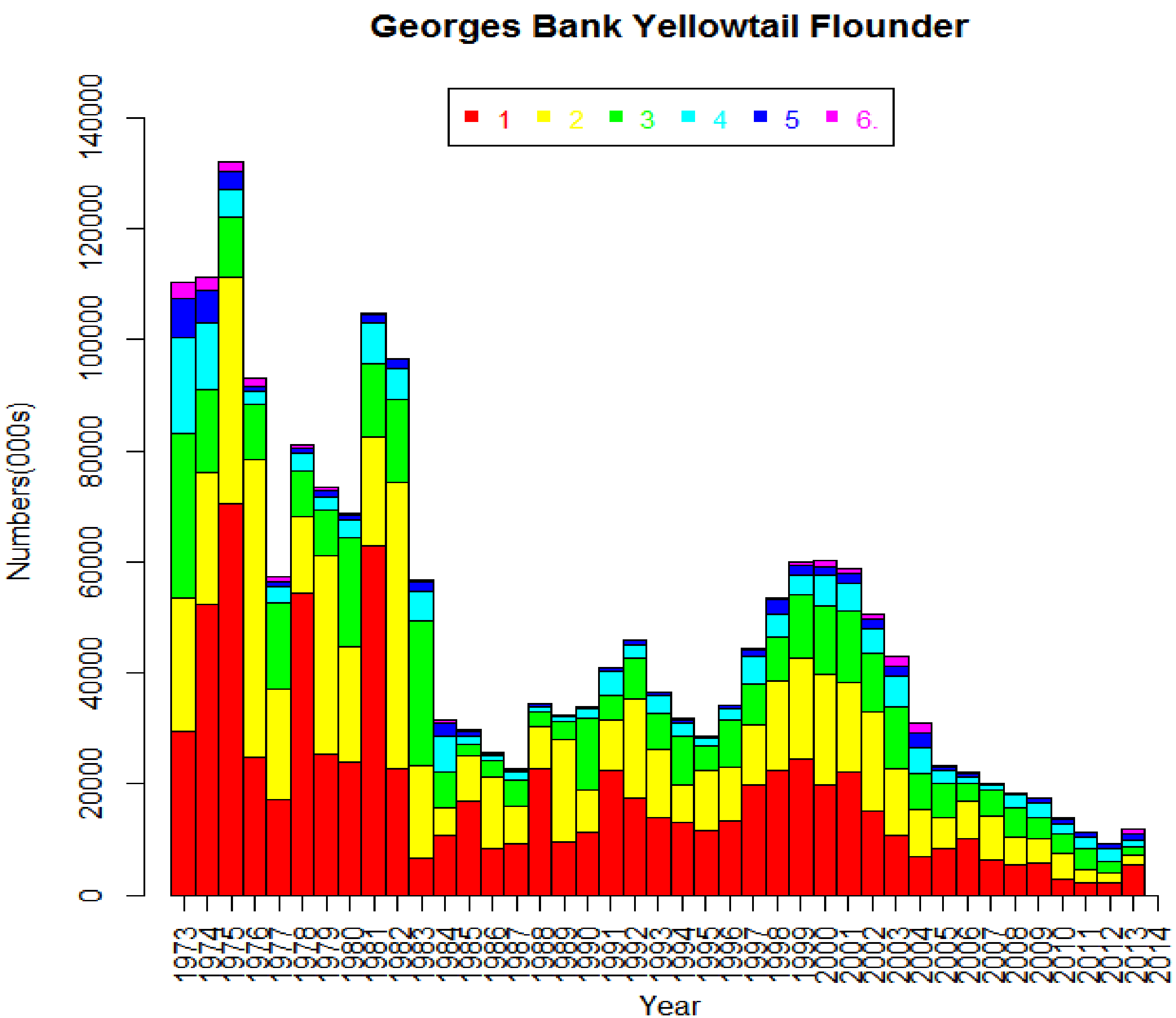
Parameter	Estimate	SE
Intercept	-3.3816805	2.7745847
LN (TL)	2.6875112	0.4542765
Mean Oocyte Diameter	-0.0023884	0.0005946
K	2.8512876	0.2466295

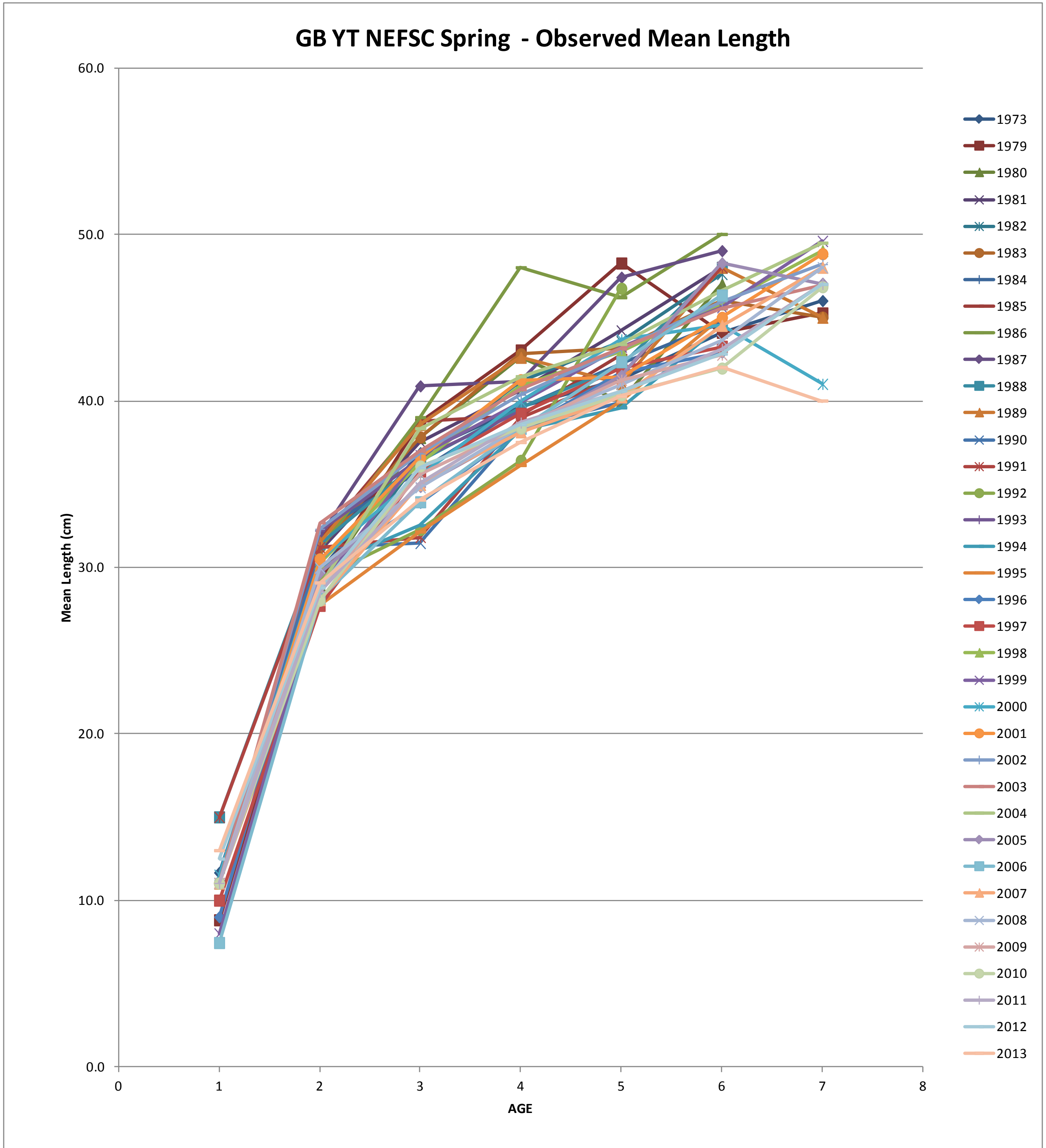
- Total Egg production at age = $TEP_a = N_a * X_a * M_a * F_a$

- Recruitment survival = $S = R_{y-1} / TEP_y$
- Average Rct Z = $(\Sigma -\ln [R/TEP]_y) / n$

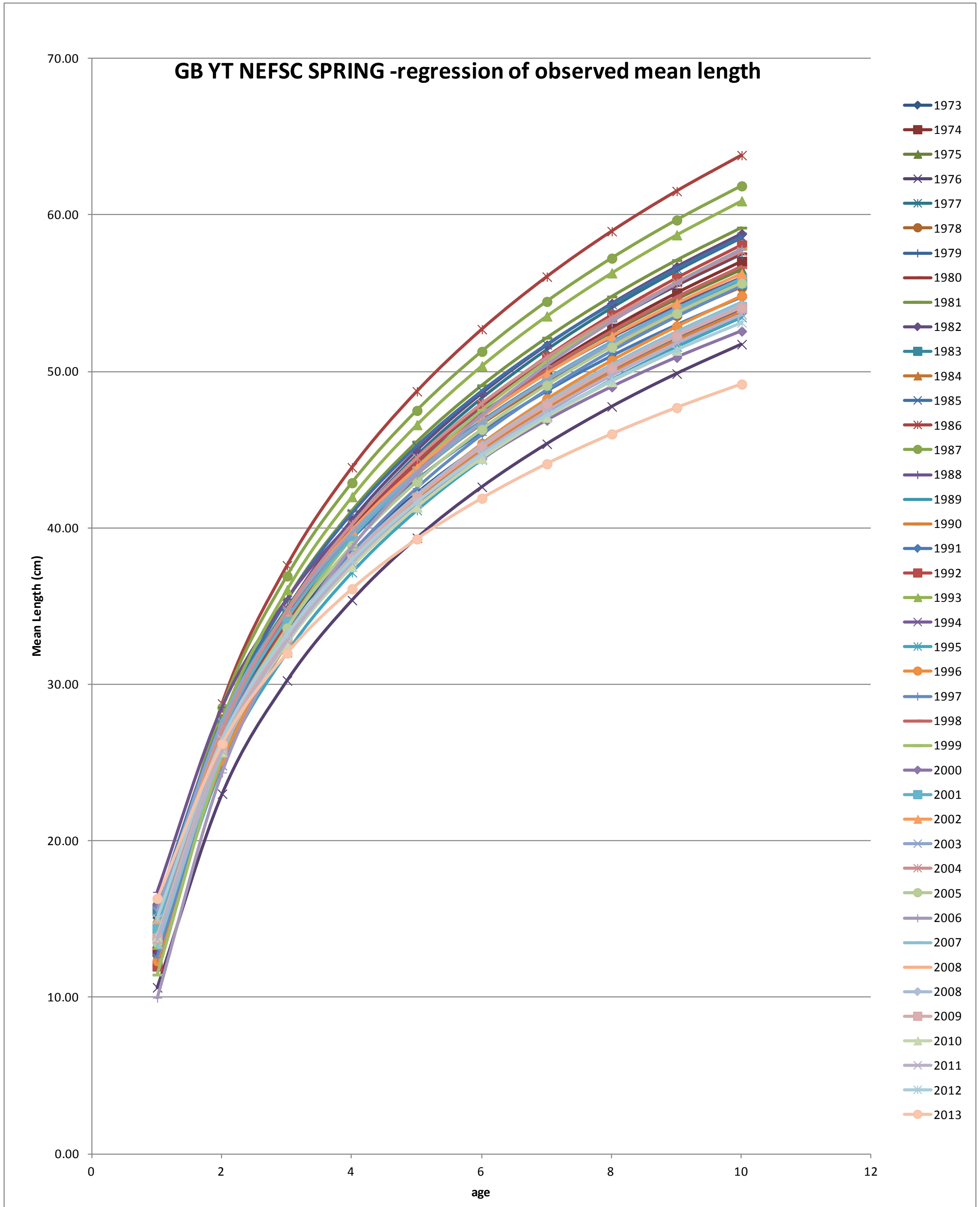
- Maximum age ~ 11

Population Numbers at ages 1-6+ from 1973-2013





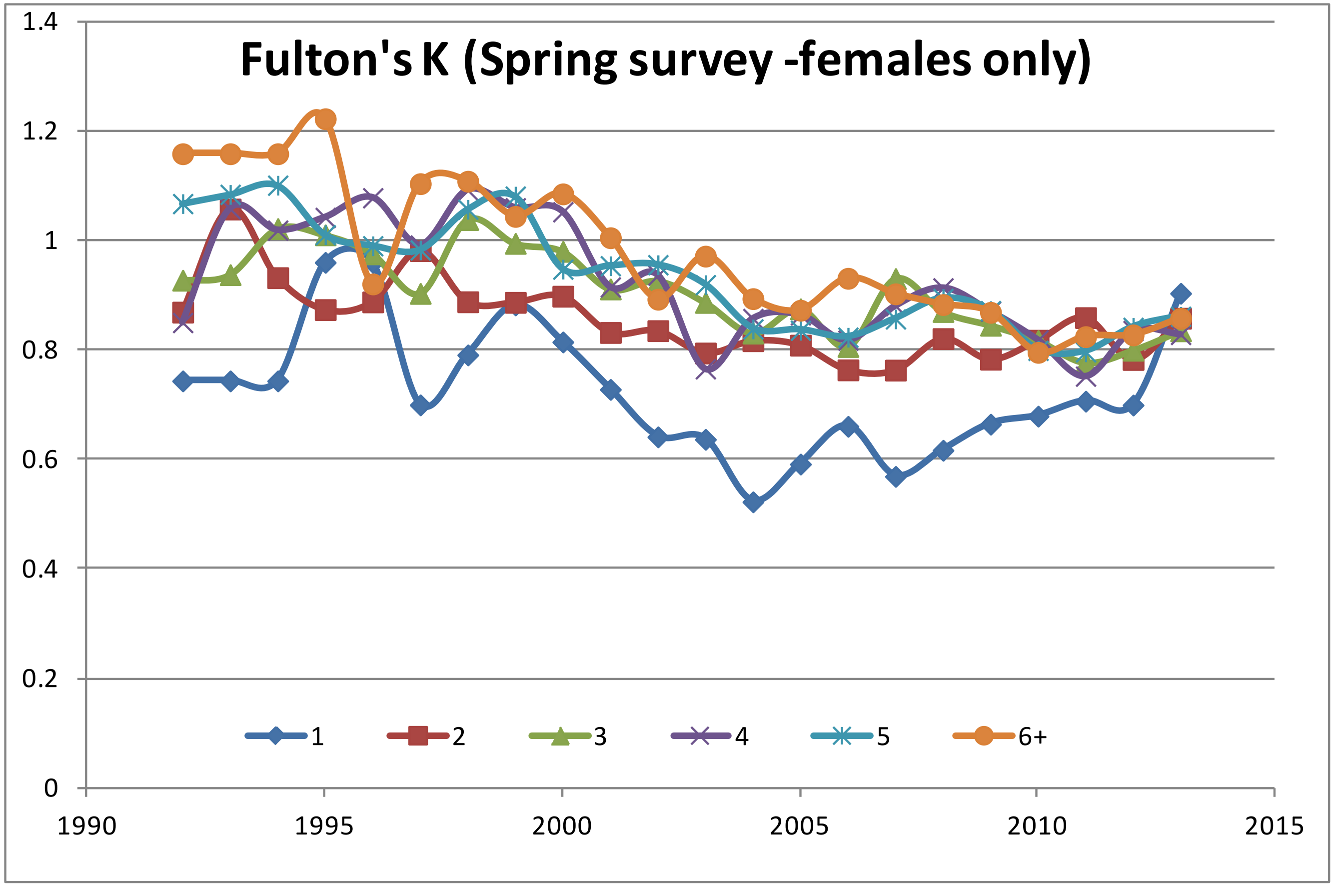
Spring Observed Mean length at age 1973-2013



Spring
Fitted mean length at age
1973-2013

Ages 7+ low sample size

Fulton's Condition



Life-Table Analysis

Euler-Lotka equation ; solve to estimate r, intrinsic rate of increase

$$\sum_{x=\alpha}^{x=\beta} e^{-rx}\, l(x)\, m(x) = 1$$

where

l(x) = the probability of surviving to age x
m(x) = number of female offspring produced at age x
α = age 0
β = maximum age

Derive annual instantaneous growth rate :

- $\lambda = \exp(r)$

Life-Table Analysis

Derive Net reproductive rate:

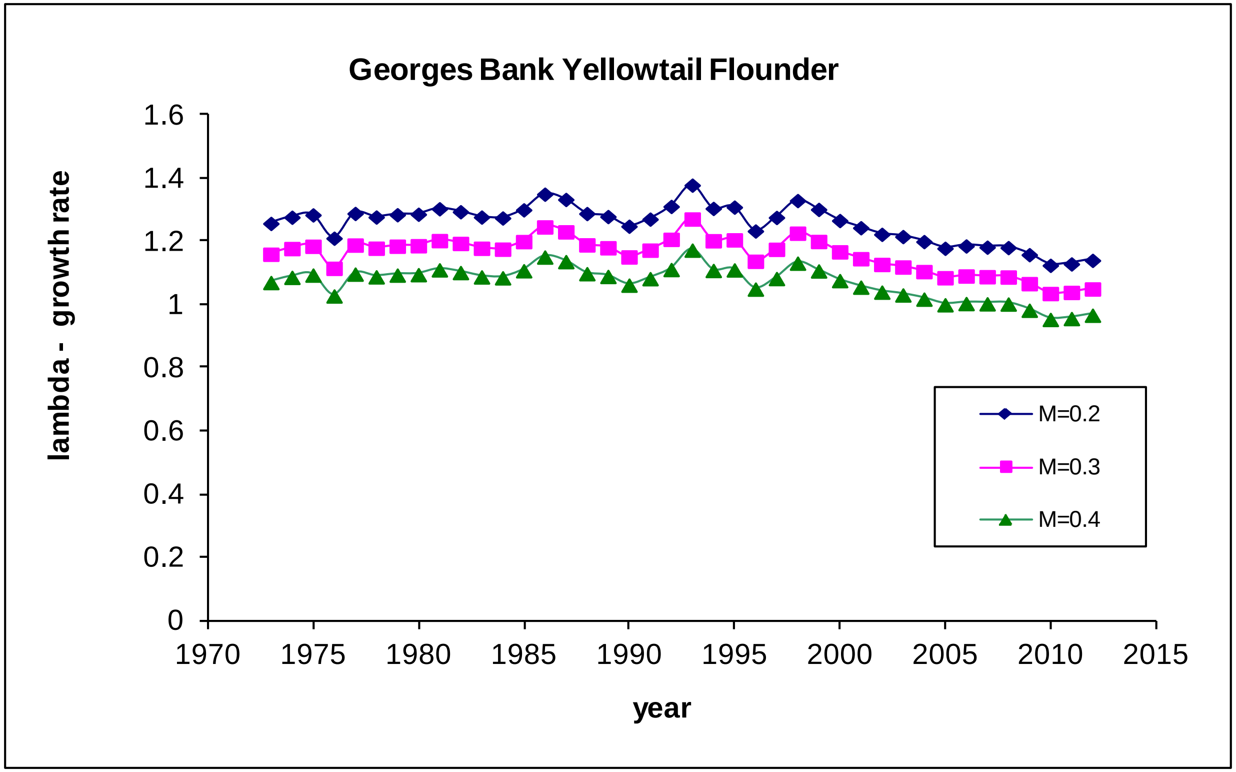
$$R_o = \sum_{x=\alpha}^{x=\beta} l(x)\, m(x)$$

where

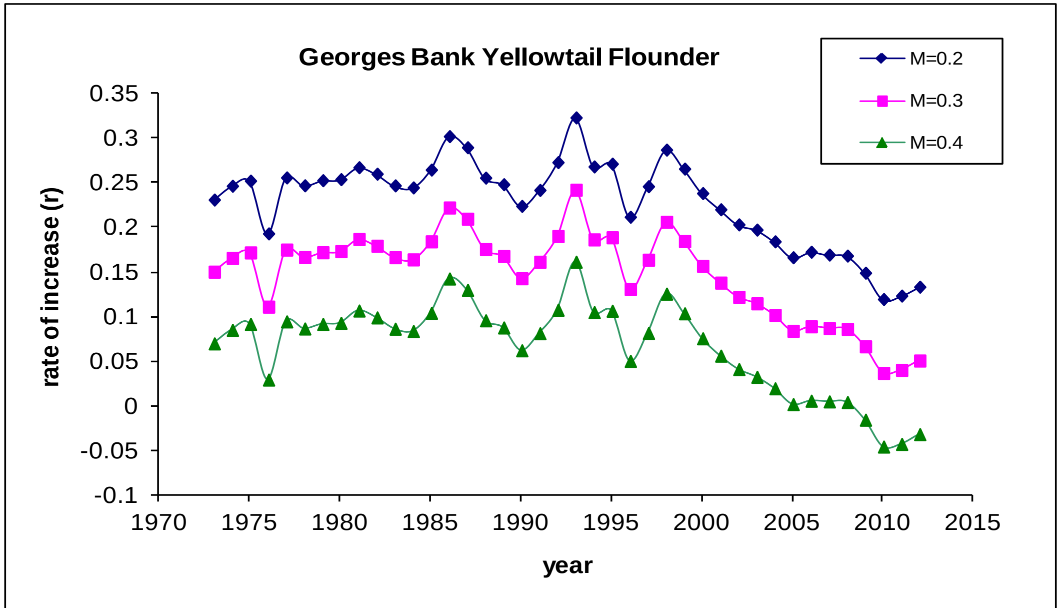
l(x) = the probability of surviving to age x
m(x) = number of female offspring produced at age x
α = age at maturity
β = age at death

Results

annual instantaneous growth rate : $\lambda = \exp(r)$



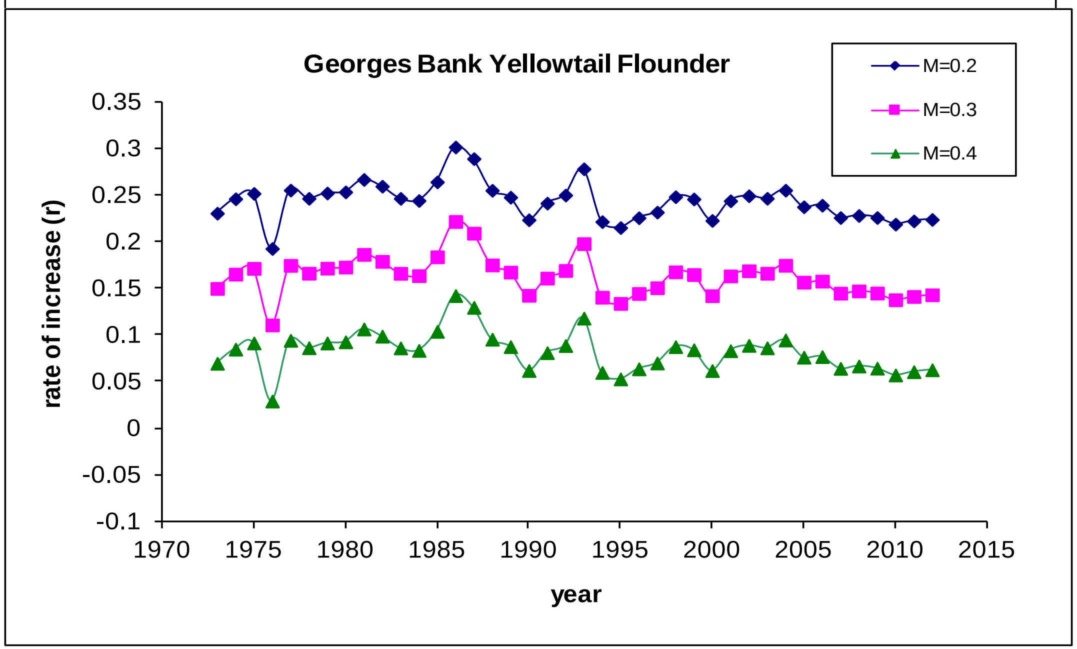
Results – influence of K on r



K has strong effect on trend in r

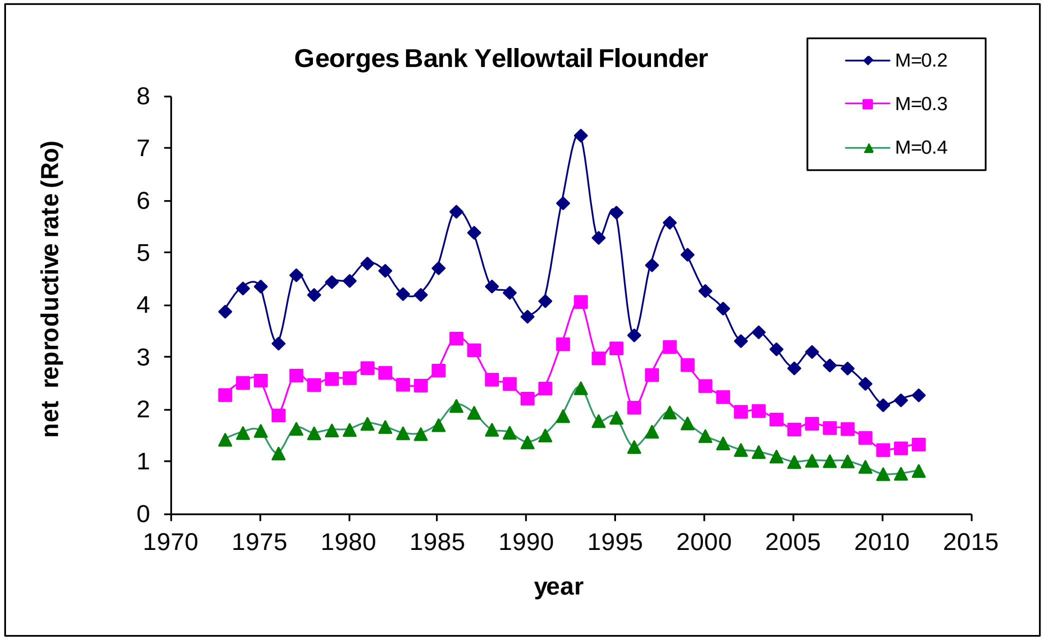
K = 1 in fecundity eqn from 1973-1991

K = observed condition from 1992→



K = 1 in all years

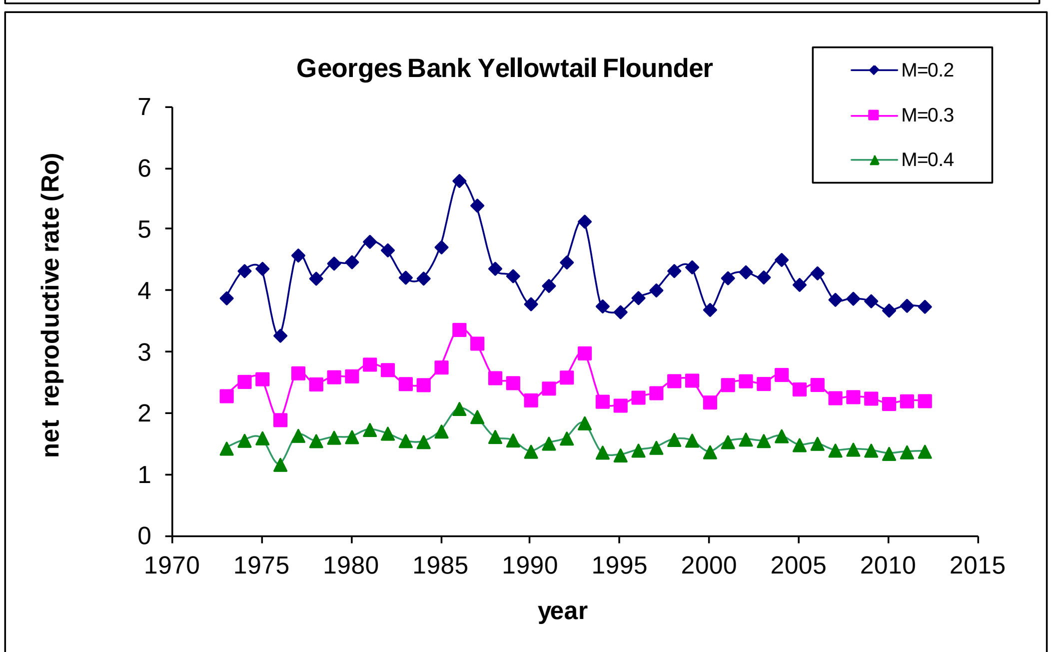
Results – influence of K on Ro



K has strong effect on trend in Ro

K = 1 in fecundity eqn from 1973-1991

K = observed condition from 1992→



K = 1 in all years

Summary

- Population growth (λ) and net reproduction (Ro) have been declining since 1998

- Estimation of r and Ro influenced strongly by inclusion of condition in fecundity estimation

- If condition is not included, would mistakenly conclude stock is relatively stable even though population numbers are declining.

Further work:

- Sensitivities to varied sex ratio, since YT have dimorphic growth; Females grow/survive to larger size than males

- Sensitivity and Elasticity (proportional effect) to measure how changes in vital rates i.e. juvenile mortality, survival at age, effect estimation of λ

- Projections of Spawning Stock Biomass (Monte Carlo Analysis)

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