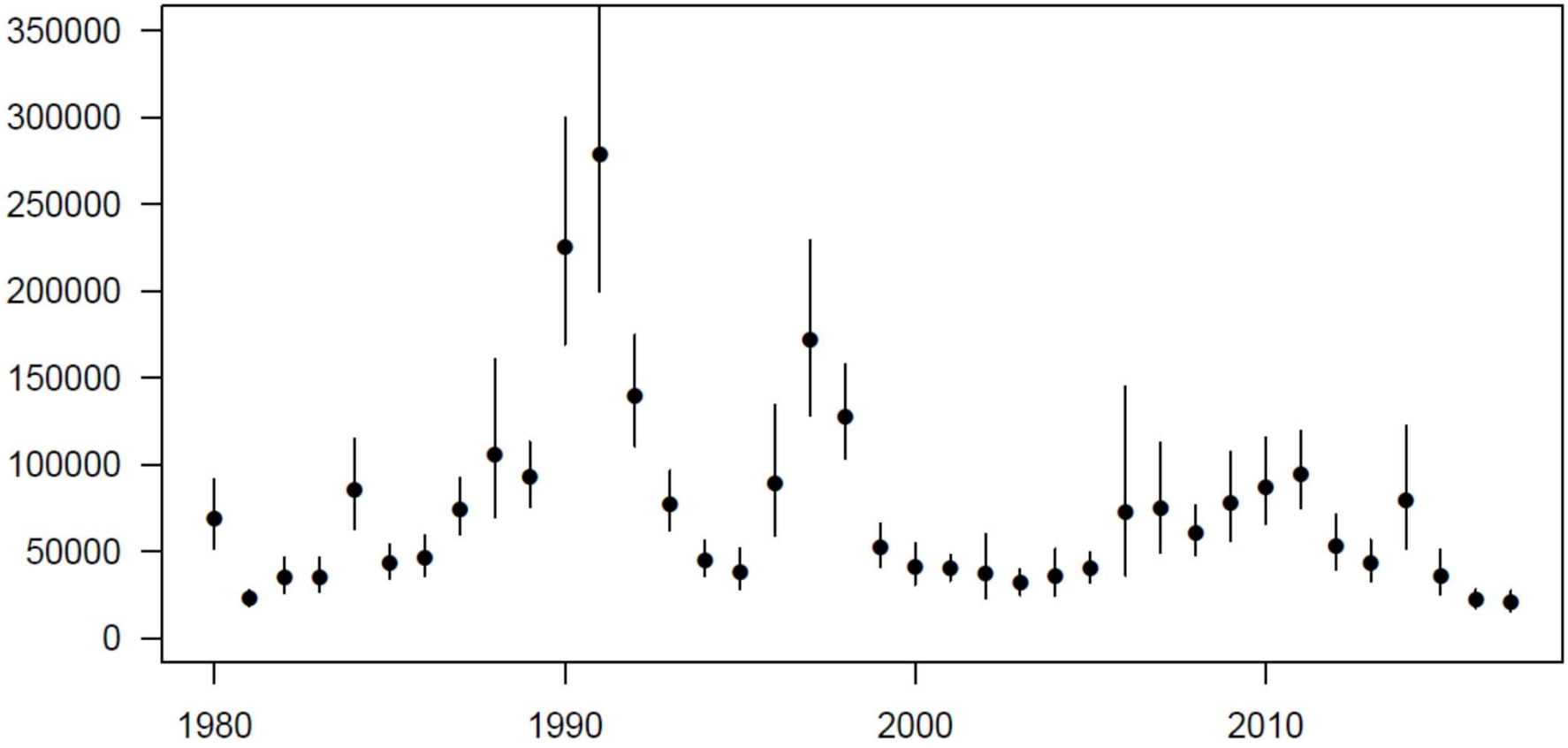
Eastern Bering Sea snow crab stock assessment brief

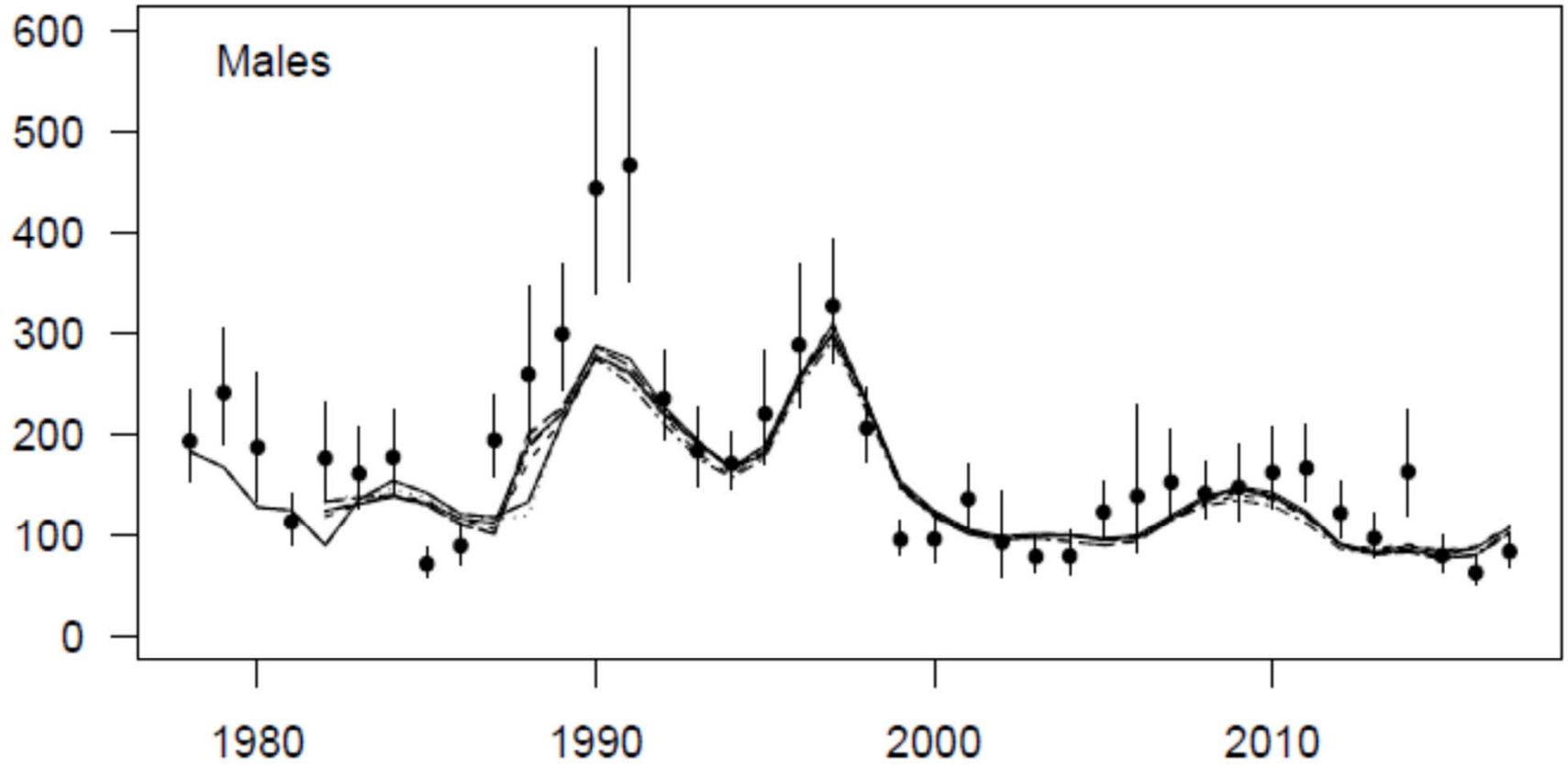
Cody Szuwalski and Jack Turnock

September 19, 2017

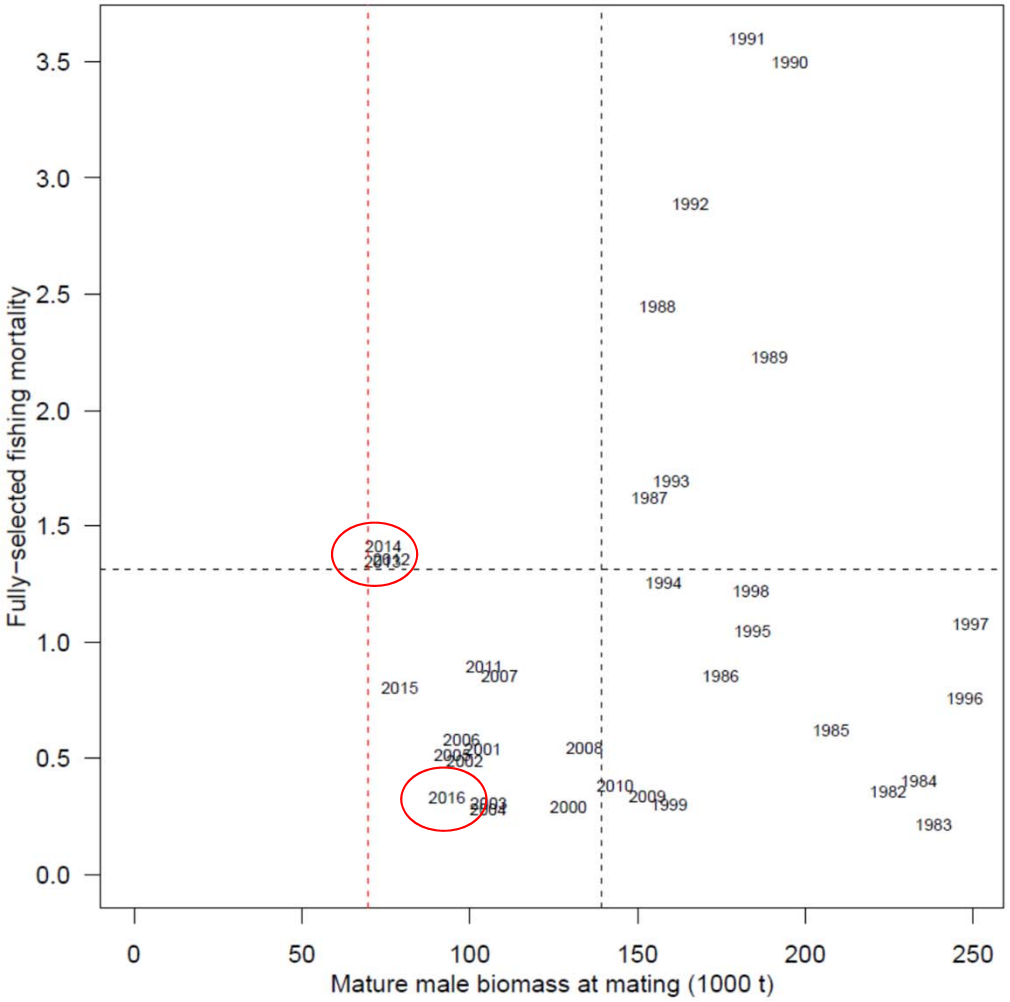
- Observed survey males >101mm lowest on record



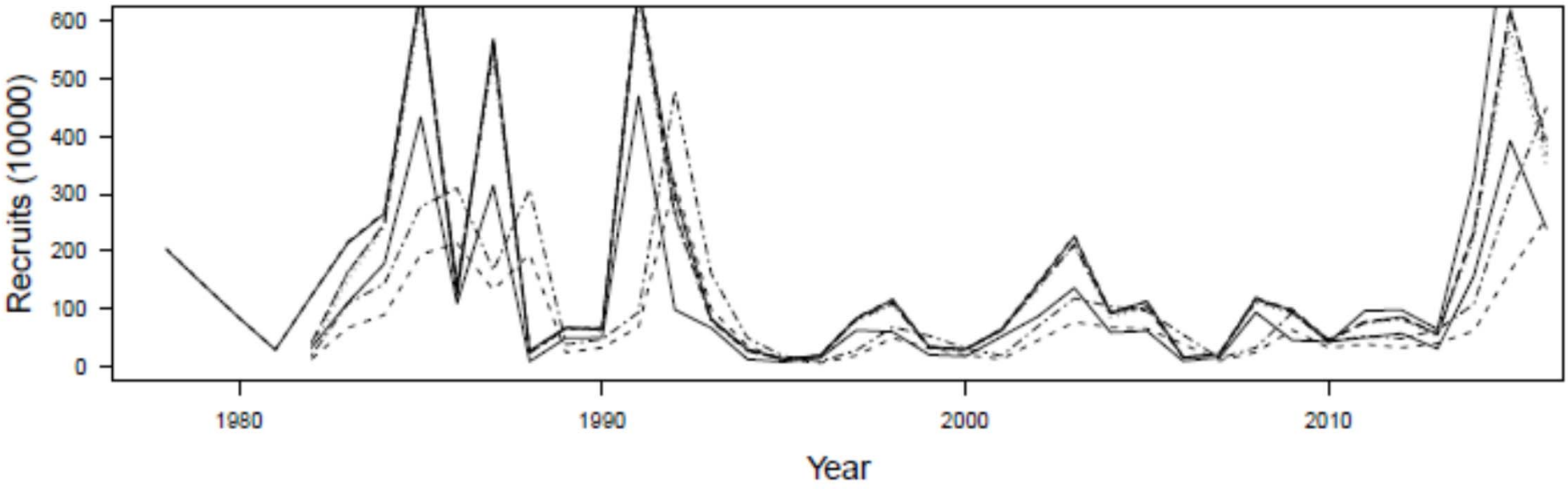
- Observed survey MMB up slightly from last year's all time low



- The stock remains above MSST and fishing pressure remains below $F_{35\%}$



- A large recruitment occurred in 2014/2015, which will likely be seen soon in the exploitable biomass



Models considered

"M16.D16" – Last year's accepted model fit to last year's data.
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"M16.D17a" – Last year's accepted model fit to this year's data, but dropping all survey data before 1982.
"M17A.D17a" – Split survey selectivity periods in 1987, based on distribution of survey stations.
"M17Aa.D17a" – Estimate survey availability parameters for BSFRF survey in logit space with a penalty
"M17B.D17a" – Remove data in length bins below the kink in growth and fit a straight line for growth.
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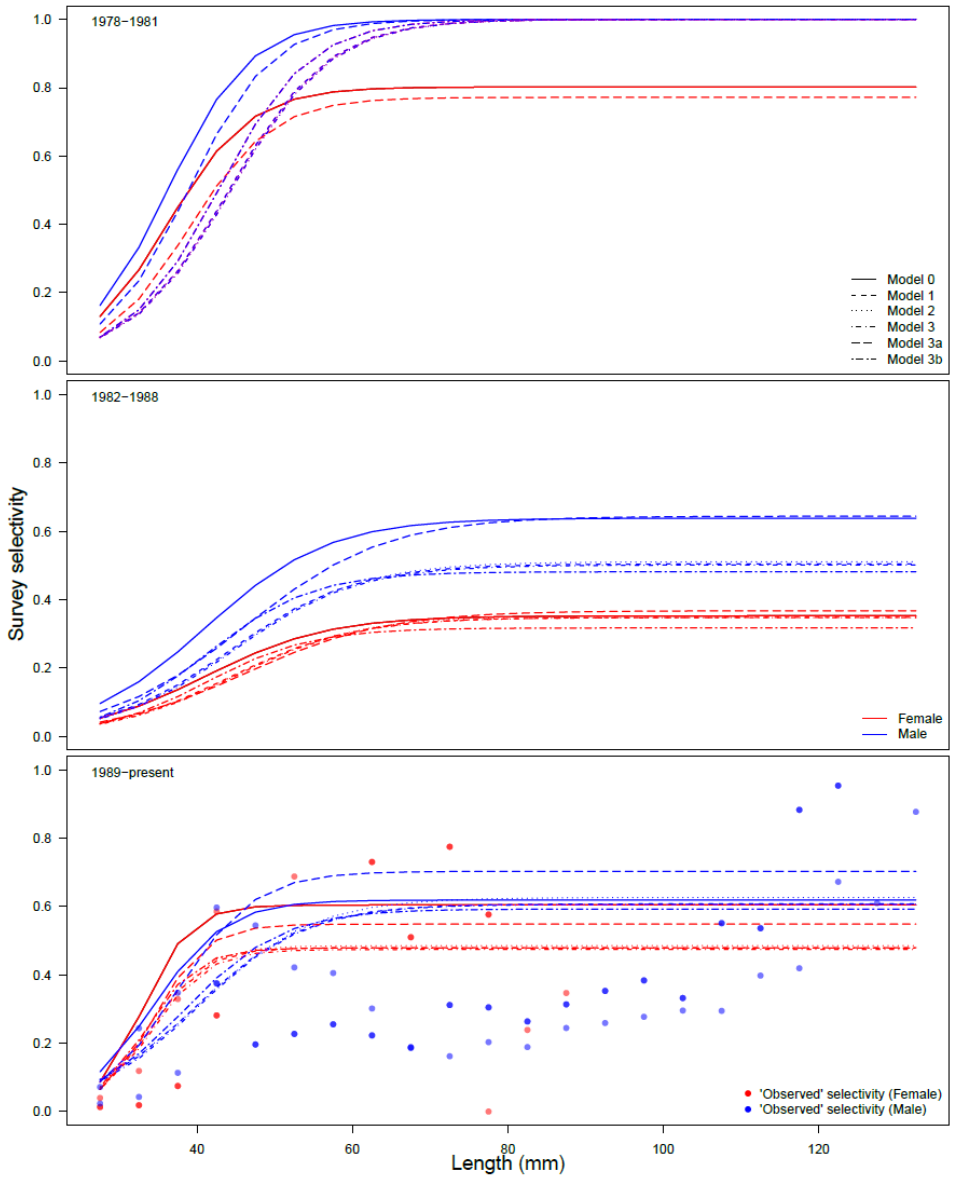
"M17BC.D17a" – Combines 'M17B.D17A' and 'M17C.D17A'


1978–1981
1982–1988
1989–present
Survey selectivity
Length (mm)
Model 0
Model 1
Model 2
Model 3
Model 3a
Model 3b
Female
Male
'Observed' selectivity (Female)
'Observed' selectivity (Male)

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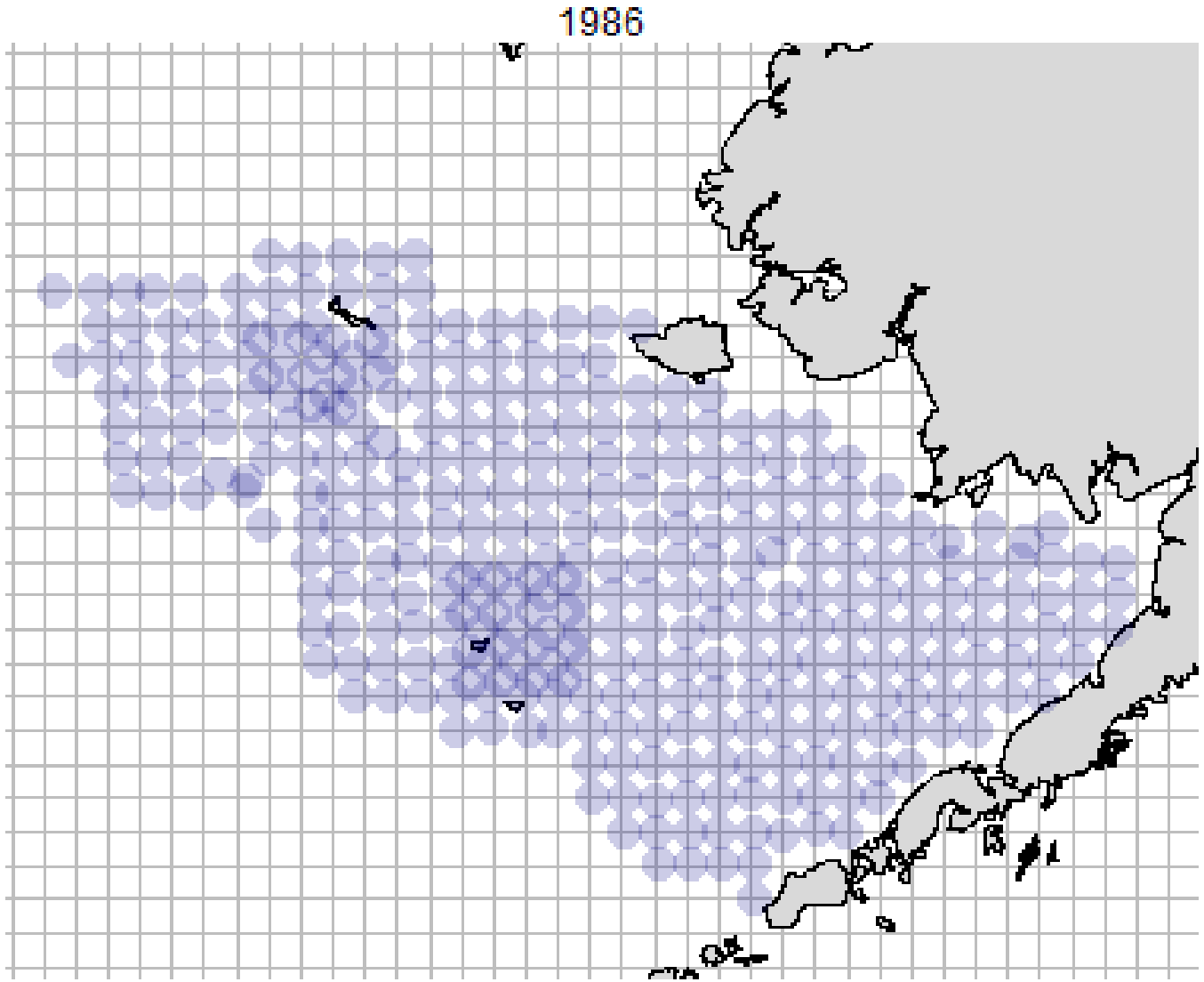
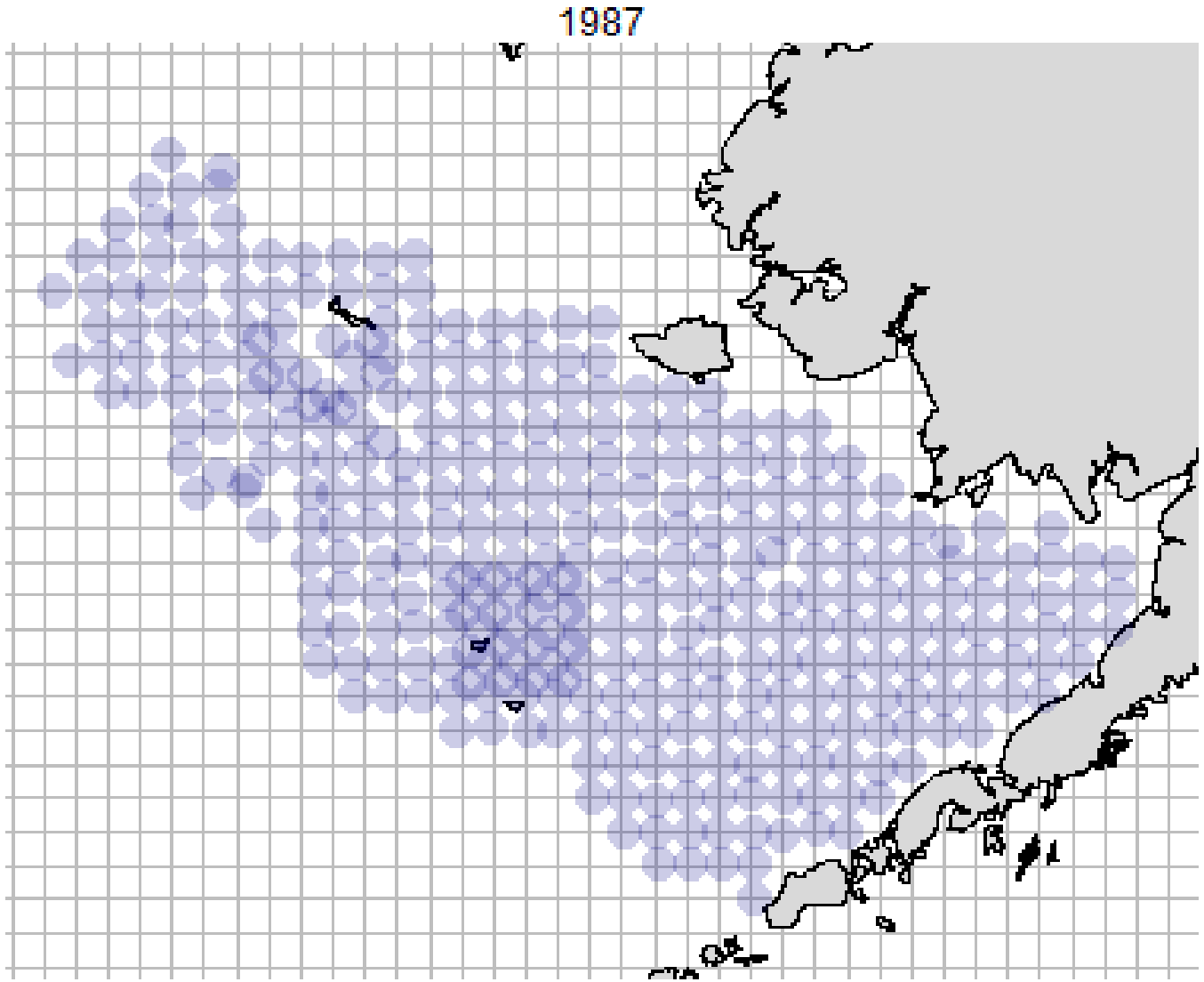
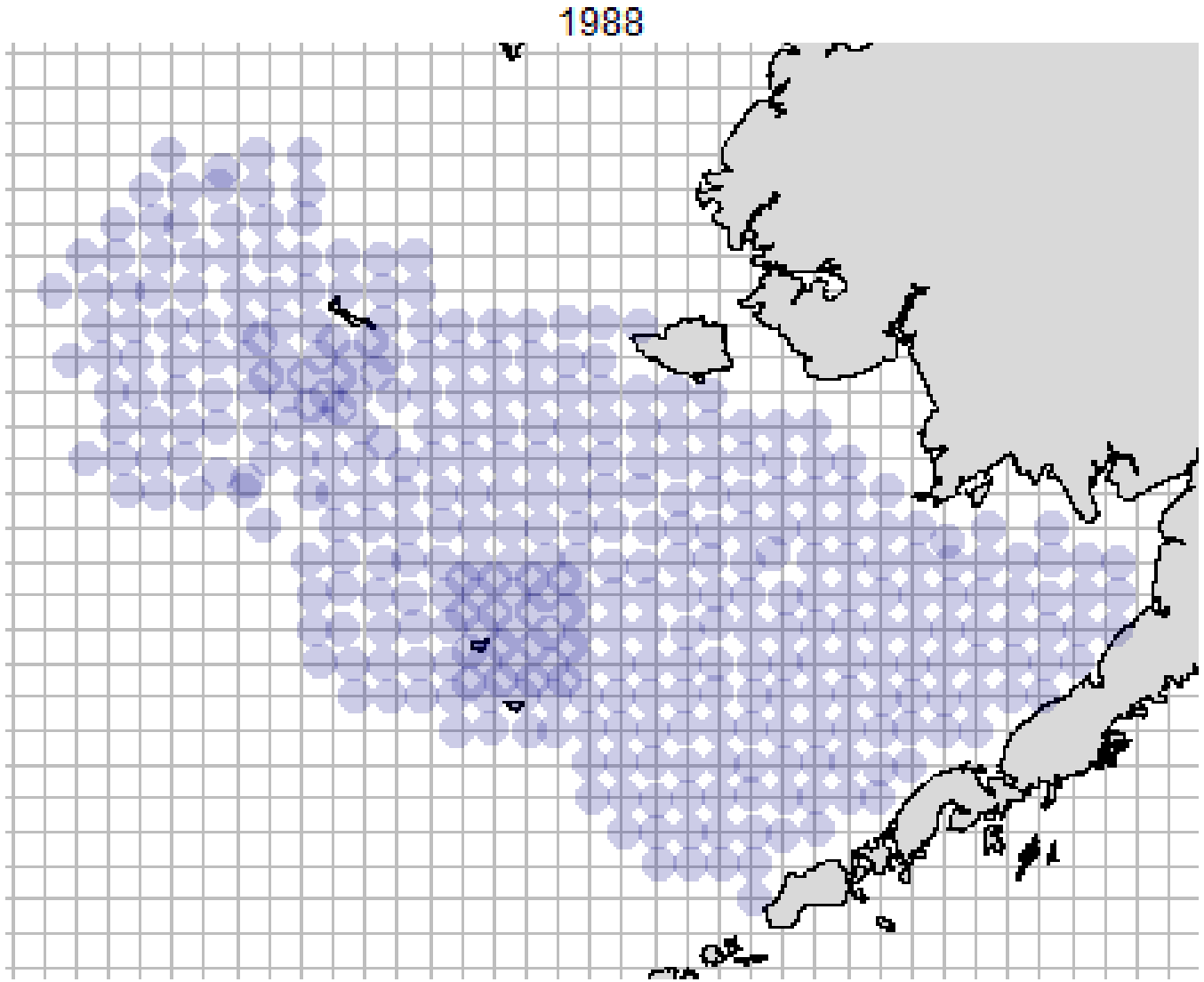
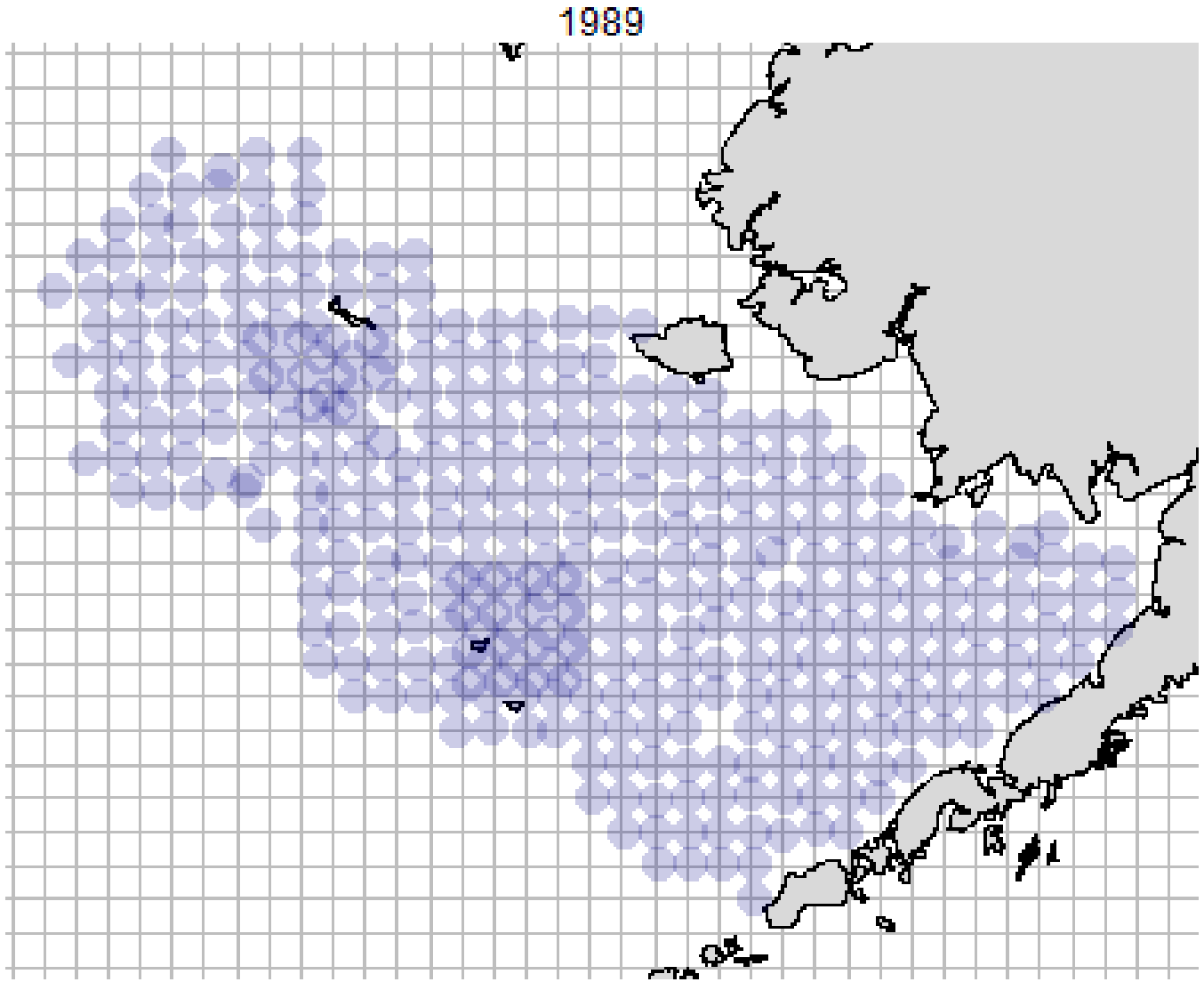
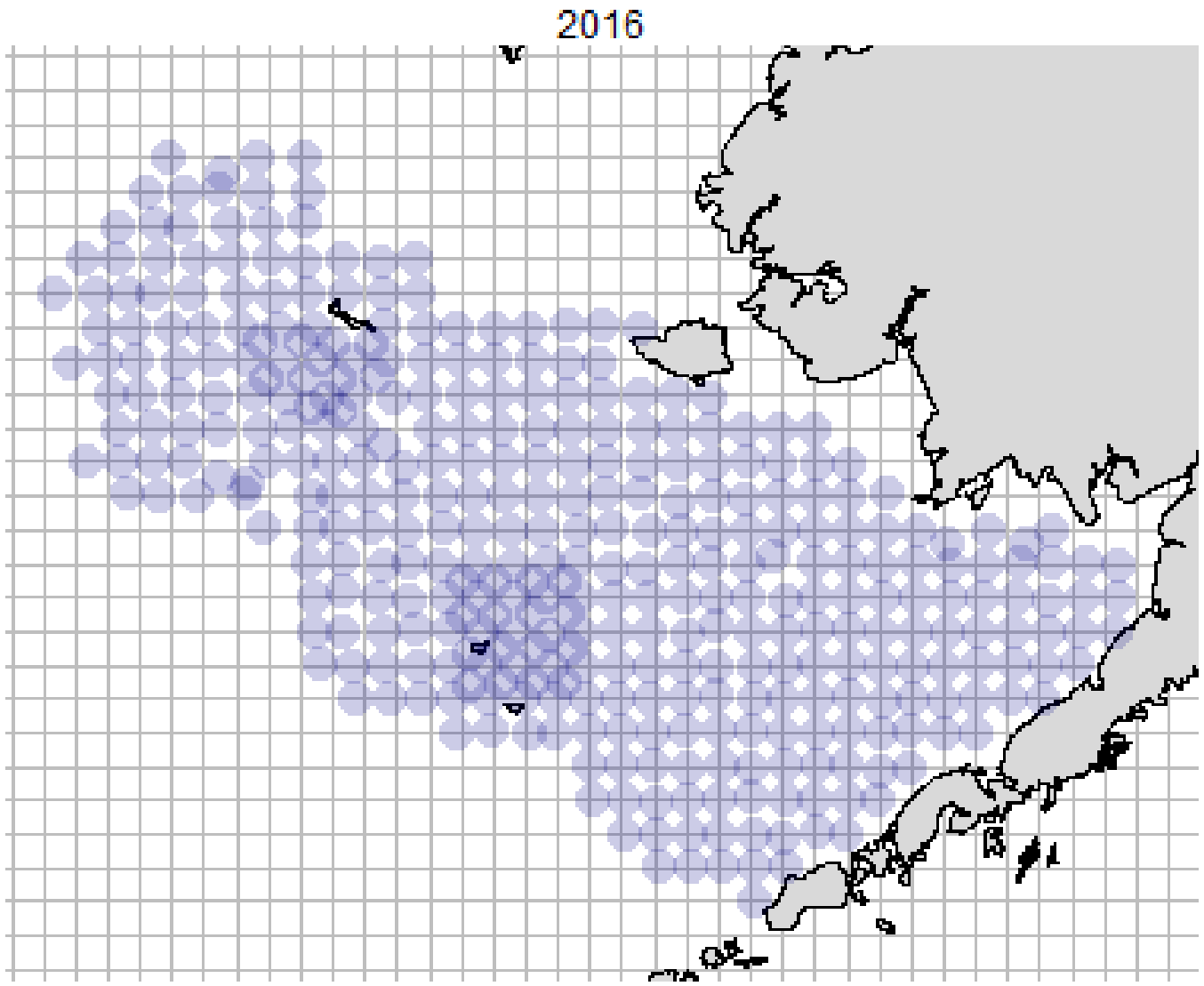

1986


1987


1988


1989


2016

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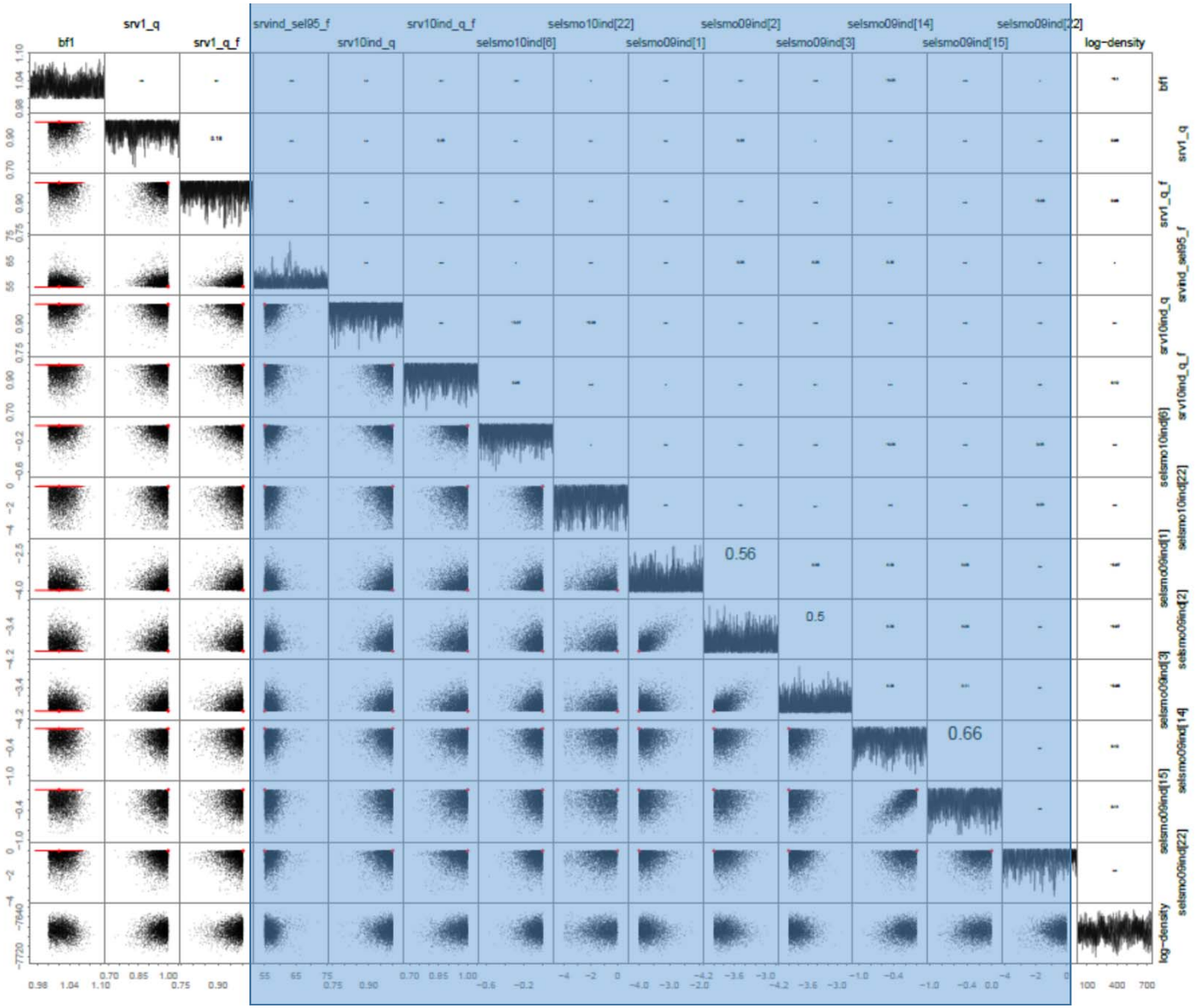
bf1
srv1_q
srv1_q_f
srvind_sel95_f
srv10ind_q
srv10ind_q_f
selsmo10ind[6]
selsmo10ind[22]
selsmo09ind[1]
selsmo09ind[2]
selsmo09ind[3]
selsmo09ind[14]
selsmo09ind[15]
selsmo09ind[22]
log−density
0.56
0.5
0.66

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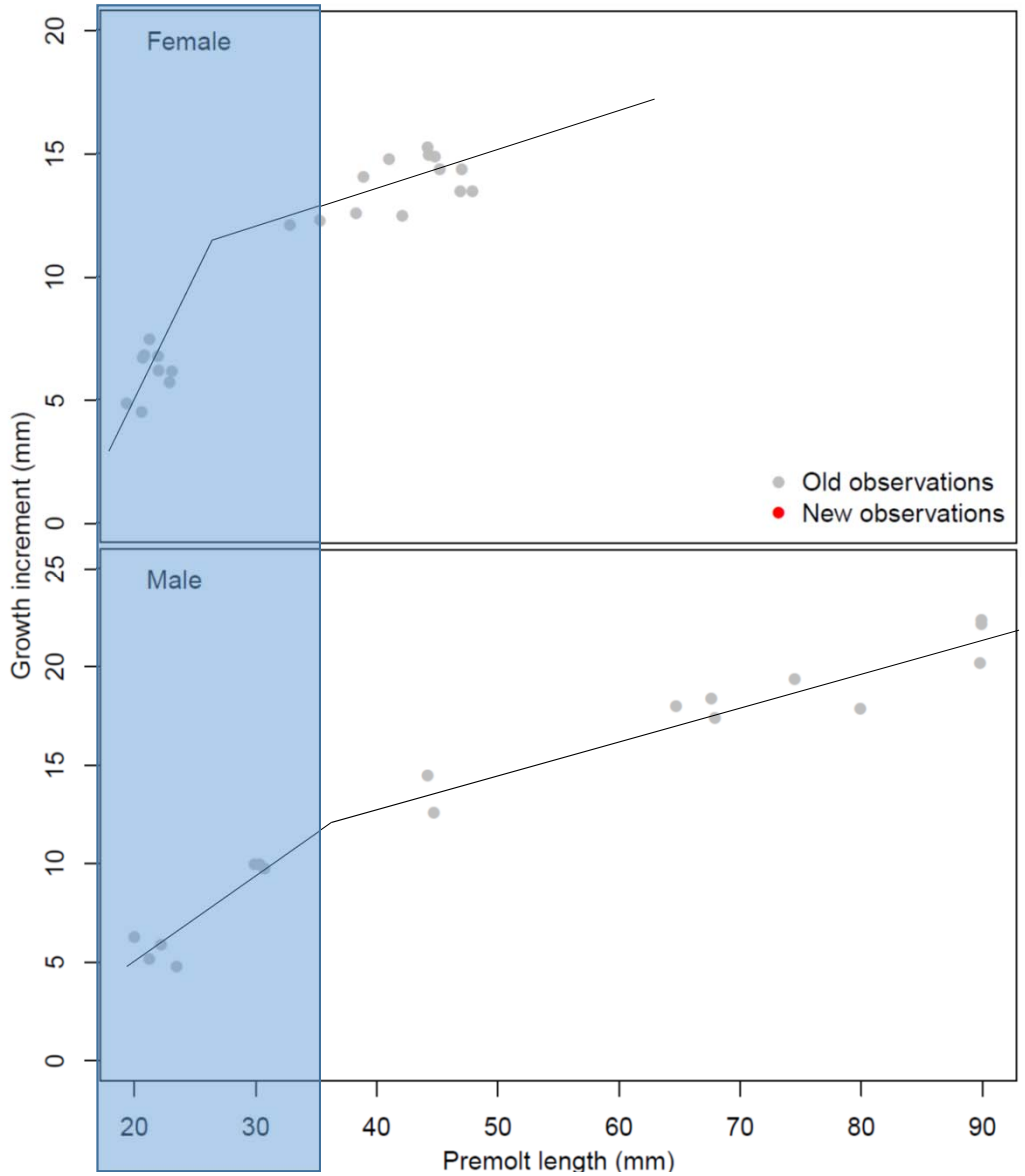
Female
Male
Old observations
New observations
Growth increment (mm)
Premolt length (mm)
0
5
10
15
20
25
20
30
40
50
60
70
80
90

Models considered

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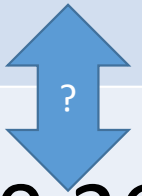
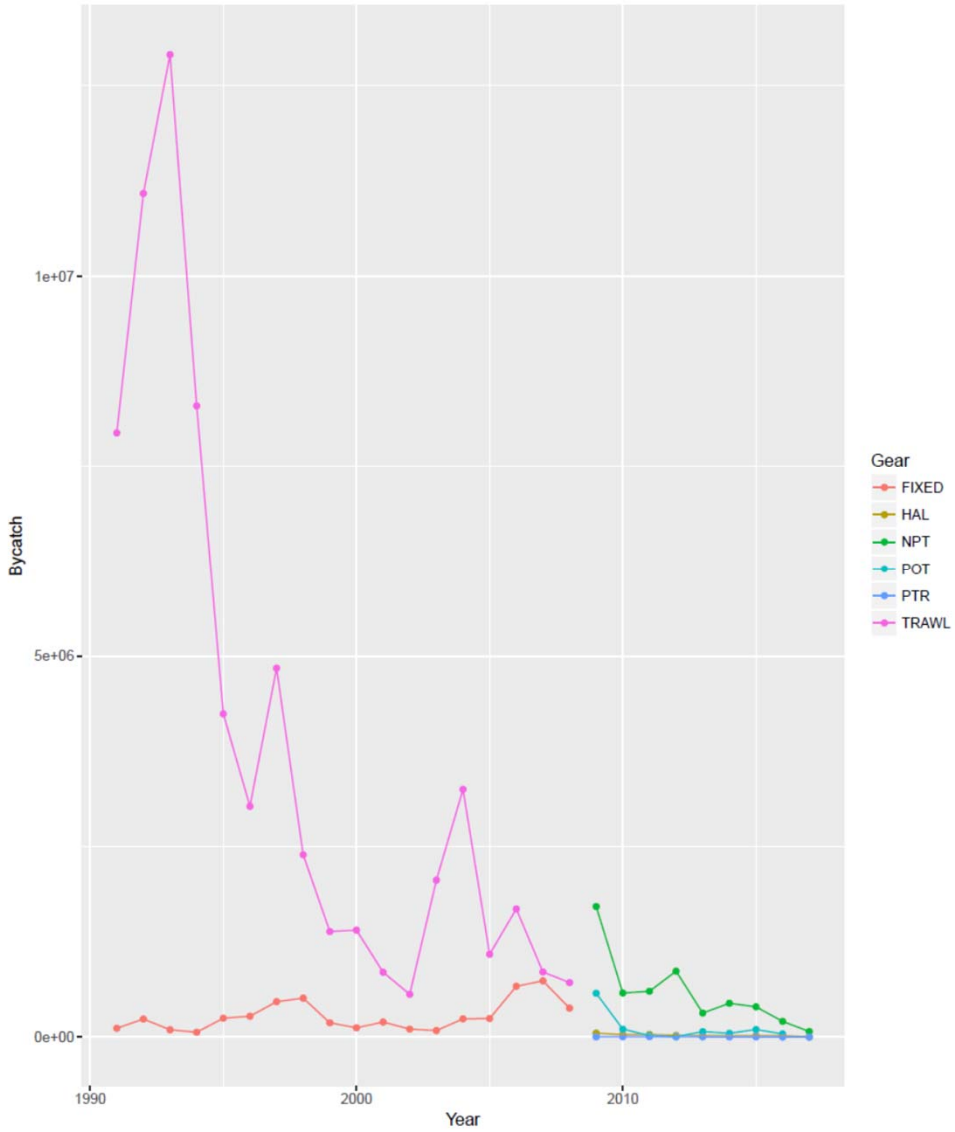
Natural mortality

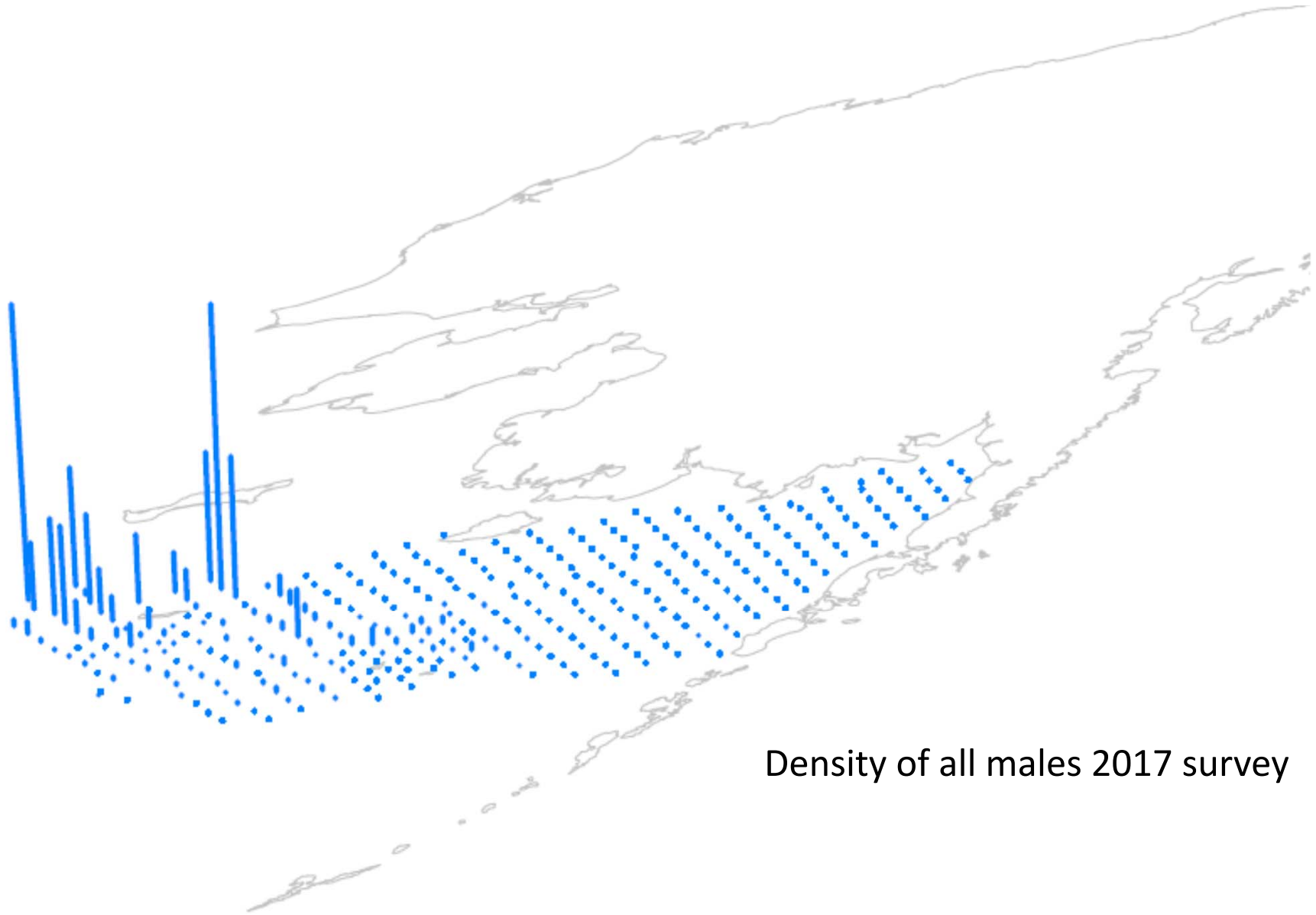
	Immature	Mature
Female	0.41	0.23
Male	0.41	0.26



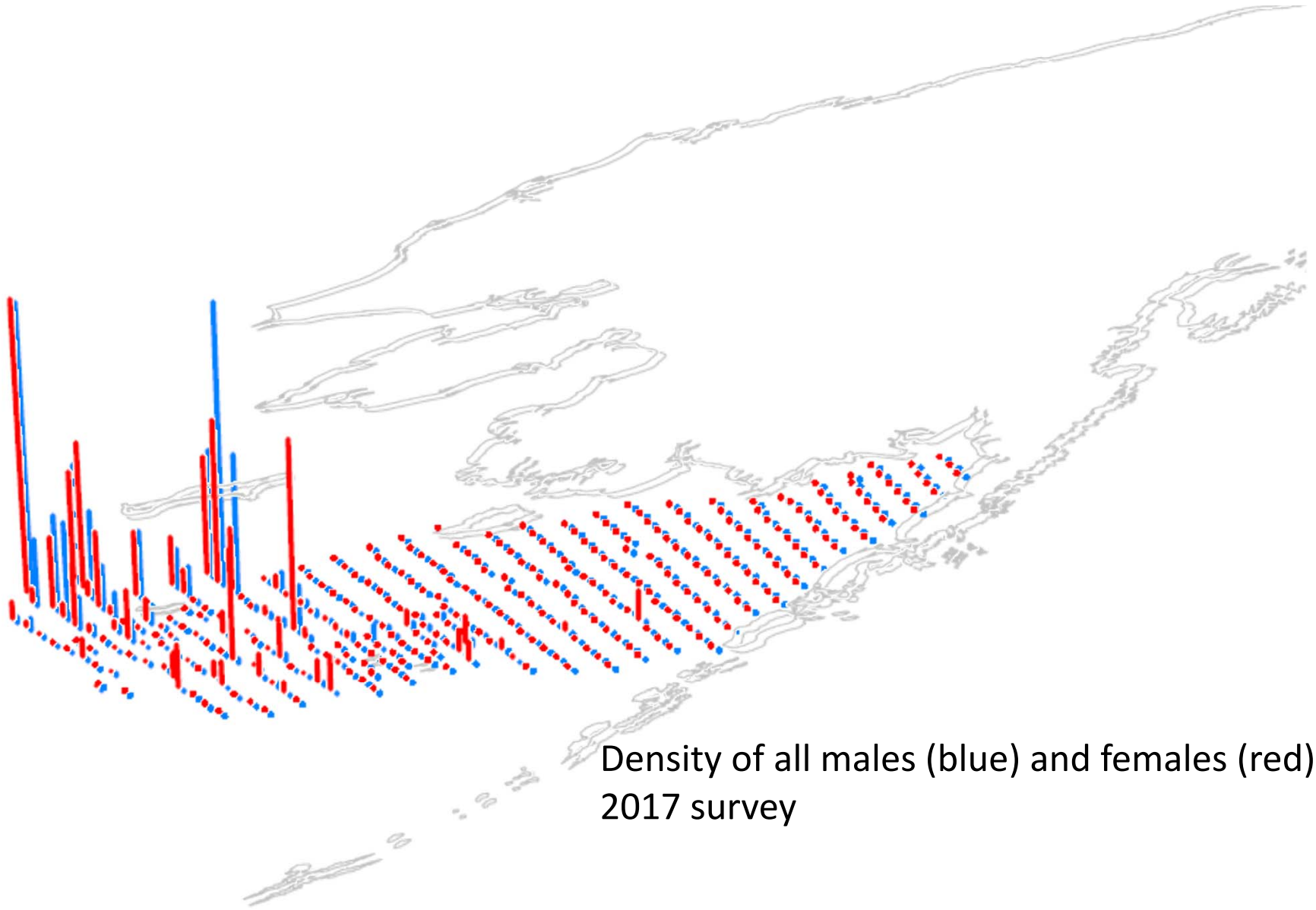
New data

Data component	Years
Retained male crab pot fishery size frequency by shell condition	1978 - 2016
Discarded Males and female crab pot fishery size frequencey	1992 - 2016
Trawl fishery bycatch size frequencies by sex	1991 - 2016
Survey size frequencies by sex and shell condition	1978 - 2017
Retained catch estimates	1978 - 2016
Discard catch estimates from crab pot fishery	1992 - 2016
Trawl bycatch estimates	1973 - 2016
Total survey biomass estimates and coefficients of variation	1978 - 2017
2009 study area biomass estimates, CVs, and size frequencey for BSFRF and NMFS tows	2009
2010 study area biomass estimates, CVs, and size frequencey for BSFRF and NMFS tows	2010

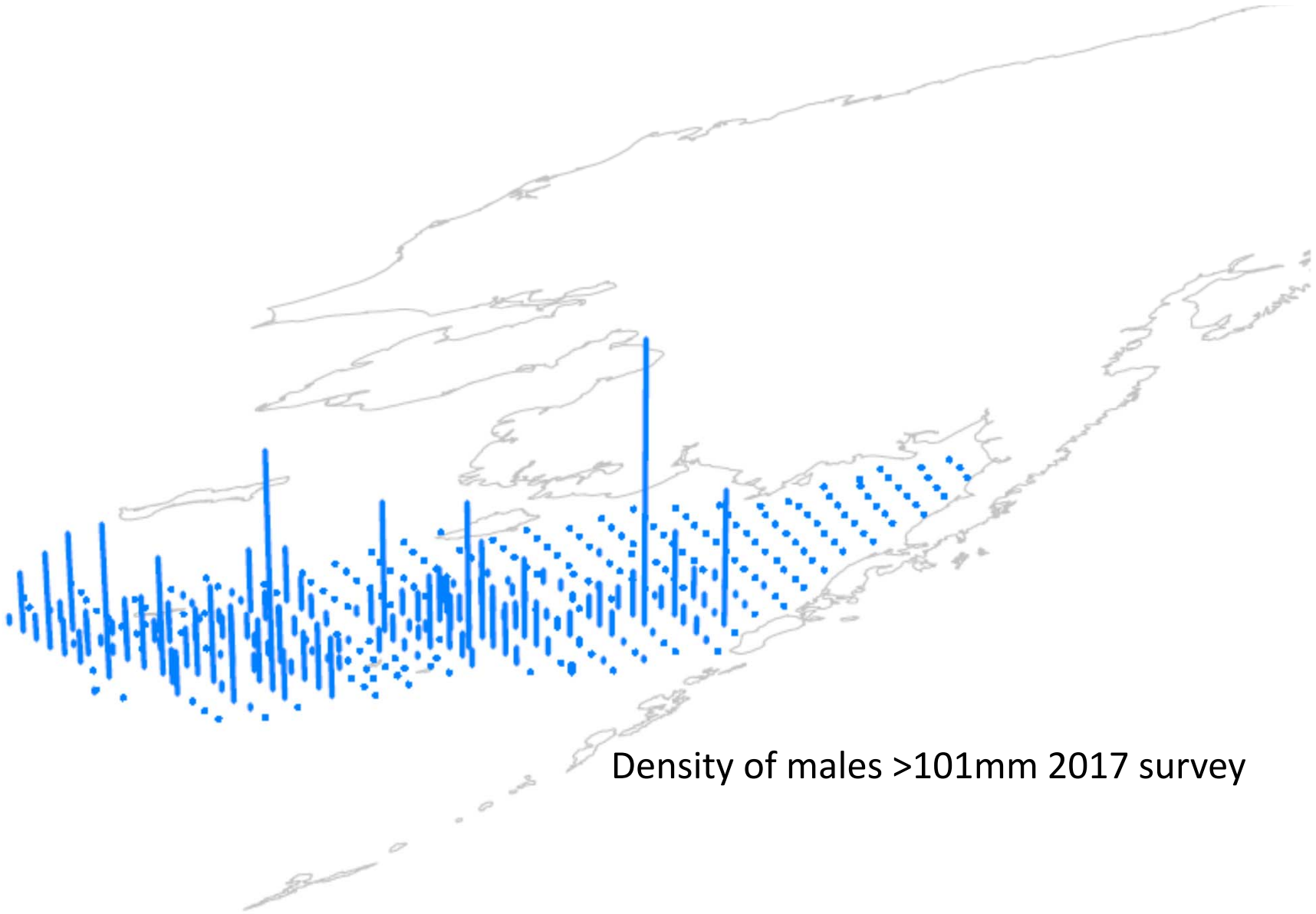

Bycatch
1e+07
5e+06
0e+00
1990
2000
2010
Year
Gear
FIXED
HAL
NPT
POT
PTR
TRAWL



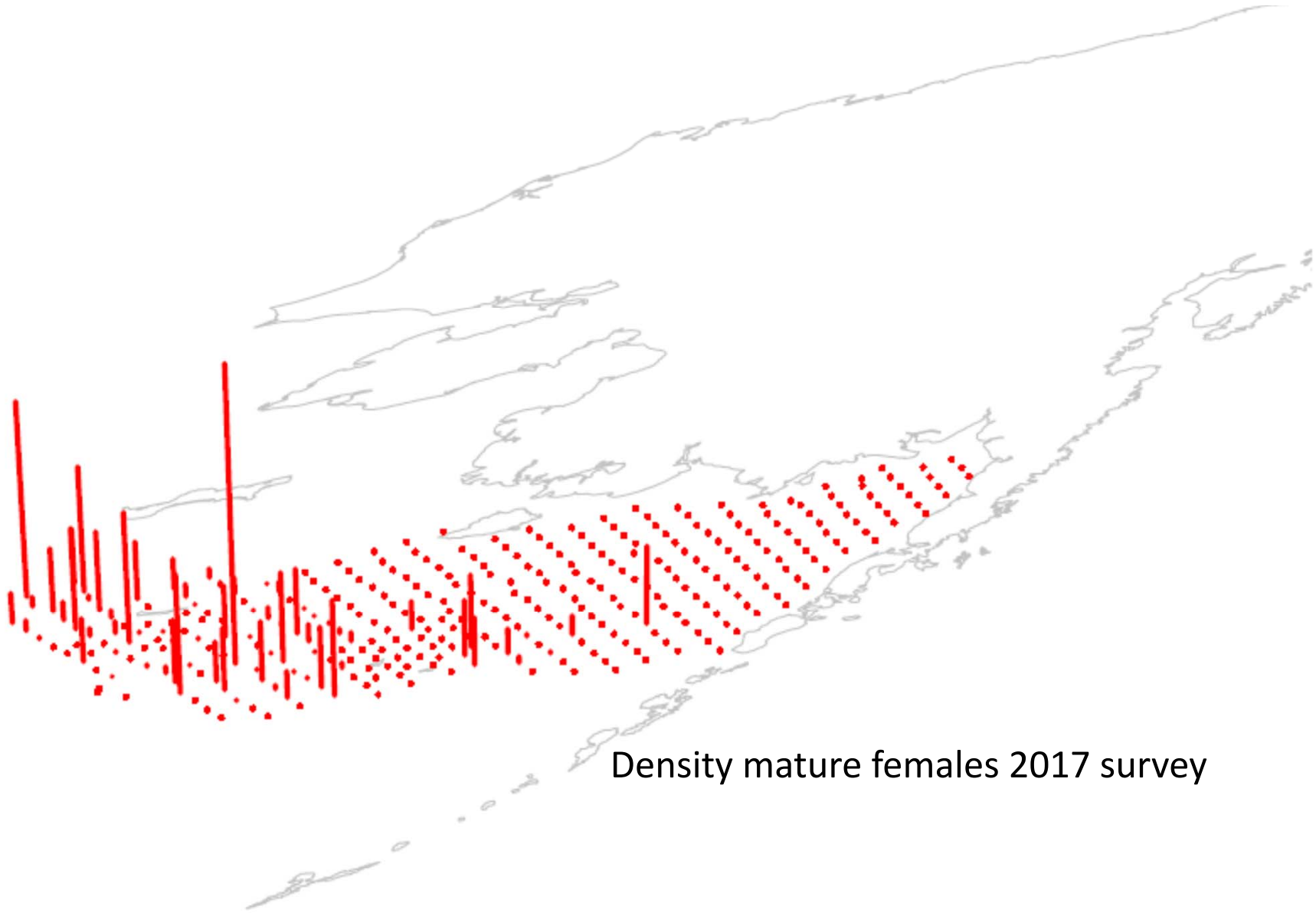
Density of all males 2017 survey



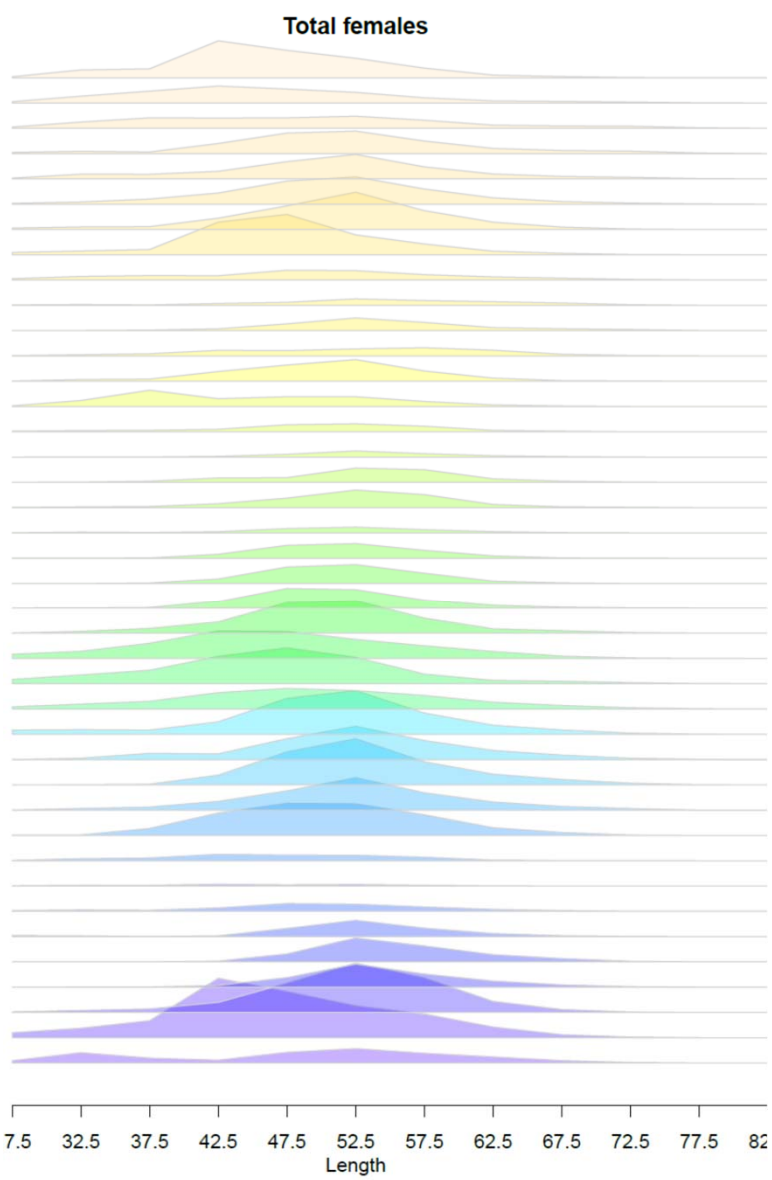
Density of all males (blue) and females (red)
2017 survey

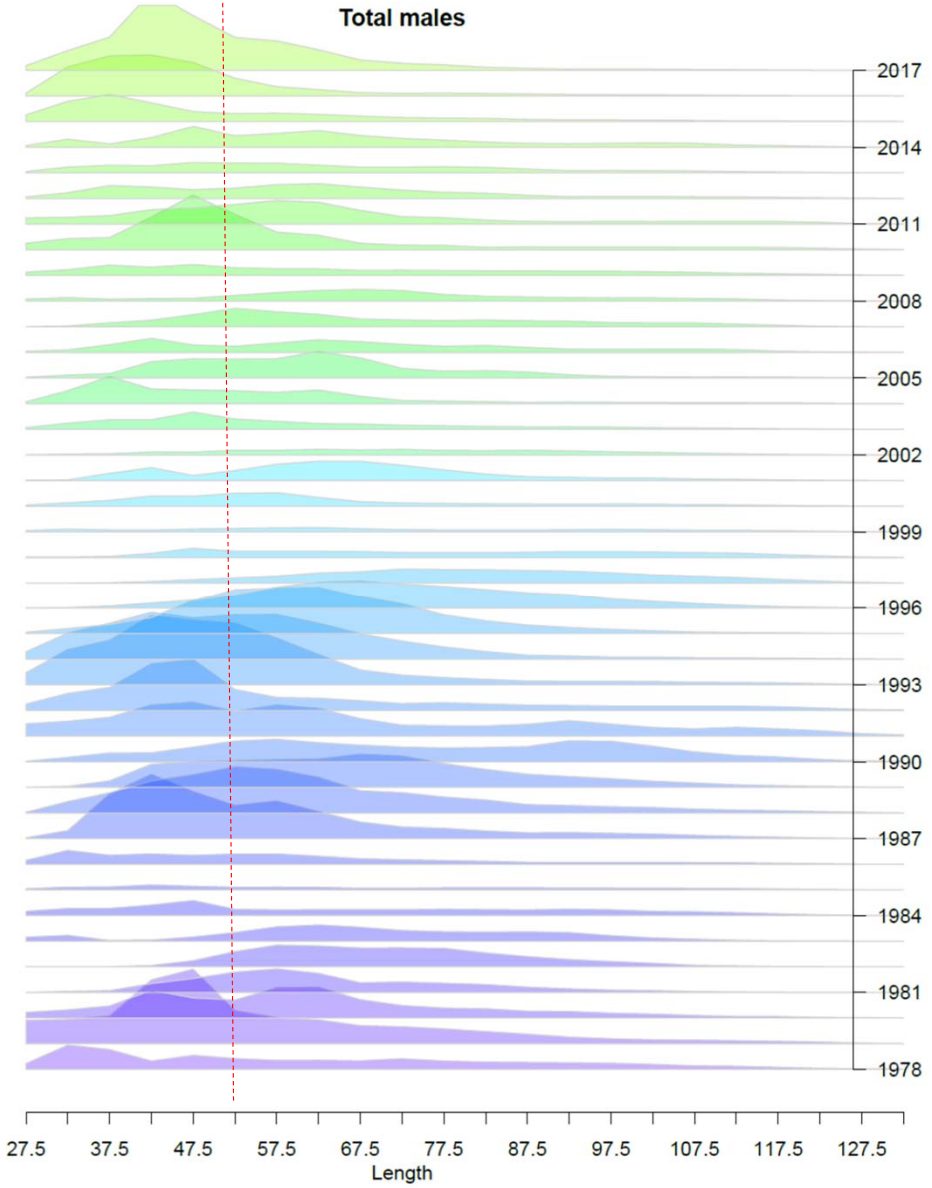


Density of males >101mm 2017 survey

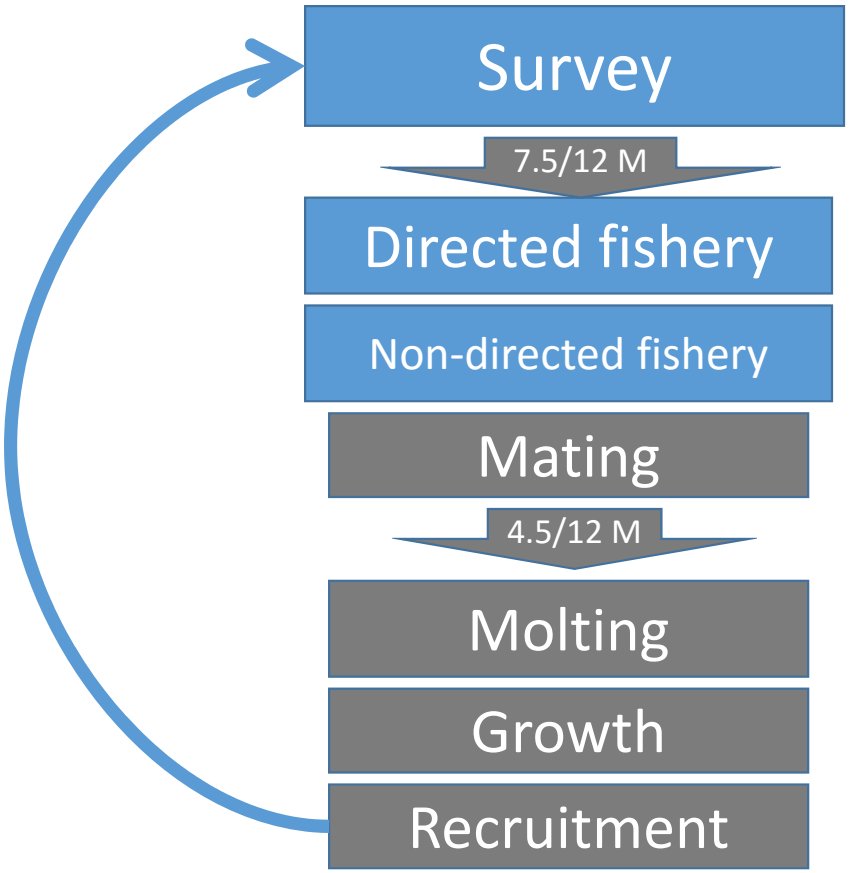


Density mature females 2017 survey


Total females
7.5
32.5
37.5
42.5
47.5
52.5
57.5
62.5
67.5
72.5
77.5
Length

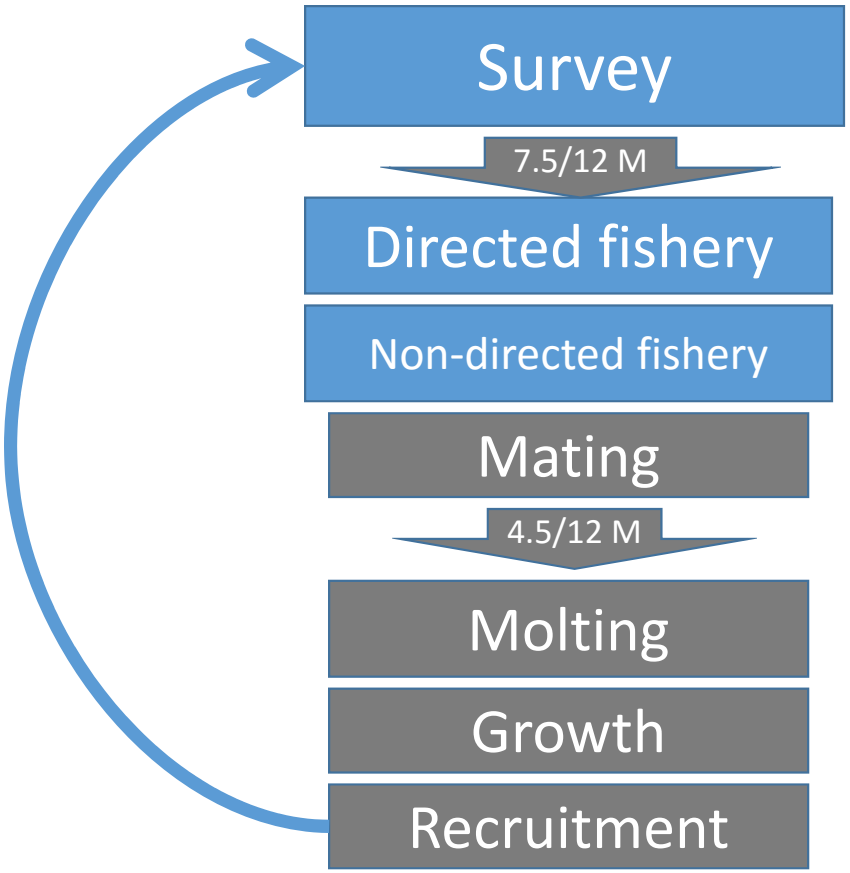

Total males
2017
2014
2011
2008
2005
2002
1999
1996
1993
1990
1987
1984
1981
1978
27.5
37.5
47.5
57.5
67.5
77.5
87.5
97.5
107.5
117.5
127.5
Length

Model overview



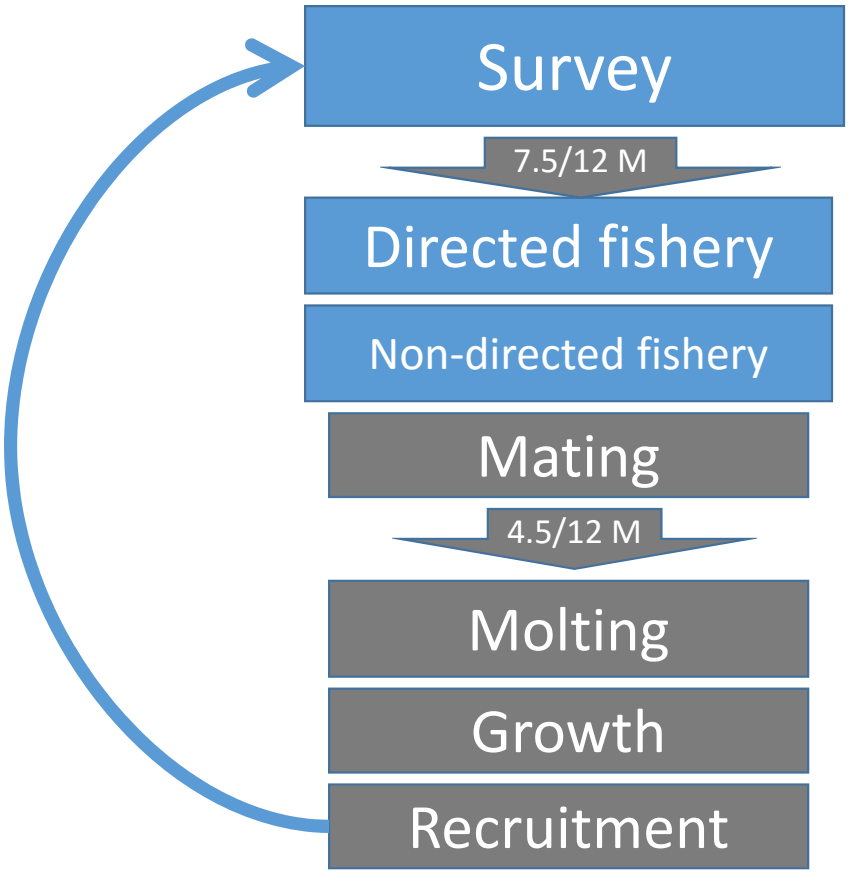
1. Logistic selectivity in 3 ‘eras’
2. Linked to BSFRF data through a common selectivity
3. Size composition and biomass index

Model overview



1. Mature males, immature for both sexes
2. Estimated with a prior

Model overview



1. Logistic selectivity
2. Retention selectivity
3. Discard mortality equal to 30%

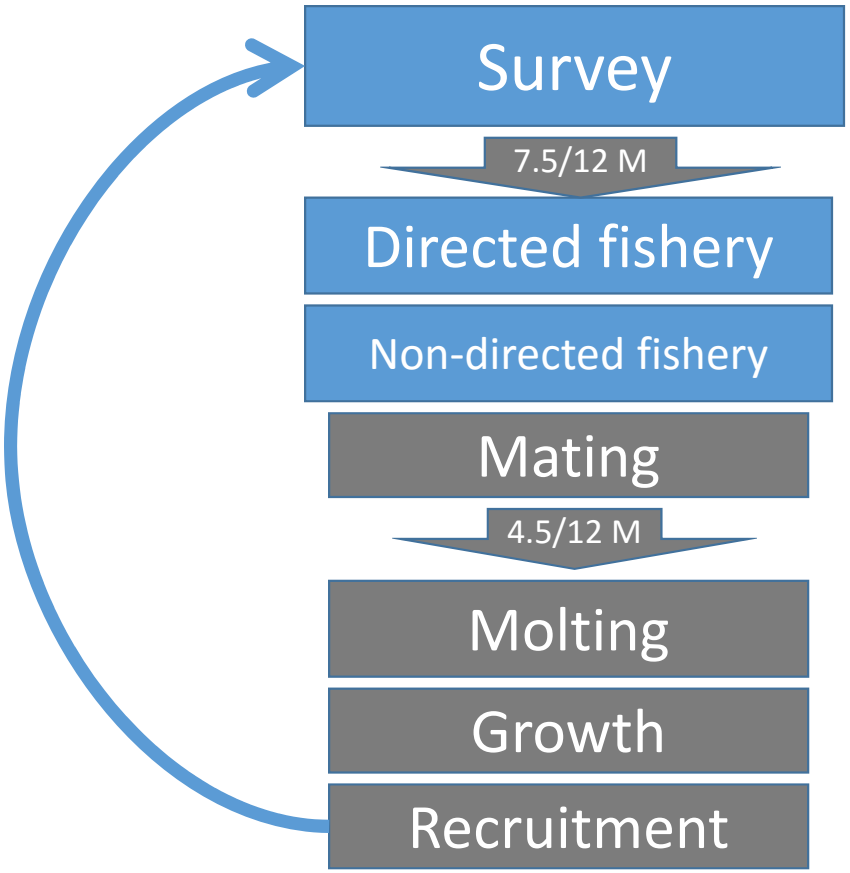
Data in:

Retained catch in t and #s

Discard numbers

Retained catch length comps

Model overview



1. Logistic selectivity
2. Retention selectivity
3. Discard mortality equal to 30%

Fit to:

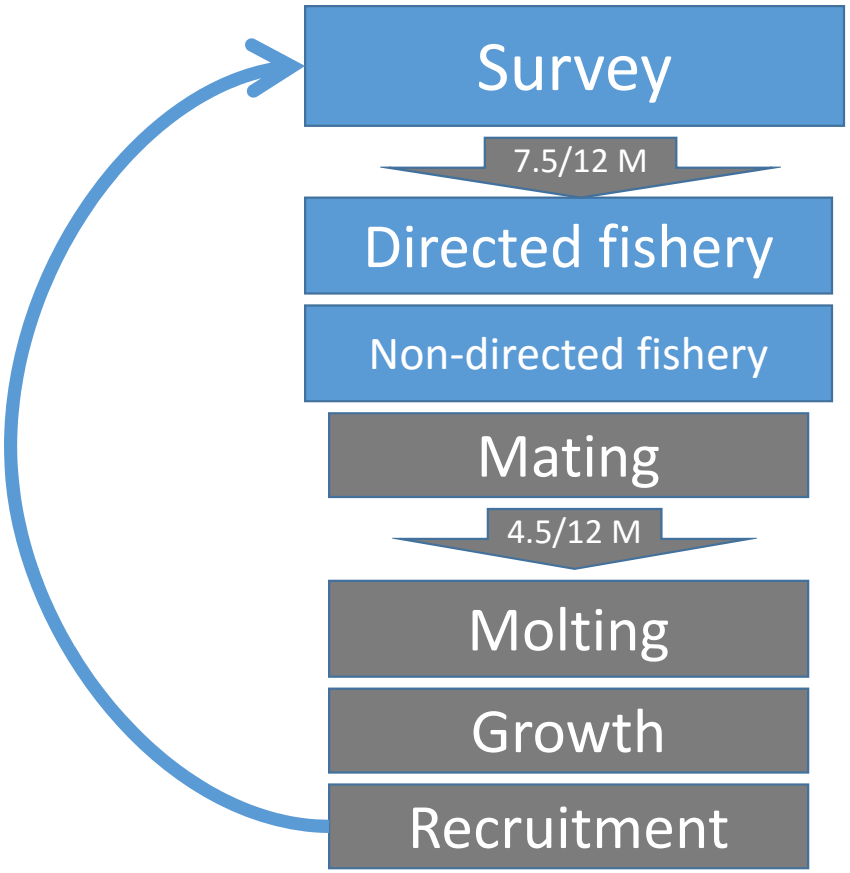
Retained length comps

Discard length comps

Retained biomass

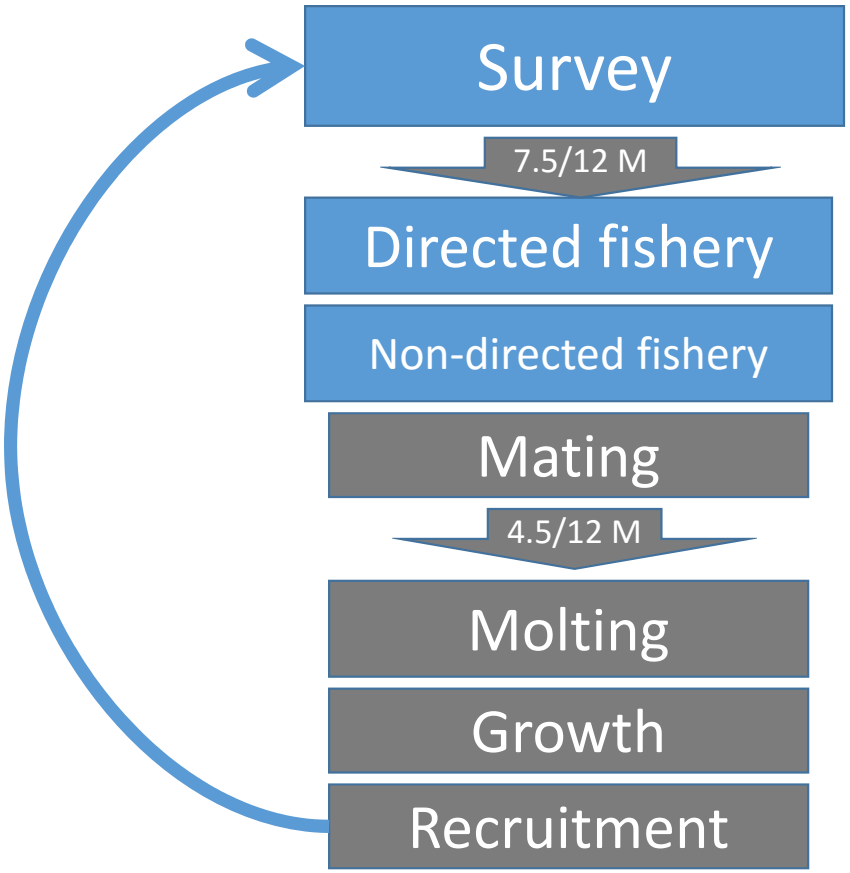
Male and female discard biomass

Model overview



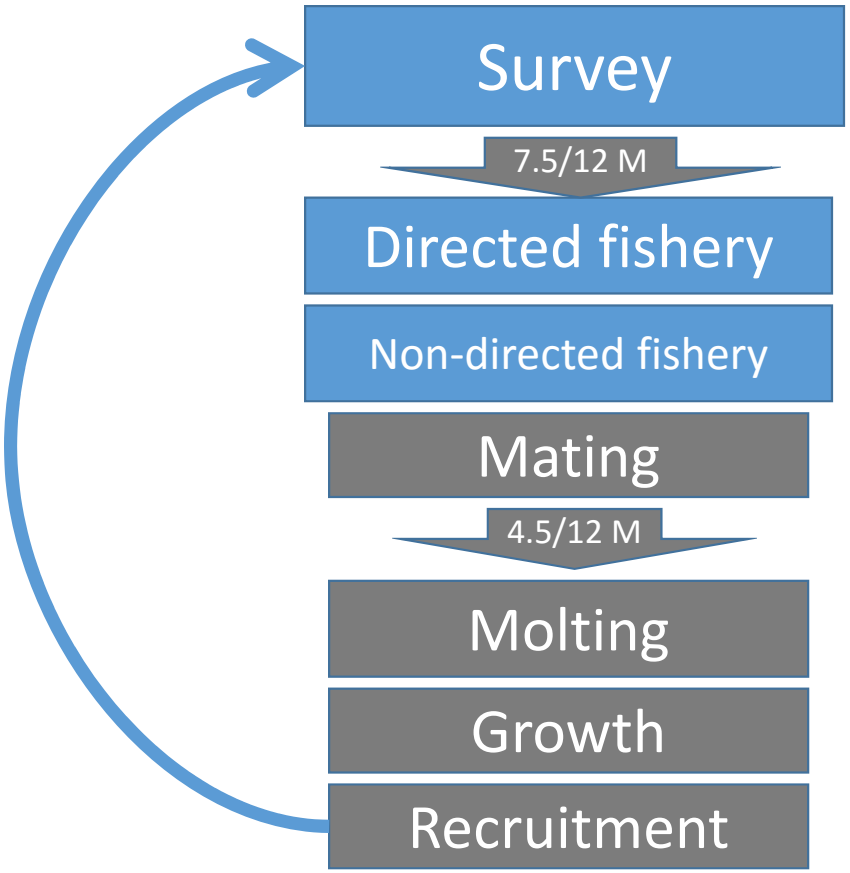
1. Logistic selectivity
2. Discard mortality equal to 80%

Model overview



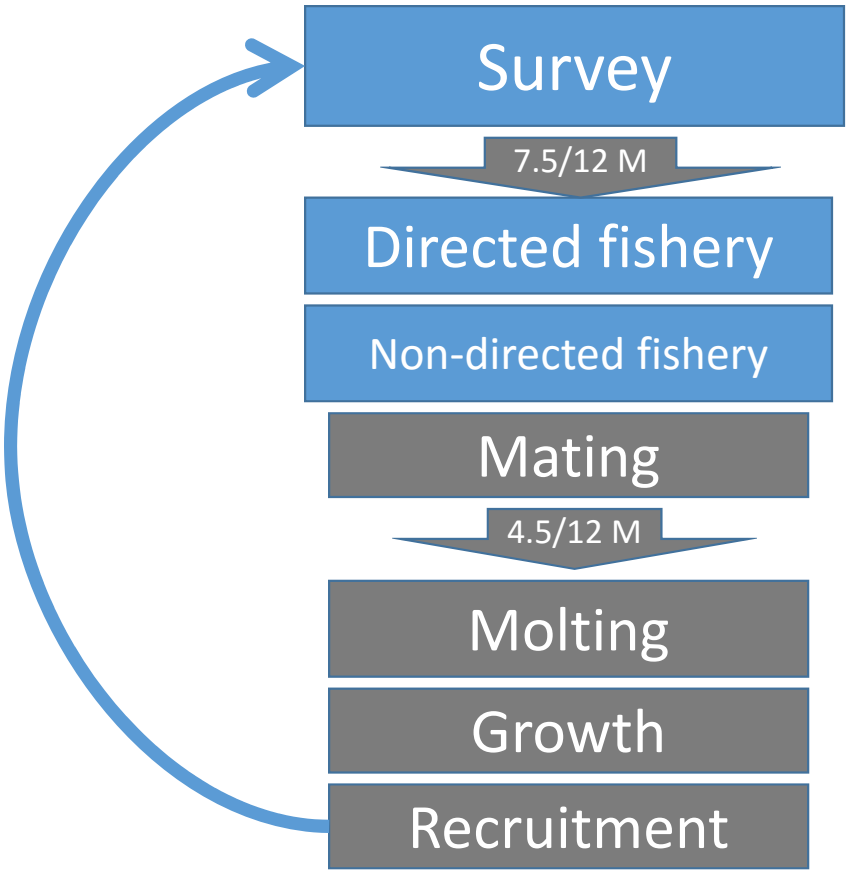
1. Freely estimated curves
2. Priors and smoothing penalties

Model overview



1. All immature crab assumed to molt
2. Terminal molt to maturity

Model overview



1. Two piece linear growth models estimated for both sexes

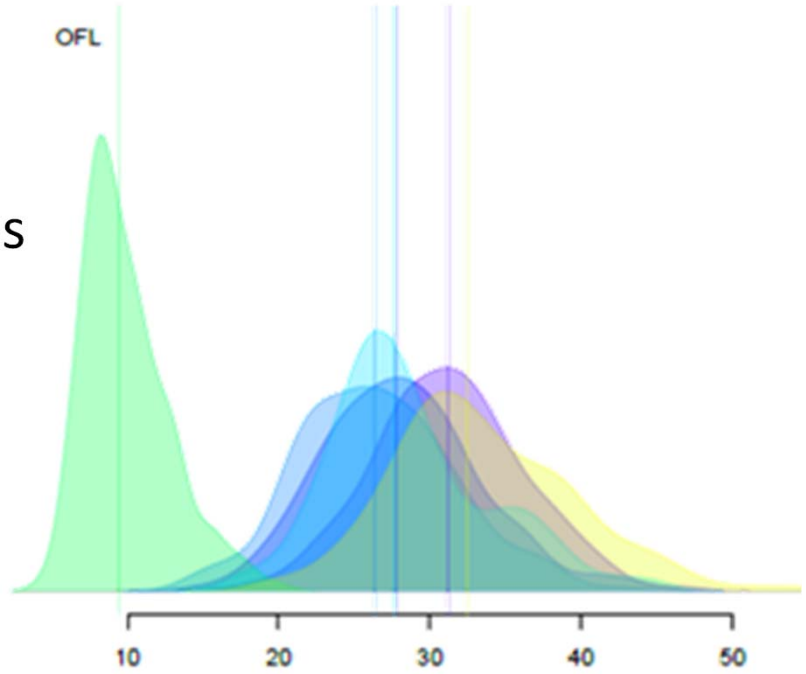
Goal: Find a stable model configuration to calculate the OFL

Methodologies:

- Maximum likelihood and jittering
- Bayesian and MCMC

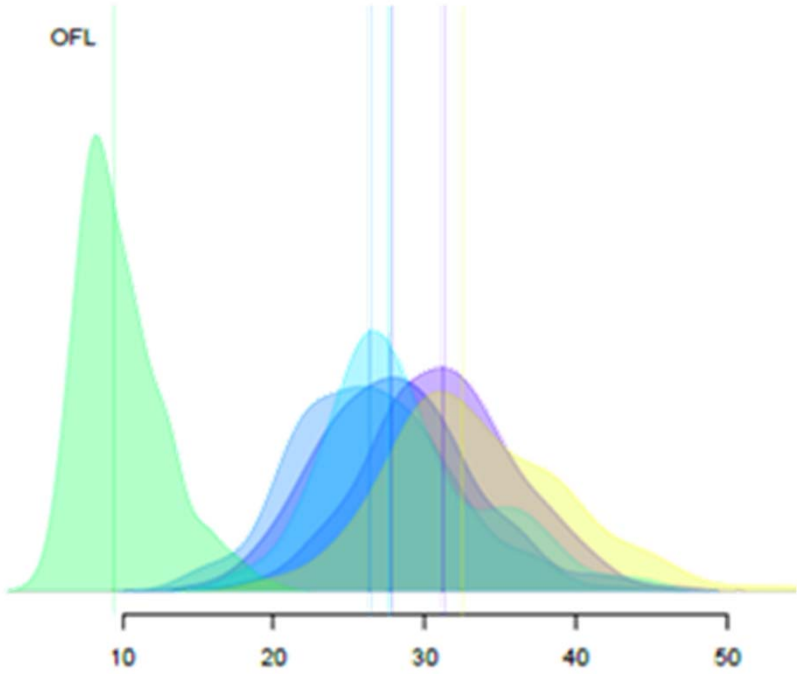
Why Bayesian?

- Incorporates uncertainty in the data into output
- Provides intuitive distributions of quantities important in management



Why not Bayesian?

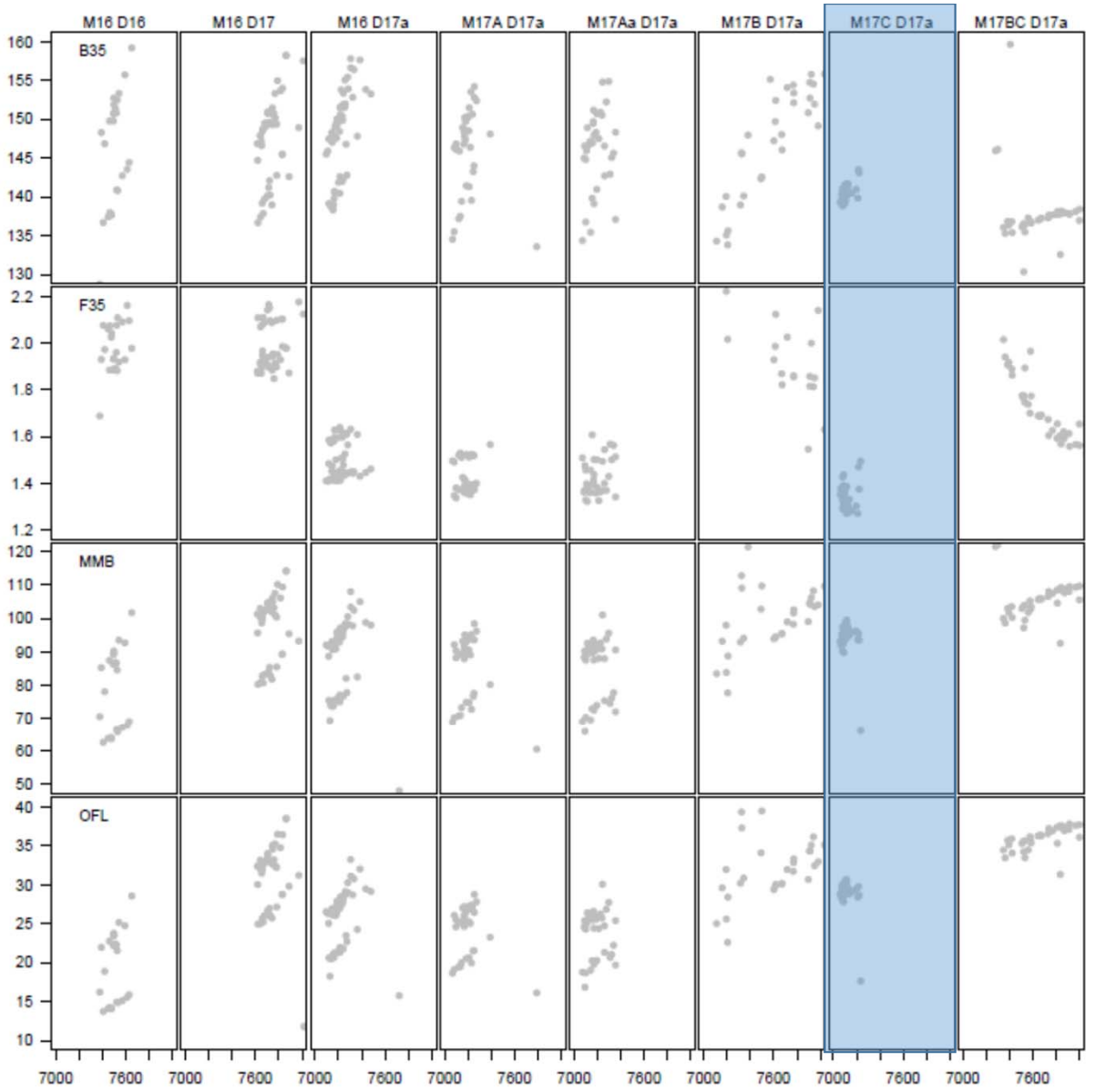
- It takes a long time.
- Priors need careful consideration.
- Posterior medians for management are usually very similar to the MLEs.
- The uncertainty isn't used in management.



Plan of attack

- Jitter and use maximum likelihood estimates
  - All models (except 1) were unstable

- Jittering showed instability in the models
- Bimodal management quantities
- Just ‘running until you get the lowest likelihood’ didn’t work



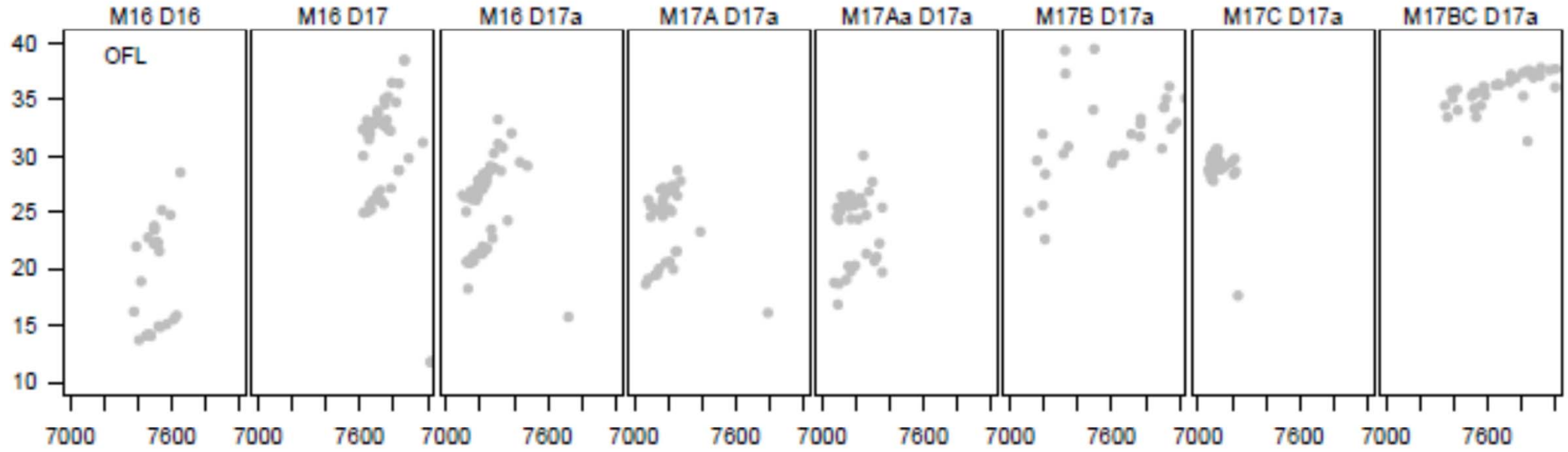
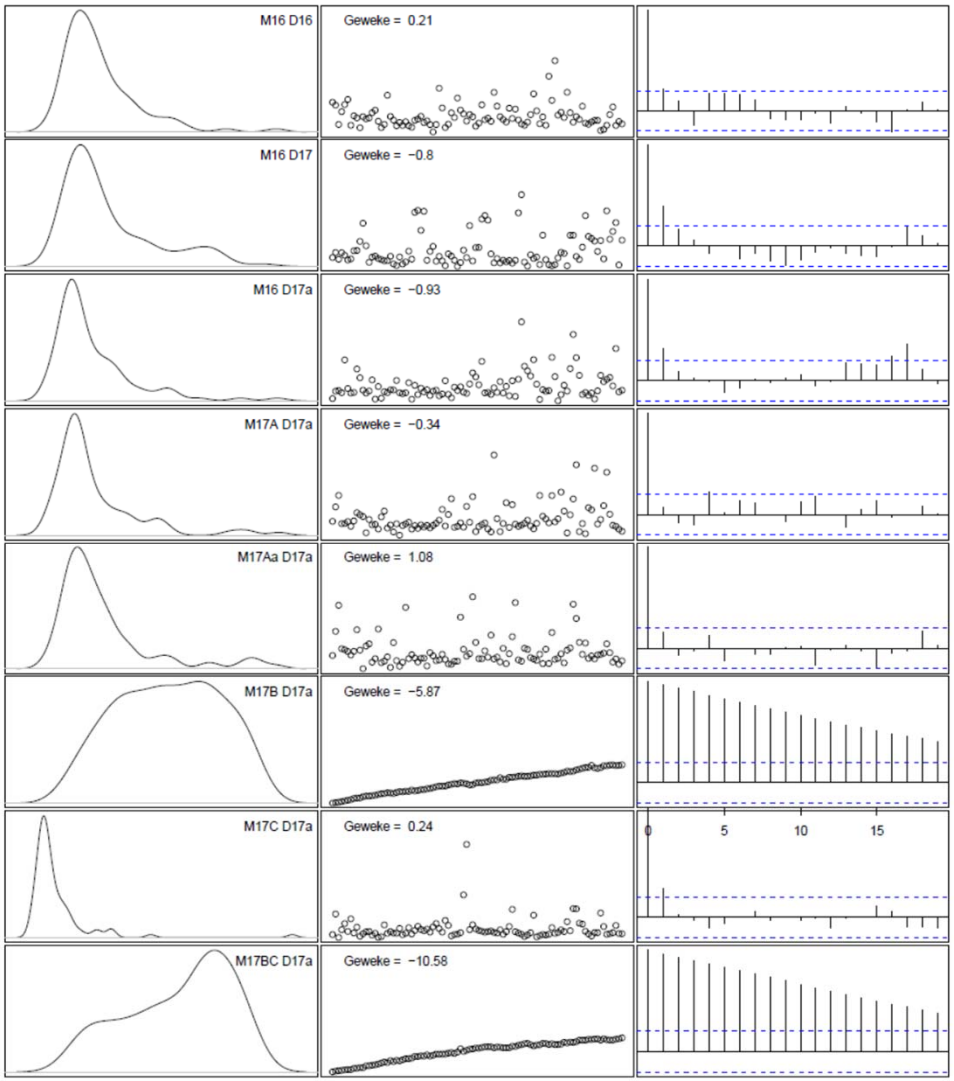


Figure 18: Management quantities after jittering all models.

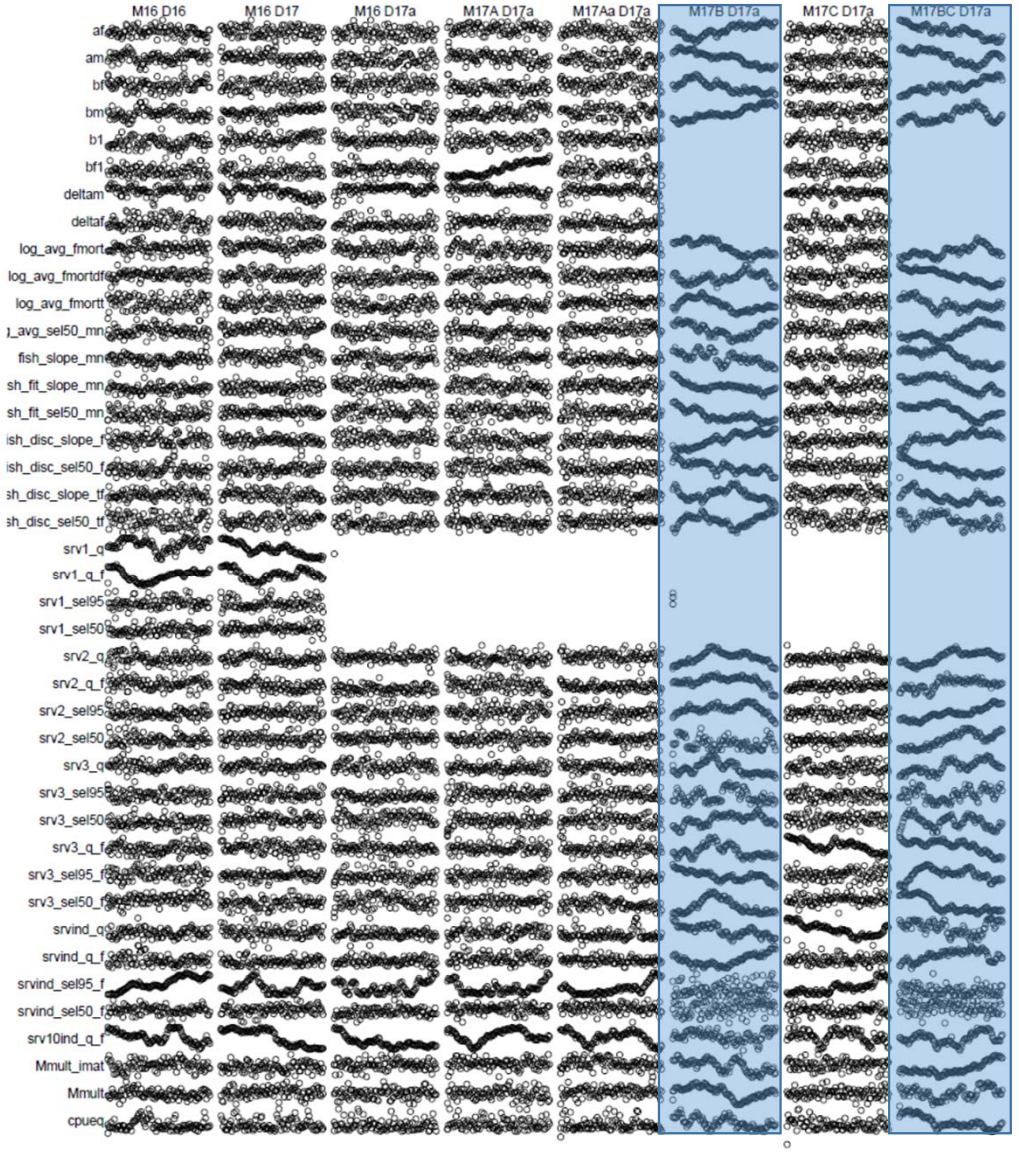
Plan of attack

- Jitter and use maximum likelihood estimates
  - All models (except 1) were unstable
- Bayes
  - Given the observed instability, can MCMC be used to smooth over the uncertainty?
  - Only long chains addressed bimodality of management quantities

- Starting MCMC at either of the ‘modes’ seen from the jittering gives different answers with 2 million draws
- This problem was circumvented last time by longer chains
- Removing lower two lengths bins led to poorly specified models with confounded processes and no data to inform them



- Removing lower two lengths bins led to poorly specified models with confounded processes and no data to inform them
- Consequently, the traces for the parameters via MCMC were not stationary
- Parameter traces for other models did a bit better, but there are still problem parameters



Likelihood component	M16 D16	M16 D17	M16 D17a	M17A D17a	M17Aa D17a	M17B D17a	M17C D17a	M17BC D17a
Total	7499.12	7707.09	7190.65	7187.95	7189.08	7995.99	7060.84	7729

Slightly different weighting

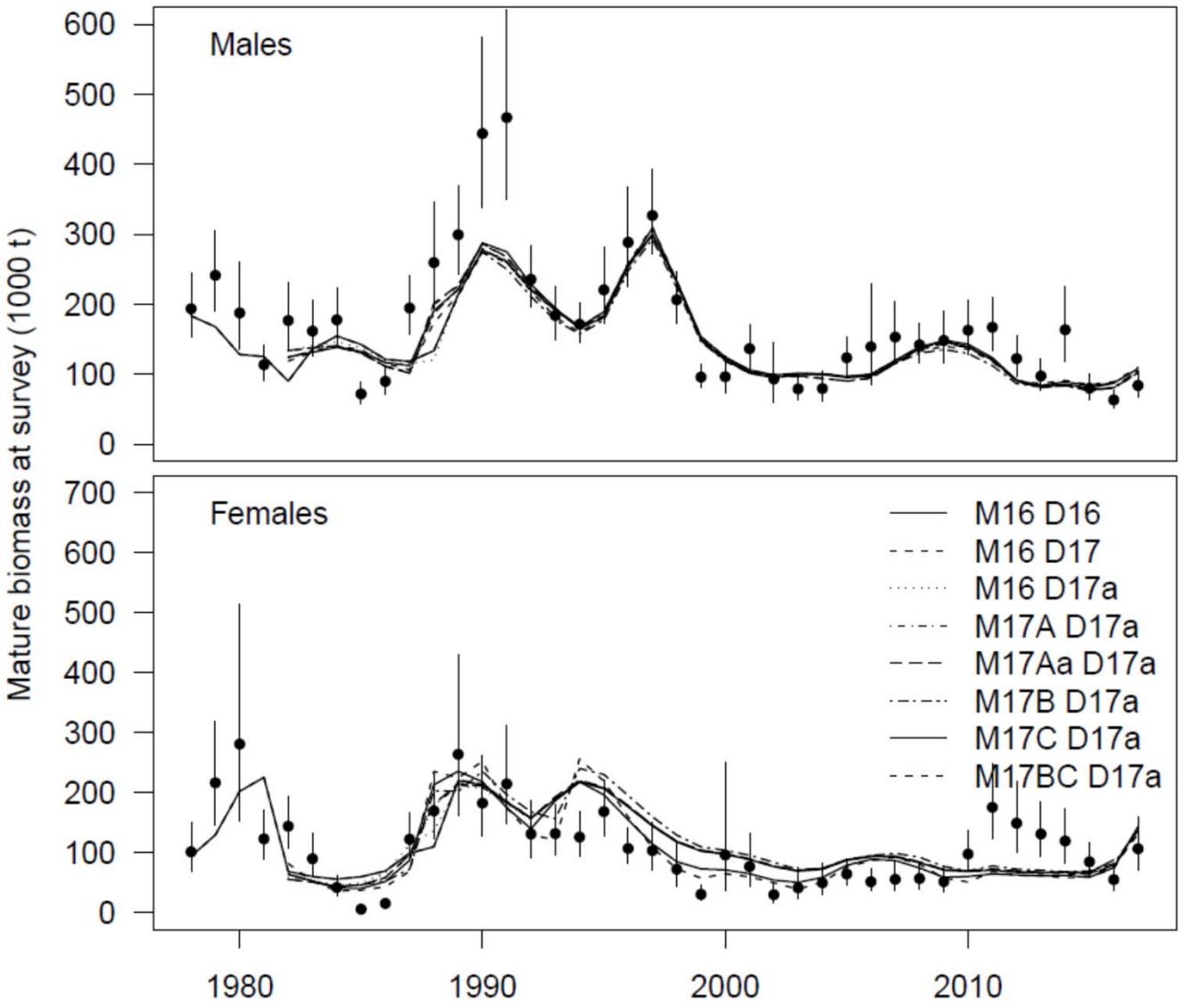
Long story short:

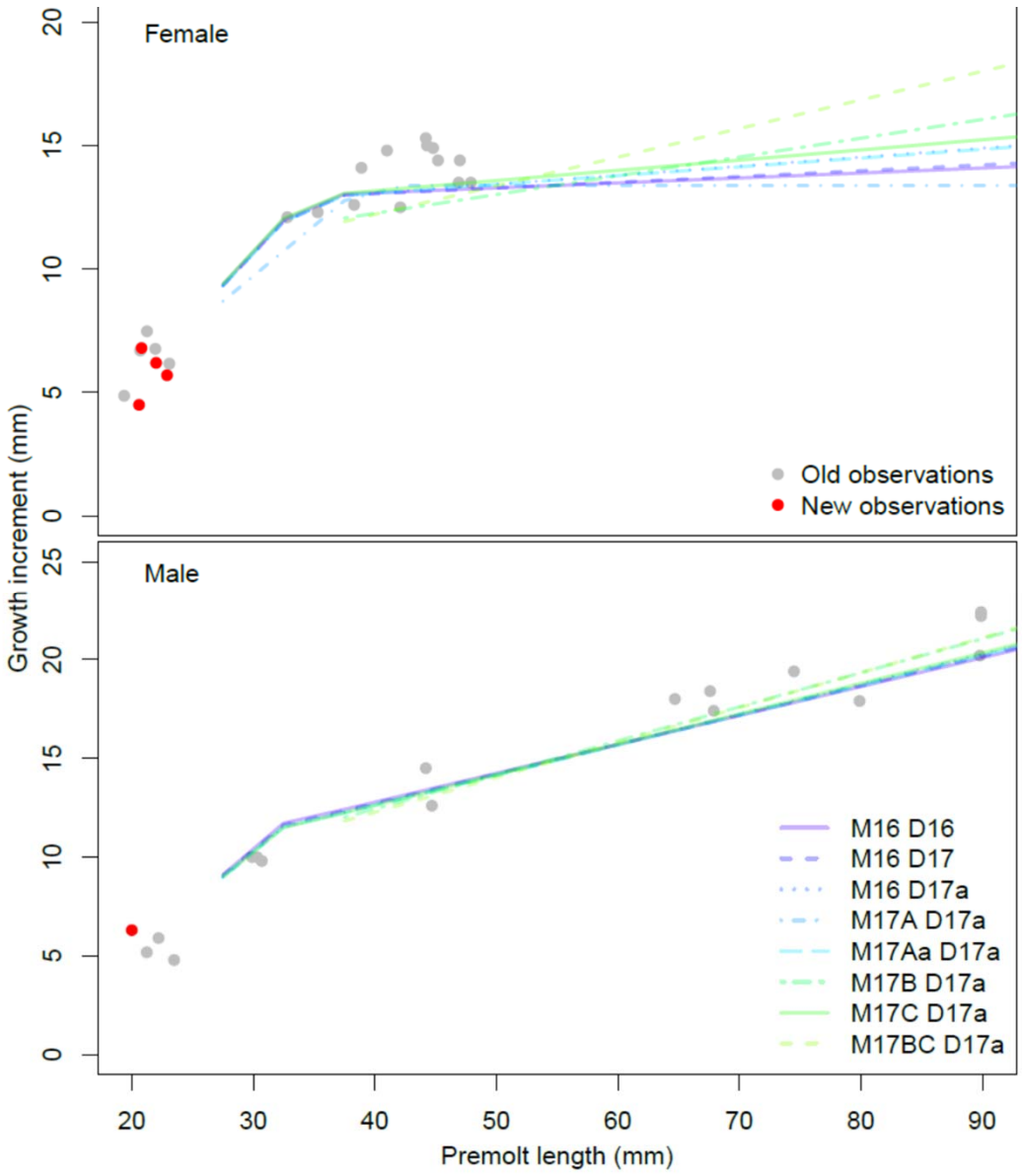
M16.D16 through M17Aa.D17a have bimodal management quantities

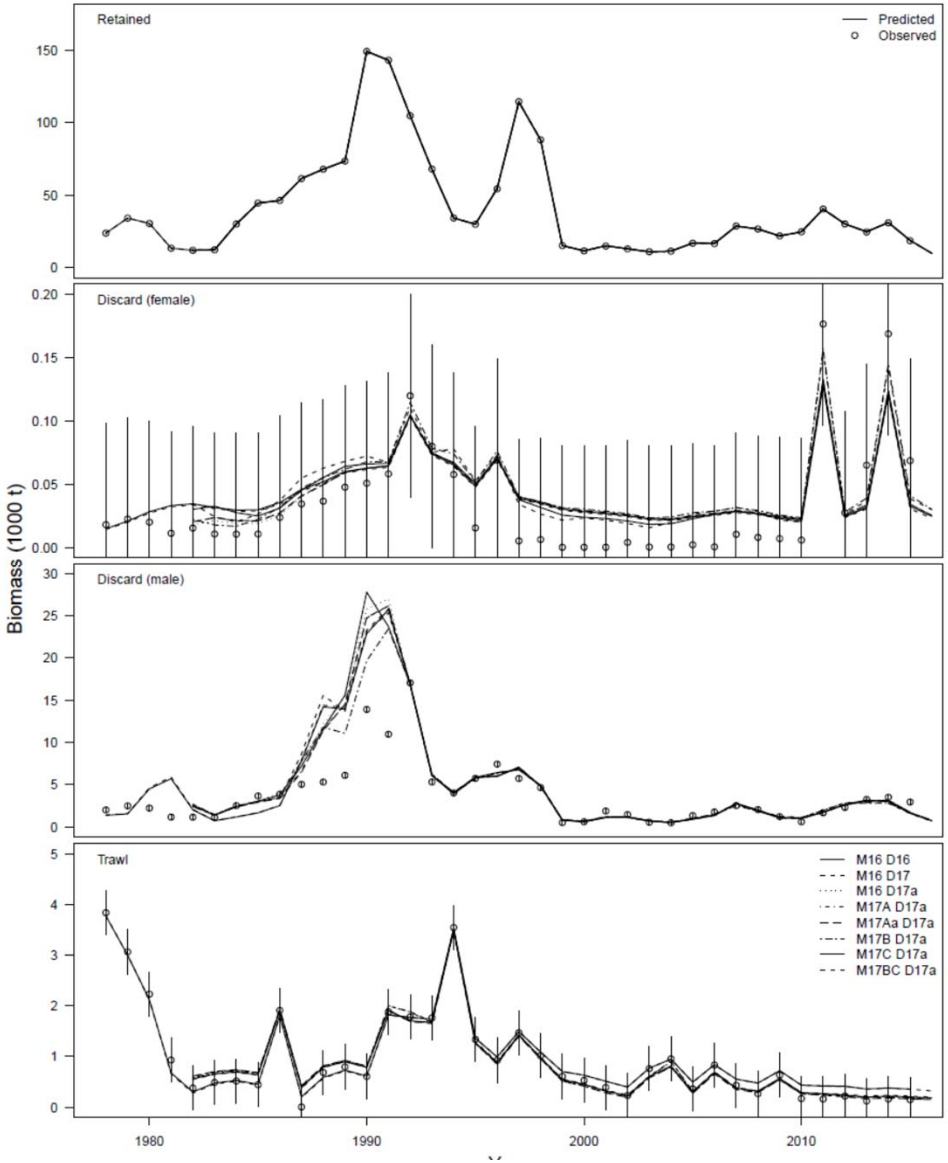
M17B.D17a and M17BC.D17are not viable because of confounded population processes.

M17C.D17a is the only model that addresses these two issues.

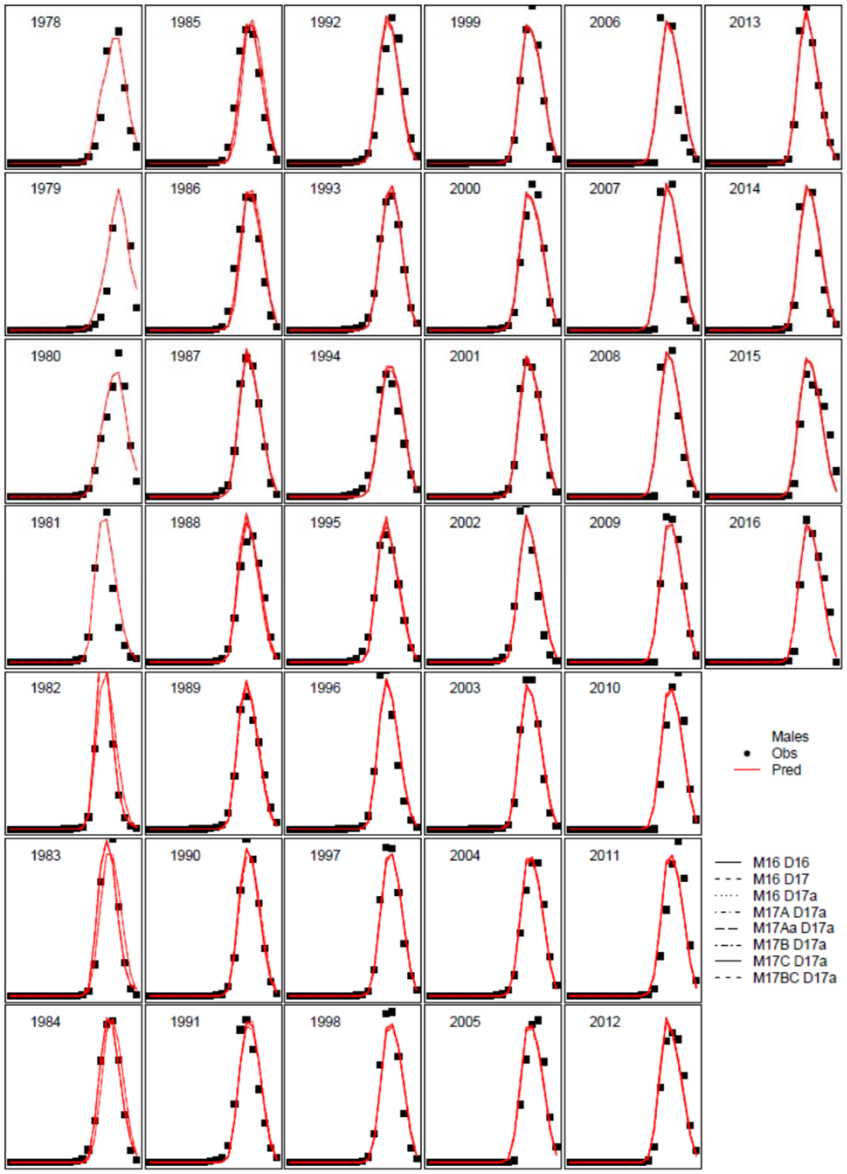
Model fits


Males
Females
Mature biomass at survey (1000 t)
0
100
200
300
400
500
600
700
1980
1990
2000
2010
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a

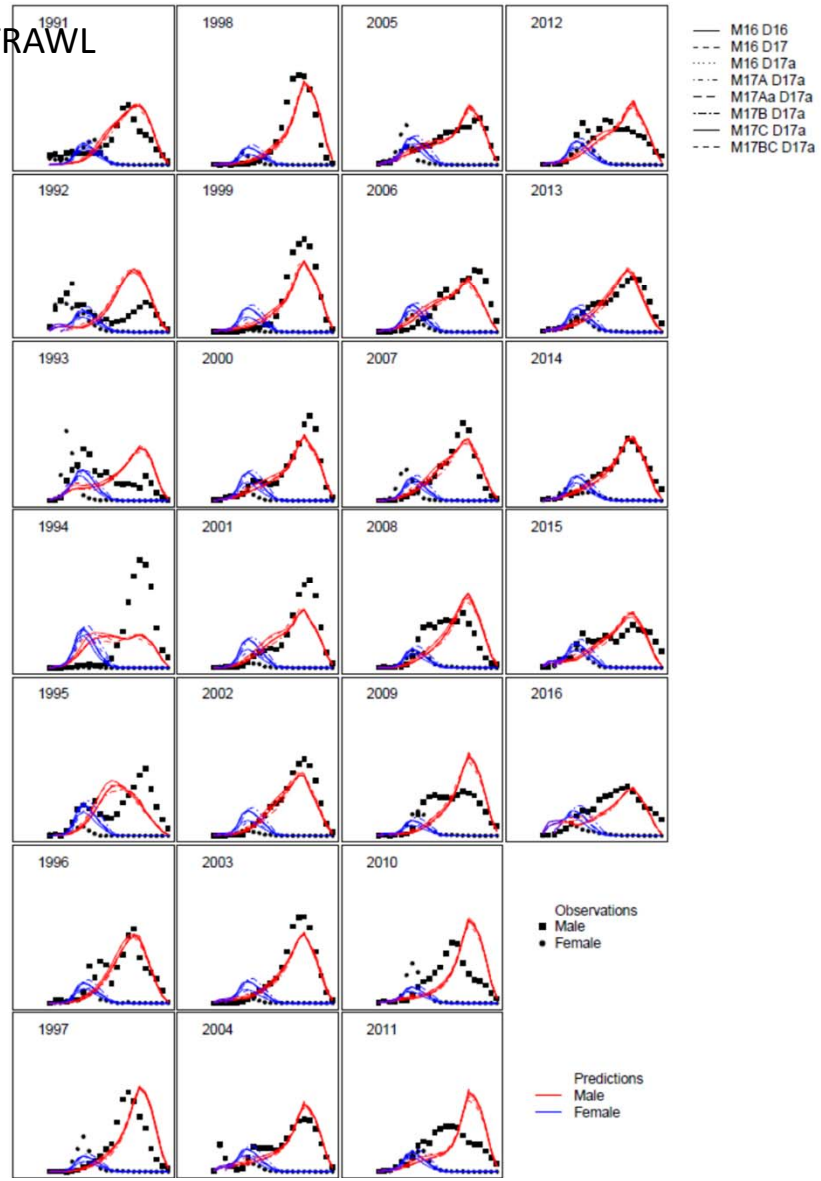

Female
Male
Old observations
New observations
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
Growth increment (mm)
Premolt length (mm)
0
5
10
15
20
25
20
30
40
50
60
70
80
90

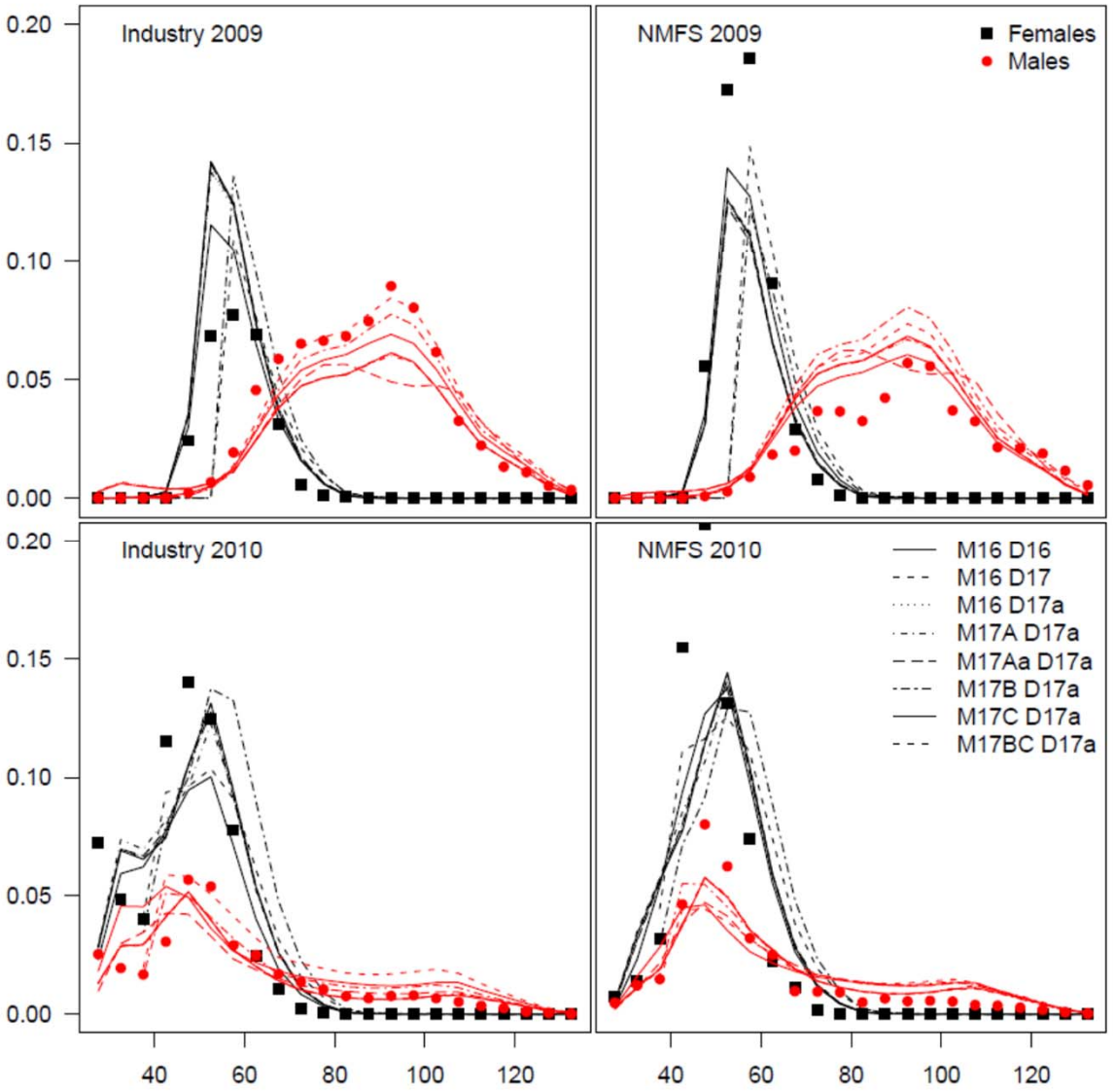

Retained
Predicted
Observed
Discard (female)
Discard (male)
Trawl
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
Biomass (1000 t)
1980
1990
2000
2010

Retained catch

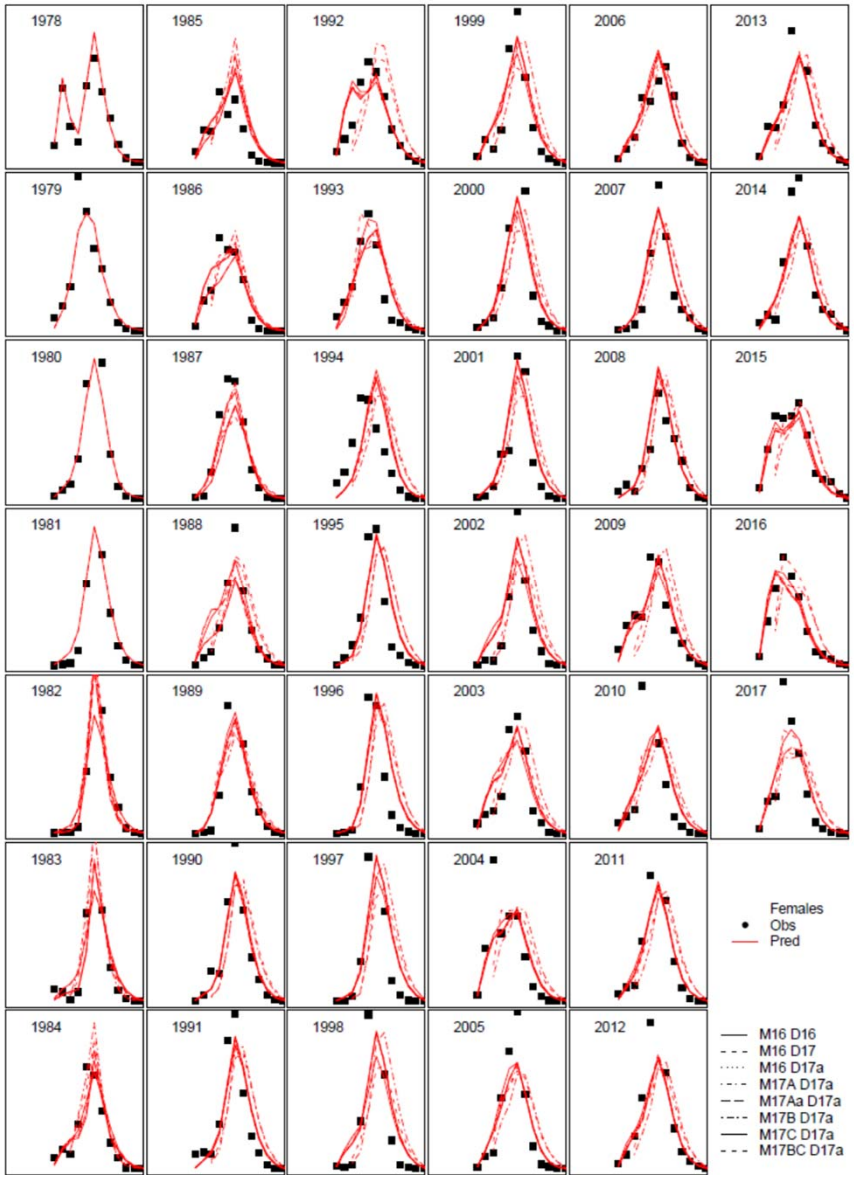


TRAWL


1991
1998
2005
2012
1992
1999
2006
2013
1993
2000
2007
2014
1994
2001
2008
2015
1995
2002
2009
2016
1996
2003
2010
1997
2004
2011
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
Observations
Male
Female
Predictions
Male
Female


Industry 2009
NMFS 2009
Females
Males
Industry 2010
NMFS 2010
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
0.20
0.15
0.10
0.05
0.00
40
60
80
100
120

SURVEY


1978
1985
1992
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2006
2013
1979
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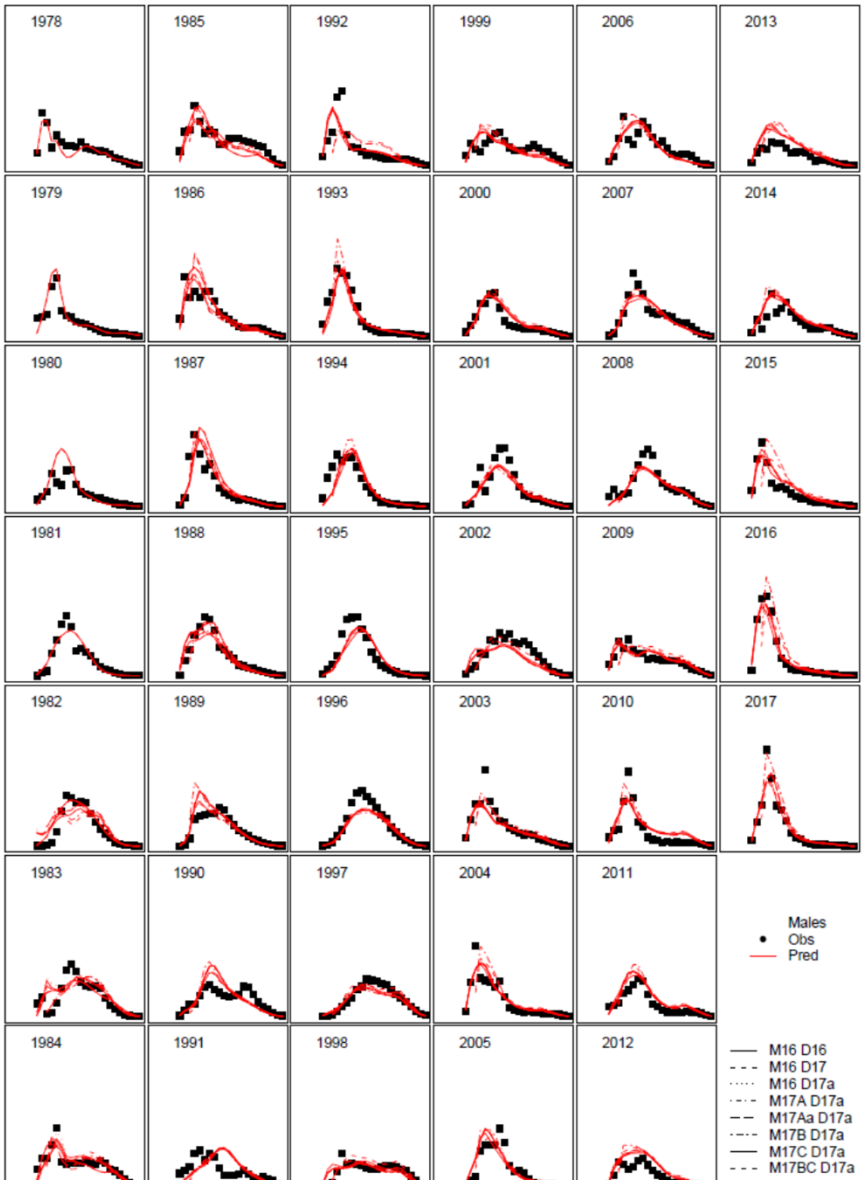
2007
2014
1980
1987
1994
2001
2008
2015
1981
1988
1995
2002
2009
2016
1982
1989
1996
2003
2010
2017
1983
1990
1997
2004
2011
1984
1991
1998
2005
2012
Females
Obs
Pred
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a


1978
1985
1992
1999
2006
2013
1979
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1993
2000
2007
2014
1980
1987
1994
2001
2008
2015
1981
1988
1995
2002
2009
2016
1982
1989
1996
2003
2010
2017
1983
1990
1997
2004
2011
1984
1991
1998
2005
2012
Males
Obs
Pred
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a

- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
- M17Aa.D17a (estimate logit BSFRF selectivity)
- M17B.D17a (Remove length bins <37.5mm)
- M17C.D17a (Estimate mature female M)
  - Fits female survey biomass best
- M17BC.D17a (Remove length bins < 37.5mm & estimate mature female M

Estimated population processes

Survey

7.5/12 M

Directed fishery

Non-directed fishery

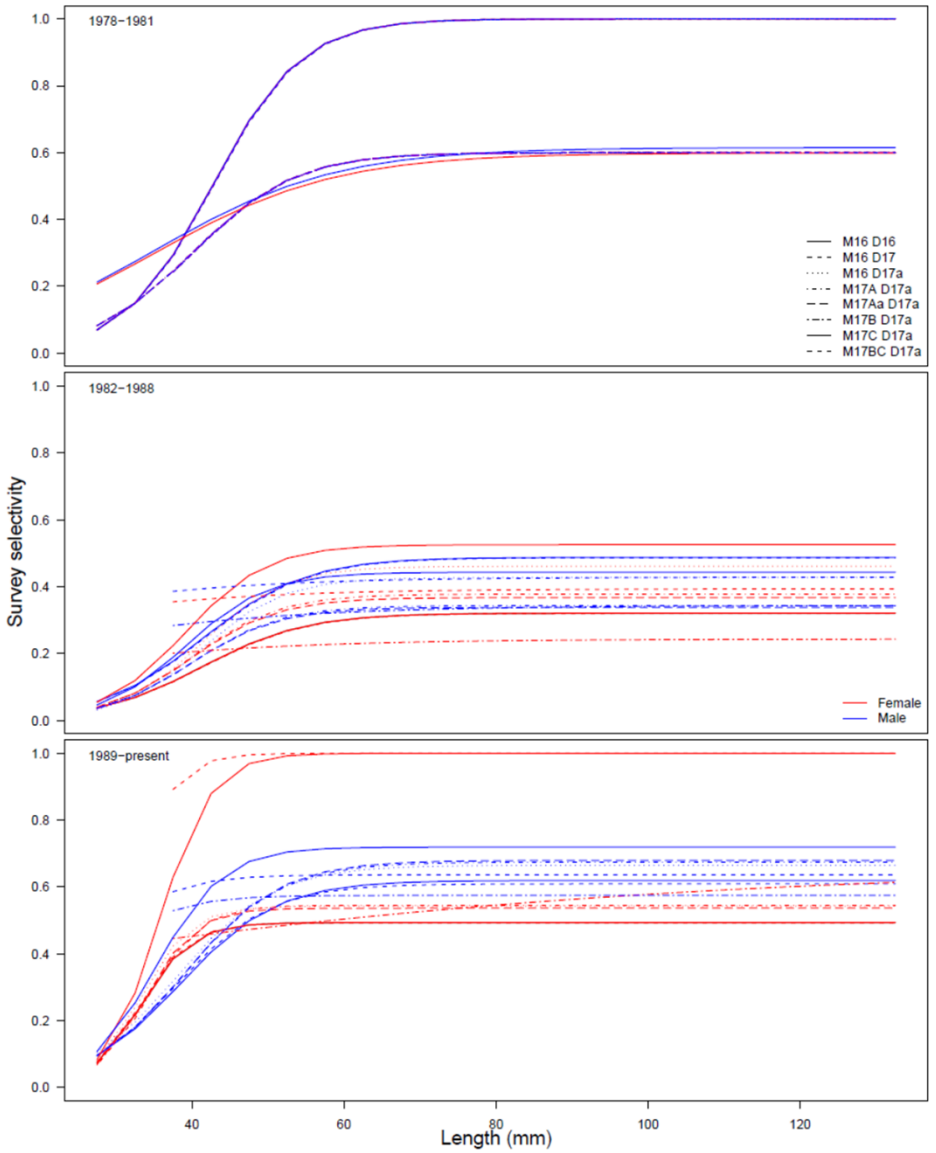
Mating

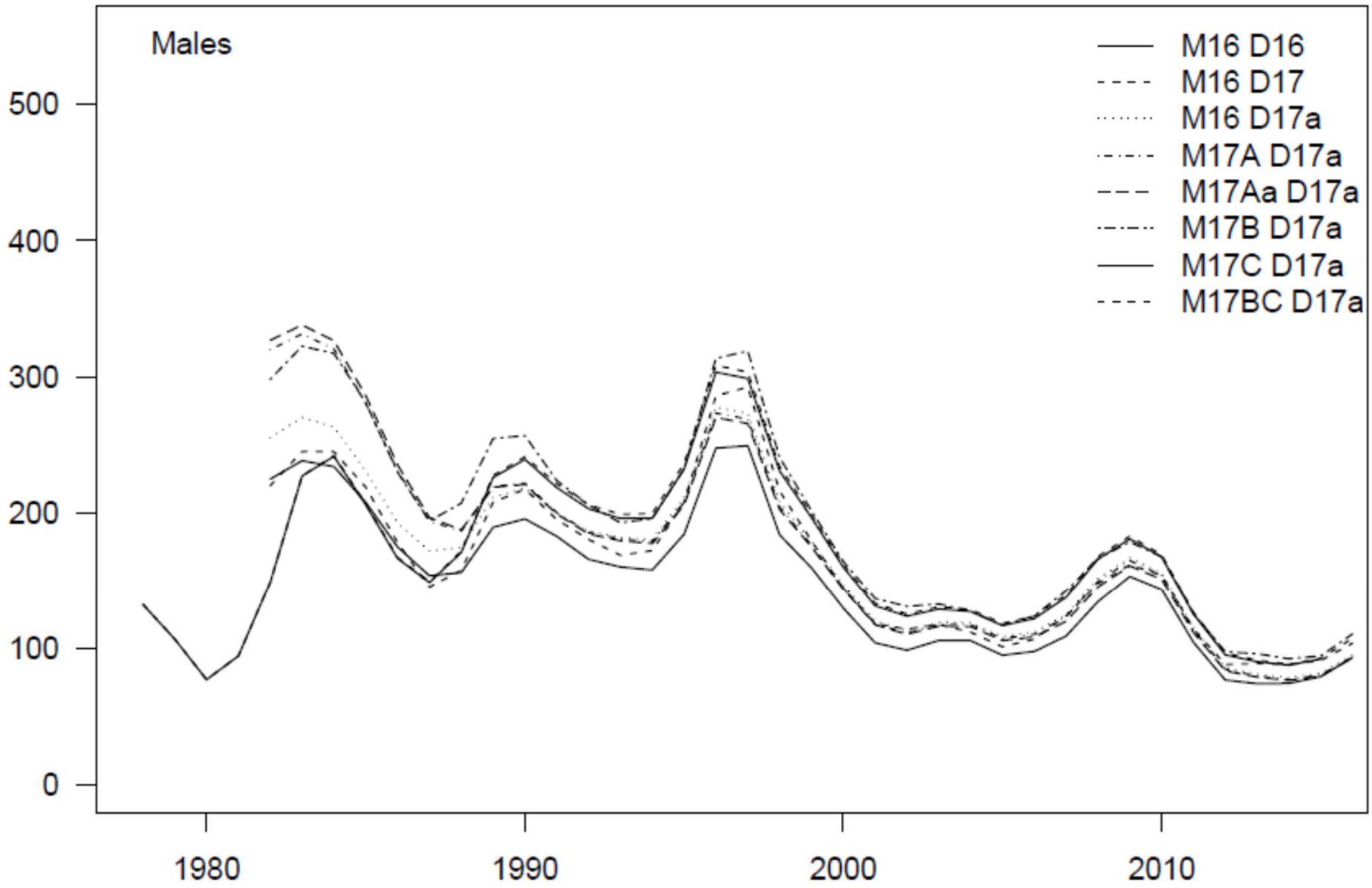
4.5/12 M

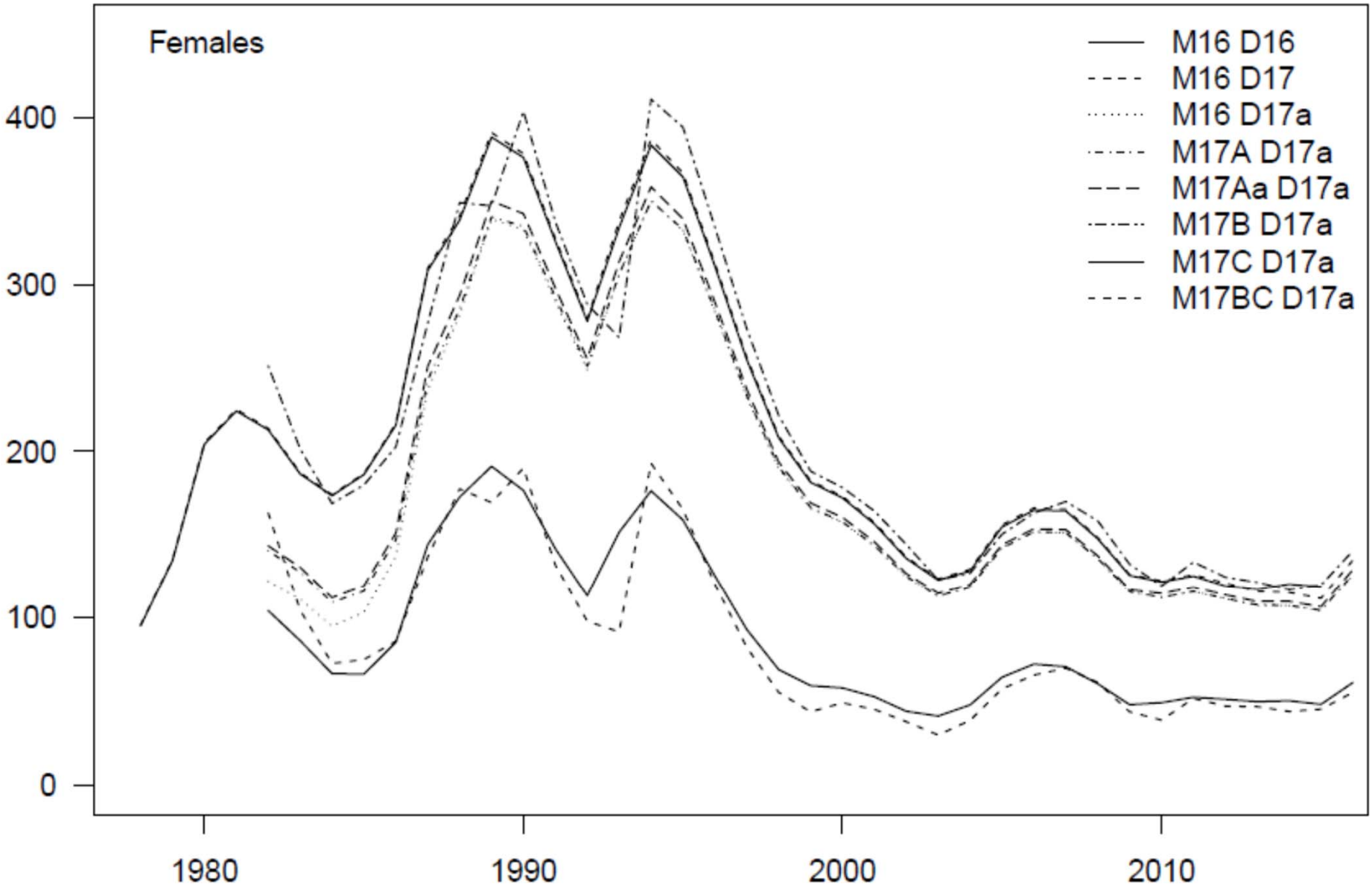
Molting

Growth

Recruitment




Males
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
500
400
300
200
100
0
1980
1990
2000
2010


Females
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
400
300
200
100
0
1980
1990
2000
2010

- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
- M17Aa.D17a (estimate logit BSFRF selectivity)
- M17B.D17a (Remove length bins <37.5mm)
  - Poor survey selectivity estimates
- M17C.D17a (Estimate mature female M)
  - Fits female survey biomass best
  - Female q in survey era 3 goes to 1
  - Highest male q in survey era 3
- M17BC.D17a (Remove length bins < 37.5mm & estimate mature female M
  - Poor survey selectivity estimates

Survey

7.5/12 M

Directed fishery

Non-directed fishery

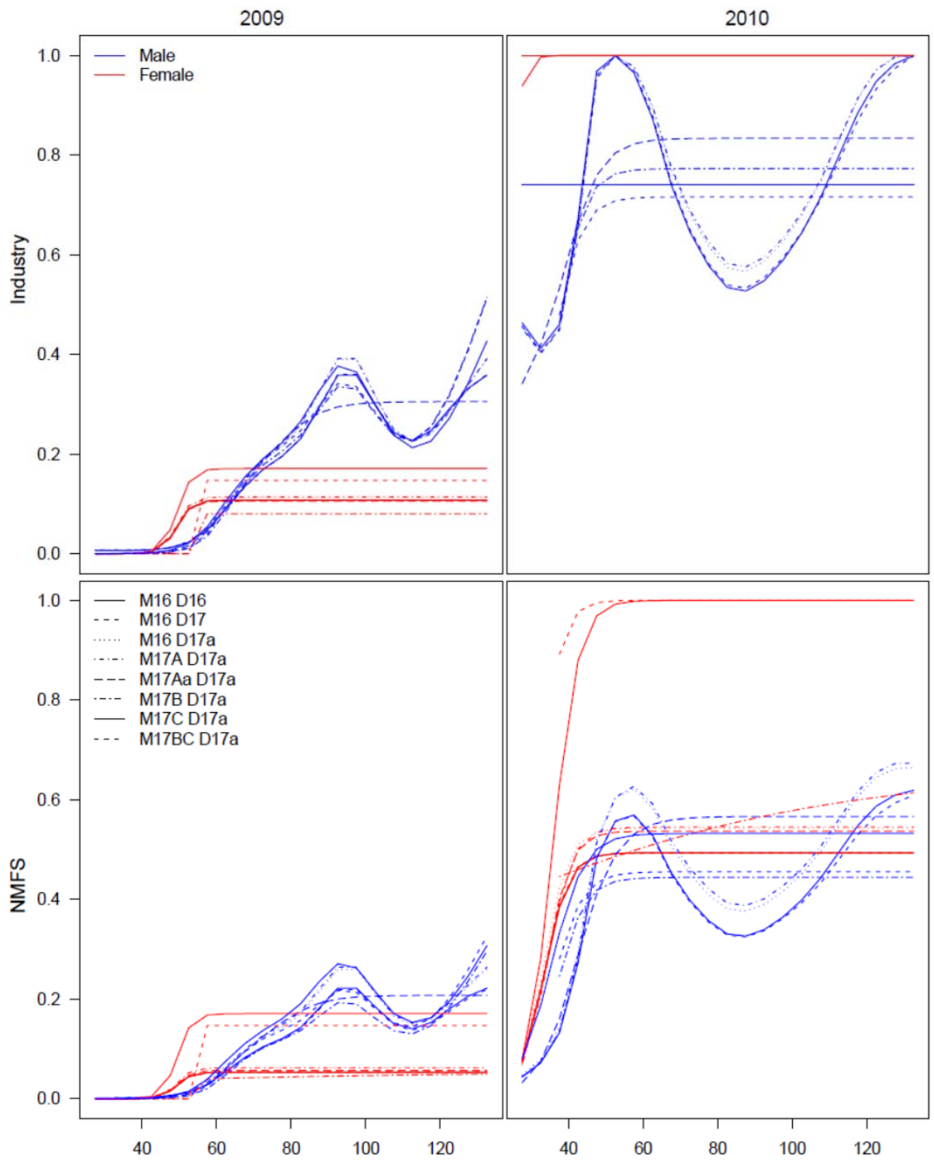
Mating

4.5/12 M

Molting

Growth

Recruitment



Survey

7.5/12 M

Directed fishery

Non-directed fishery

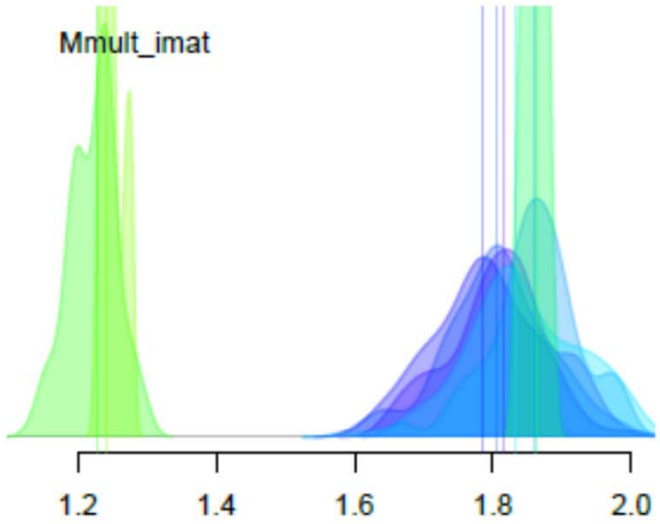
Mating

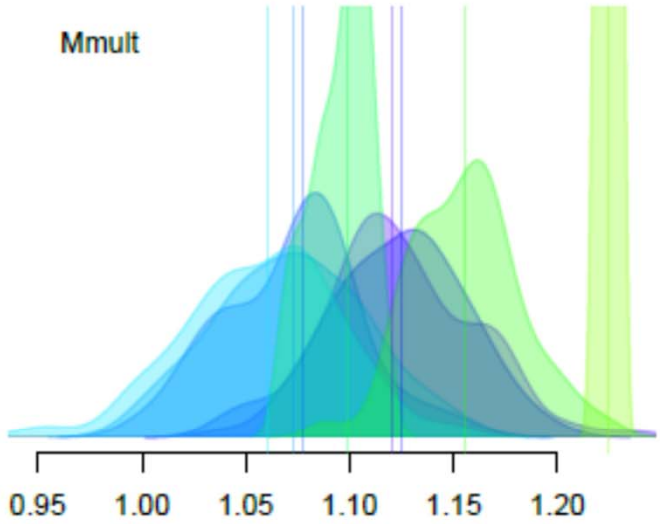
4.5/12 M

Molting

Growth

Recruitment





M17C.D17a

	Immature	Mature
Female	0.28	0.35
Male	0.28	0.27

- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
- M17Aa.D17a (estimate logit BSFRF selectivity)
- M17B.D17a (Remove length bins <37.5mm)
  - Poor survey selectivity estimates
- M17C.D17a (Estimate mature female M)
  - Fits female biomass the best
  - Female q in survey era 3 goes to 1
  - Correct relationship for M for mature males and females, but immature M decreases
- M17BC.D17a (Remove length bins < 37.5mm & estimate mature female M
  - Poor survey selectivity estimates

Survey

7.5/12 M

Directed fishery

Non-directed fishery

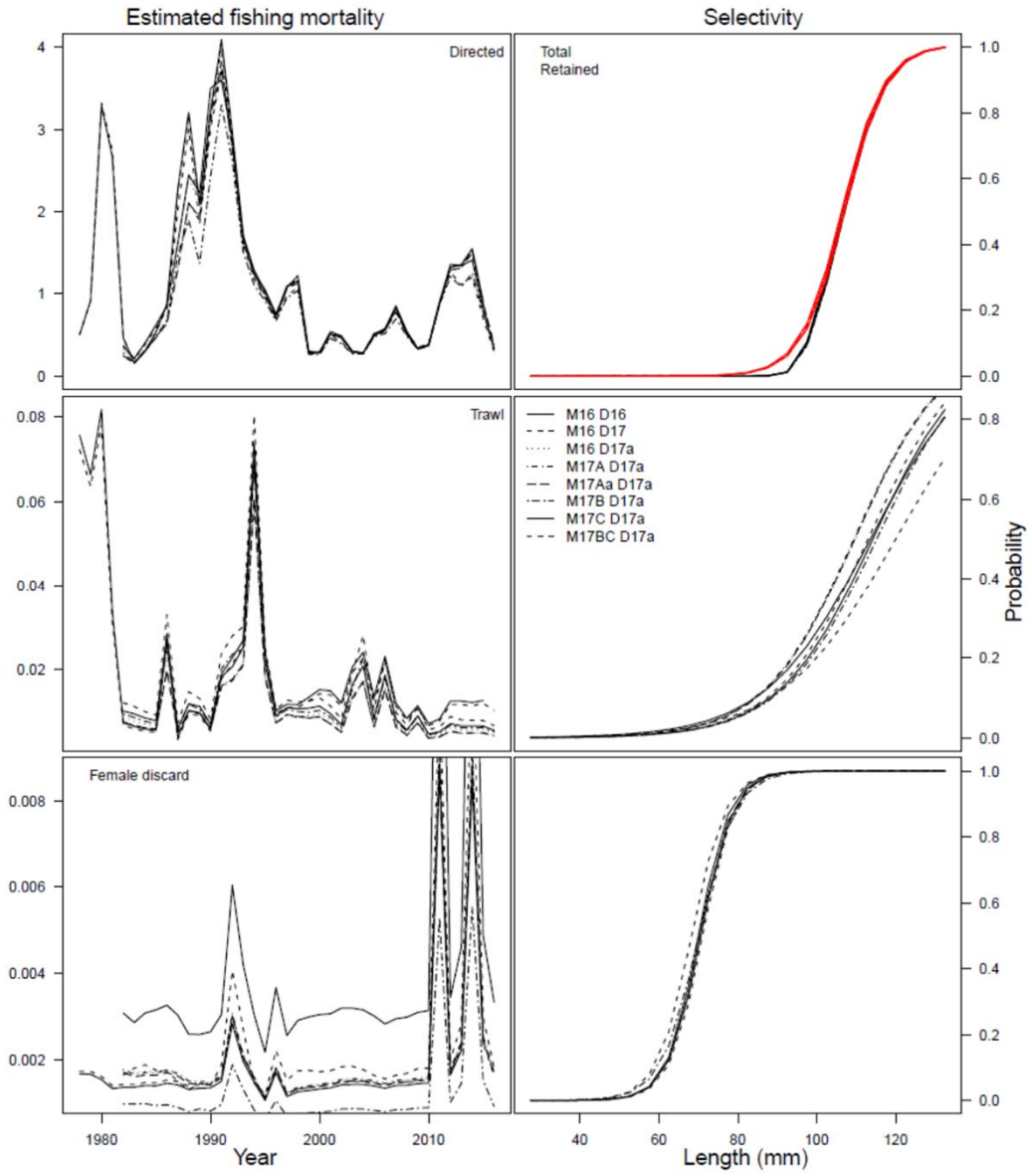
Mating

4.5/12 M

Molting

Growth

Recruitment



Survey

7.5/12 M

Directed fishery

Non-directed fishery

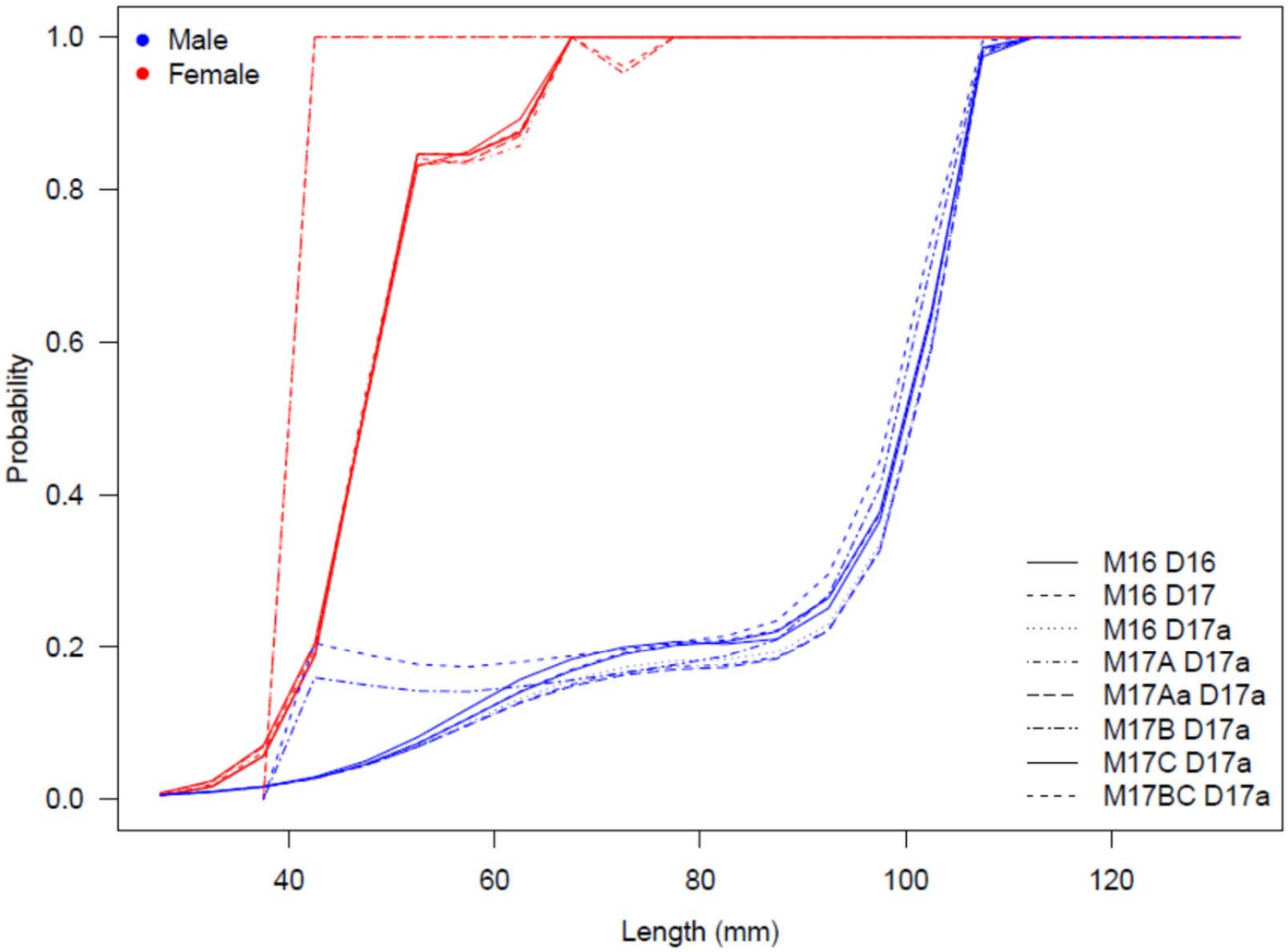
Mating

4.5/12 M

Molting

Growth

Recruitment



- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
- M17Aa.D17a (estimate logit BSFRF selectivity)
- M17B.D17a (Remove length bins <37.5mm)
  - Poor survey selectivity estimates and probability of maturing
- M17C.D17a (Estimate mature female M)
  - Fits female biomass the best
  - Female q in survey era 3 goes to 1
  - Correct relationship for M for mature males and females, but immature M decreases
- M17BC.D17a (Remove length bins < 37.5mm & estimate mature female M
  - Poor survey selectivity estimates and probability of maturing

Survey

7.5/12 M

Directed fishery

Non-directed fishery

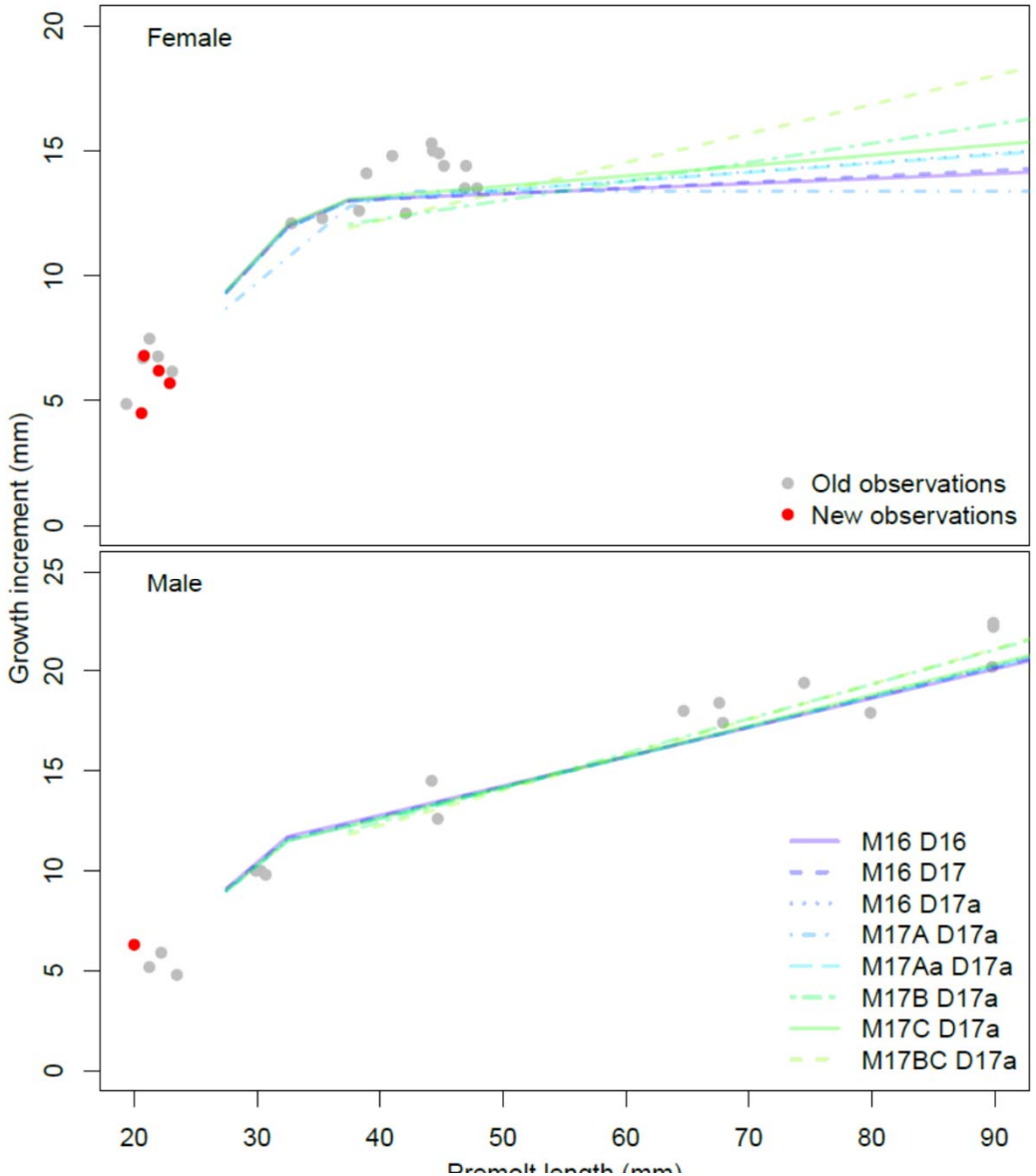
Mating

4.5/12 M

Molting

Growth

Recruitment



- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
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- M17B.D17a (Remove length bins <37.5mm)
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Survey

7.5/12 M

Directed fishery

Non-directed fishery

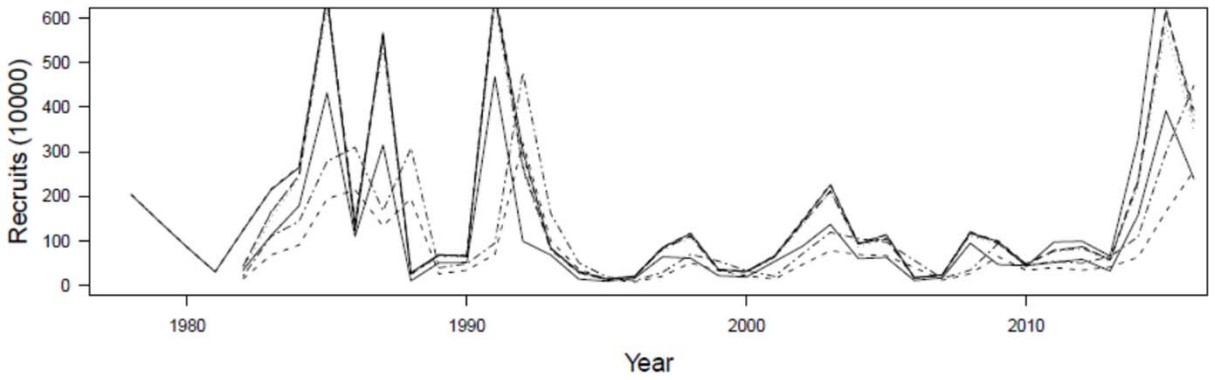
Mating

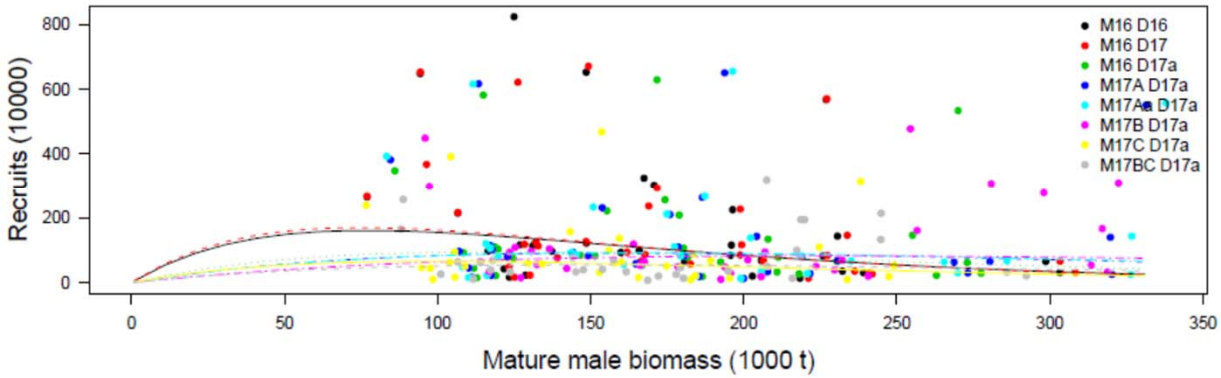
4.5/12 M

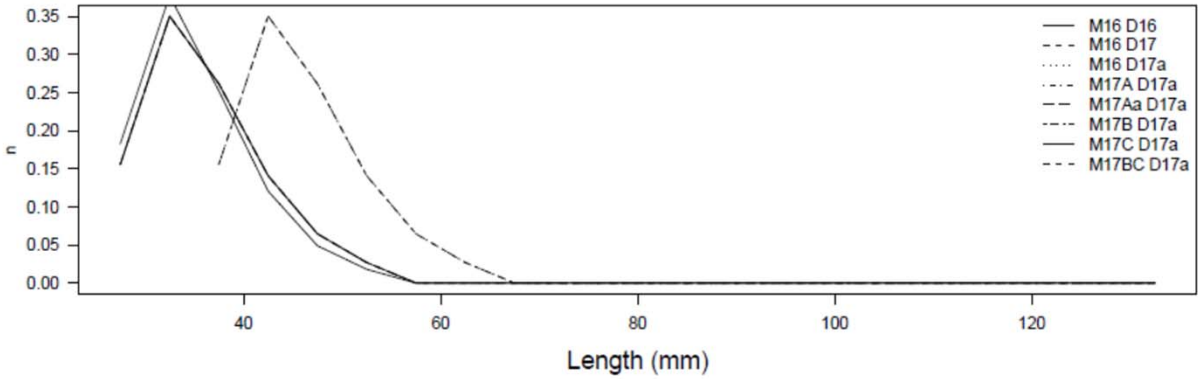
Molting

Growth

Recruitment







- M16.D17 (new data)
- M16.D17a (remove survey era 1)
- M17A.D17a (split survey era in 1987)
- M17Aa.D17a (estimate logit BSFRF selectivity)
- M17B.D17a (Remove length bins <37.5mm)
  - Poor survey selectivity estimates and probability of maturing
- M17C.D17a (Estimate mature female M)
  - Fits female biomass the best
  - Female q in survey era 3 goes to 1
  - Correct relationship for M for mature males and females, but immature M decreases
- M17BC.D17a (Remove length bins < 37.5mm & estimate mature female M
  - Poor survey selectivity estimates and probability of maturing

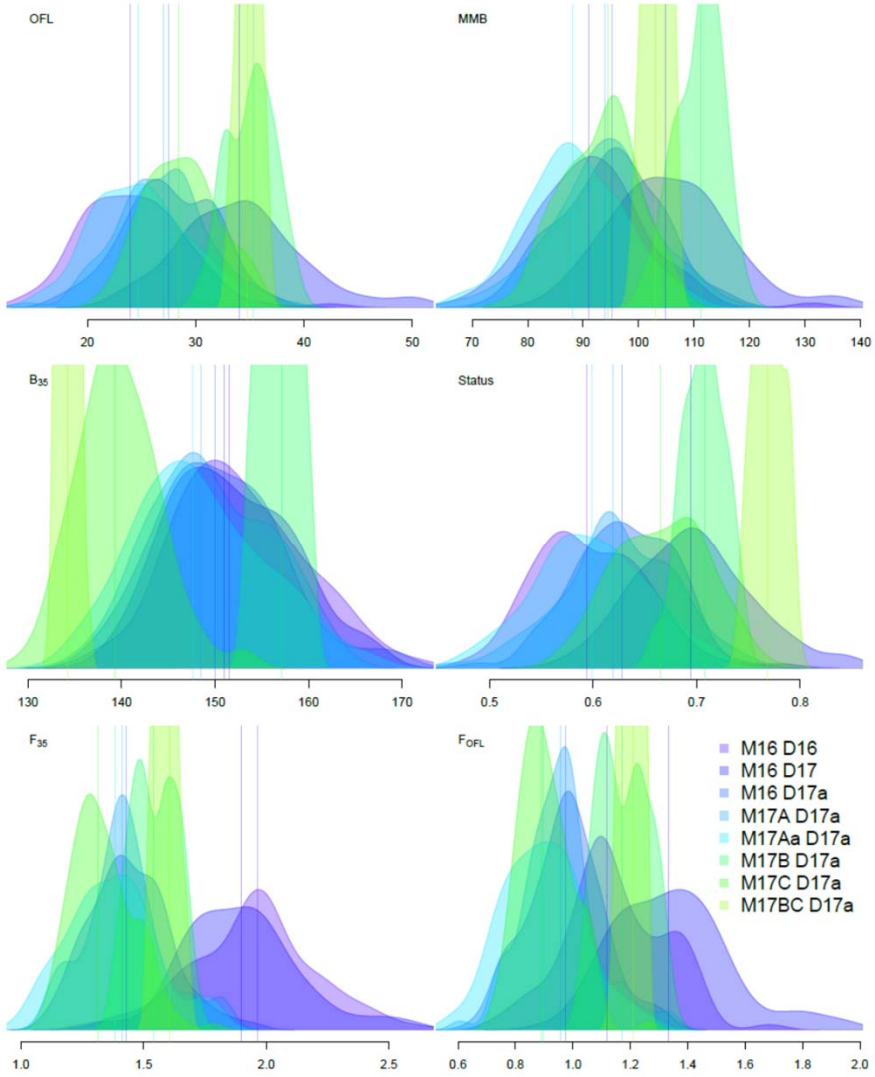
The OFL is 28.4 kt

The ABC is 25.6 kt

ML vs. Bayesian methods produce very similar OFLs for the chosen model

Table 1: Historical status and catch specifications for snow crab (1,000t).

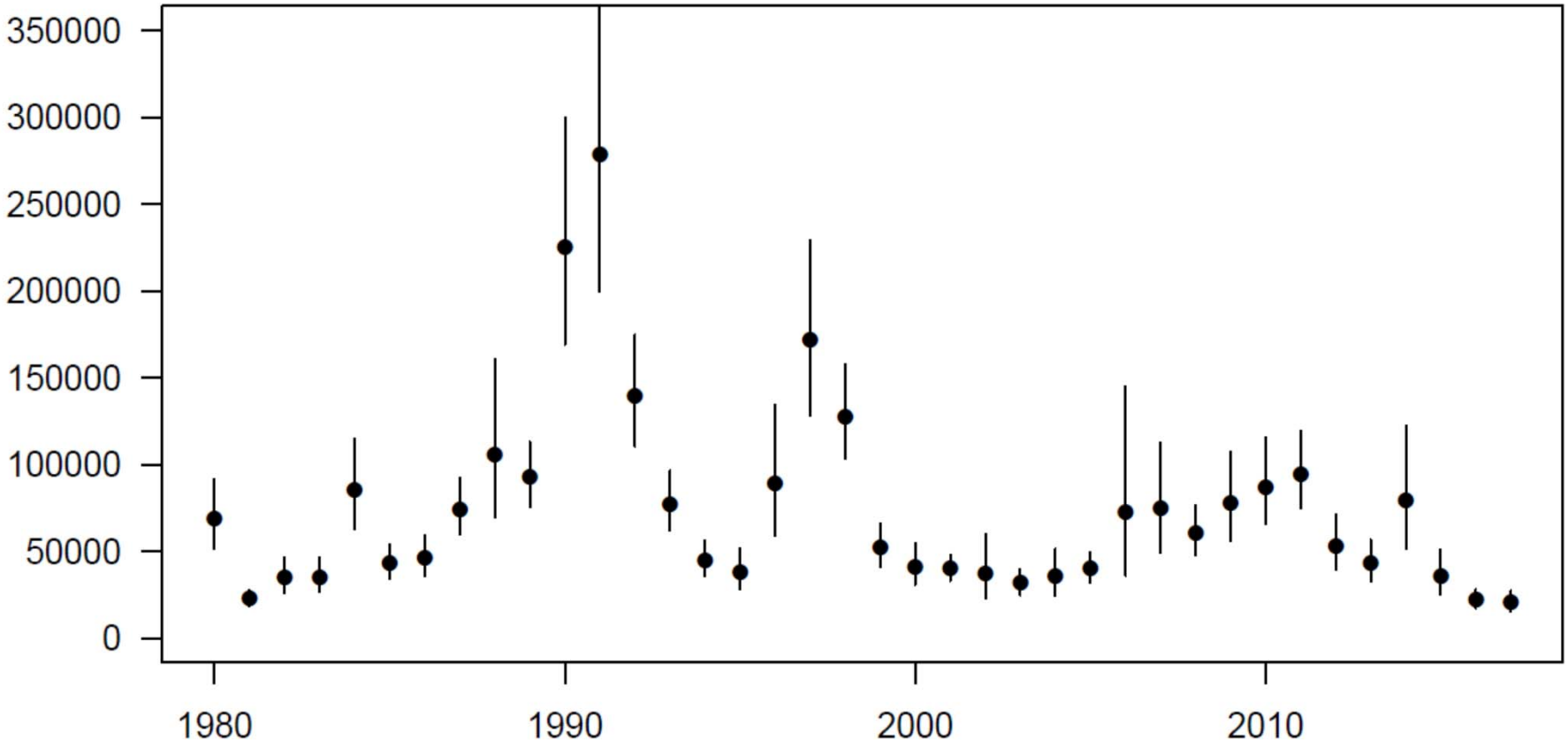
Year	MSST	Biomass (MMB)	TAC	Retained catch	Total catch	OFL	ABC
2011/2012	77.3	165.2	40.3	40.5	42	73.5	66.2
2012/2013	77.1	170.1	30.1	30.1	32.4	67.8	61
2013/2014	71.5	126.5	24.5	24.5	27.7	78.1	69.3
2014/2015	73.2	129.3	30.8	30.8	34.3	69	62.1
2015/2016	75.8	91.6	18.4	18.4	21.4	61.5	55.4
2016/2017	69.7	94.4	9.7	9.7	11	23.7	21.3
2017/2018	69.7	99.6				28.4	25.6


OFL
MMB
B_{35}
Status
F_{35}
F_{OFL}
20
30
40
50
70
80
90
100
110
120
130
140
130
140
150
160
170
0.5
0.6
0.7
0.8
1.0
1.5
2.0
2.5
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a

Things to think about

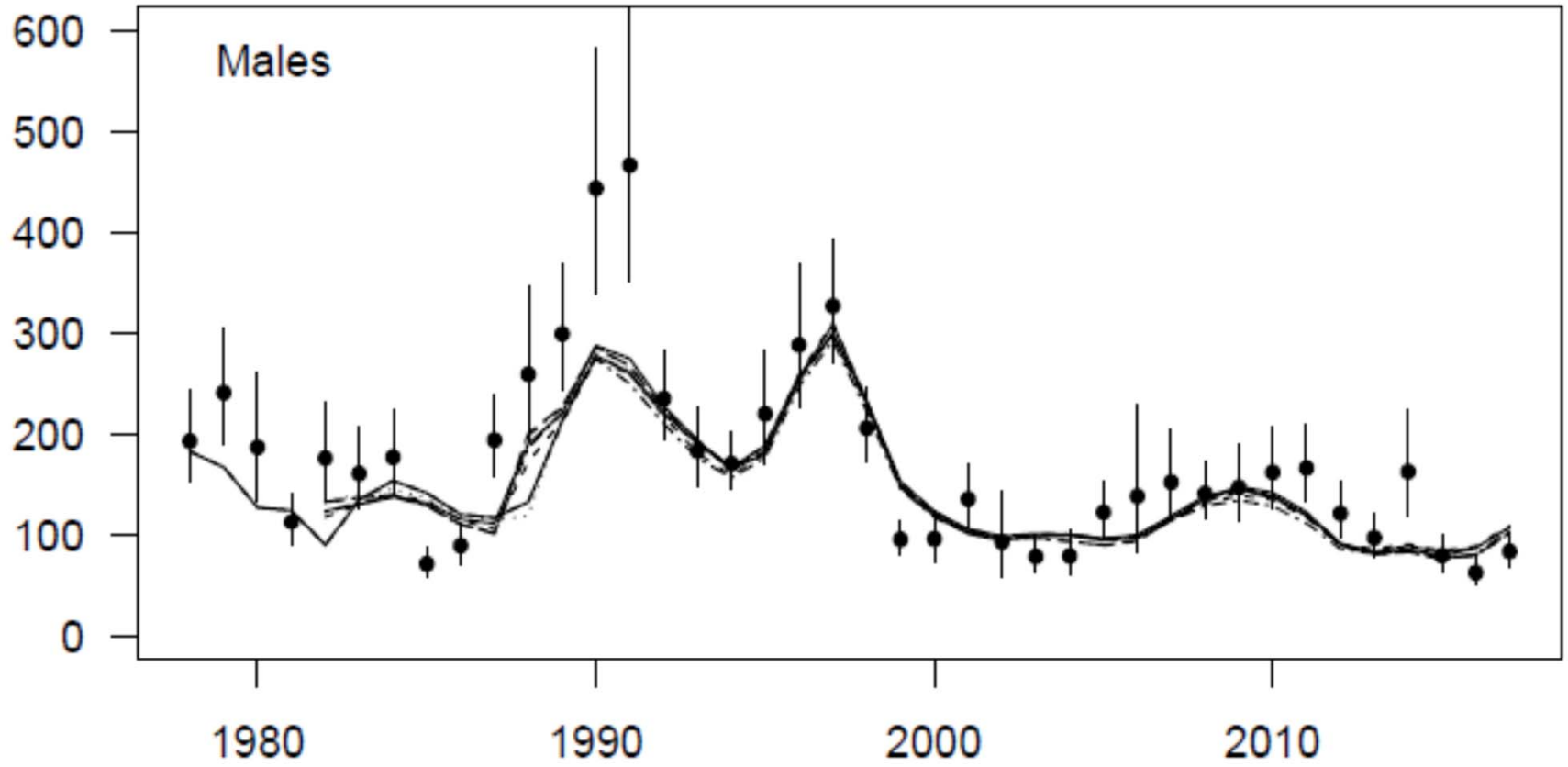
- If there are fewer legal males this year, why is the OFL higher than last year?
- Is a survey catchability of 1 in era 3 reasonable for females?
- When will we get growth data to fill the gaps?
- Data for the probability of maturing?
- Data weighting

- Observed survey males >101mm lowest on record



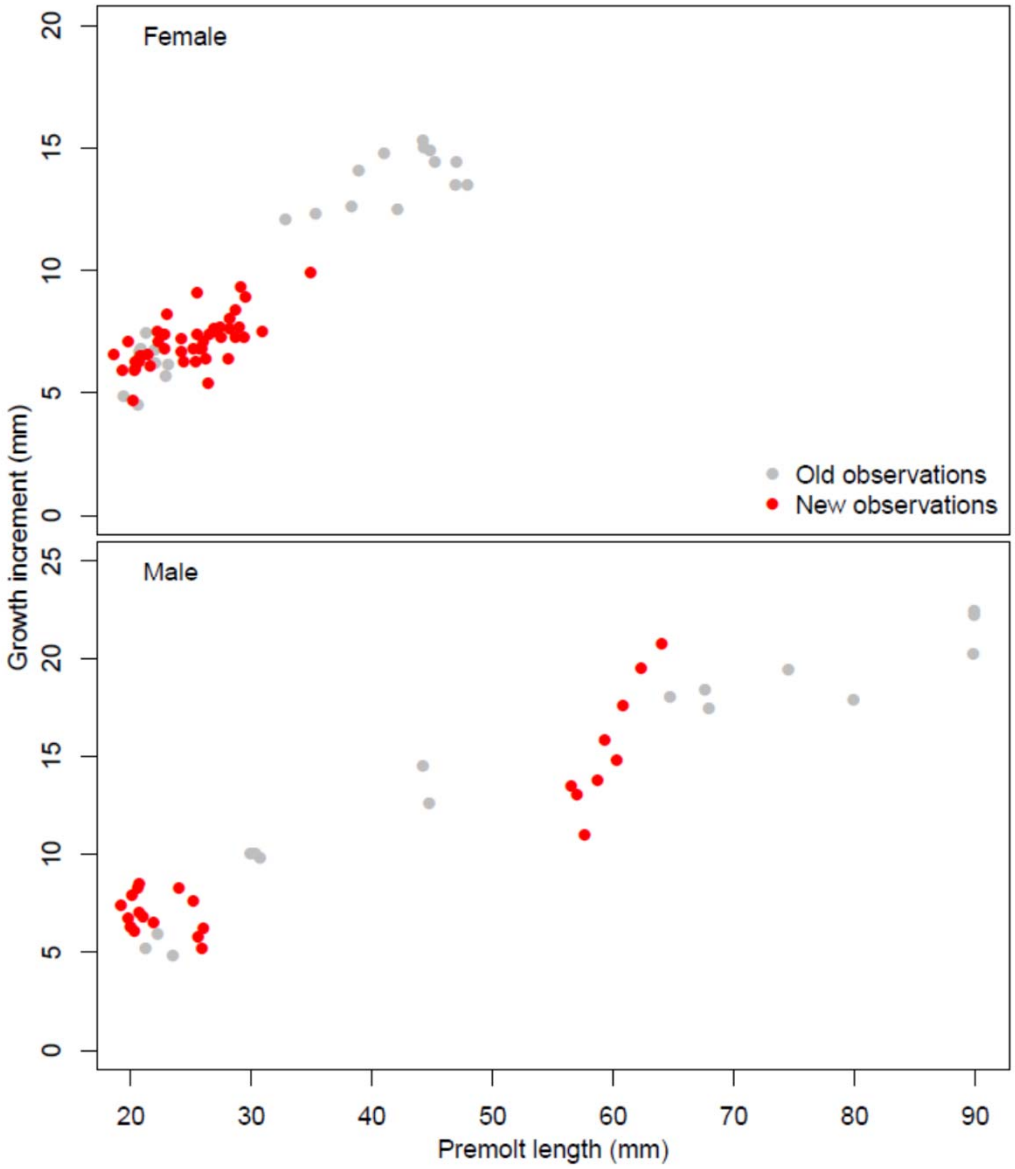
Model	MMB	B35	F35	FOFL	OFL
M16 D16	90.98	151.5	1.96	1.12	23.91
M16 D17	104.9	151	1.9	1.33	34.04
M17C D17a	94.43	139.3	1.31	0.89	28.41

- Observed survey MMB up slightly from last year's all time low



Things to think about

- If there are fewer legal males this year, why is the OFL higher than last year?
- Is a survey catchability of 1 in era 3 reasonable for females?
- When will we get growth data to fill the gaps?
- Data for the probability of maturing?
- Data weighting


Female
Male
Old observations
New observations
Growth increment (mm)
Premolt length (mm)
0
5
10
15
20
25
20
30
40
50
60
70
80
90

Things to think about

- If there are fewer legal males this year, why is the OFL higher than last year?
- Is a survey catchability of 1 in era 3 reasonable for females?
- When will we get growth data to fill the gaps?
  - Is a model with a change point still appropriate?
- Data for the probability of maturing?
- Data weighting and priors

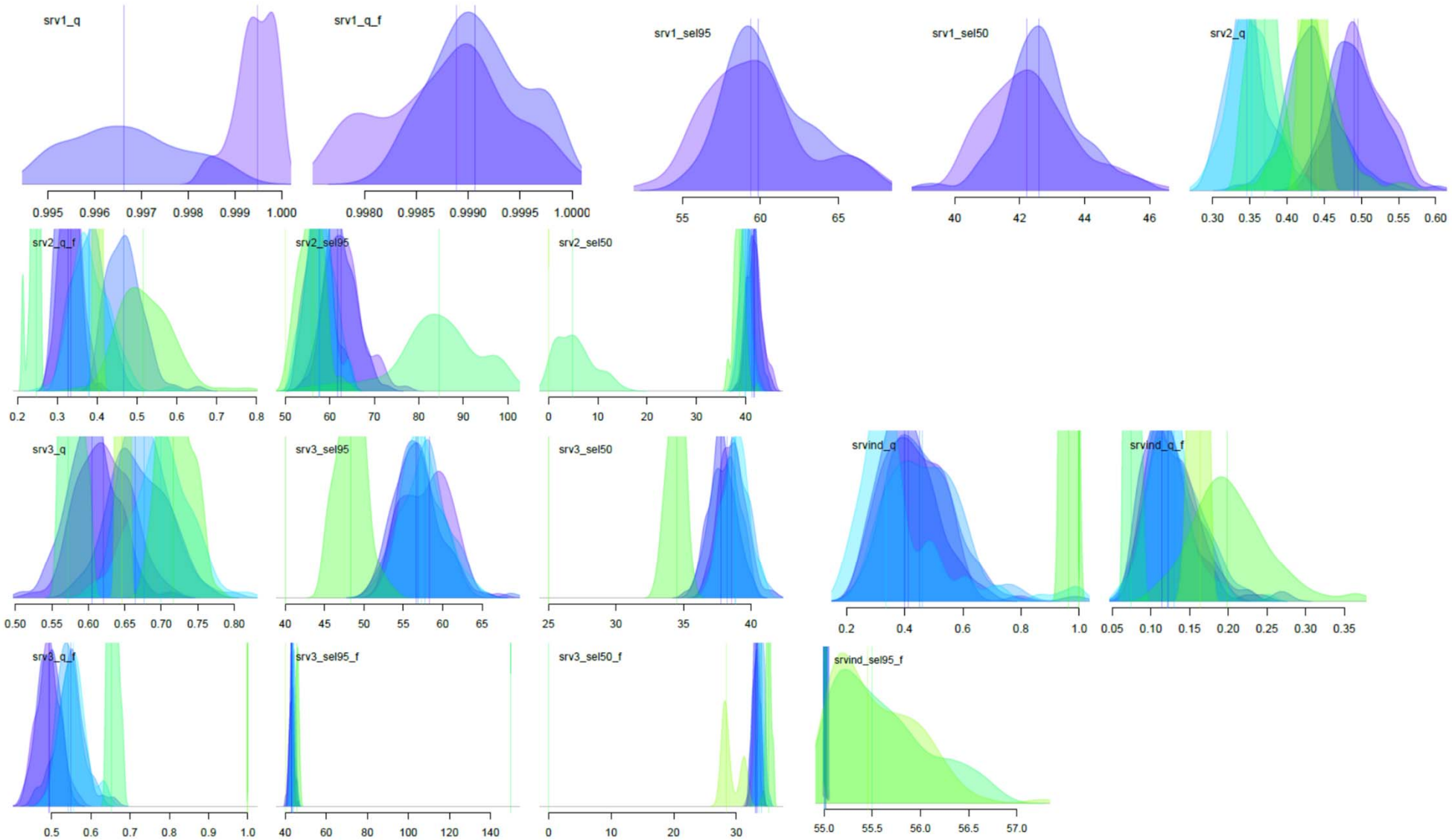
The OFL is 28.4 kt

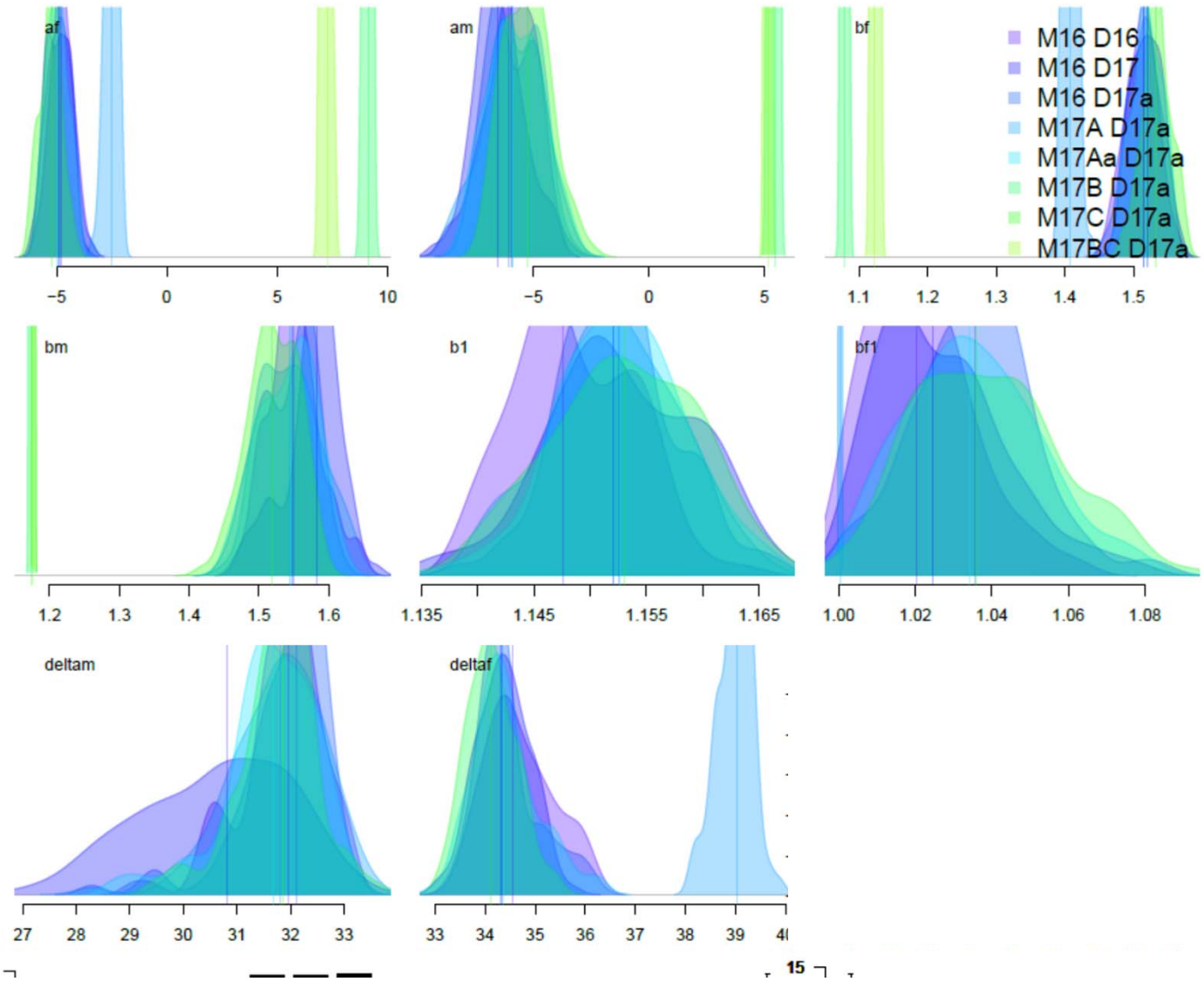
The ABC is 25.6 kt

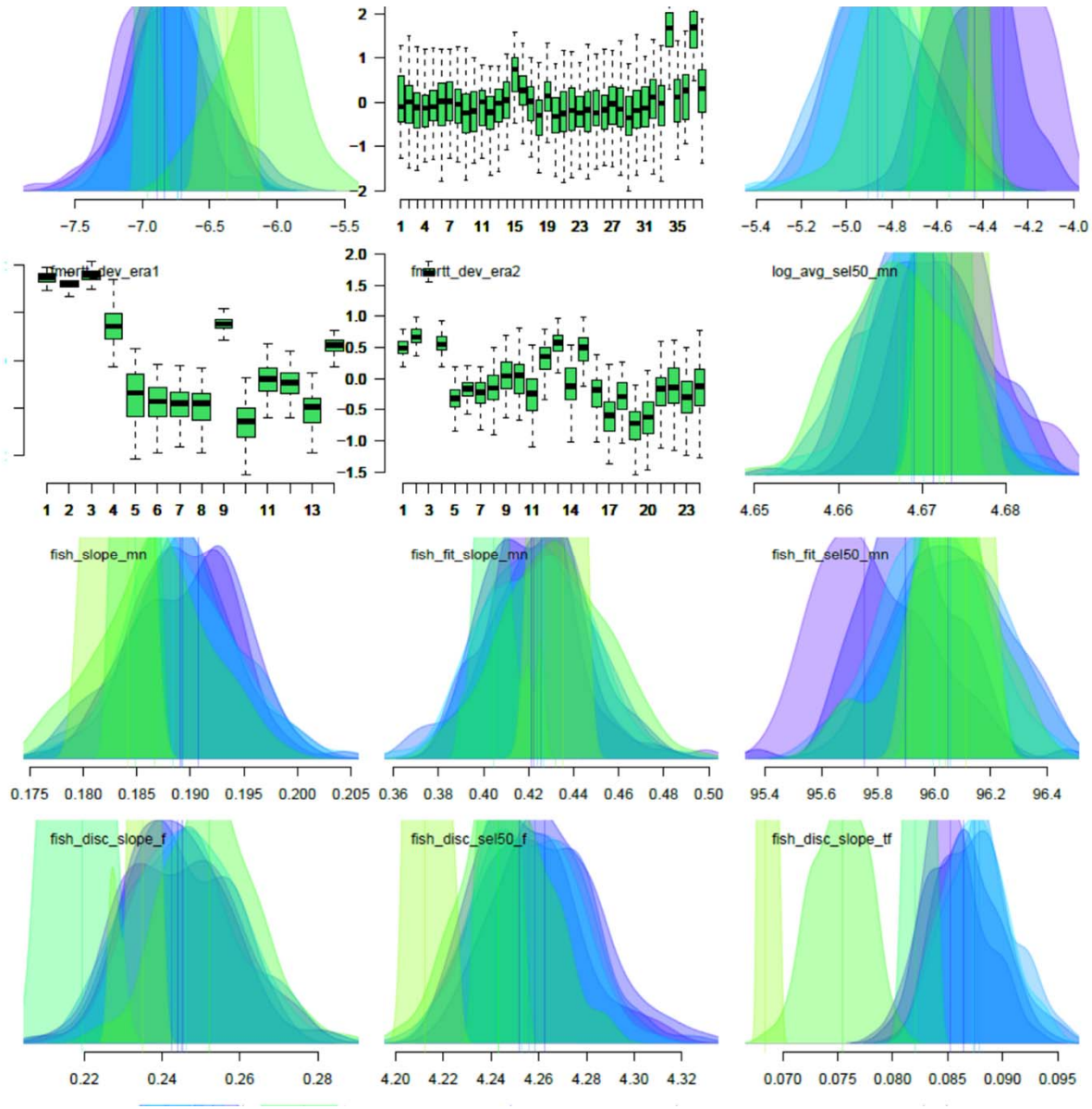
ML vs. Bayesian methods produce very similar OFLs for the chosen model

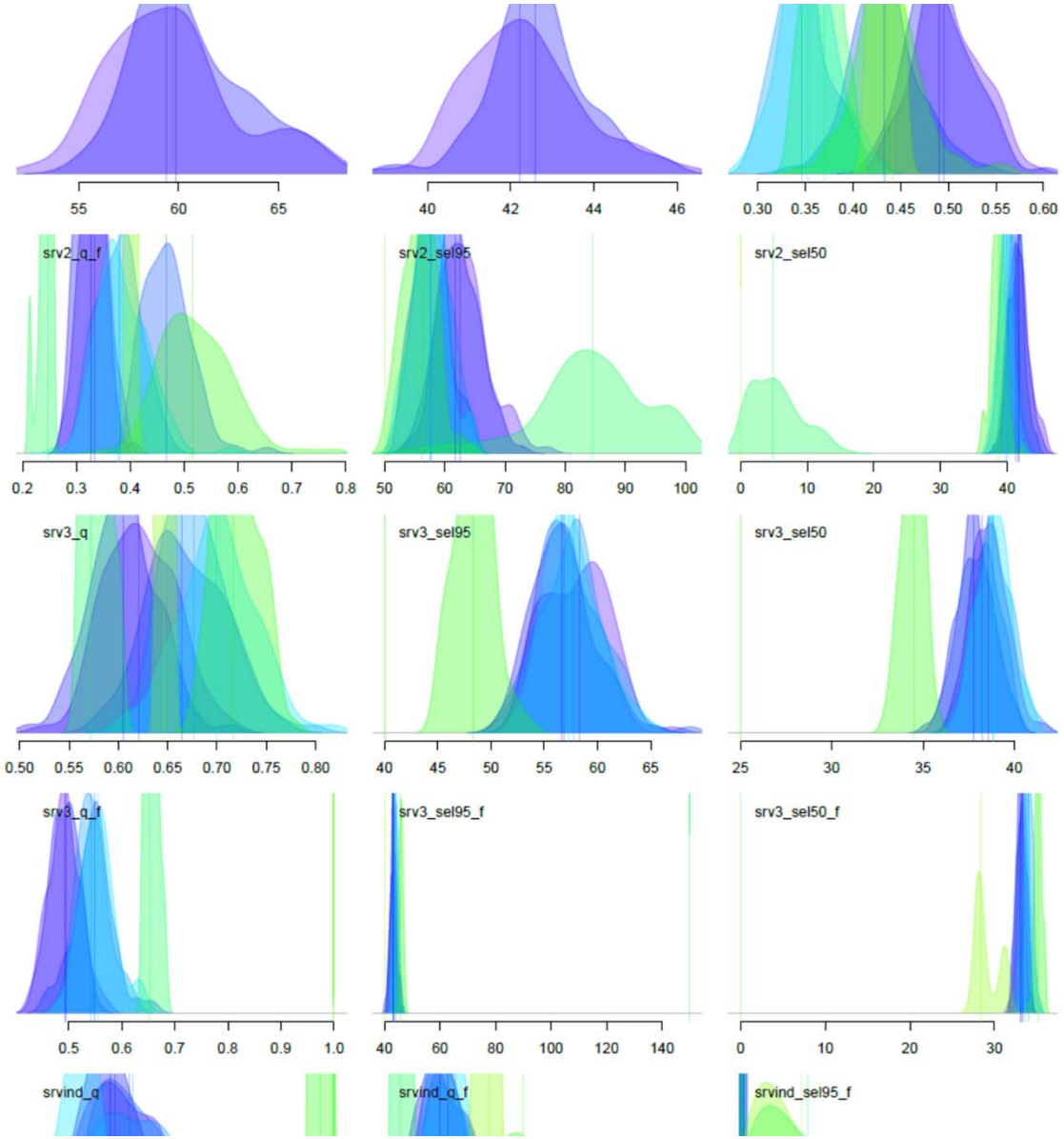
Table 1: Historical status and catch specifications for snow crab (1,000t).

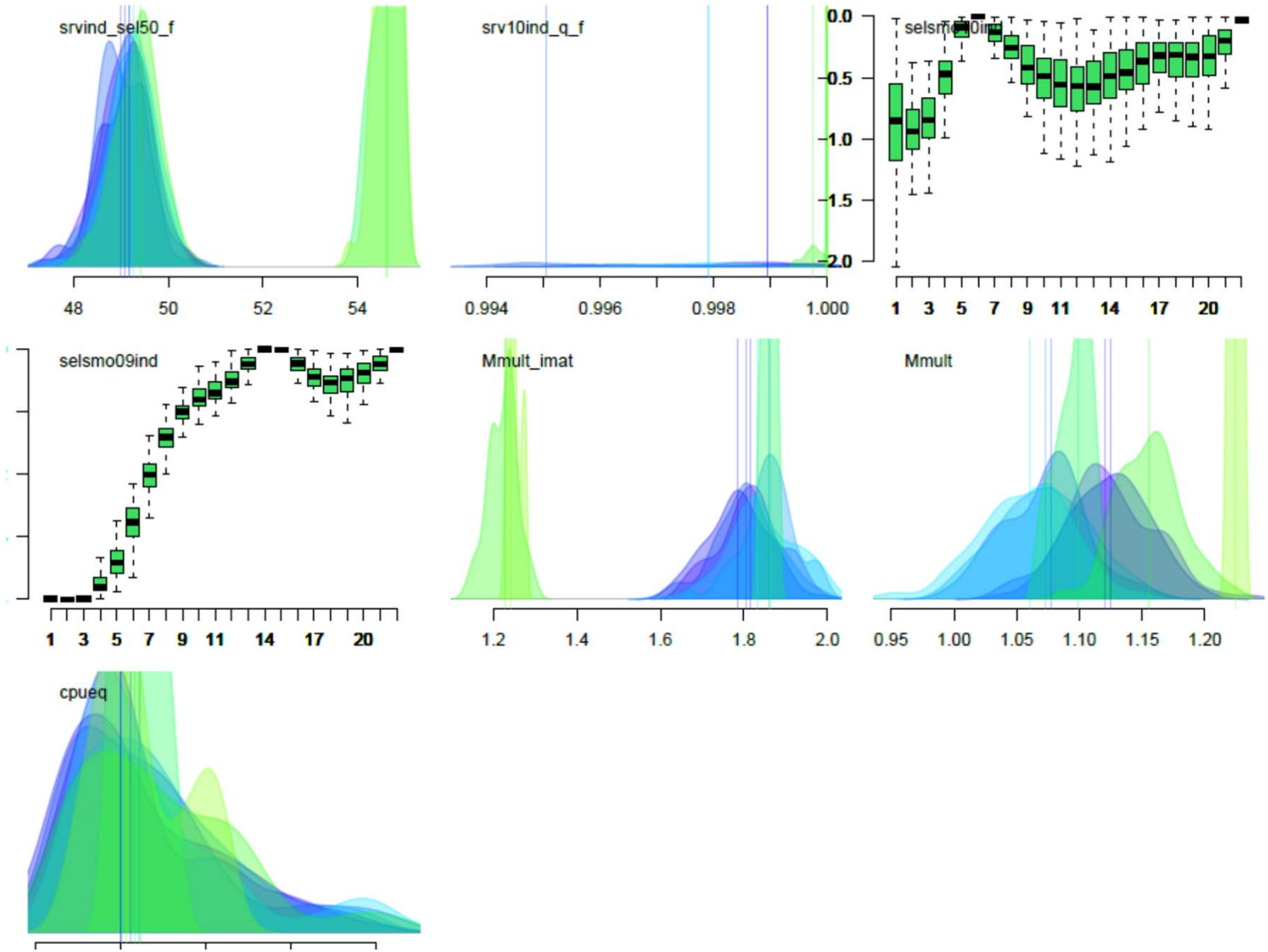
Year	MSST	Biomass (MMB)	TAC	Retained catch	Total catch	OFL	ABC
2011/2012	77.3	165.2	40.3	40.5	42	73.5	66.2
2012/2013	77.1	170.1	30.1	30.1	32.4	67.8	61
2013/2014	71.5	126.5	24.5	24.5	27.7	78.1	69.3
2014/2015	73.2	129.3	30.8	30.8	34.3	69	62.1
2015/2016	75.8	91.6	18.4	18.4	21.4	61.5	55.4
2016/2017	69.7	94.4	9.7	9.7	11	23.7	21.3
2017/2018	69.7	99.6				28.4	25.6


srv1_q
0.995 0.996 0.997 0.998 0.999 1.000
srv1_q_f
0.9980 0.9985 0.9990 0.9995 1.0000
srv1_sel95
55 60 65
srv1_sel50
40 42 44 46
srv2_q
0.30 0.35 0.40 0.45 0.50 0.55 0.60
srv2_q_f
0.2 0.3 0.4 0.5 0.6 0.7 0.8
srv2_sel95
50 60 70 80 90 100
srv2_sel50
0 10 20 30 40
srv3_q
0.50 0.55 0.60 0.65 0.70 0.75 0.80
srv3_sel95
40 45 50 55 60 65
srv3_sel50
25 30 35 40
srvind_q
0.2 0.4 0.6 0.8 1.0
srvind_q_f
0.05 0.10 0.15 0.20 0.25 0.30 0.35
srv3_q_f
0.5 0.6 0.7 0.8 0.9 1.0
srv3_sel95_f
40 60 80 100 120 140
srv3_sel50_f
0 10 20 30
srvind_sel95_f
55.0 55.5 56.0 56.5 57.0


af
am
bf
M16 D16
M16 D17
M16 D17a
M17A D17a
M17Aa D17a
M17B D17a
M17C D17a
M17BC D17a
bm
b1
bf1
deltam
deltaf


fish_slope_mn
fish_fit_slope_mn
fish_fit_sel50_mn
log_avg_sel50_mn
fish_disc_slope_f
fish_disc_sel50_f
fish_disc_slope_tf


55 60 65
40 42 44 46
0.30 0.35 0.40 0.45 0.50 0.55 0.60
srv2_q_f
0.2 0.3 0.4 0.5 0.6 0.7 0.8
srv2_sel95
50 60 70 80 90 100
srv2_sel50
0 10 20 30 40
srv3_q
0.50 0.55 0.60 0.65 0.70 0.75 0.80
srv3_sel95
40 45 50 55 60 65
srv3_sel50
25 30 35 40
srv3_q_f
0.5 0.6 0.7 0.8 0.9 1.0
srv3_sel95_f
40 60 80 100 120 140
srv3_sel50_f
0 10 20 30
srvind_q
srvind_q_f
srvind_sel95_f


srvind_sel50_f
48
50
52
54
srv10ind_q_f
0.994
0.996
0.998
1.000
0.0
-0.5
-1.0
-1.5
-2.0
1
3
5
7
9
11
14
17
20
selsmo09ind
Mmult_imat
1.2
1.4
1.6
1.8
2.0
Mmult
0.95
1.00
1.05
1.10
1.15
1.20
cpueq

Model	MMB	B35	F35	FOFL	OFL
M16 D16	90.98	151.5	1.96	1.12	23.91
M16 D17	104.9	151	1.9	1.33	34.04
M16 D17a	95.26	150	1.43	0.97	27.46
M17A D17a	93.86	148.5	1.41	0.96	26.99
M17Aa D17a	88.16	147.6	1.38	0.9	24.66
M17B D17a	111.3	157.1	1.54	1.17	35.3
M17C D17a	94.43	139.3	1.31	0.89	28.41
M17BC D17a	102.9	134.2	1.6	1.21	34.81