Marine Institute

Lab2: 3Ps cod length-at-age 2019 course

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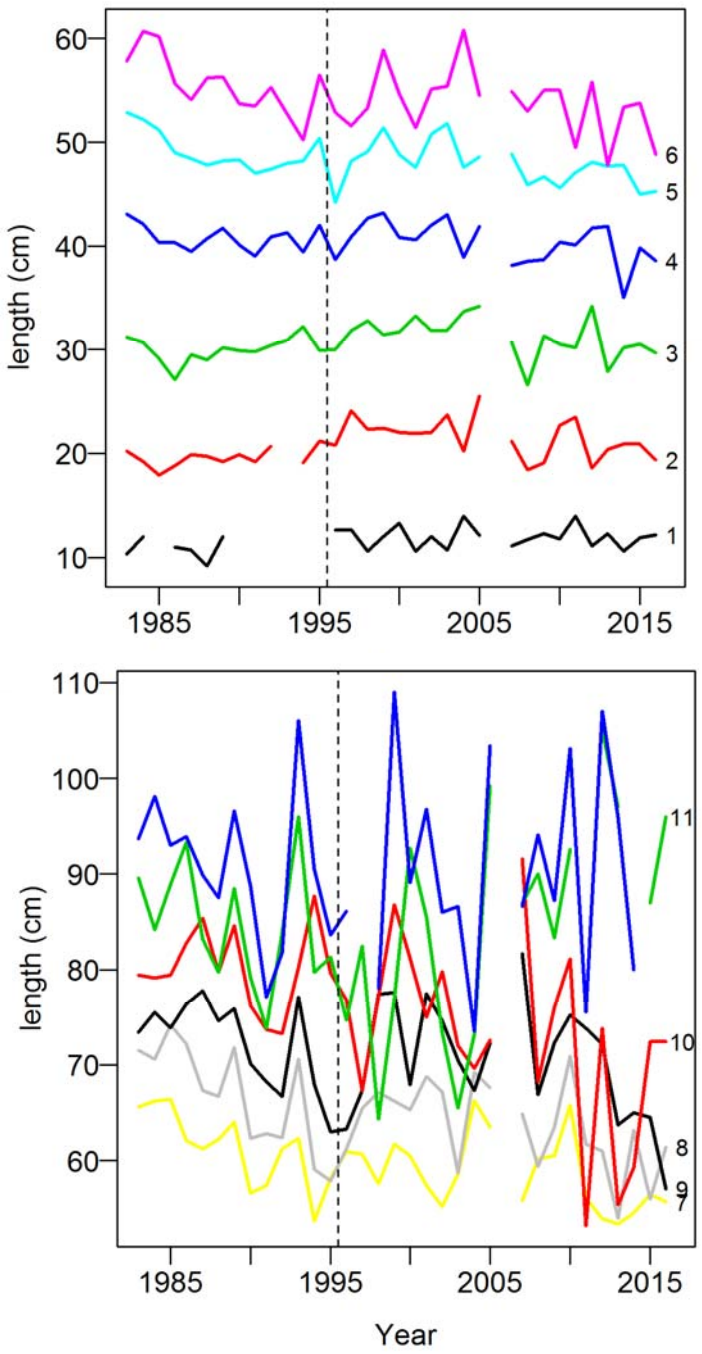
CFER

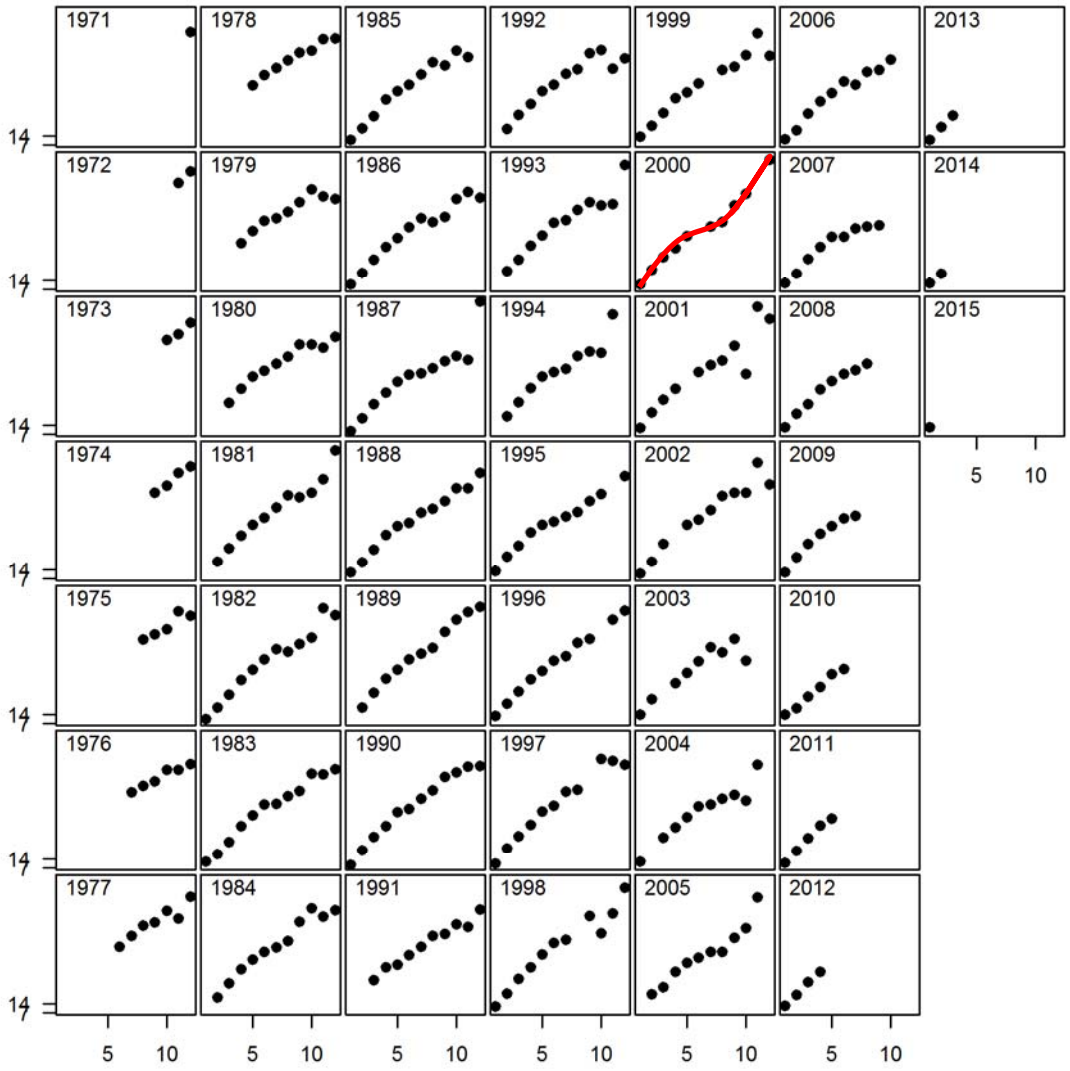
Centre for Fisheries Ecosystems Research

MARINE INSTITUTE

MEMORIAL UNIVERSITY

The Data


length (cm)
60
50
40
30
20
10
1985
1995
2005
2015
6
5
4
3
2
1
length (cm)
110
100
90
80
70
60
11
10
8
9
7
Year


1971
1978
1985
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2008
2015
1974
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1975
1982
1989
1996
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2010
1976
1983
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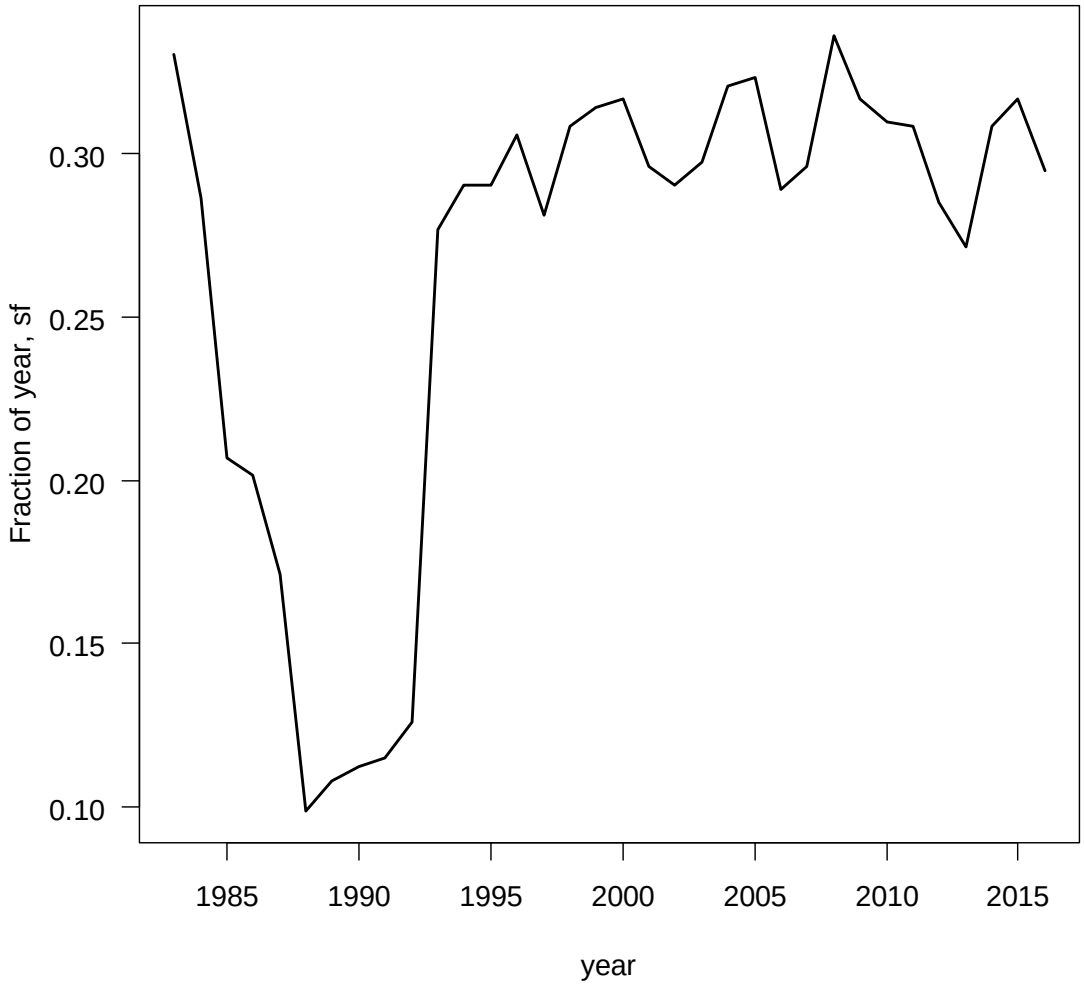
1997
2004
2011
1977
1984
1991
1998
2005
2012
5
10

Survey Timing

Year	Start Date	End Date
1983	23-Apr-83	8-May-83
1984	10-Apr-84	17-Apr-84
1985	8-Mar-85	25-Mar-85
1986	6-Mar-86	23-Mar-86
1987	13-Feb-87	22-Mar-87
1988	27-Jan-88	14-Feb-88
1989	1-Feb-89	16-Feb-89
1990	1-Feb-90	19-Feb-90
1991	2-Feb-91	20-Feb-91
1992	6-Feb-92	24-Feb-92
1993.4	2-Apr-93	20-Apr-93
1994	6-Apr-94	26-Apr-94
1995	4-Apr-95	28-Apr-95
1996	10-Apr-96	1-May-96
1997	2-Apr-97	23-Apr-97
1998	10-Apr-98	5-May-98
1999	13-Apr-99	6-May-99
2000	8-Apr-00	11-May-00
2001	7-Apr-01	29-Apr-01
2002	5-Apr-02	27-Apr-02
2003	5-Apr-03	2-May-03
2004	11-Apr-04	11-May-04
2005	17-Apr-05	9-May-05
2006	13-Apr-06	18-Apr-06
2007	4-Apr-07	2-May-07
2008	10-Apr-08	23-May-08
2009	8-Apr-09	13-May-09
2010	8-Apr-10	8-May-10
2011	7-Apr-11	8-May-11
2012	31-Mar-12	26-Apr-12
2013	26-Mar-13	23-Apr-13
2014	5-Apr-14	10-May-14
2015	11-Apr-15	10-May-15
2016	2-Apr-16	1-May-16



Time-varying SR

- I fit models with various combinations of time-varying (i.e. RW) Linf, k, and po, $l_c(a) = L_{c,\infty}\{1 - (1 - \rho_{c,o})exp(-k_c a)\}$

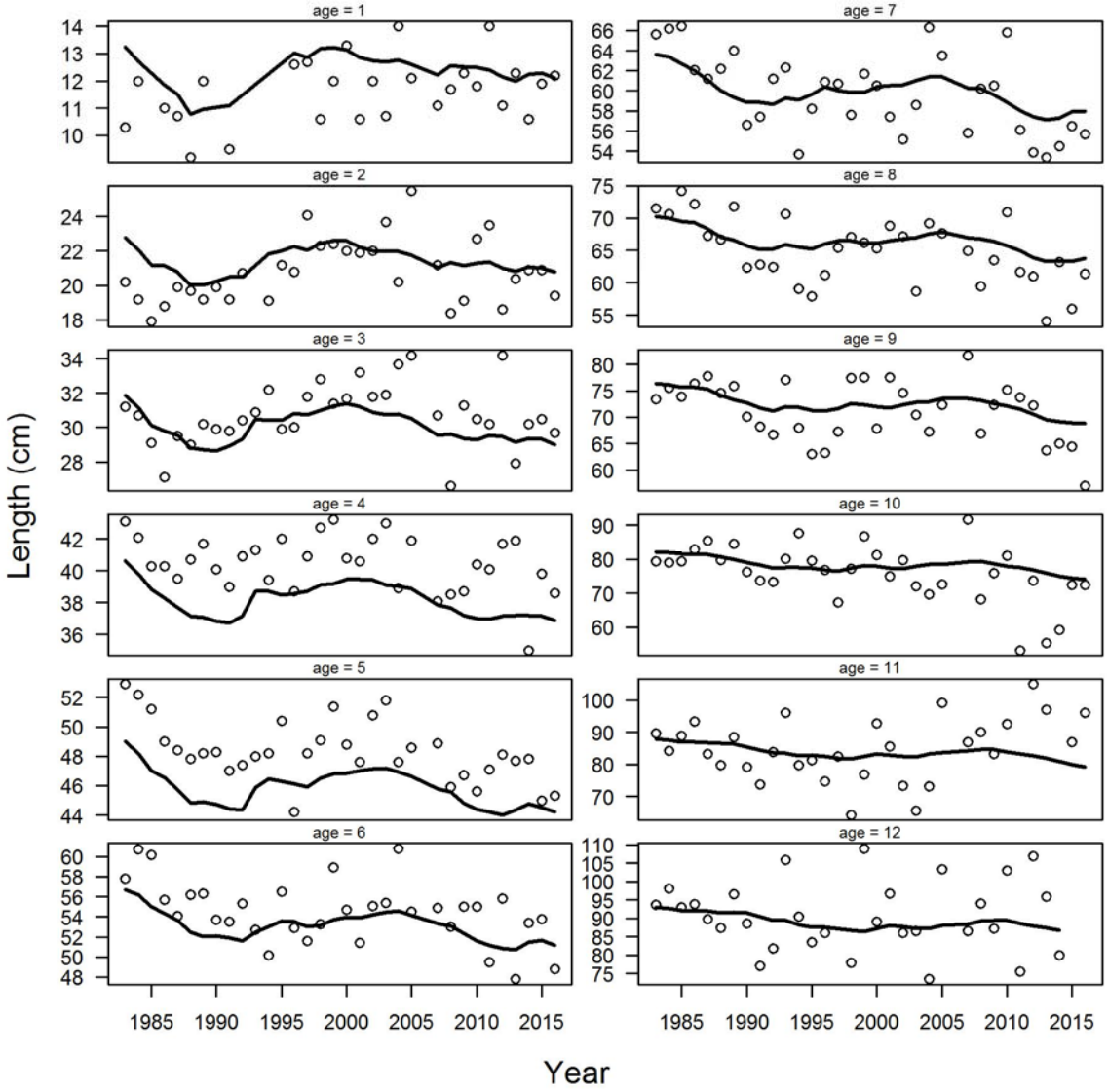
	k+Linf+po	(k+Linf+po)|C	k+po+(Linf|C)	Linf+po+(k|C)	Linf+(po+k|C)
Dev	-777.161	-803.080	-803.080	-802.098	-802.098
Nparm	4.000	7.000	5.000	5.000	6.000
AIC	-769.161	-789.080	**-793.080**	-792.098	-790.098
BIC	-753.358	-761.425	**-773.327**	-772.345	-766.394
MSE	0.008	0.007	0.007	0.007	0.007
Linf	176.359	170.268	170.268	161.020	161.020
k	0.057	0.064	0.064	0.069	0.069
logit_po	-24.638	-33.391	-24.409	-24.503	-25.228
std_Linf		0.014	0.014	0.017	0.017
std_k		0.000		0.083	0.275
std_lpo		0.000			0.083
std_me	0.088	0.083	0.083		

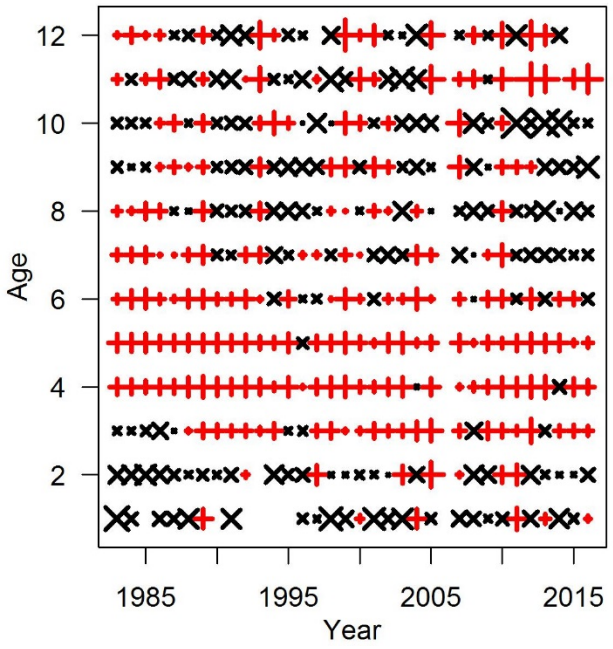
best

close

Fit using age+sf

3Ps cod RW VonB





VonB2 model did not help much!

None of these models fit the data well – under-estimate size at ages 3-6

Time-Varying Bi-phasic Growth Model

TMB

```
//Fixed effects
  PARAMETER(log_Linf);
  PARAMETER(log_k1);
  PARAMETER(log_k2);
  PARAMETER(theta0);
  PARAMETER(theta1);
  PARAMETER(log_po);
  PARAMETER(log_std_log_Linf);
  PARAMETER(log_std_log_k1);
  PARAMETER(log_std_log_k2);
  PARAMETER(log_std_me);

//Random Effects;
  PARAMETER_VECTOR(rlog_Linf);
  PARAMETER_VECTOR(rlog_k1);
  PARAMETER_VECTOR(rlog_k2);

  vector<Type> k1 = k1_c(ic);
  vector<Type> k2 = k2_c(ic);
  vector<Type> logit_p = theta0 + theta1*age;
  vector<Type> pmat = exp(logit_p)/(one + exp(logit_p));
  vector<Type> k = k1*pmat + k2*(one-pmat);
  log_pred = log_Linf_c(ic) + log(one - (one - po)*exp(-k*age));
```

R

```
lts = data.frame(
  len=as.numeric(unlist(len[,2:(n.age+1)])),
  age = as.numeric(unlist(agem)),
  year = as.numeric(unlist(yearm)),
  sf=as.numeric(unlist(sfm)))

lts$cohort = lts$year - lts$age
lts$age = lts$age + lts$sf
ltsp = subset(lts,!is.na(len))

tmb.data = list(
  nobs = nrow(ltsp),
   nc = length(unique(ltsp$cohort)),
   y = ltsp$len,
   cohort = ltsp$cohort,
   age = ltsp$age,
   ic = as.numeric(as.factor(ltsp$cohort))-1 ,
   REk = 0, #0 for no, 1 for yes;
   RELinf = 0 #0 for no, 1 for yes;
)
```

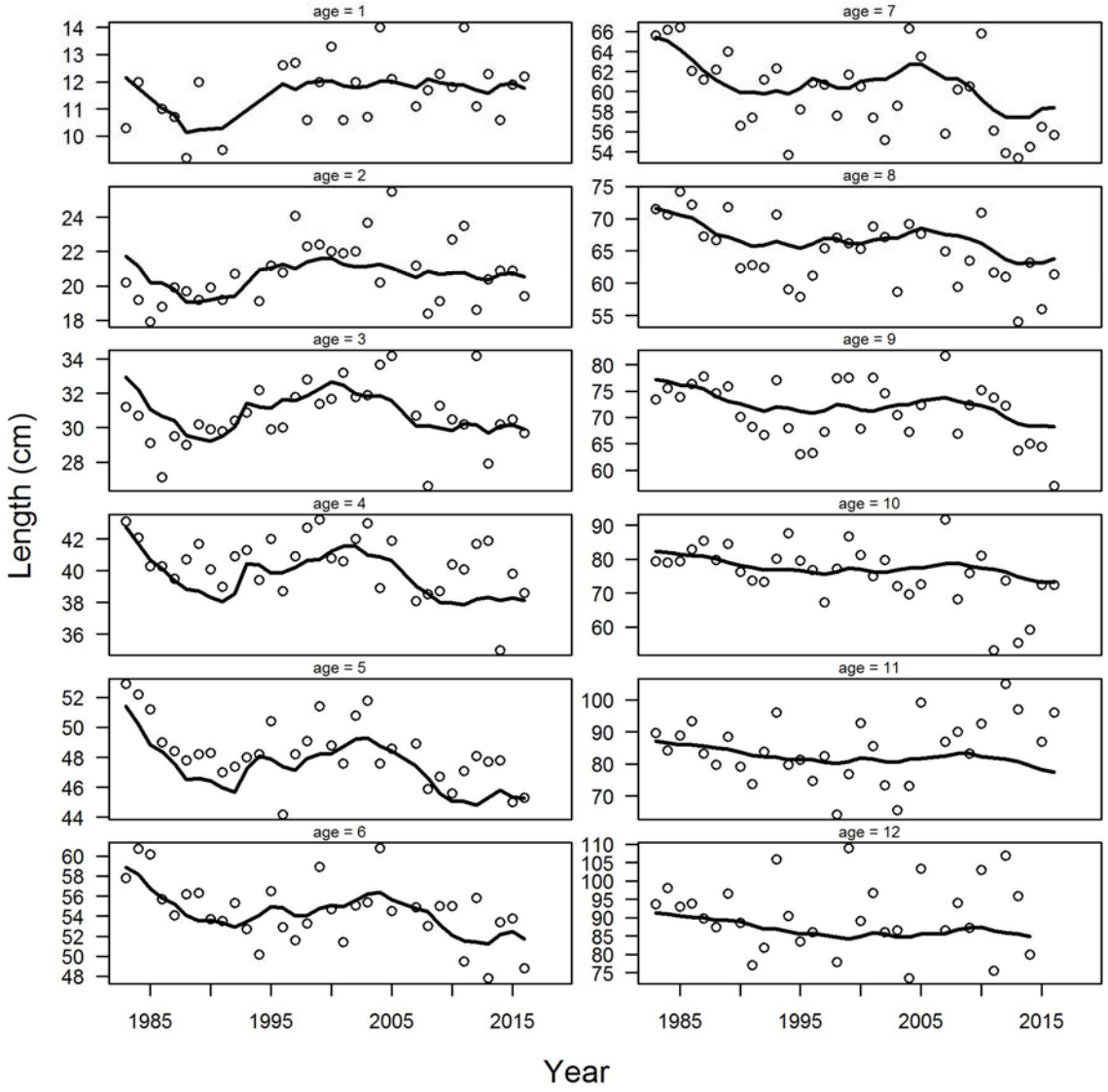
Time-Varying Bi-phasic Growth Model

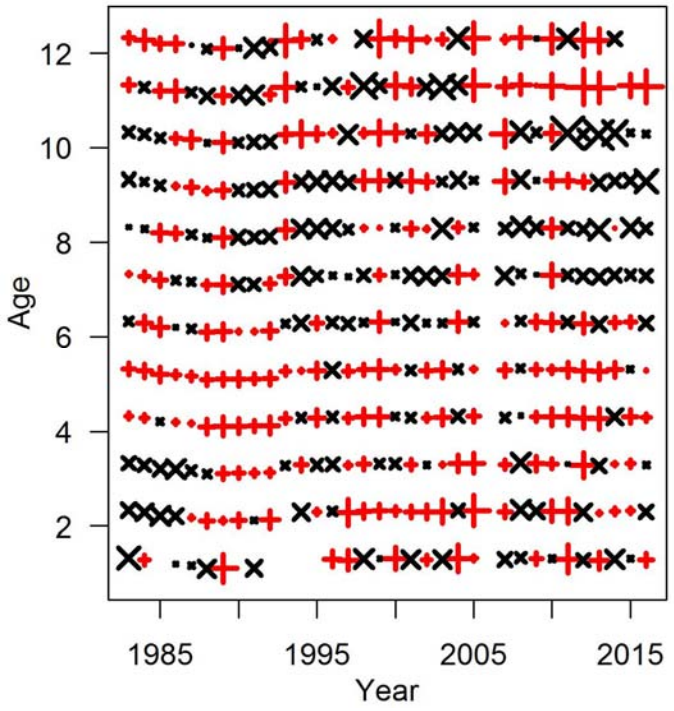
	Const. k and Linf	Cohort k and Linf	Cohort k and const. Linf
Dev	-820.640	-857.135	-859.587
Nparm	6.000	9.000	8.000
AIC	-808.640	-839.135	**-843.587**
BIC	-784.936	-803.579	**-811.982**
MSE	0.007	0.006	0.006
Linf	145.286	141.534	133.004
k1	0.074	0.085	0.094
k2	0.061	0.064	0.067
theta0	-5.536	-5.396	-5.583
theta1	2.224	2.106	2.199
std_Linf		0.015	
std_k1		0.000	0.023
std_k2		0.015	0.000
std_me	0.083	0.076	0.077

Bi-phasic model fit much better

best

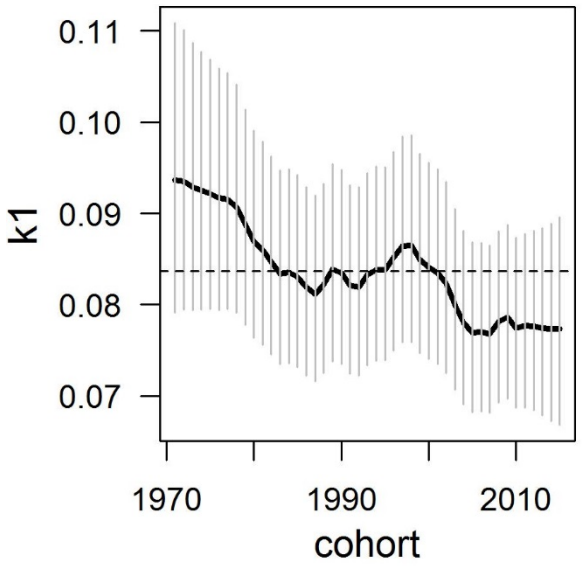
3Ps cod RW Bi-Phasic VonB

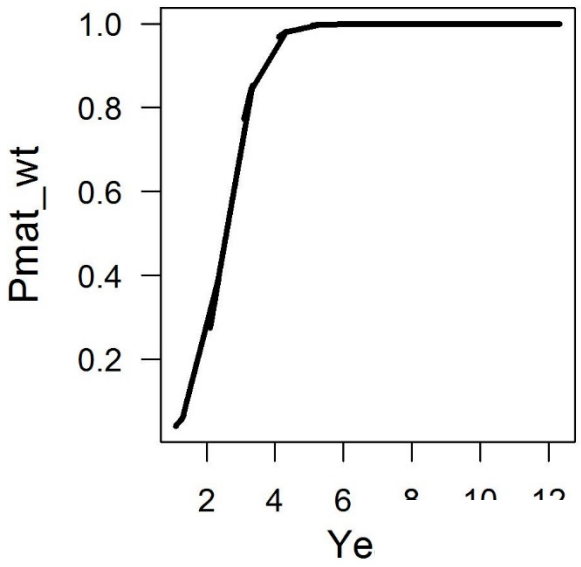




Still some residual “bias” at ages 4+5

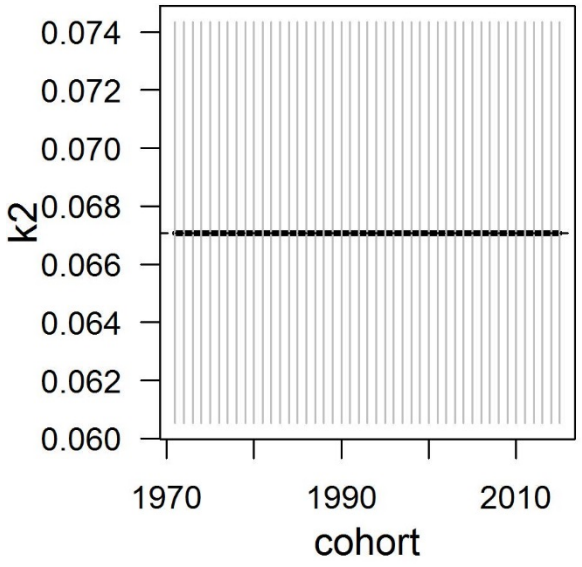
3Ps cod RW Bi-Phasic VonB



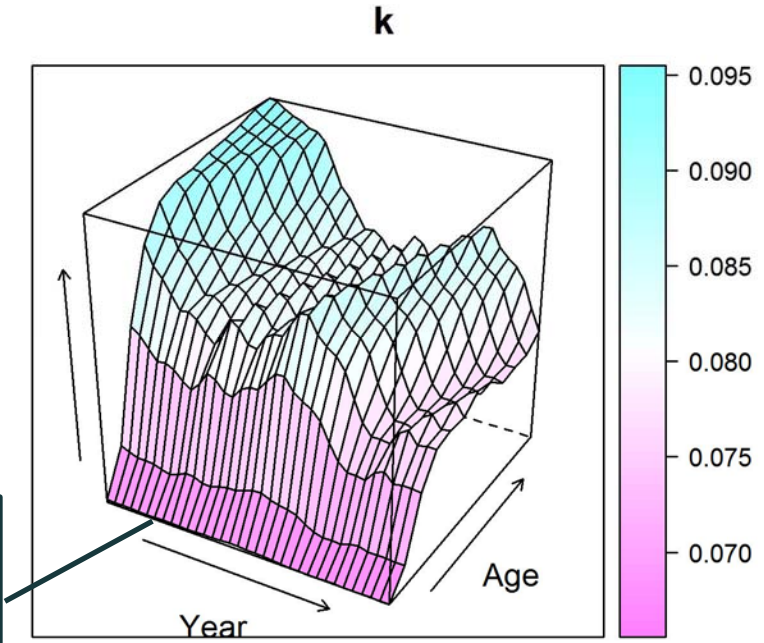


Bi-Phasic VonB better, but still some bias.

Lets go more semi-parametric to see what data want



Using age+sf got rid of change in k at young ages



3Ps cod agexyear RW K VonB

A nonparametric Von Bertalanffy model for estimating growth curves of Atlantic cod

By N. G. Cadigan and J. Brattey[1]

The VONB equation (2) can be developed from the differential equation

$$\frac{\partial L(t)}{\partial t} = k\{\lambda_\infty - L(t)\}.$$

We modify this simple model to accommodate annual/seasonal variations in growth rates by allowing k to be a smooth function of t; that is,

$$\frac{\partial L(t)}{\partial t} = k(t)\{\lambda_\infty - L(t)\}. \quad (3)$$

Given that a fish is known to be length l_r at the time-of-release t_r, then the solution to (3) is

$$L(t) = l_r + (\lambda_\infty - l_r)\left\{1 - e^{-K(t,t_r)}\right\}, \quad (4)$$

where $K(t, t_r) = \int_{t_r}^{t} k(u)du$. By subtracting l_r from both sides of this equation we get

3Ps cod agexyear RW K VonB

- $K_c(a) = \sum_{i=1}^{a} \delta_{c,i}$
- I use a bi-variate RW for $\delta_{c,a}$, over cohorts (c) and ages (a)

If $K(a) = k \times a$ then $K(a+1) - K(a) = k$

```
//Fixed effects
  PARAMETER(log_Linf);
  PARAMETER(log_k_main);
  PARAMETER(logit_po);
  PARAMETER(log_std_log_Linf);
  PARAMETER(log_std_log_k);
  PARAMETER(log_std_lpo);
  PARAMETER(log_std_me);

//Random Effects;
  PARAMETER_VECTOR(rlog_Linf);
  PARAMETER_MATRIX(rlog_k_dev);
  PARAMETER_VECTOR(rlogit_po);
```

```
matrix<Type> log_k(na,nc);
matrix<Type> ka(na,nc);
for (int j = 0; j < nc; ++j){
  log_k(0,j) = log_k_main + rlog_k_dev(0,j);
  ka(0,j) = exp(log_k(0,j));
  for (int i = 1; i < na; ++i){
    log_k(i,j) = log_k_main + rlog_k_dev(i,j);
    ka(i,j) = ka(i-1,j) + exp(log_k(i,j));
  }
}
```

3Ps cod agexyear RW K VonB

- Bi-variate RW for $\delta_{c,a}$, over cohorts (c) and ages (a)

```
for(int j = 0;j < nc;++j){
  for(int i = 0;i < na;++i){

   if((i==0)&(j == 0)){mZ = zero;}
   if((i>0)&(j == 0)){mZ = rlog_k_dev(i-1,j);}
   if((i == 0)&(j > 0)){mZ = rlog_k_dev(i,j-1);}
   if((i > 0)&(j > 0)){mZ = rlog_k_dev(i,j-1) + rlog_k_dev(i-1,j) - rlog_k_dev(i-1,j-1);}

    nll -= dnorm(rlog_k_dev(i,j),mZ,std_log_k,true);
}}}
```

agexyear RW K VonB

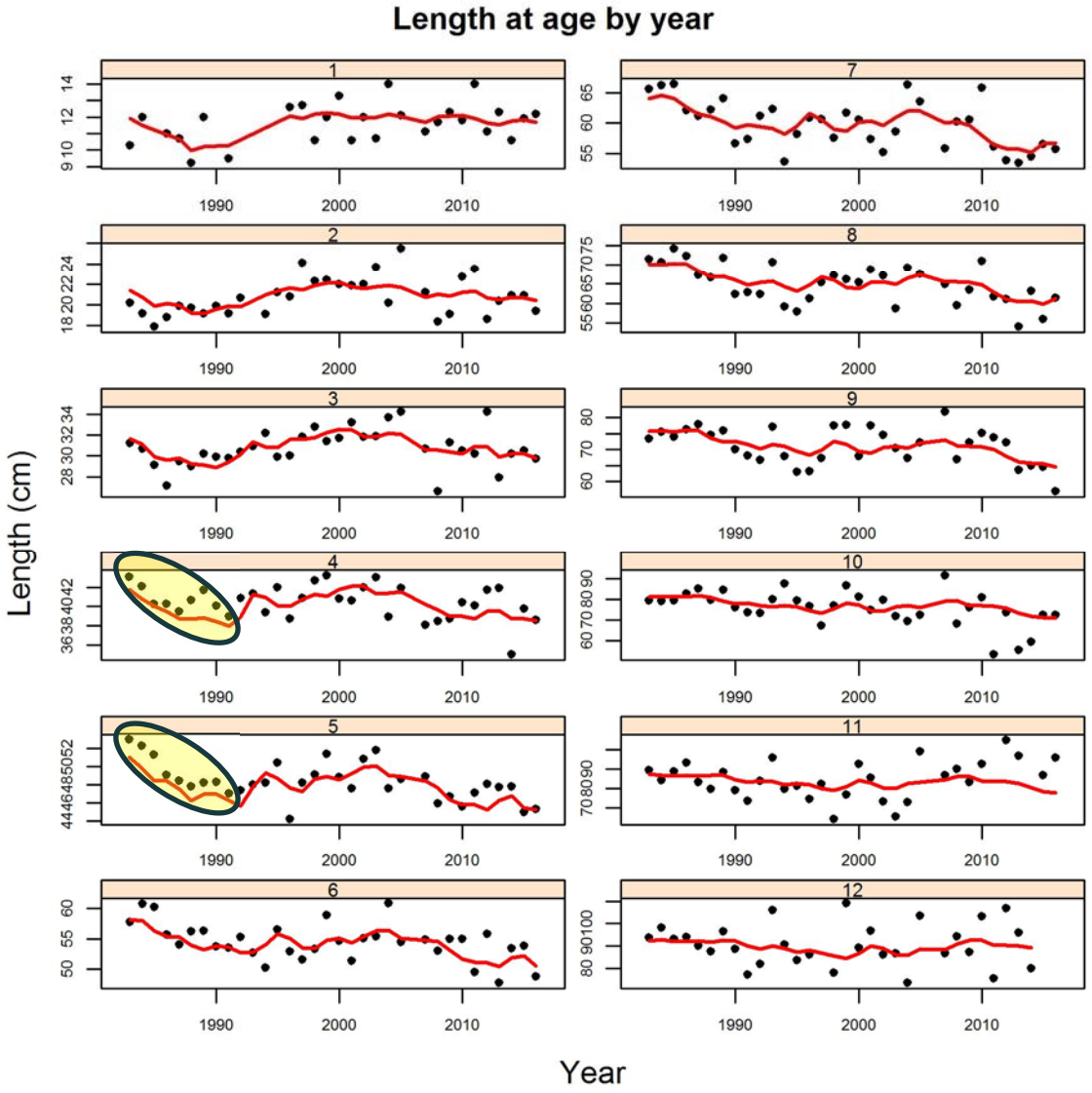
Exactly the same fit as slide 4, because it is the same model

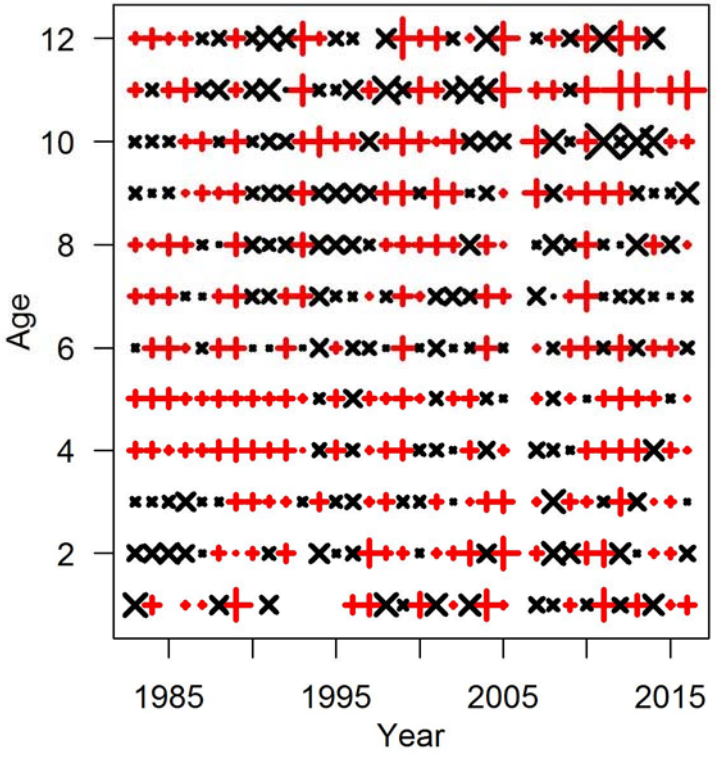
	k+Linf+po	po+(k+Linf)|C	k+po+(Linf|C)	Linf+po+(k|C)
Dev	-777.161	-854.655	-803.080	-854.655
Nparm	4.000	6.000	5.000	5.000
AIC	-769.161	-842.655	-793.080	**-844.655**
BIC	-753.358	-818.951	-773.327	**-824.902**
MSE	0.008	0.005	0.007	0.005
Linf	176.359	192.101	170.268	192.101
k_main	0.057	0.052	0.064	0.052
logit_po	-24.747	-20.118	-24.529	-22.908
std_Linf		0.000	0.014	0.021
std_k		0.021		0.073
std_me	0.088	0.073	0.083	

This model fits good! AIC and BIC a little lower than bi-phasic

best

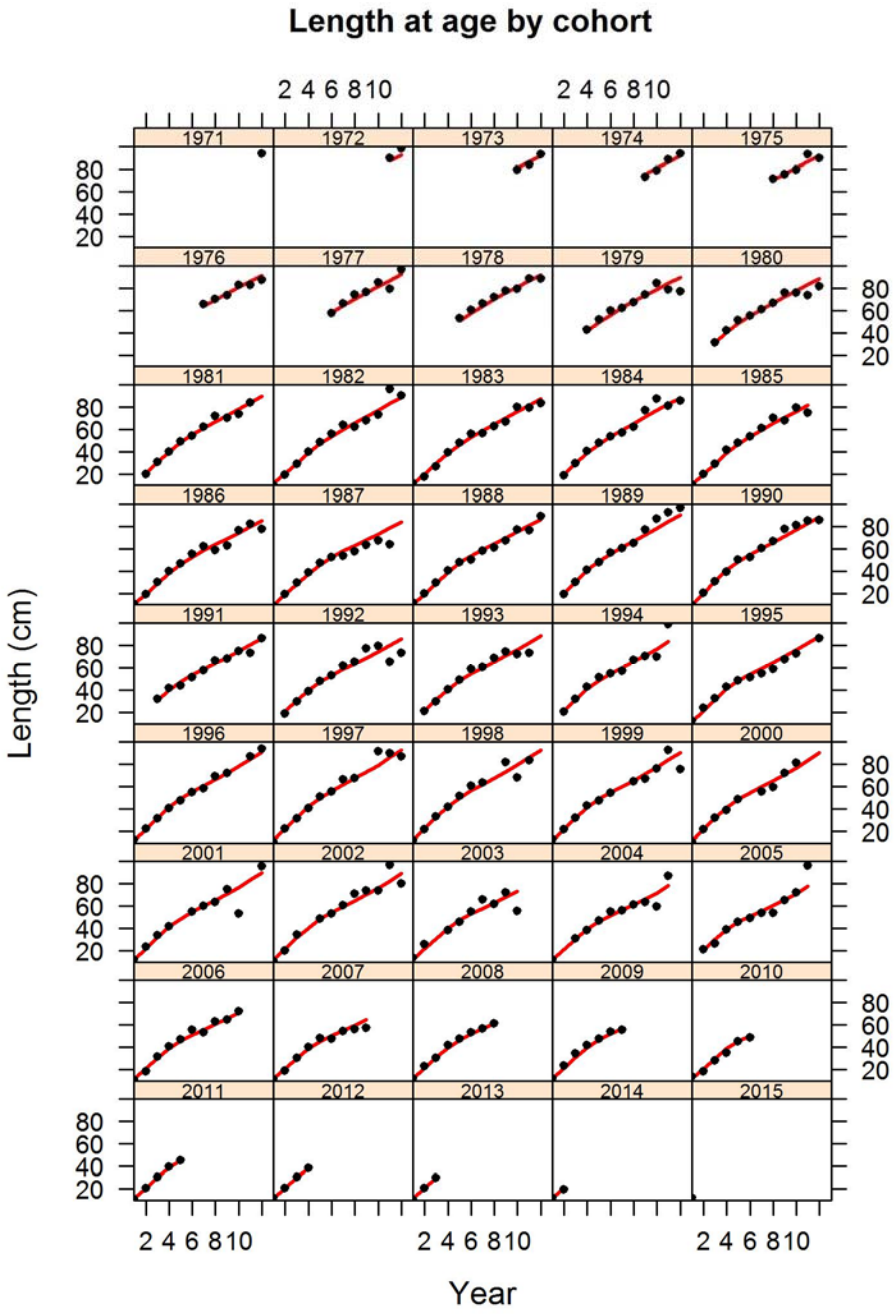
agexyear RW K VonB

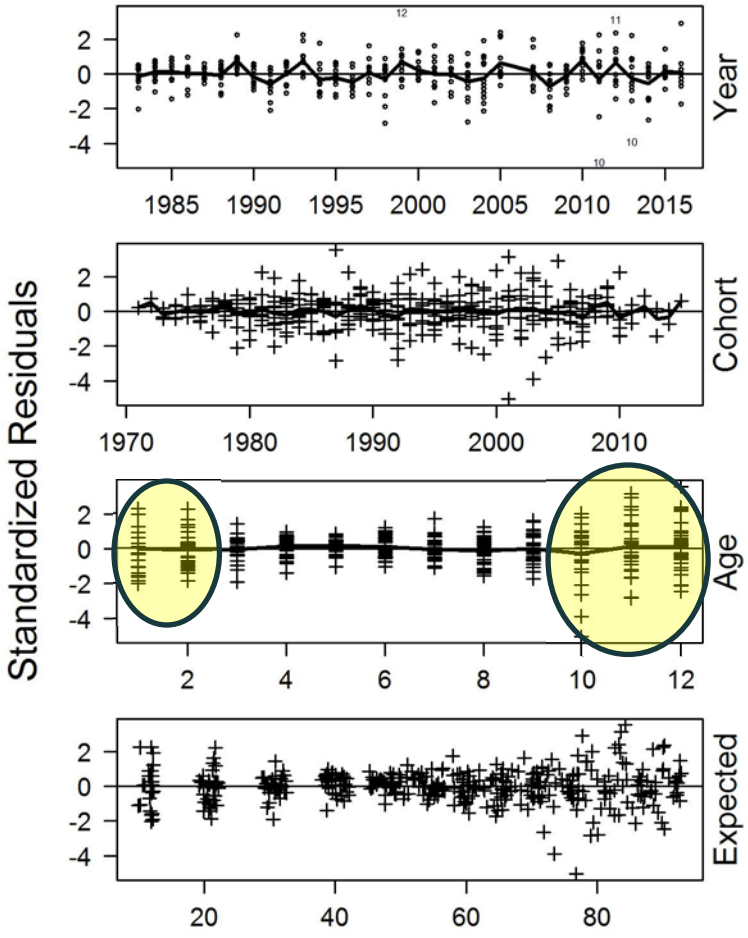




Some “bias” at ages 4+5

agexyear RW K VonB



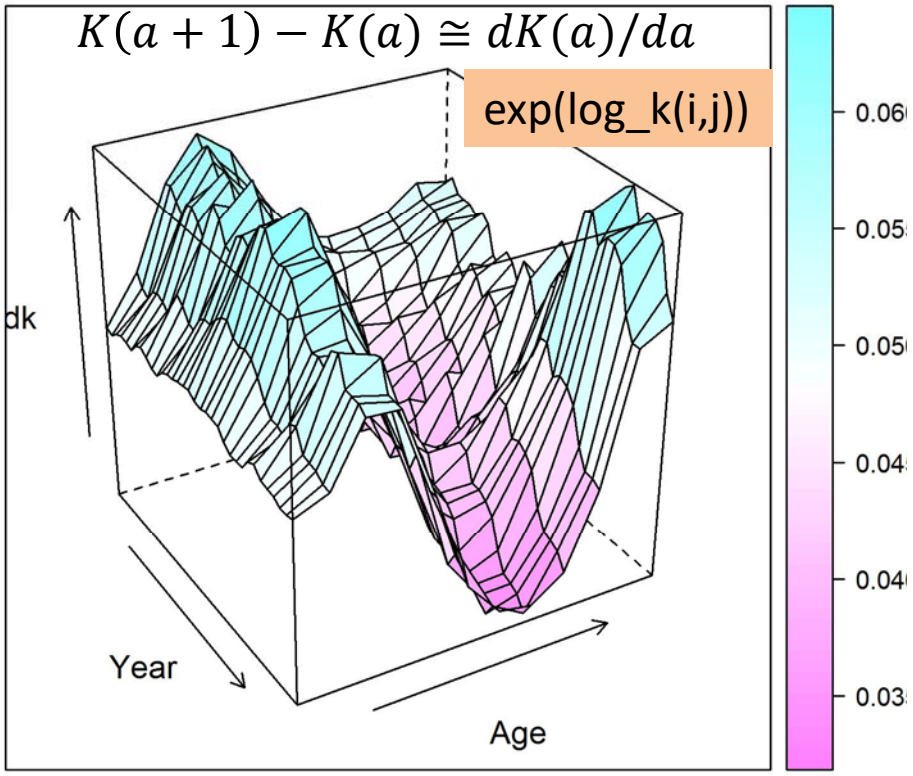


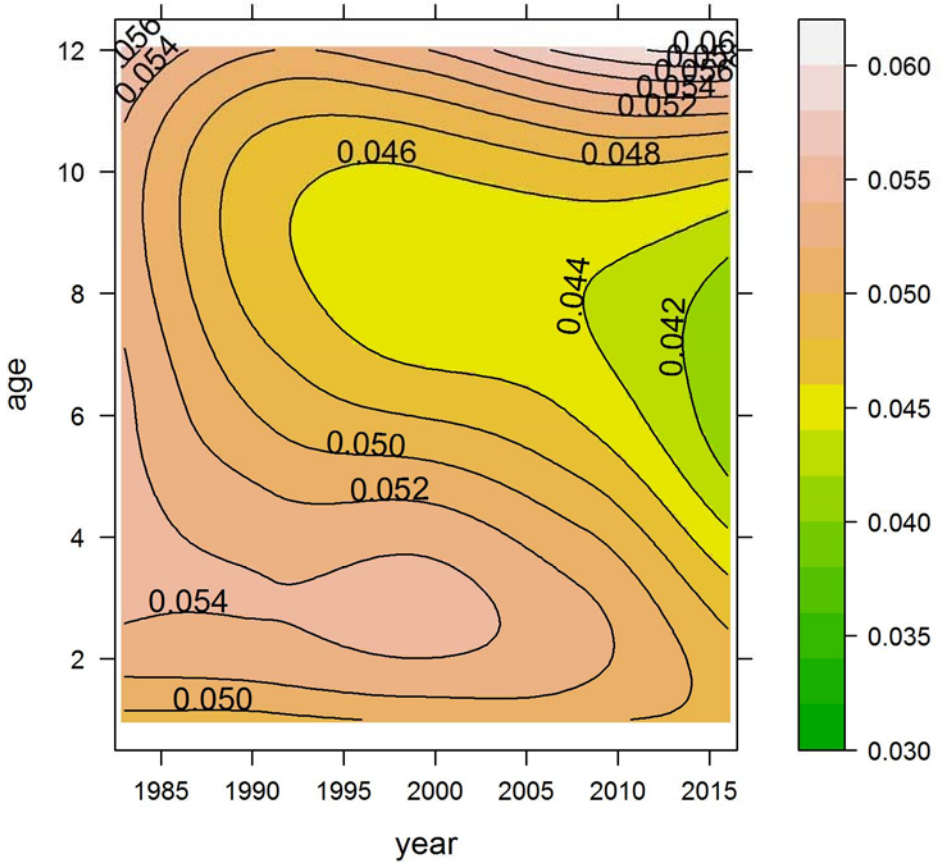
Error at young and old ages seems higher

agexyear RW K VonB - the fix?

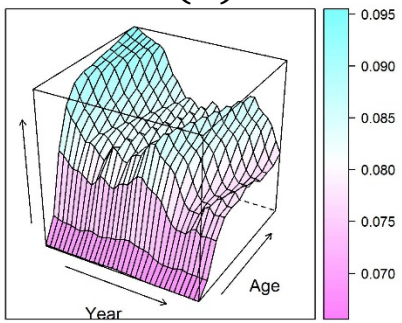
$K(a+1) - K(a) \cong dK(a)/da$

exp(log_k(i,j))



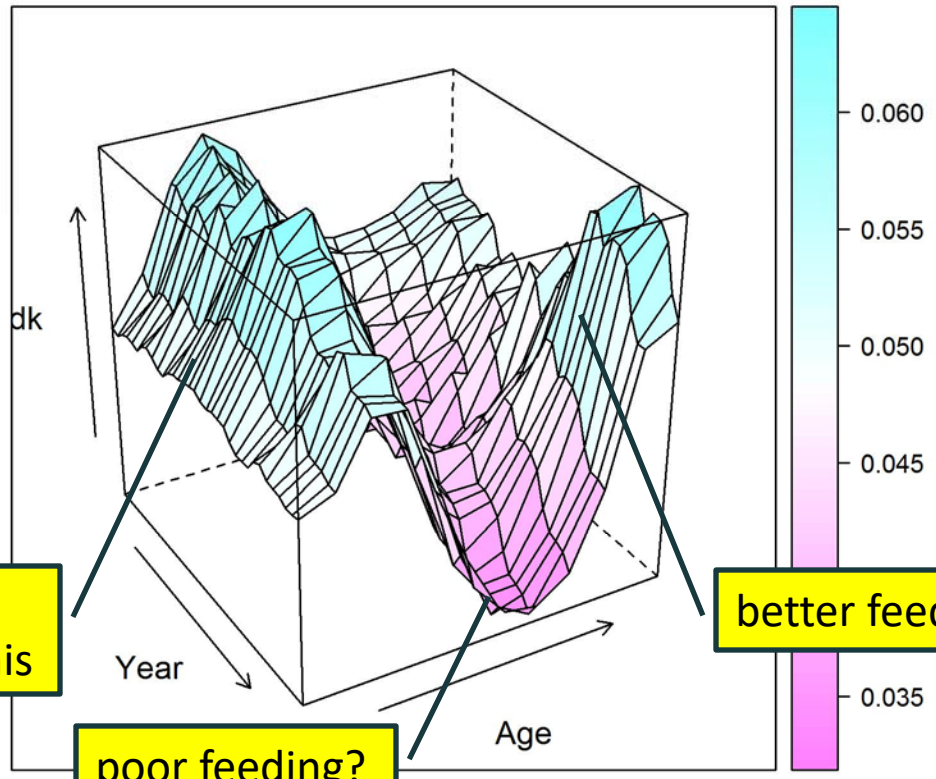


$K(a)$



agexyear RW K VonB -the fix?

$dK(a)/da$



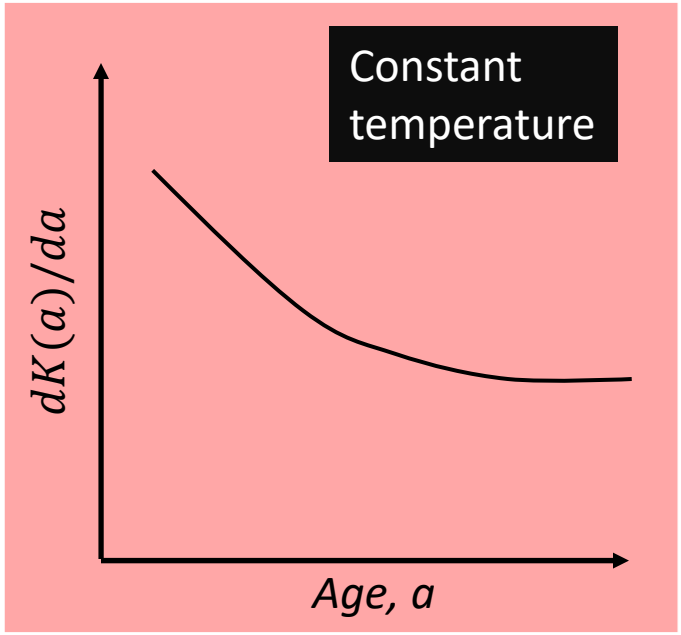
Maybe campelen selectivity causes this

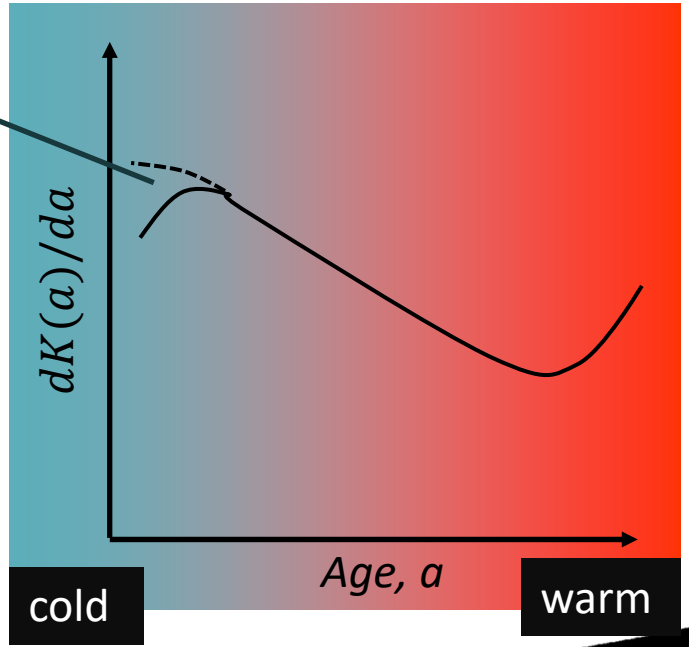
better feeding?

poor feeding?

Cod in 3Ps have ontogenetic? change in spatial distribution, and tend to occupy water with different temperatures. Older ages may be more on warm water slopes?

A Hypothesis





Could also be explained by:

1) Diet
2) Stock mixing
3) etc

Slide 18

NC3 Noel Cadigan, 1/19/2019