Estimation of selectivity, growth, and natural mortality in the assessment for EBS snow crab

Cody Szuwalski and Jack Turnock

May 4, 2017

Juneau, AK

and SSC comments

PT had several comments and questions related to formatting and presentation from the Septe
eeting:

- eview SAFE guidelines to make sure required tables and figures are present
- lot the relative proportion of new to old shell males to see how important the lack of fit to old
  ales really is
- lot Bayesian posterior intervals for growth parameters
- odel 0 has to be last year's accepted model

issues will be corrected in the SAFE document presented at the September meeting. The CPT
veral suggestions for potential model runs and expanded analyses, including:

- stimate M for mature females
- ocument rationale for prior on M for immature crab
- ry starting the assessment in 1982 to check the behavior of the survey qs when the first survey s
  excluded
- pply priors to the survey qs so they are somewhat constrained
- rovide more detailed MCMC chain diagnostics
- xtract bycatch mortality from the Tanner crab directed fisheries that is currently lumped int
  roundfish trawl bycatch (in a table in the assessment chapter, not necessarily in the model)

rview

- CMC diagnostics and Bayesian vs. maximum likelihood
  - Bayesian methods designed to produce distributions
  - Diagnostics suggests some problematic population processes
- rvey selectivity
  - Eliminate the first 4 years of data
  - Think about how to use BSFRF data
- rowth
  - Piece-wise models causes problems, but contributes little to the model
  - Unclear what the best model is
- atural mortality
  - Mature female natural mortality should be estimated
  - Priors for immature natural mortality should be revisited

esian methods vs. maximum likelihood

set a TAC that accounts for scientific uncertainty

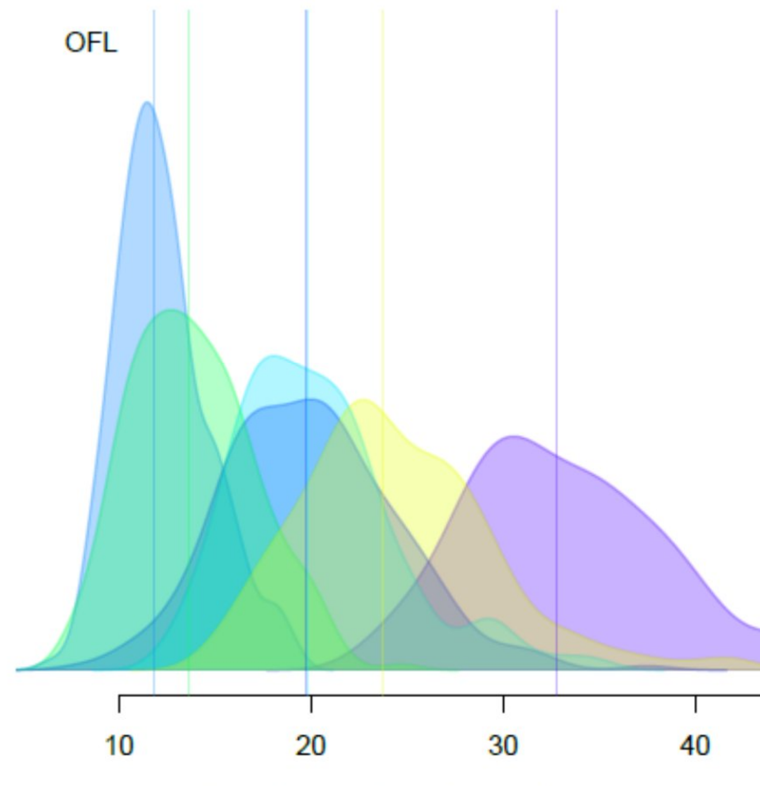
cal methods:

nate parameters via ML

t parameters into projection script

t numbers at length for the final year in the ection script with error

ulate a distribution of the OFL based on the error ed to the numbers at length



ms with historical methods:

meter values are not perfectly know, but are med so.

r added to numbers at length is arbitrary, but rmines the distribution of the OFL.

ring was required to ensure MLEs were found

esian methods vs. maximum likelihood

set a TAC that accounts for scientific uncertainty

an methods:

me a distribution for each parameter

ot require copying and pasting model output

erior distributions of the OFL are a result of the
rtainty in parameter estimates

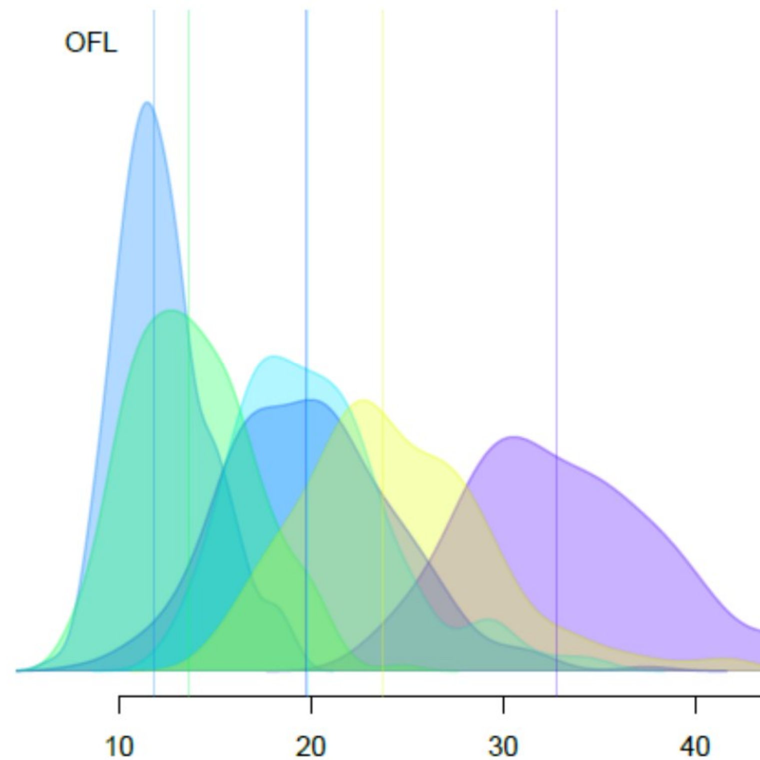
with Bayesian methods:

s must be specified

e-consuming

ving the model has converged is difficult (though
e are many diagnostics to identify non-
ergence)

nt on the var/covar matrix; therefore reliant on an
opriately specified model



esian methods vs. maximum likelihood

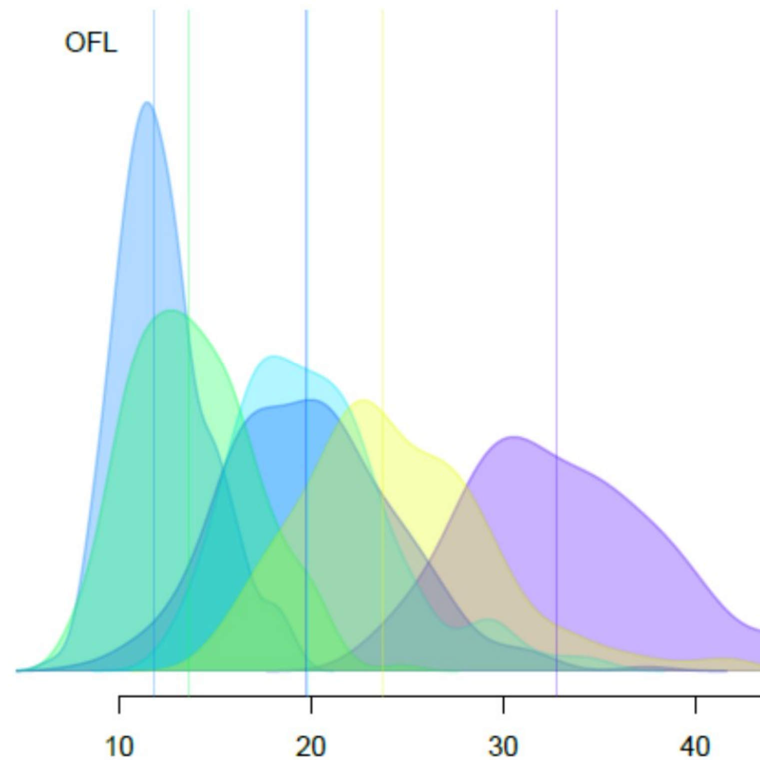
sible modification of historical methods
avoids Bayesian methods:

ulate the OFL during the fitting of the
del instead of in the report section and
ude the OFL as a sd_report variable

n produce a distribution of the OFL with its
ulated standard deviation

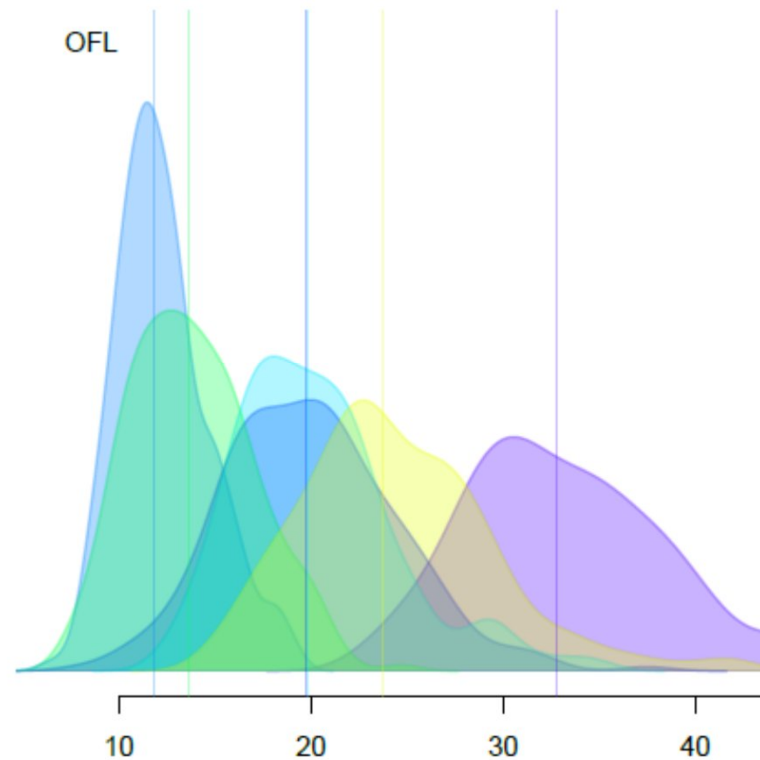
ed this once with the 'Trim data' model,
the model blew up.

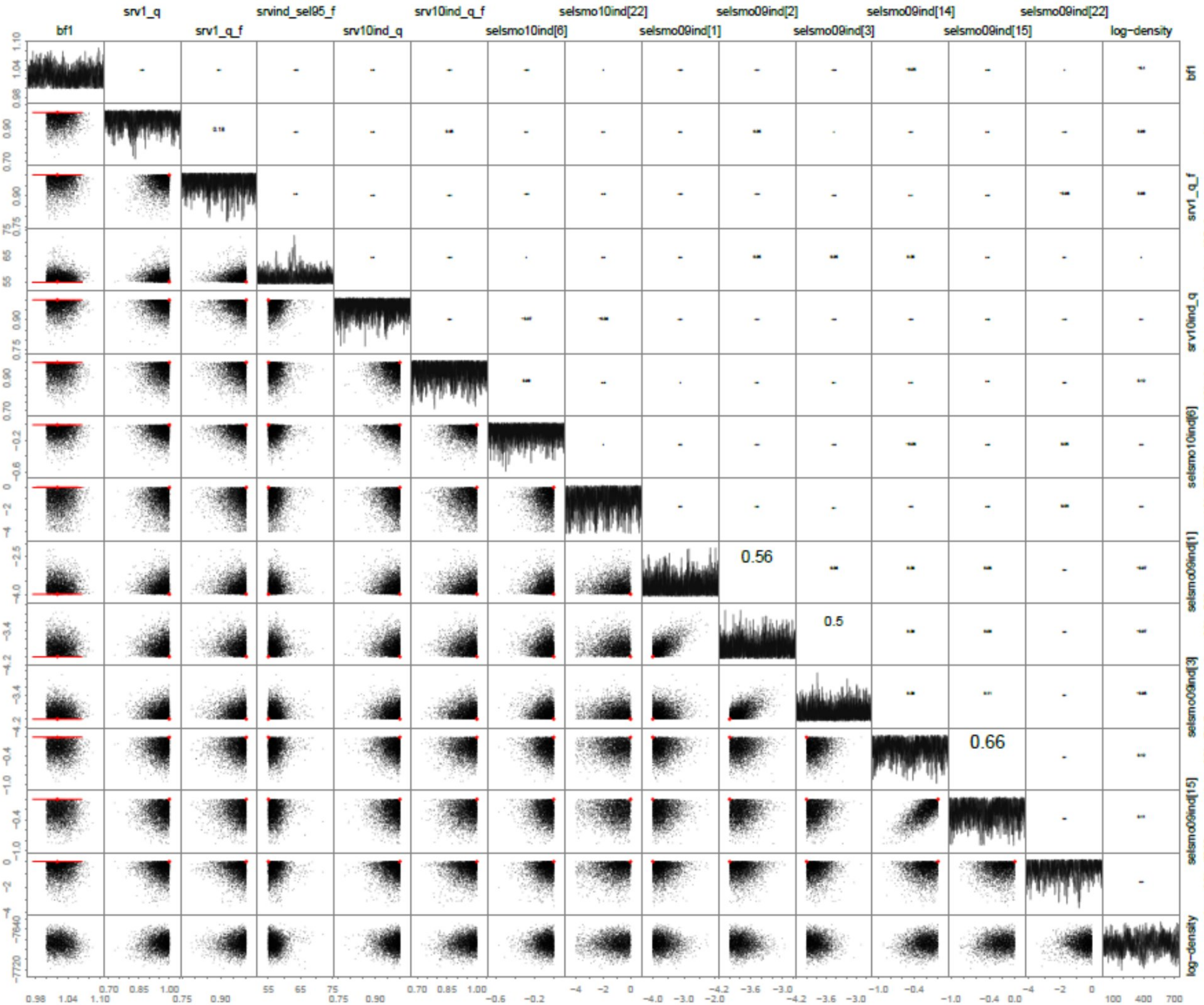
kes forever to fit the model because
rence points and the OFL have to be
ulated in every step.



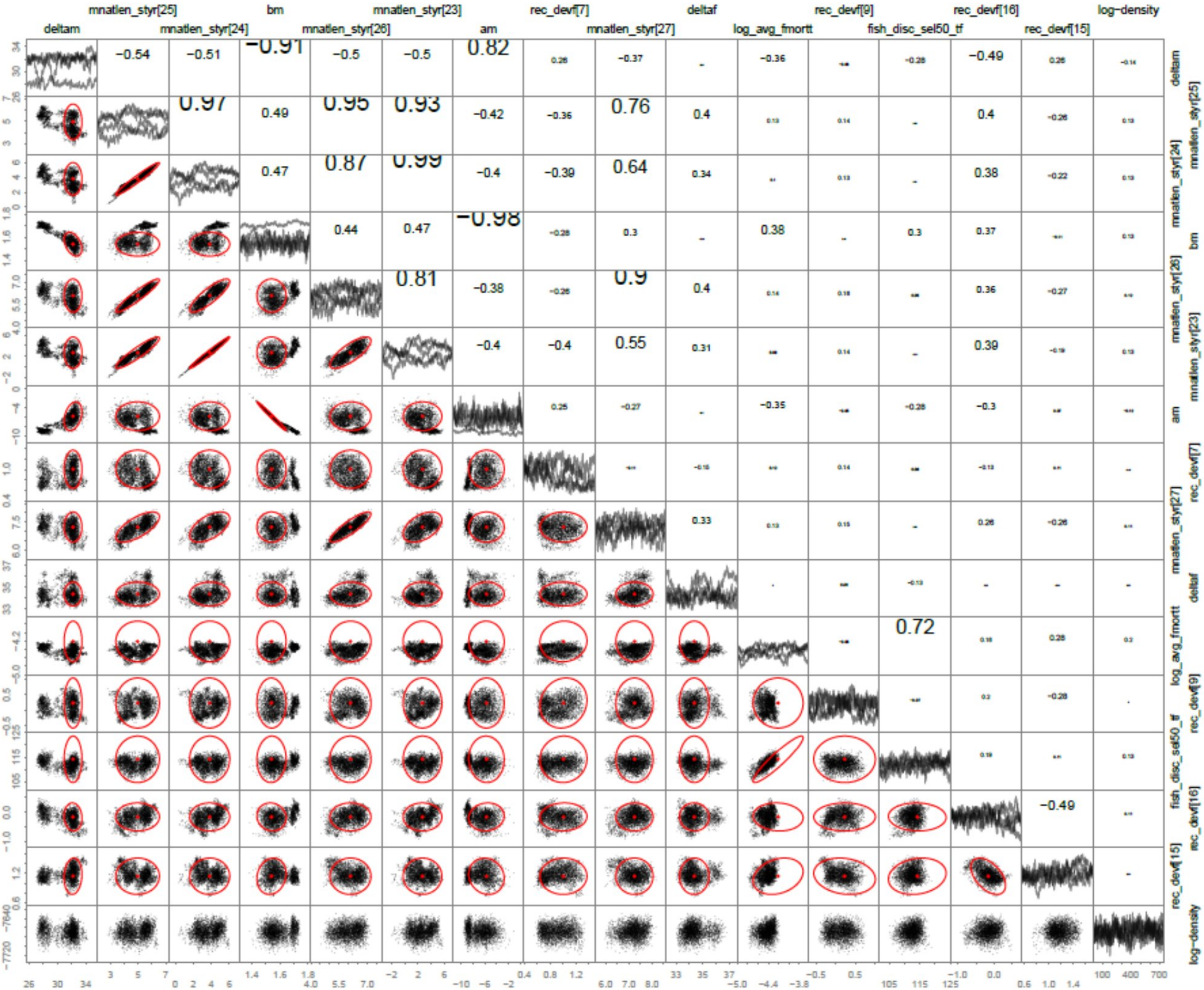
MC diagnostics

- C is used to 'build' the distributions of neters and derived quantities
- gnostics check for appropriate specification ne model and var/covar matrix (used to ore the posterior)
- ionarity in the traces for parameters and objective function (mixing)
- parameters hitting bounds
- ere are problems in these diagnostics, be tious about inference from the model





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


deltam
mnatlen_styr[25]
mnatlen_styr[24]
bm
mnatlen_styr[26]
mnatlen_styr[23]
am
rec_devf[7]
mnatlen_styr[27]
deltaf
log_avg_fmortt
rec_devf[9]
fish_disc_sel50_tf
rec_devf[16]
rec_devf[15]
log-density

gnostic summary

- eral processes have problem parameters
- y mixing:
  - Growth parameters
  - Rec devs
  - nitial numbers at length
- nd hitting
  - Growth parameters
  - urvey selectivity (NMFS) during era 1
  - ndustry survey selectivity parameters
- t with slow mixing by using really long chains last year, but this takes a very time
- hods for adjustment
  - riors on parameters hitting their bounds
  - Reformulating the model
  - xcluding problematic periods of data

mating survey selectivity

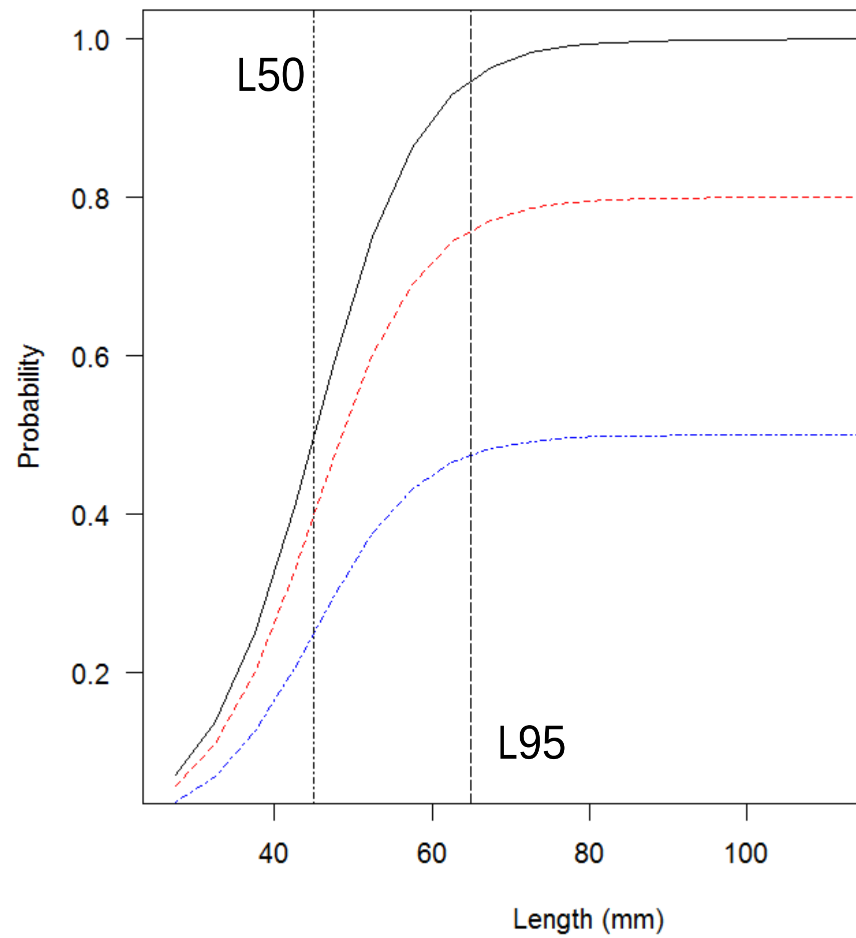
- storical methods
- ta
- odel runs
- odel results
  - Fits
  - OFL and reference points
  - Processes influenced
- commendations

torical methods

$$S_l = \frac{q}{1 + e^{\left(-\ln(19)\frac{L_{?}-L_{??}}{L_{??}-L_{?}}\right)}}$$

gistic selectivity

- ree eras
  - 1978-1981: different gear
  - 1982-1988: different area
  - 1989-present: current
- chability coefficient (q)
  - Changes in estimates over time
  - Era 1 has always been fixed at 1
- ues
  - Q modulates the impact of catch on the survey index
  - Foreign fleets were excluded starting 1980, so it's not clear if the catches are fully represented in era 1
  - Q in the first era is consistently estimated on its bounds and anchors the catchability in the other era
- e the survey eras appropriately chosen?
- e there alternate sensible configurations?



torical methods

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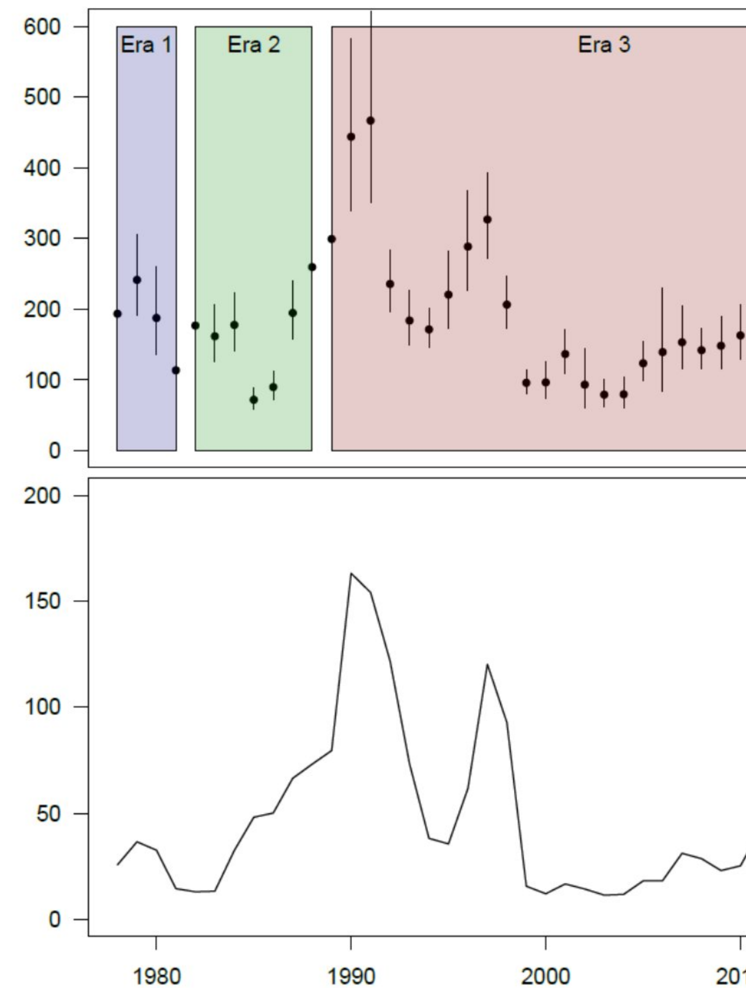
$$S_l = \frac{q}{1 + e^{\left(-\ln(19)\frac{L_{?} - \beta_{??}}{\beta_{??} - \beta_{?}}\right)}}$$



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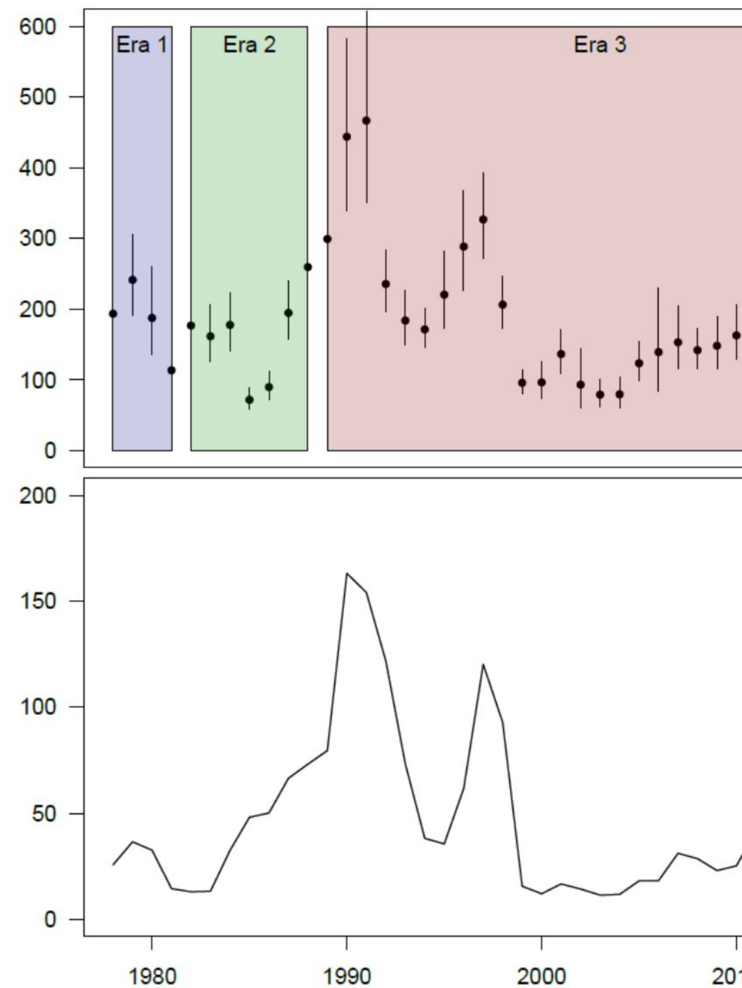

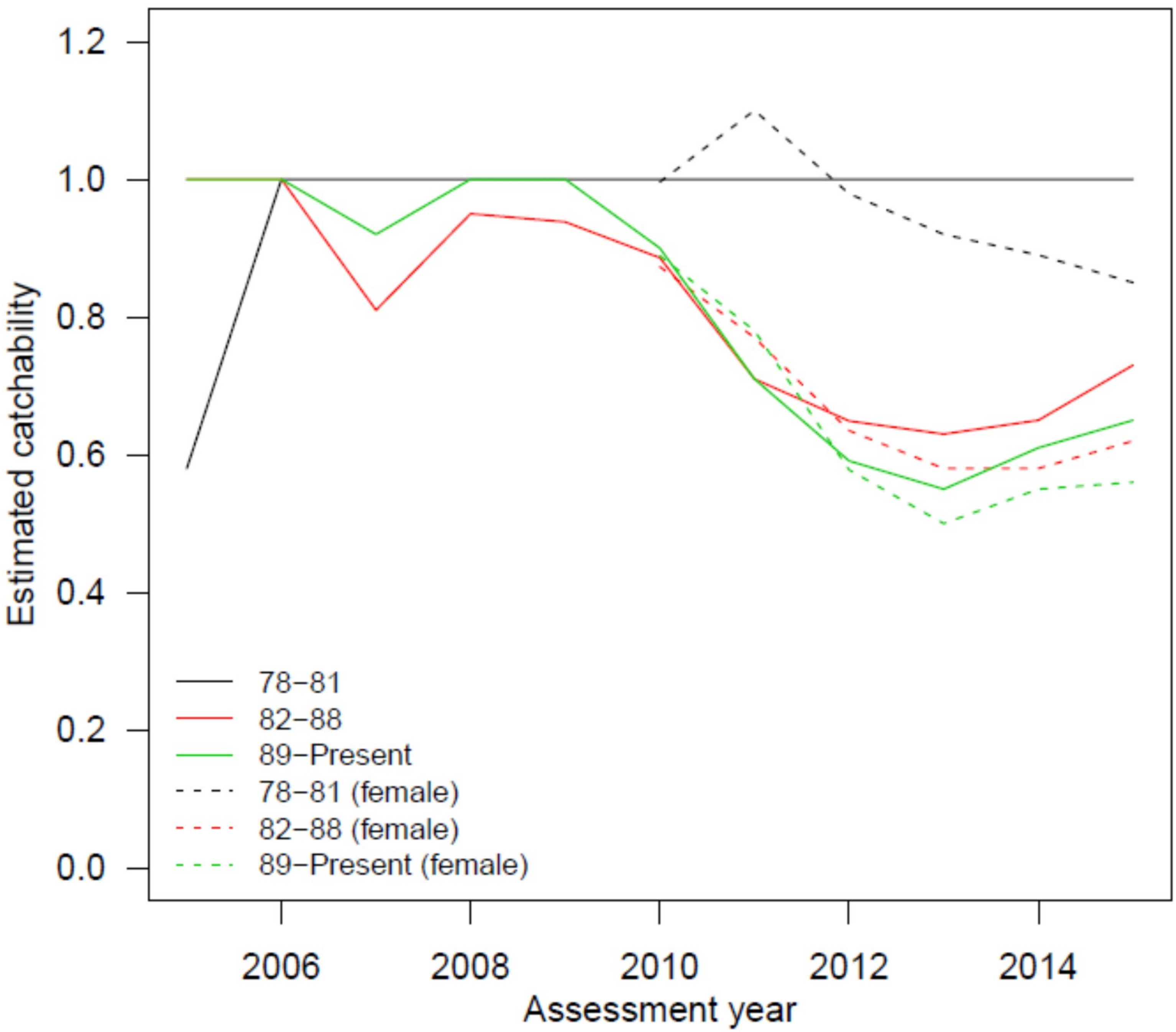

Estimated catchability
Assessment year
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2006
2008
2010
2012
2014
78−81
82−88
89−Present
78−81 (female)
82−88 (female)
89−Present (female)

torical methods

$$S_l = \frac{q}{1 + e^{\left(-\ln(19)\frac{L_? - \beta_{??}}{\beta_{??} - \beta_{?}}\right)}}$$

- gistic selectivity
- ree eras
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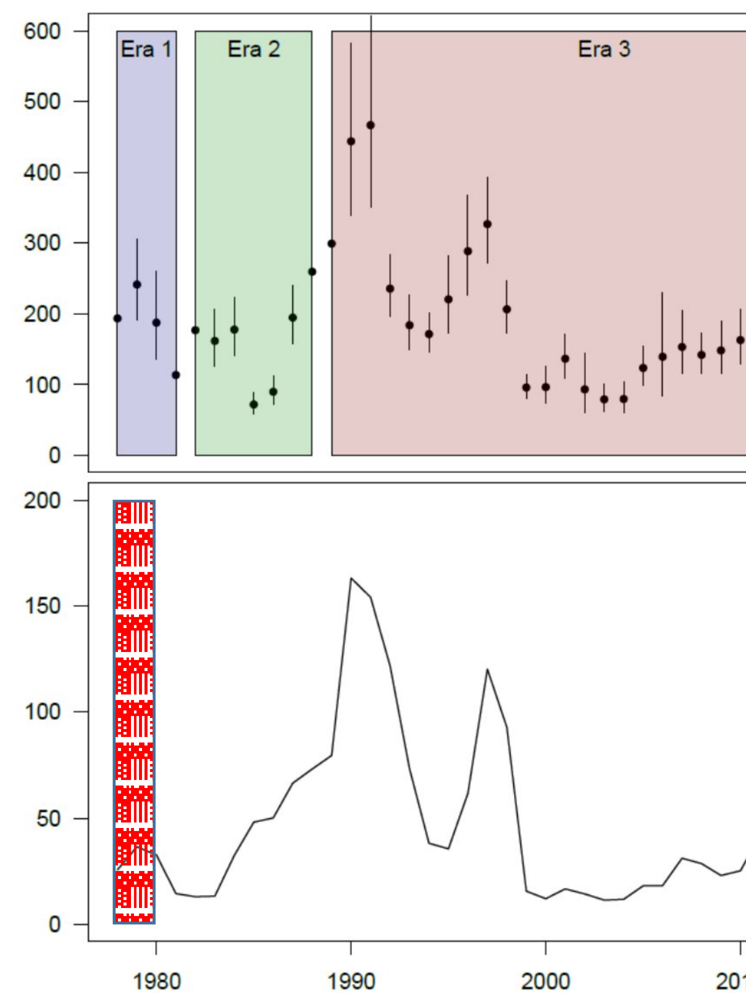
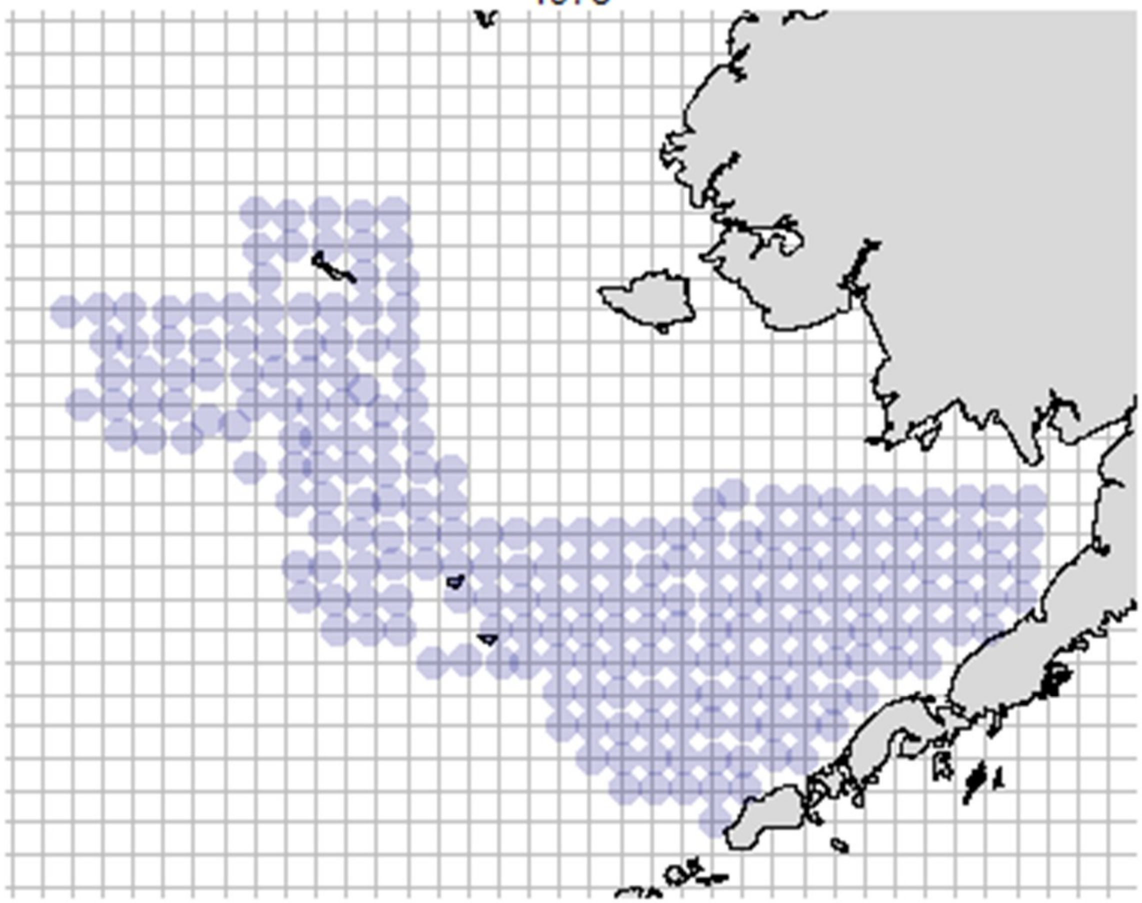
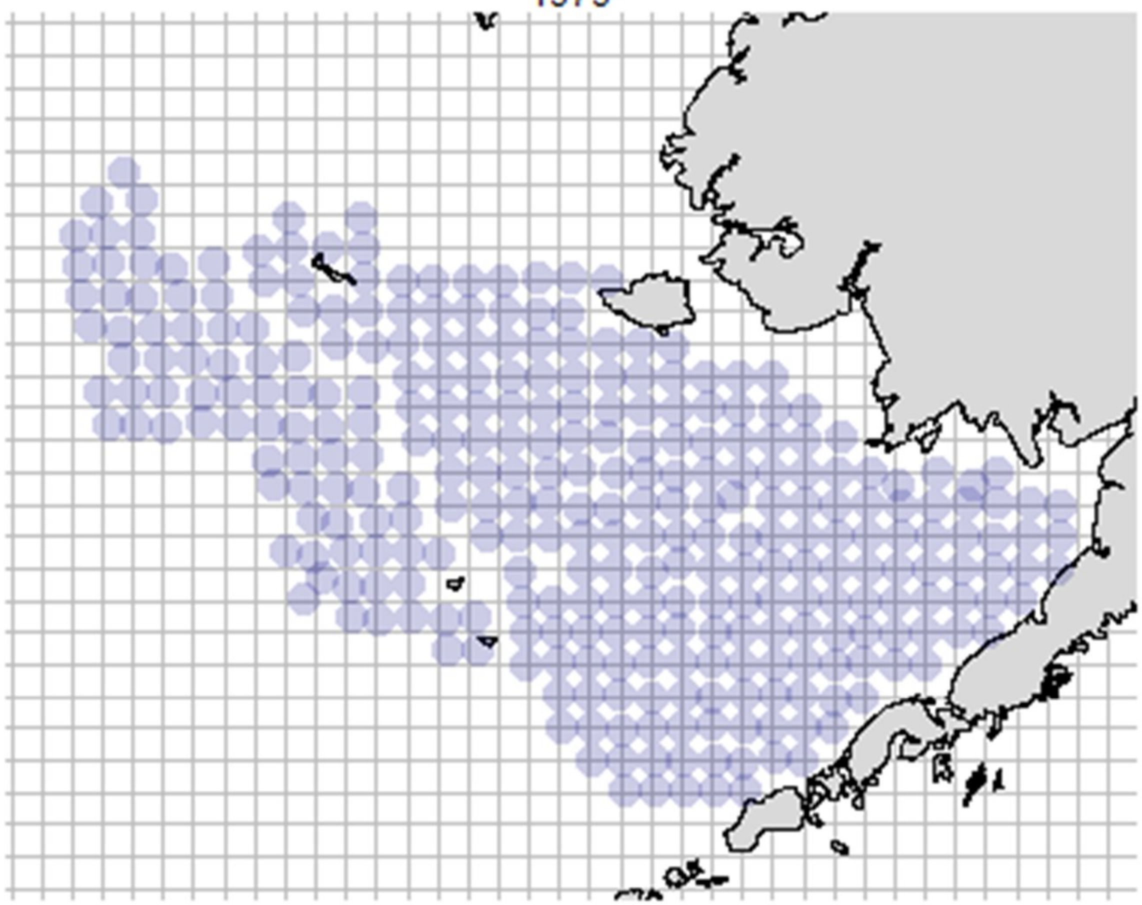


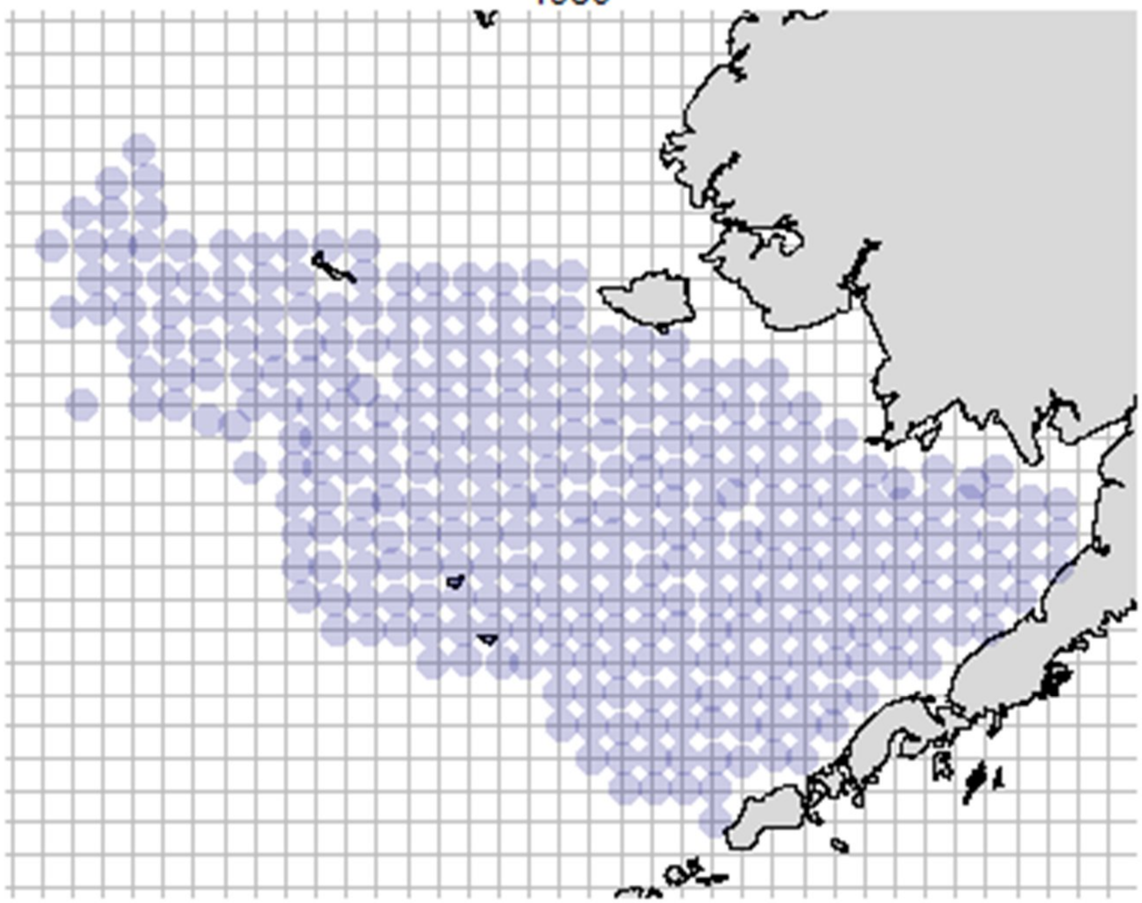
1978



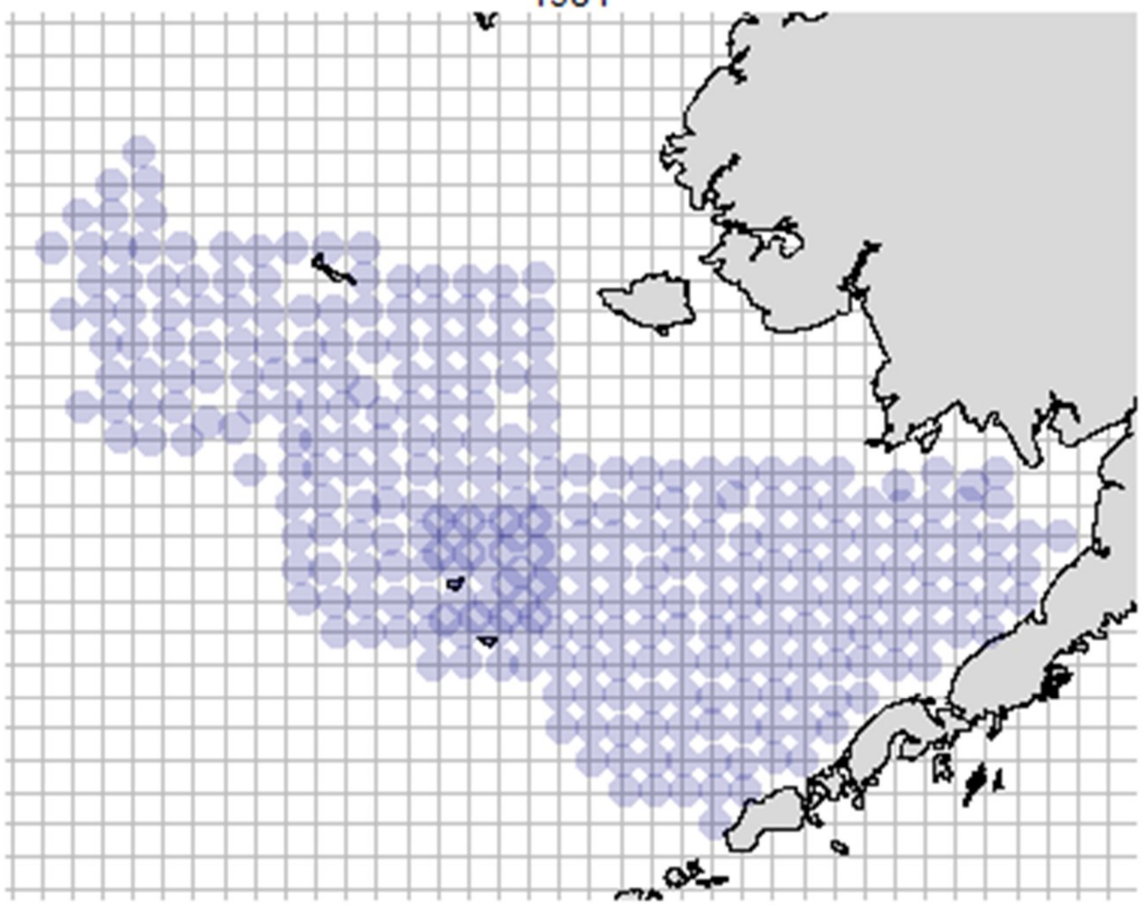
1979



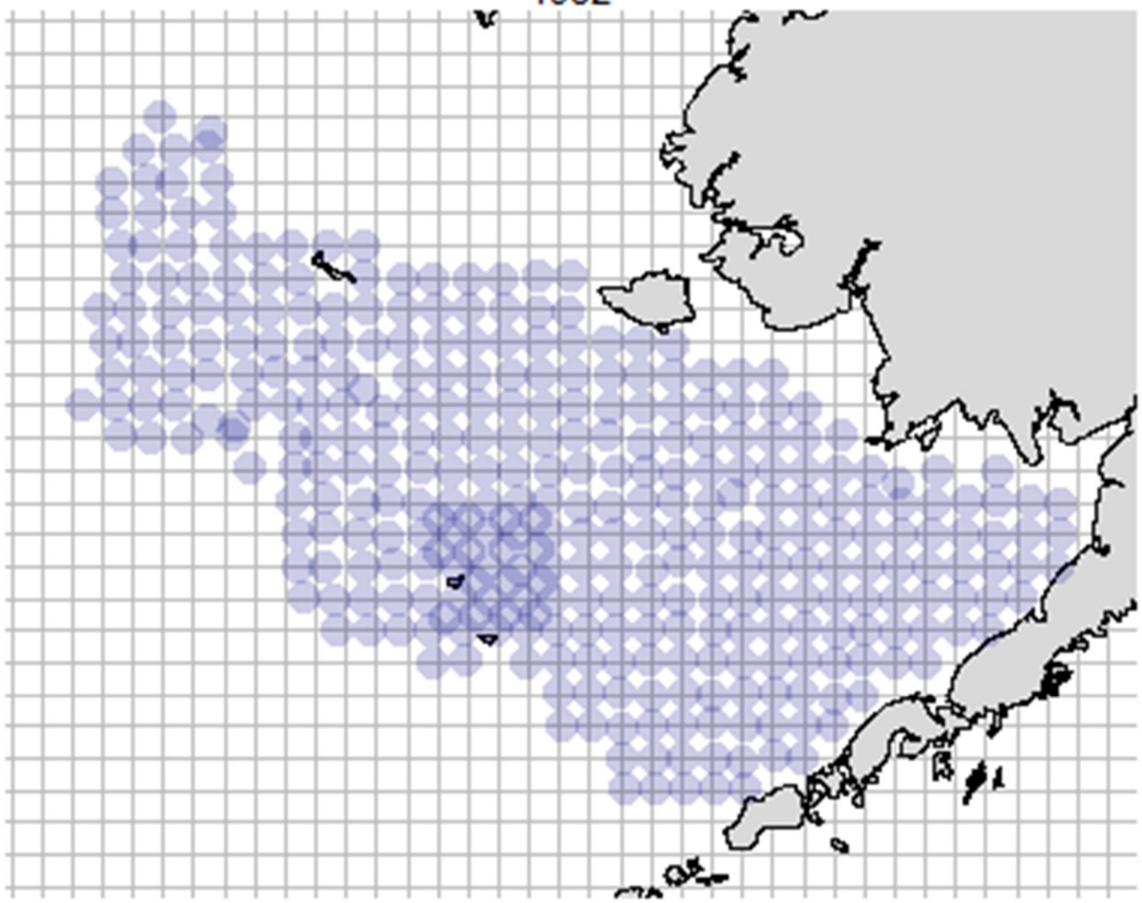
1980



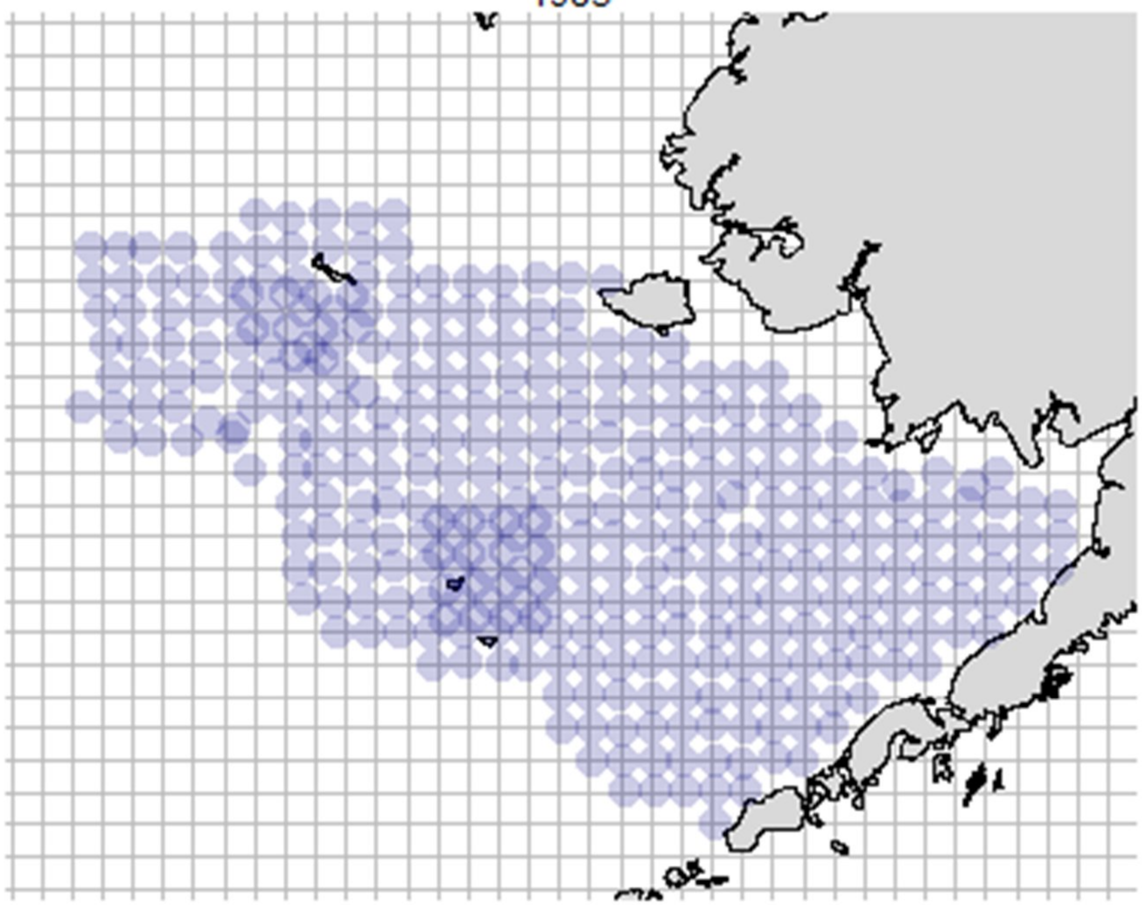
1981



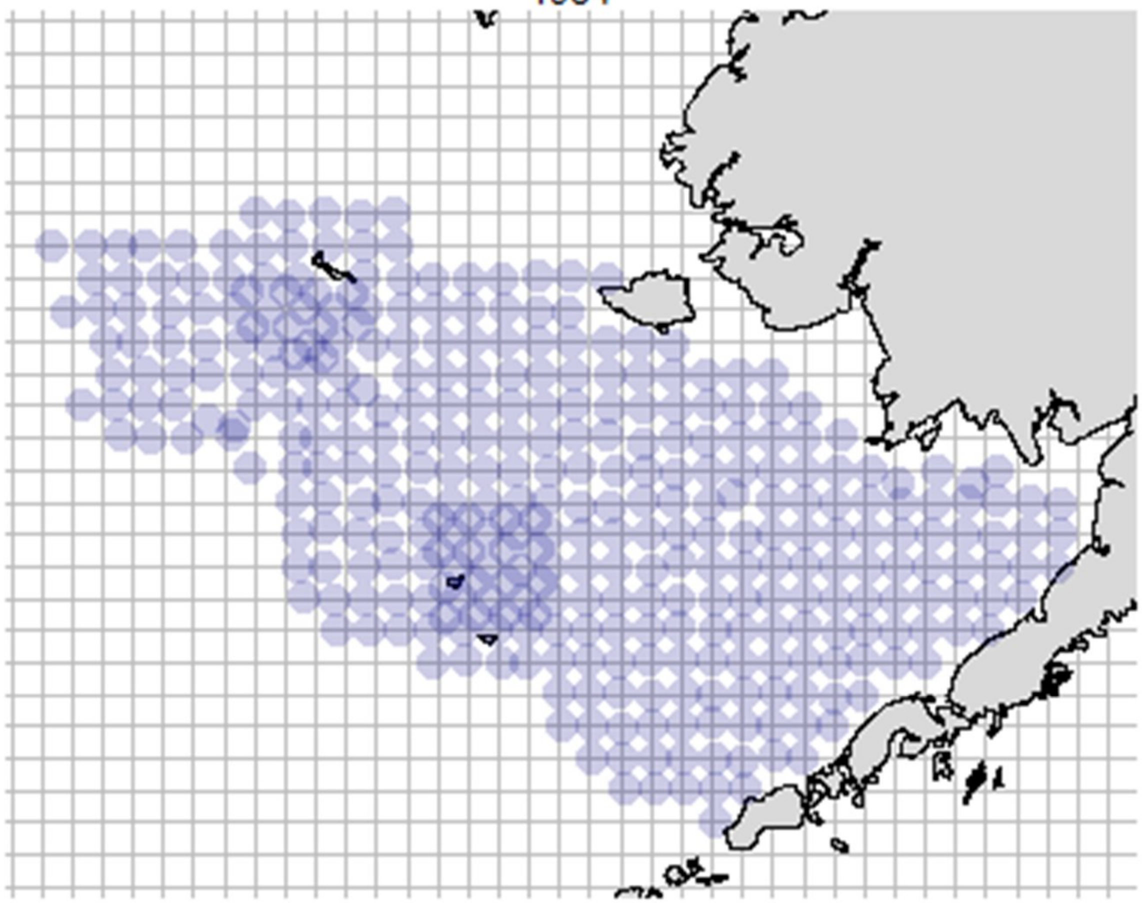
1982



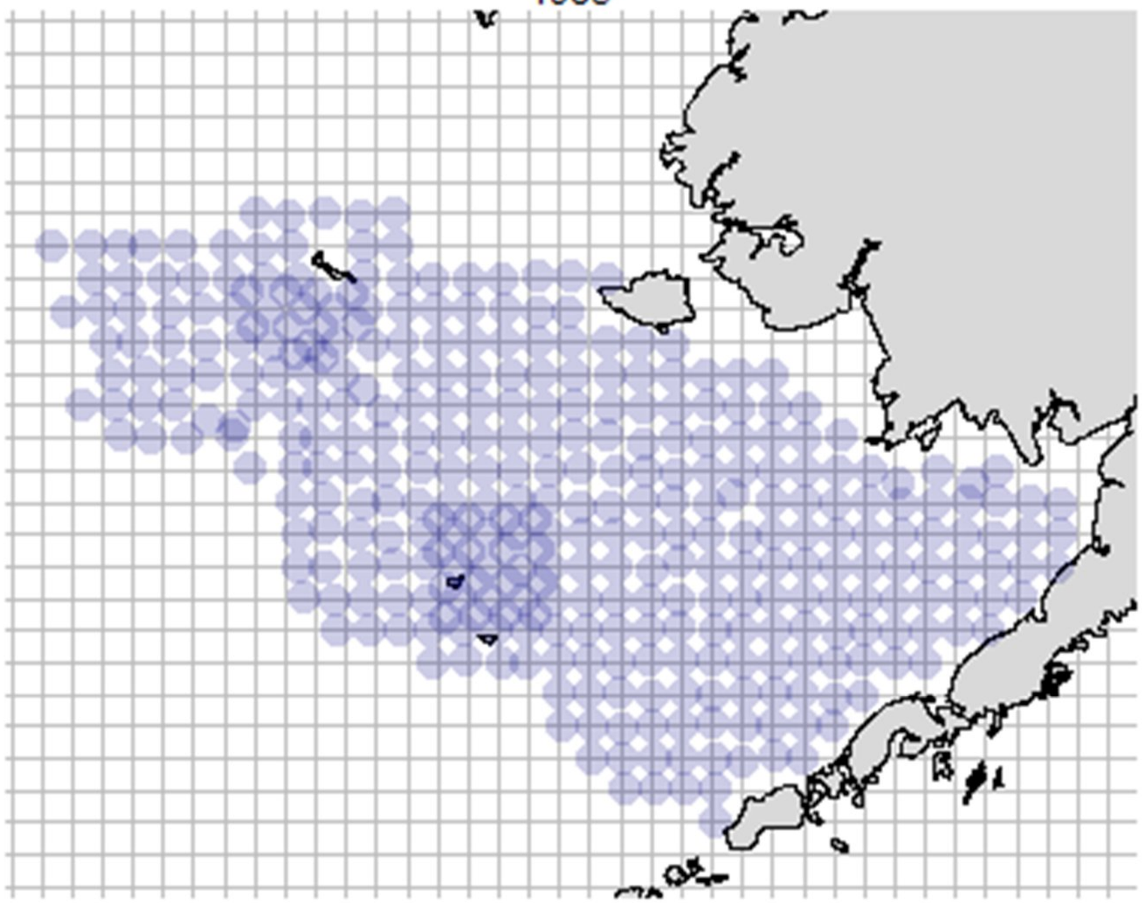
1983



1984



1985



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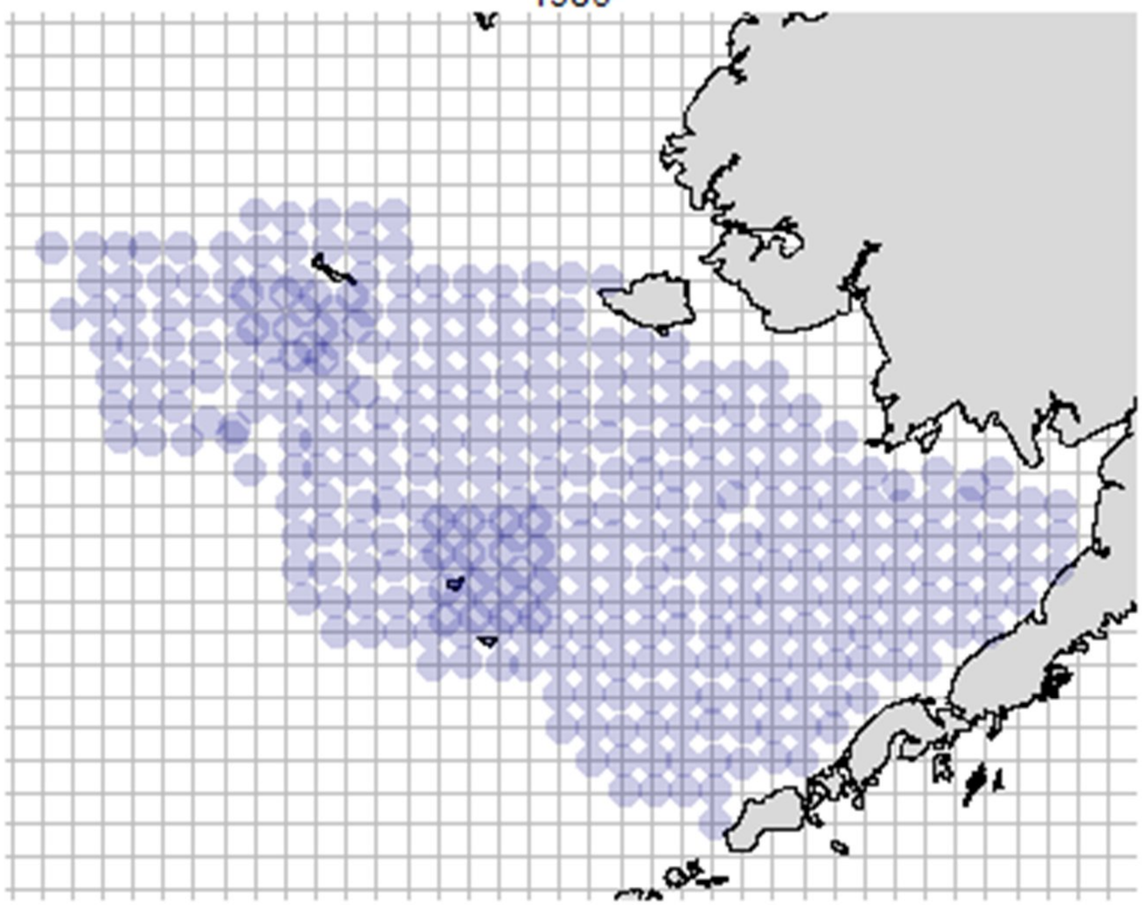
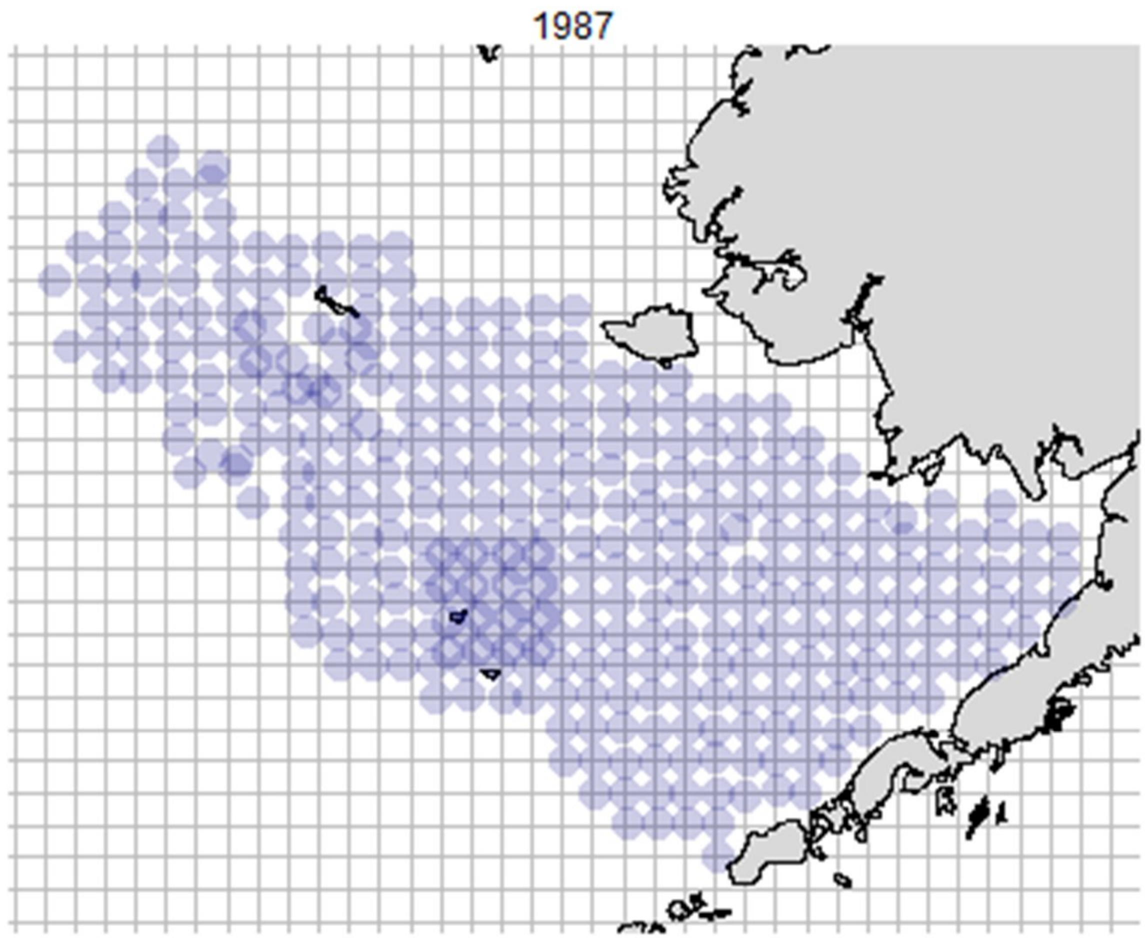
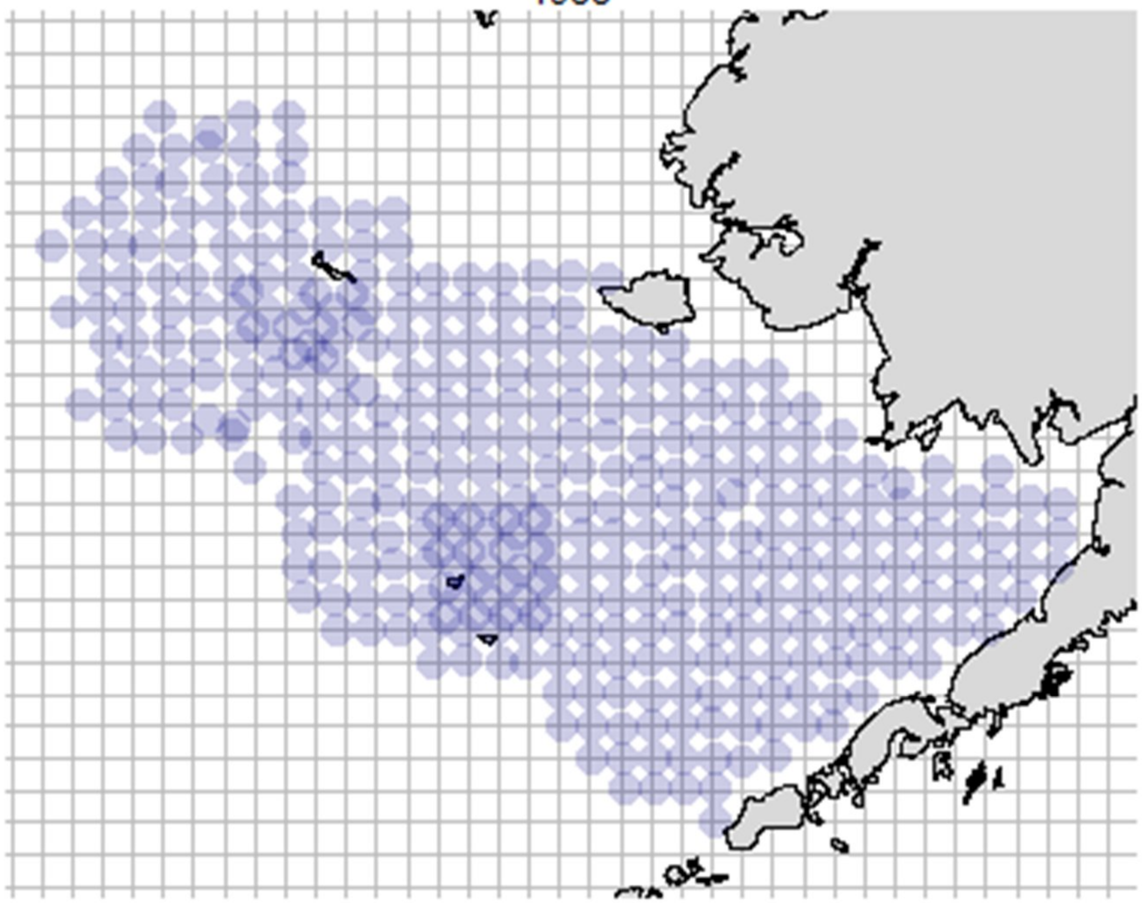
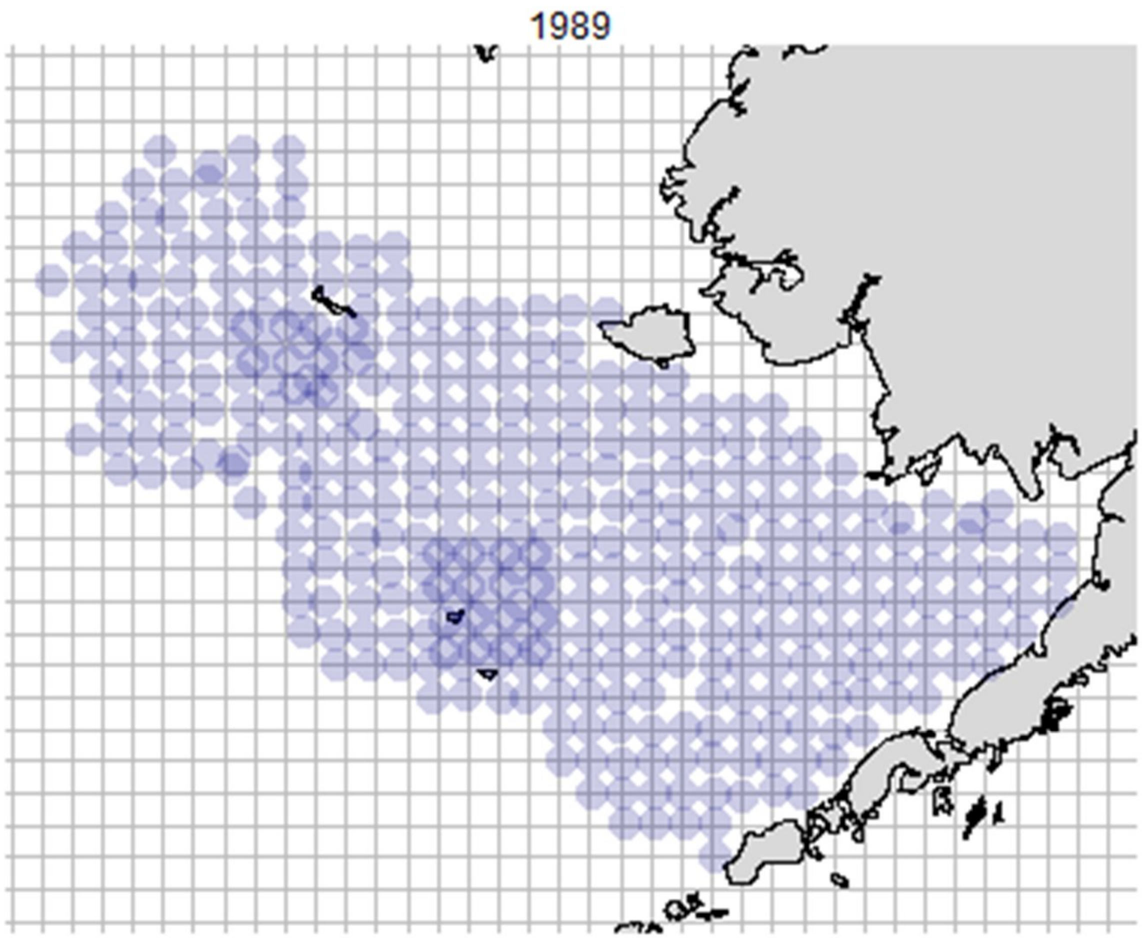



1987

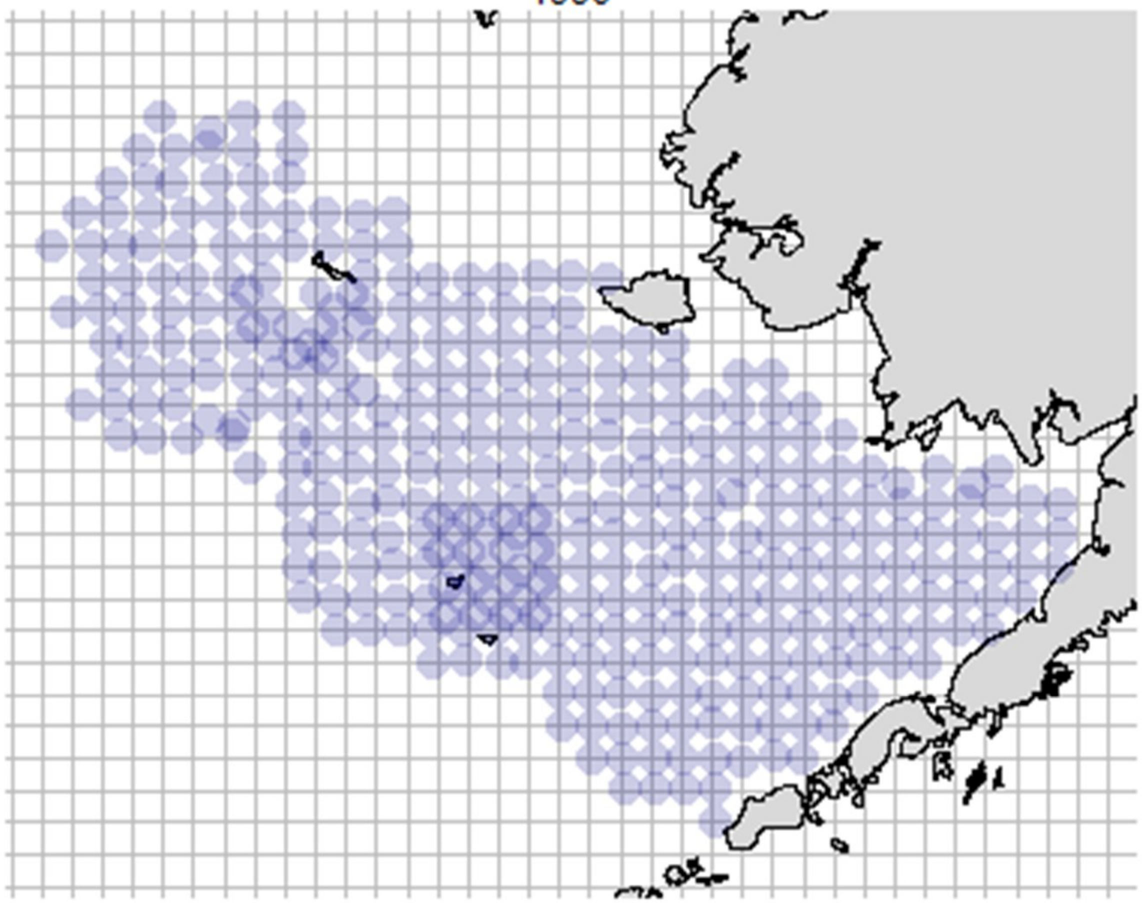
1988



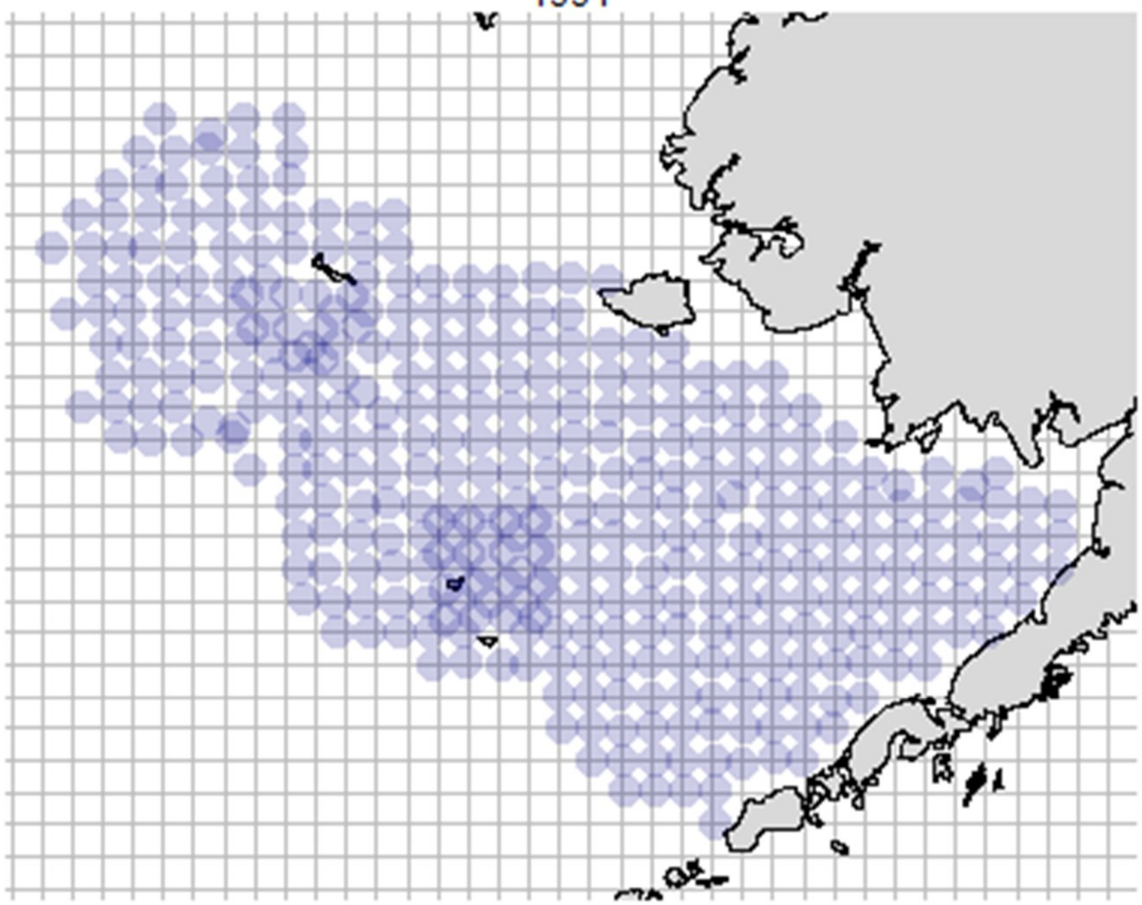


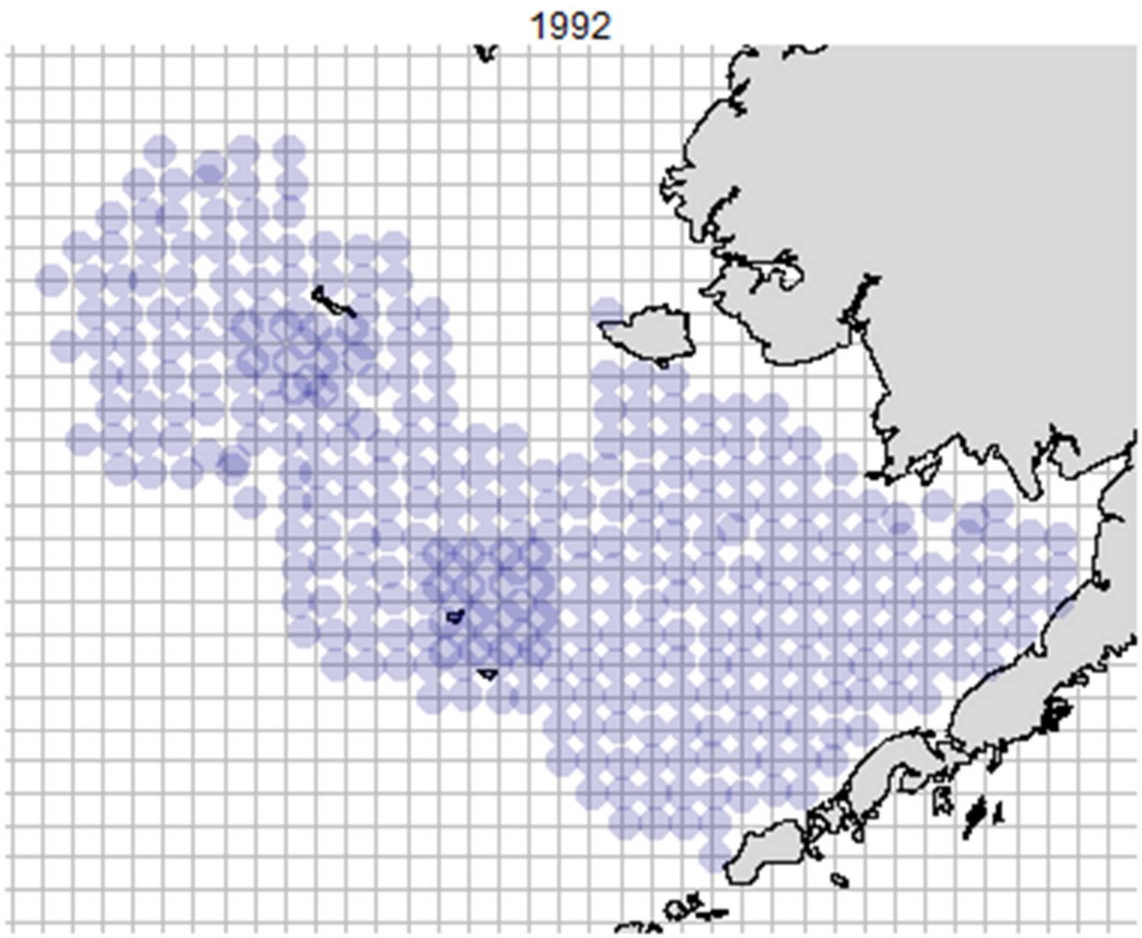
1989

1990

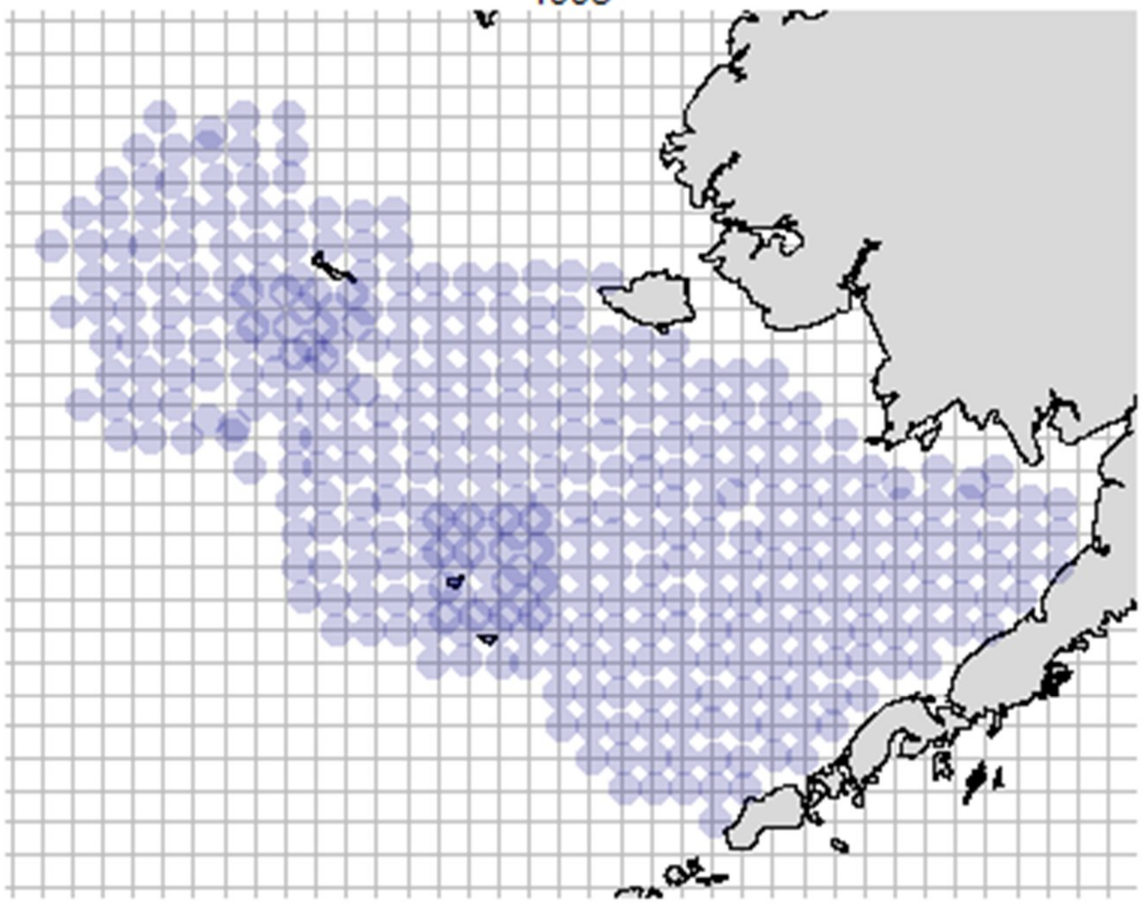


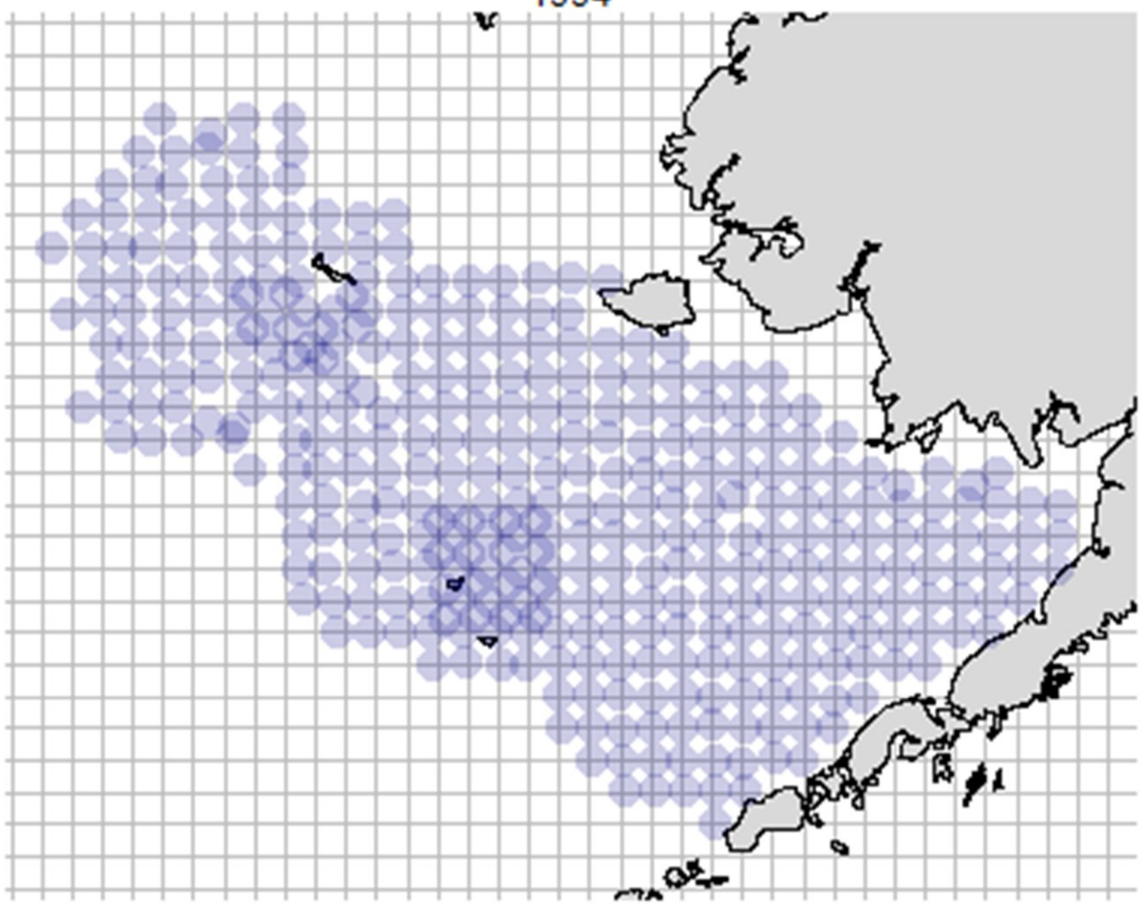
1991




1992

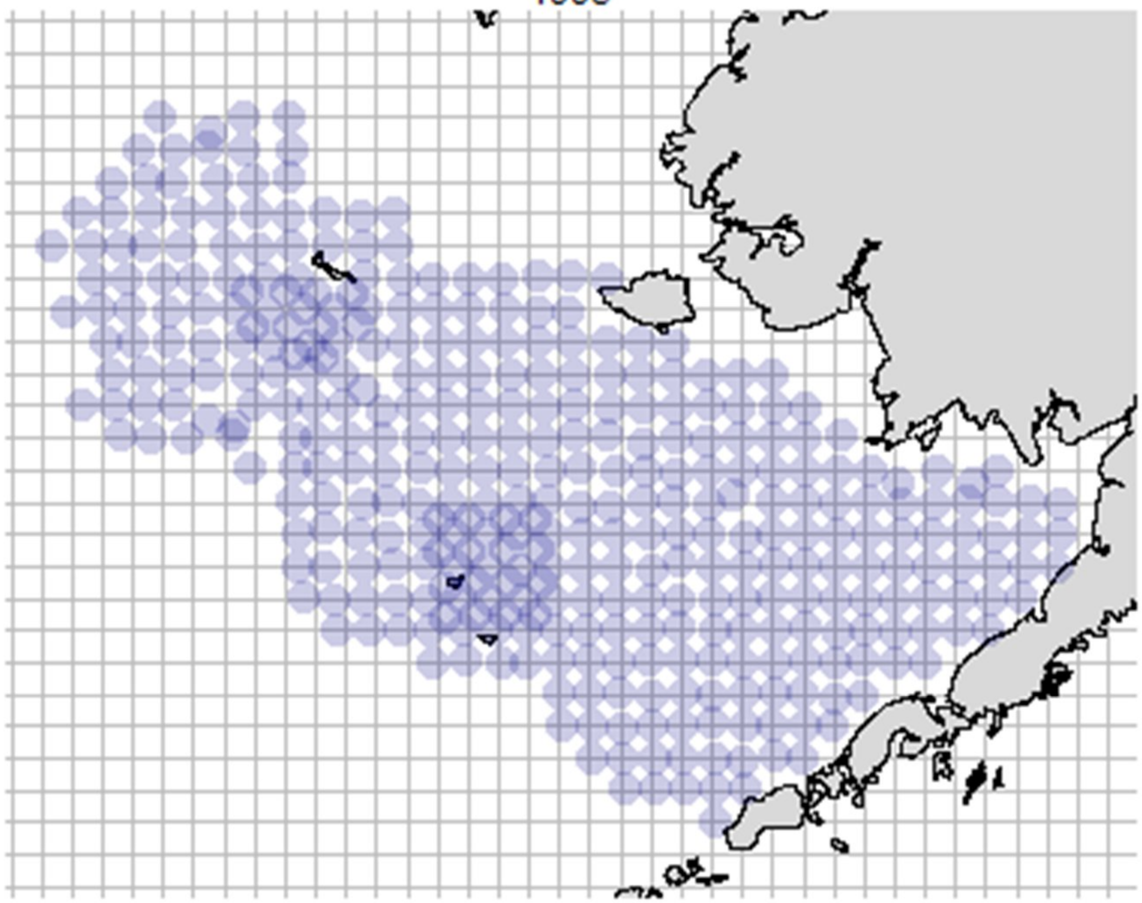
1993



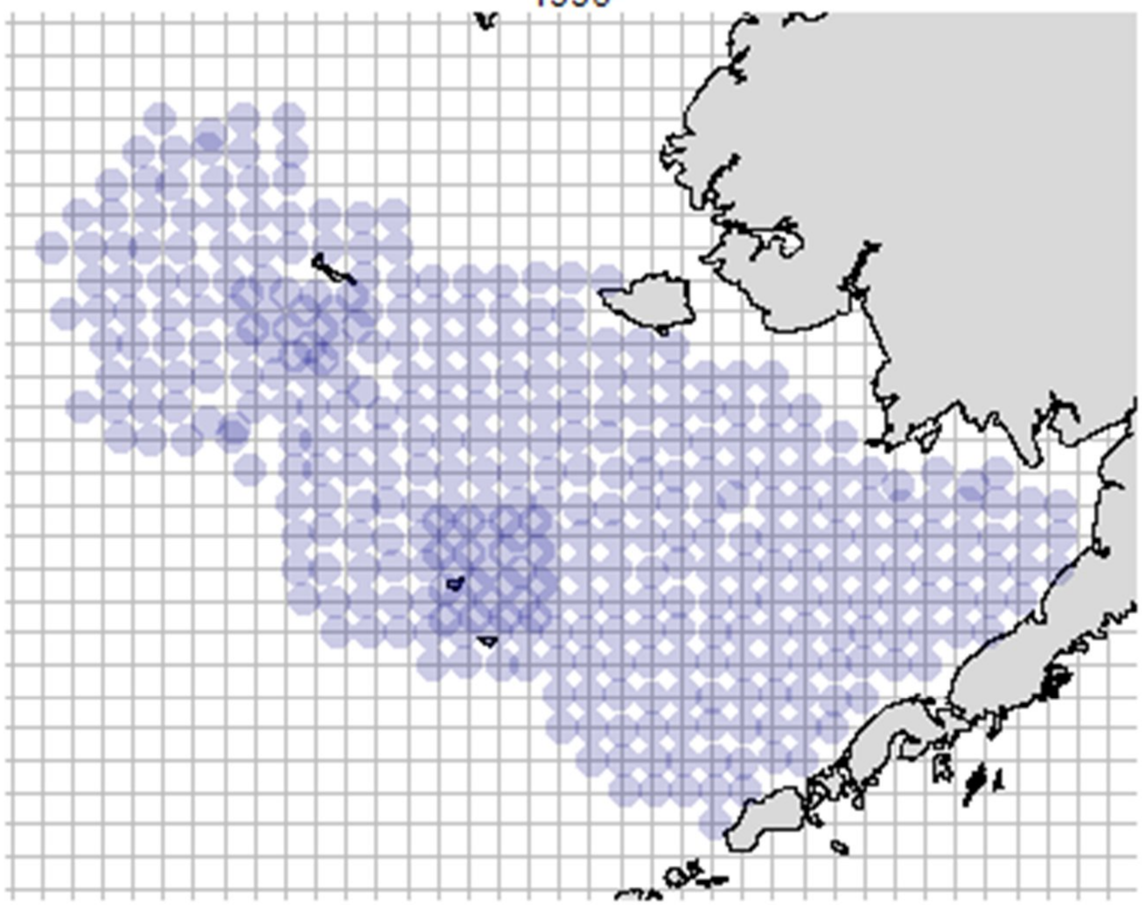


1994

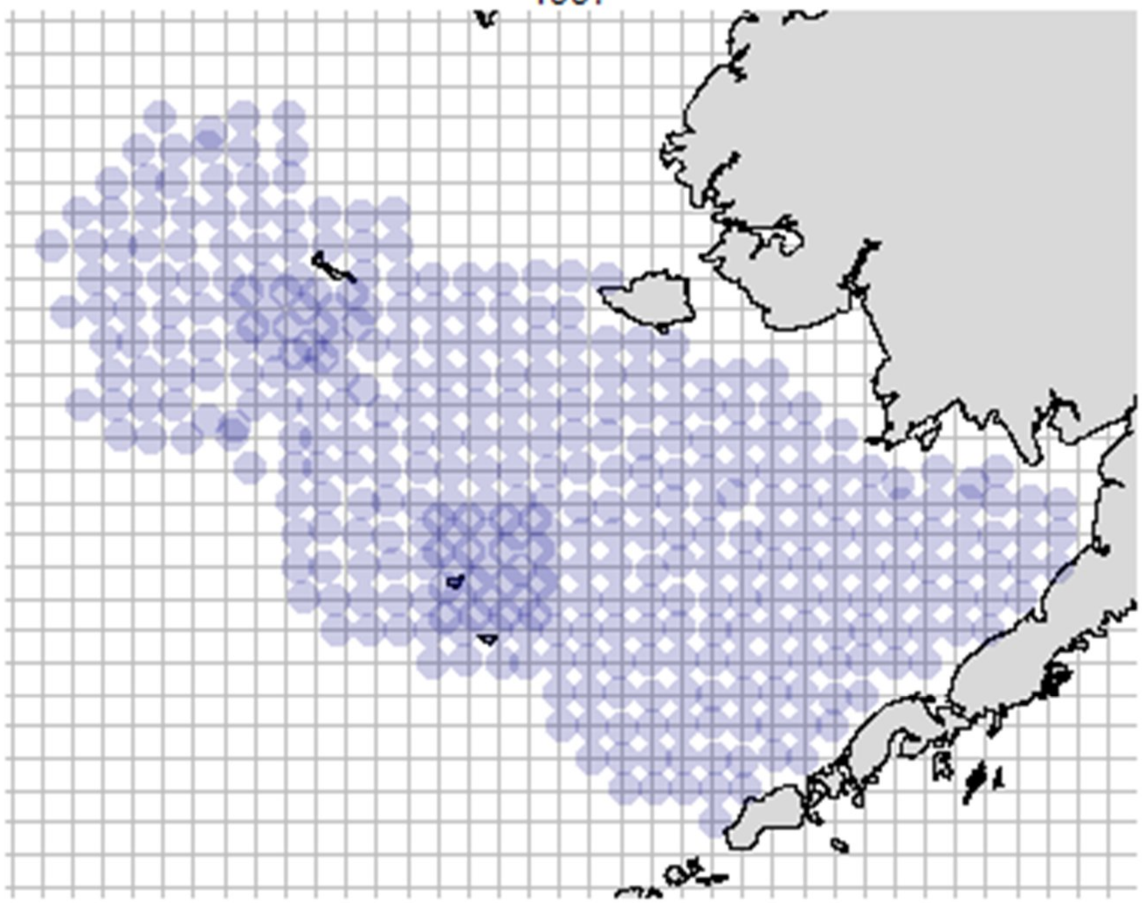
1995



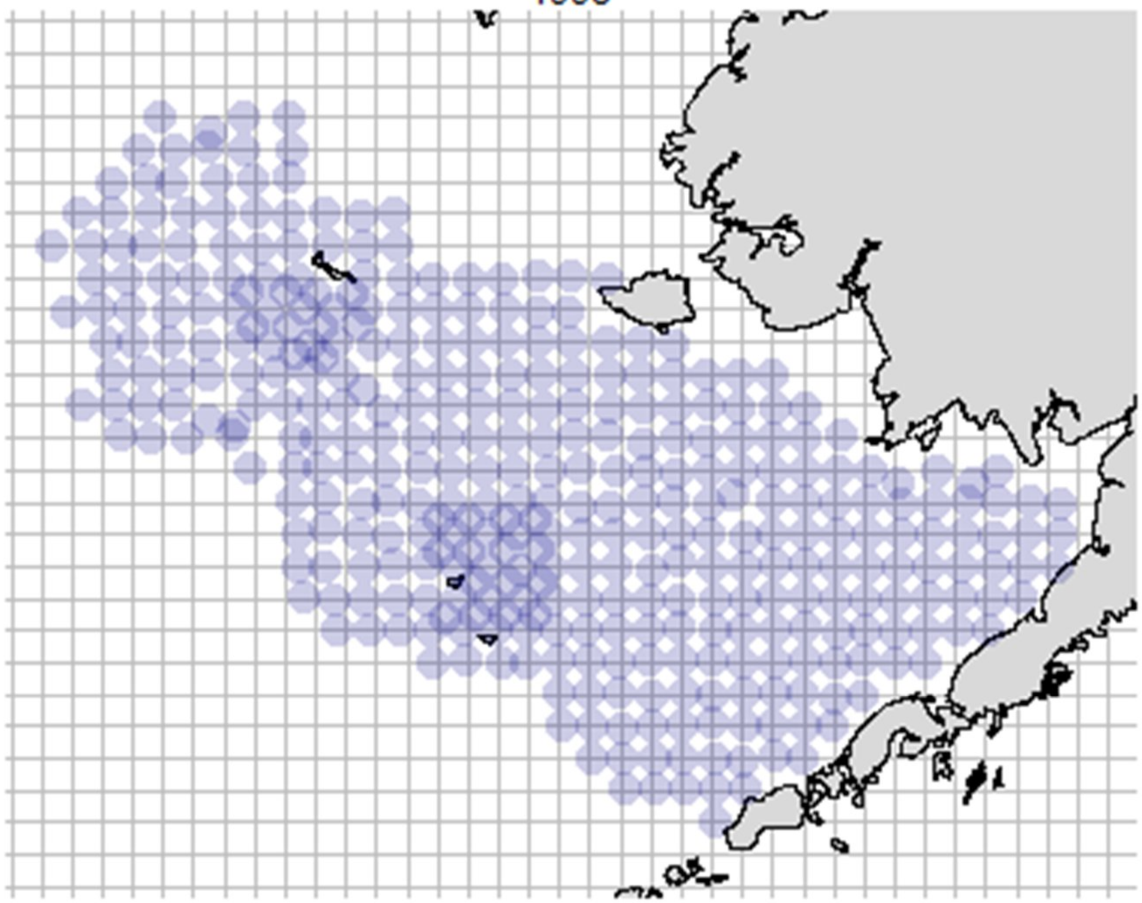
1996



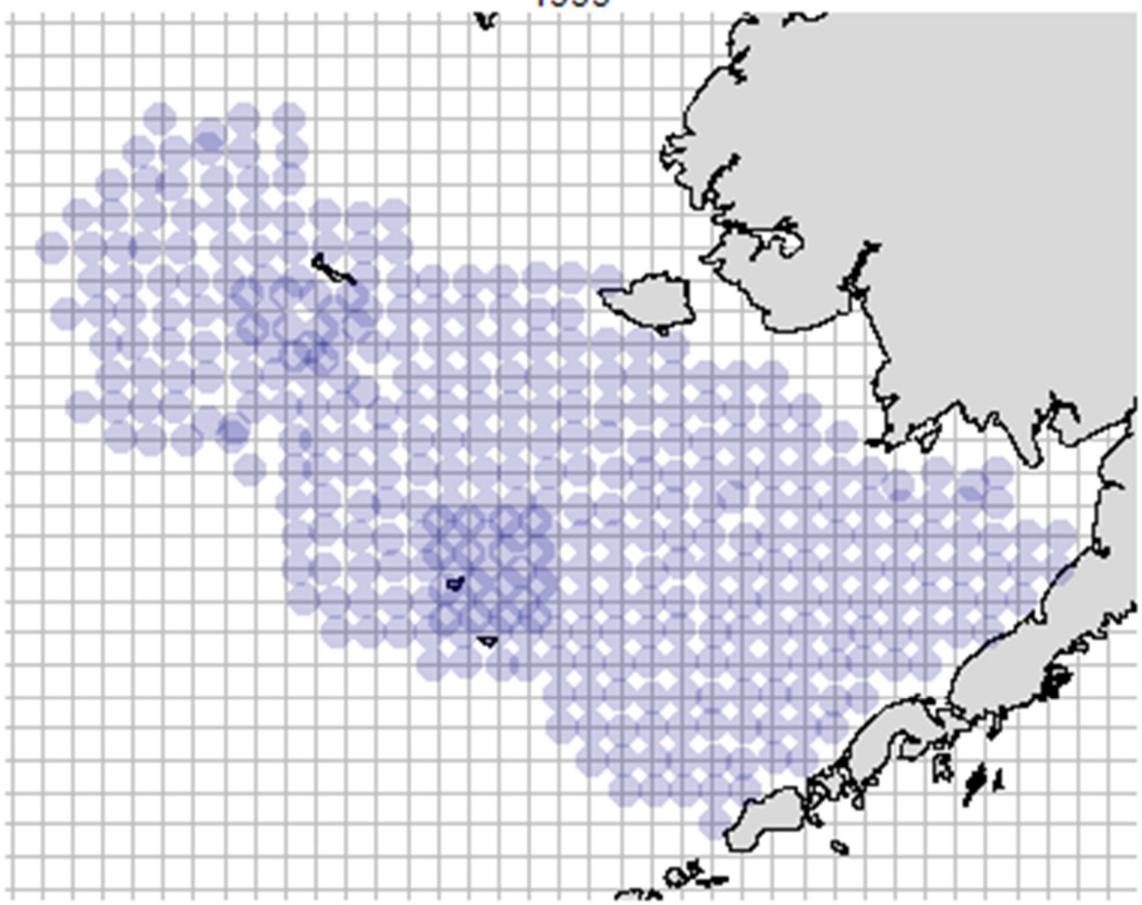
1997

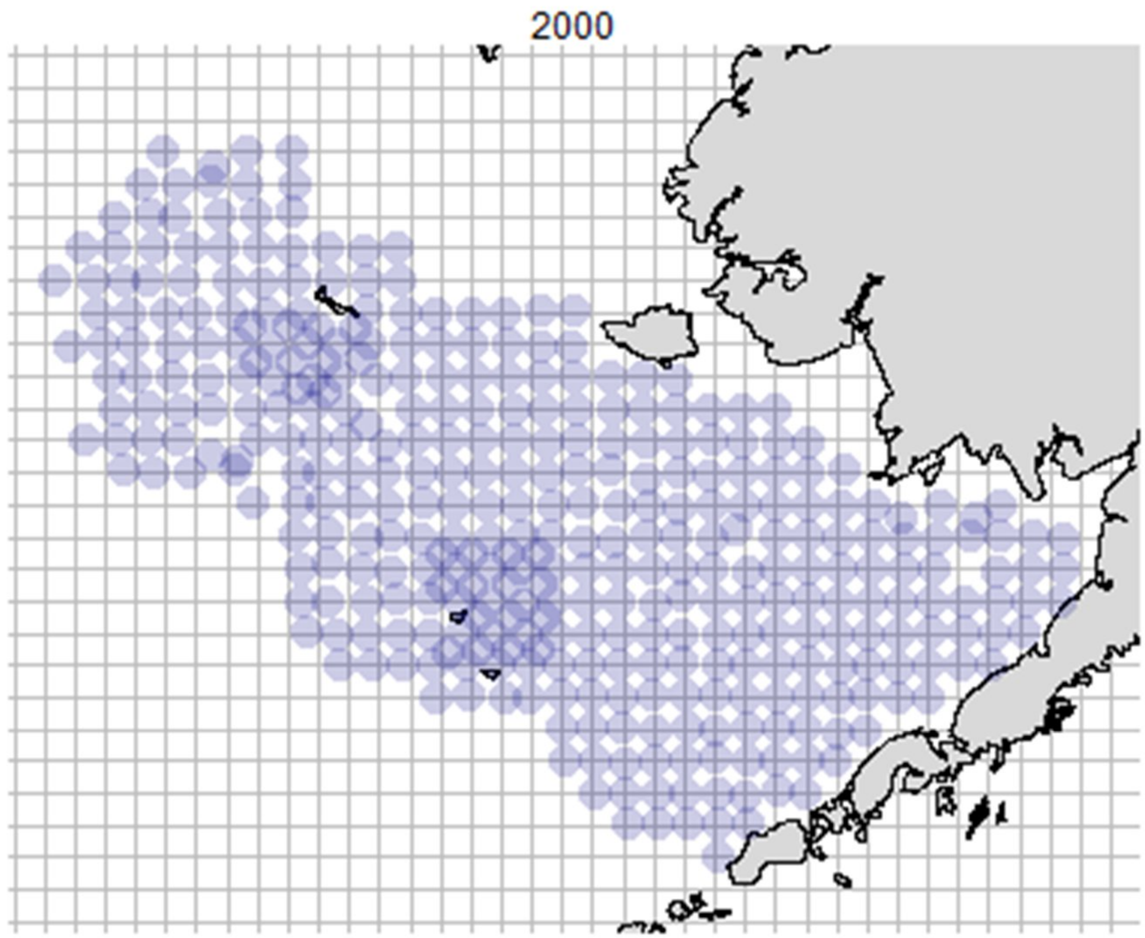


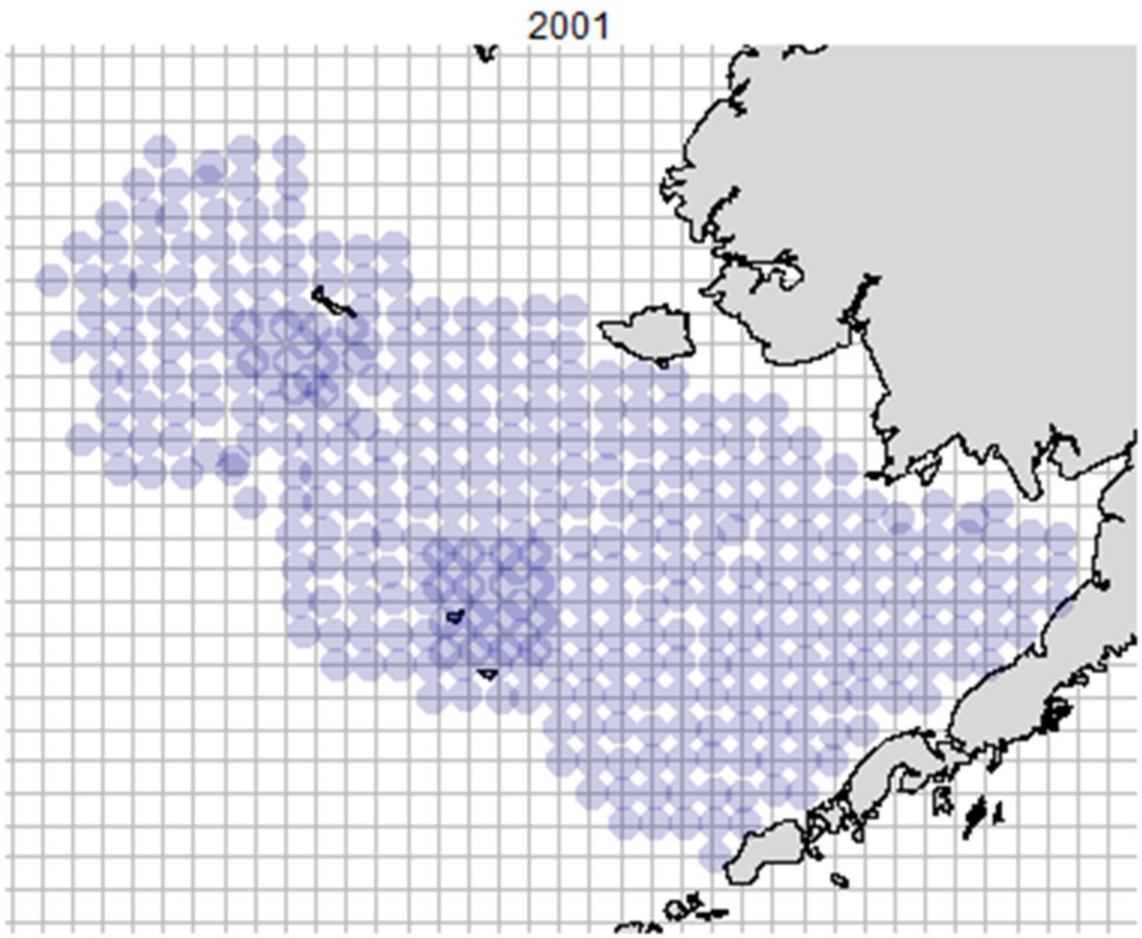
1998



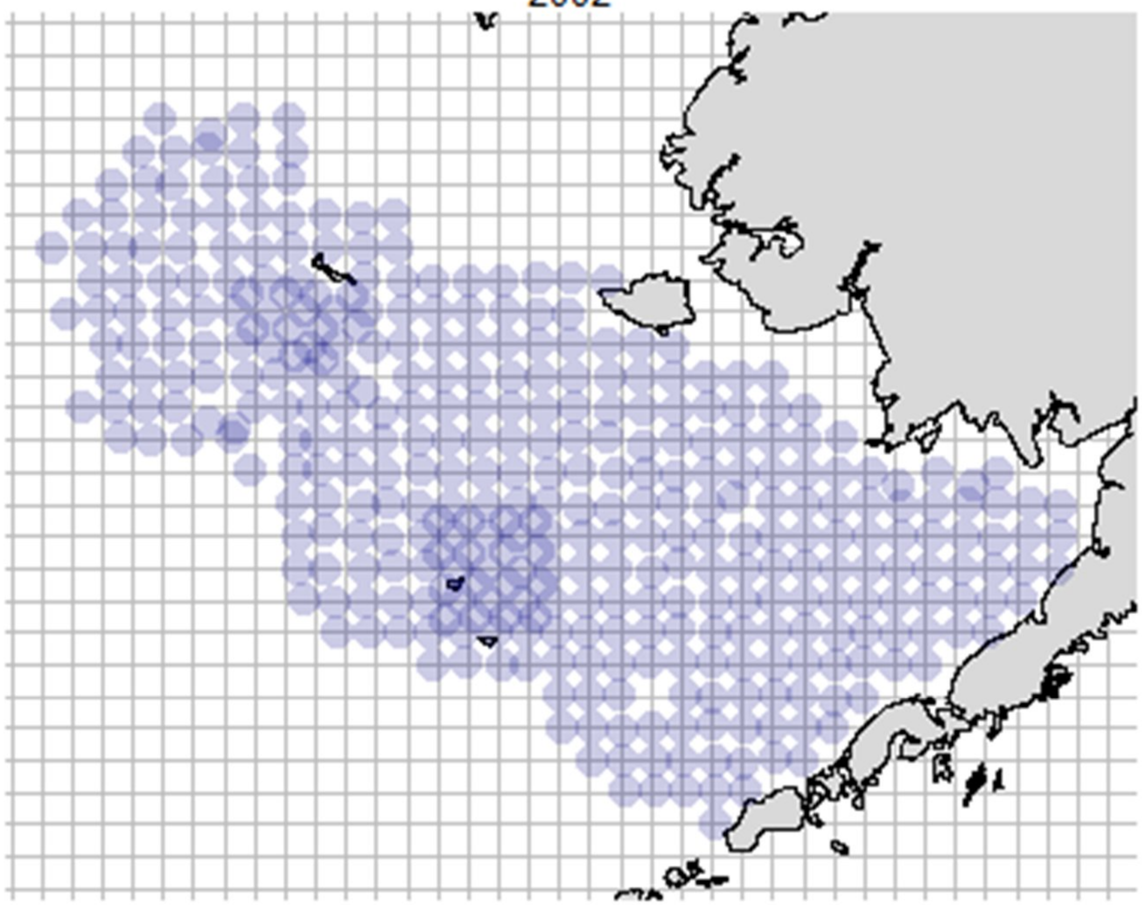
1999



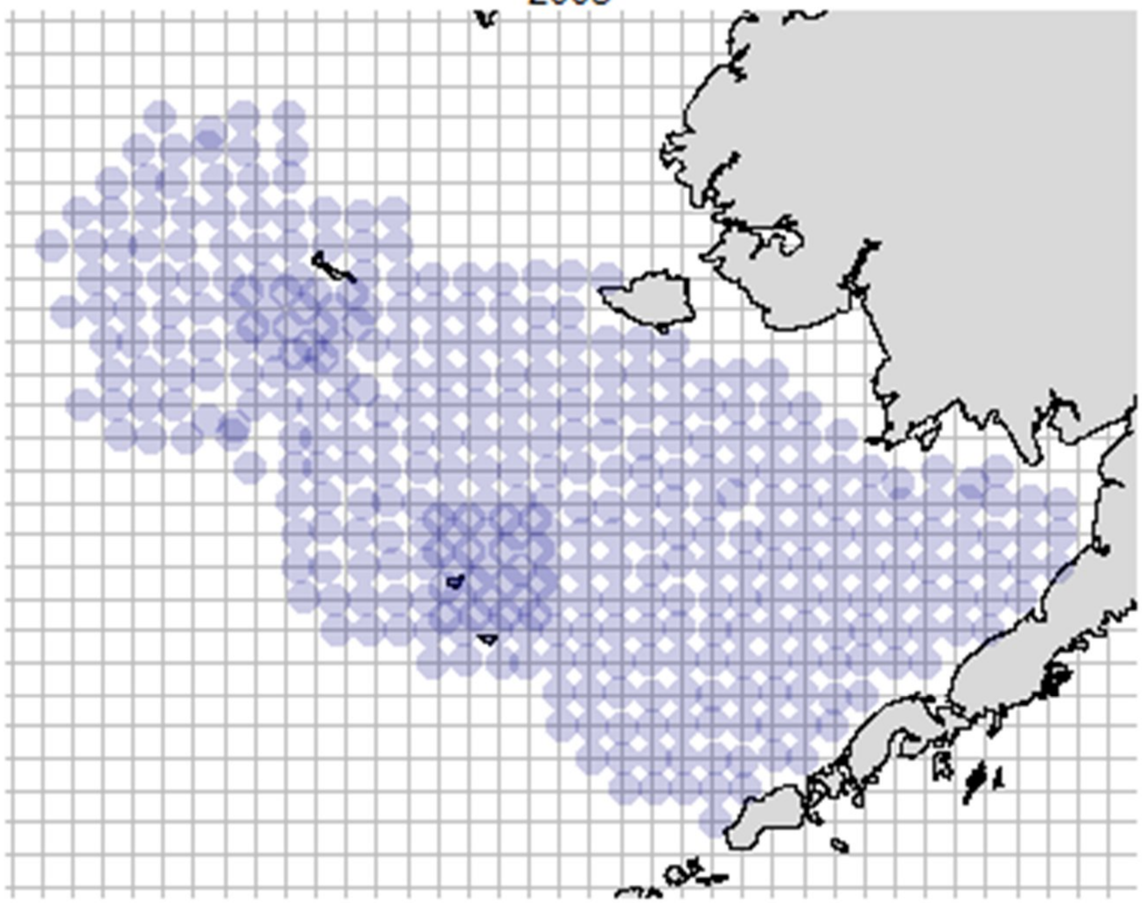

2000

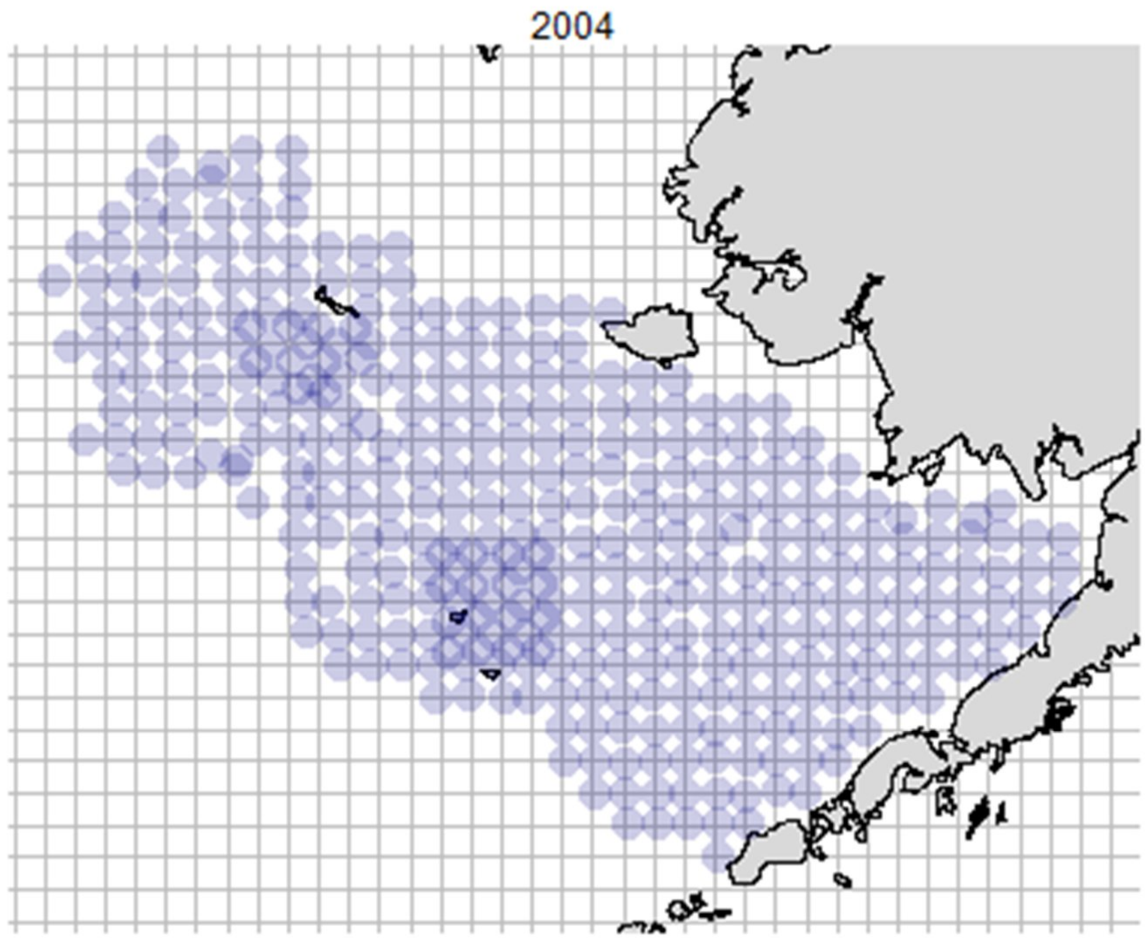


2002

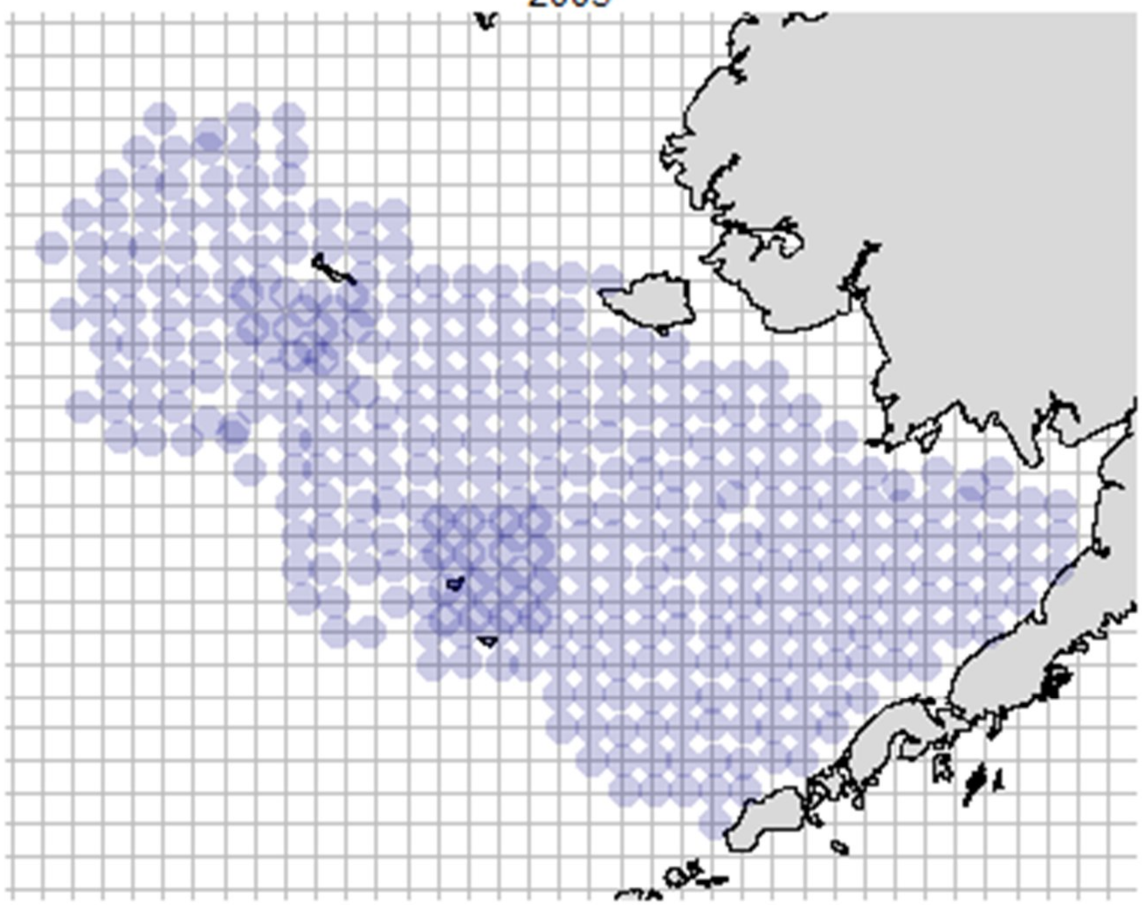


2003

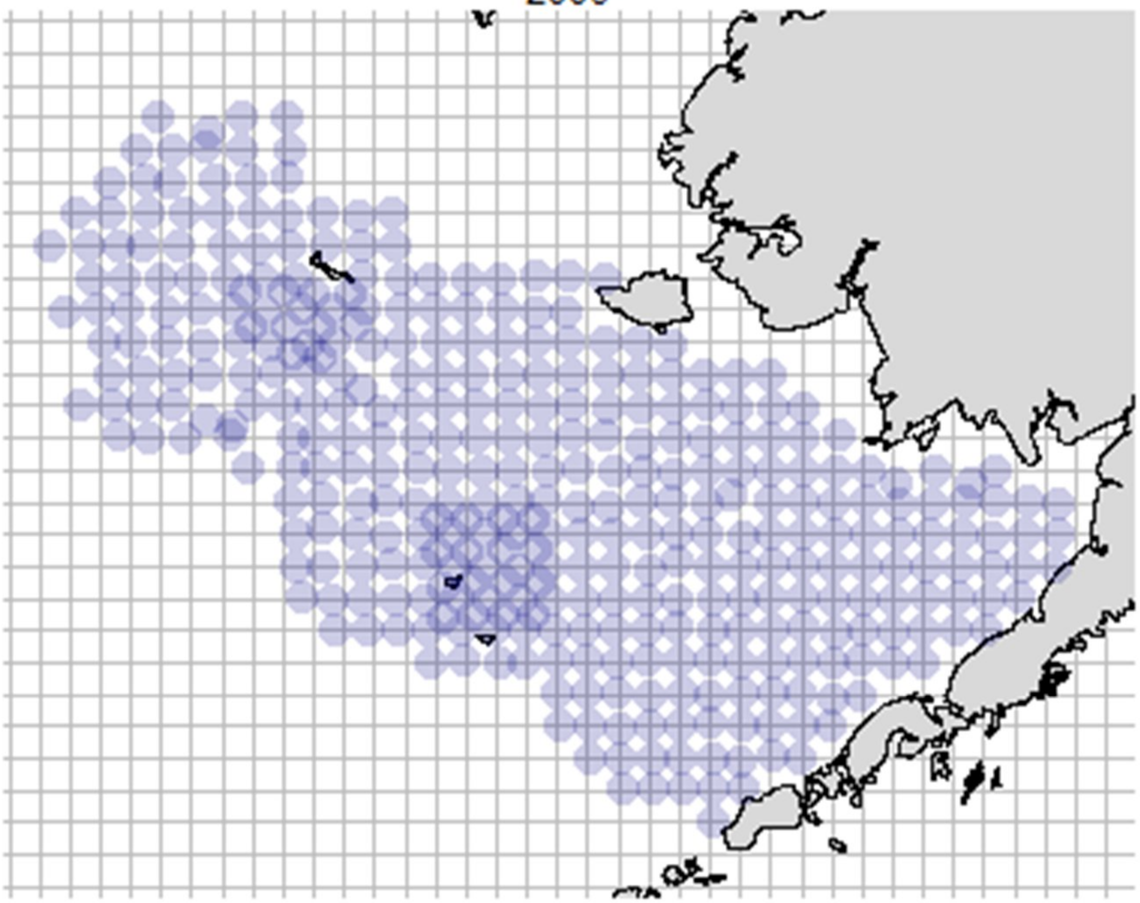



2004

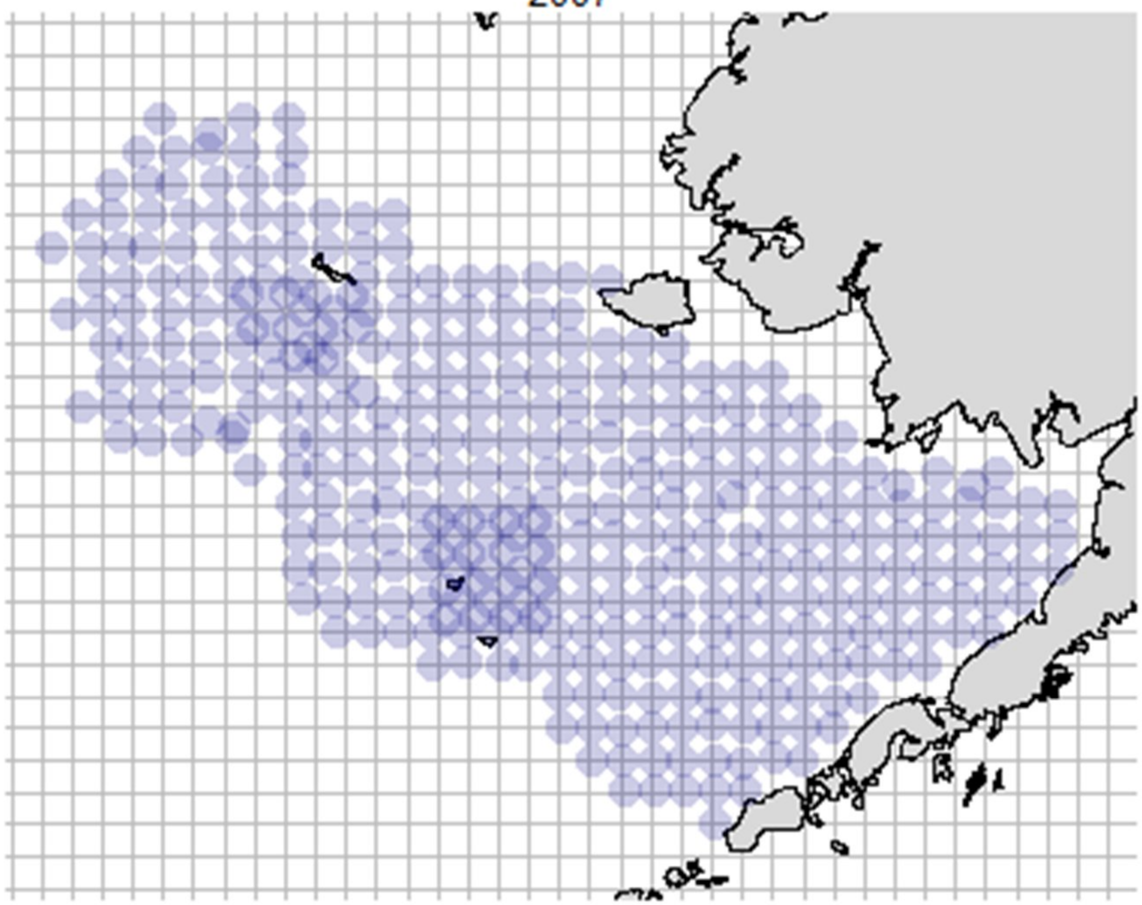
2005



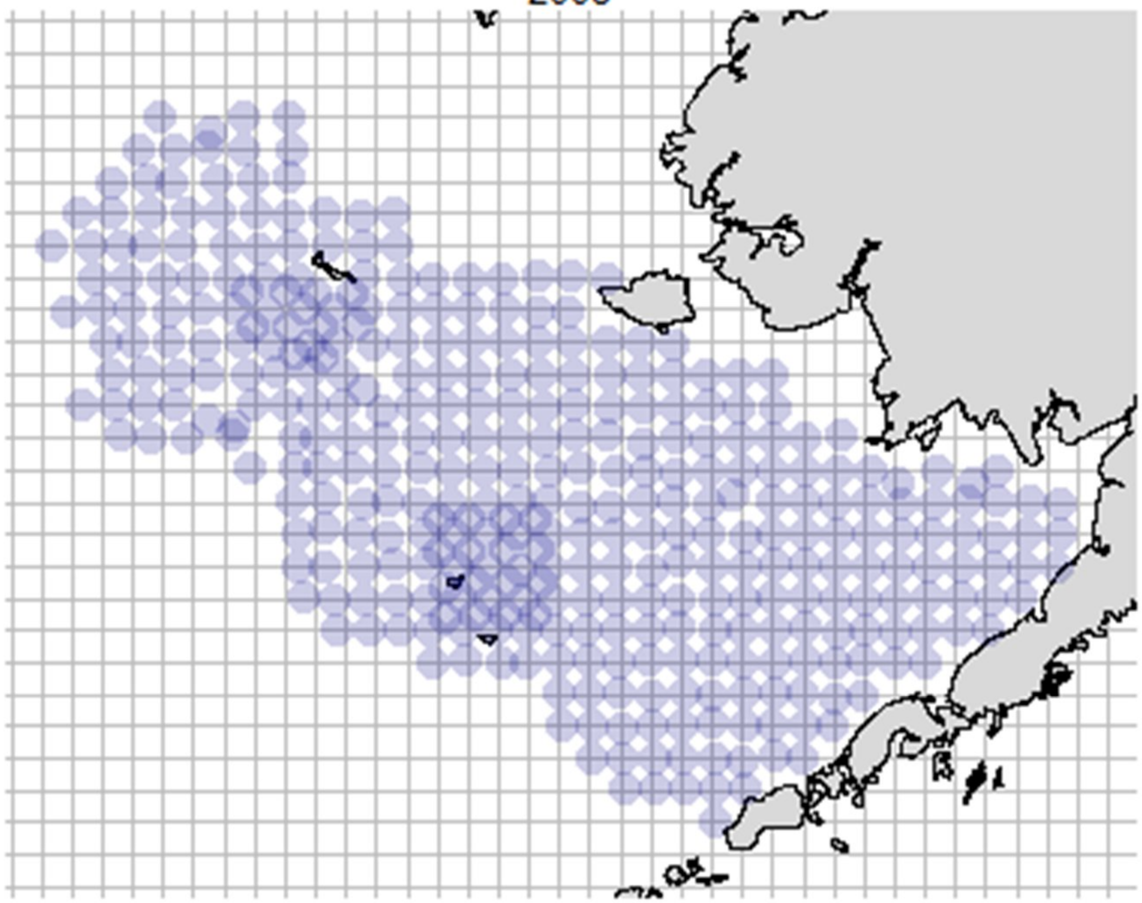
2006



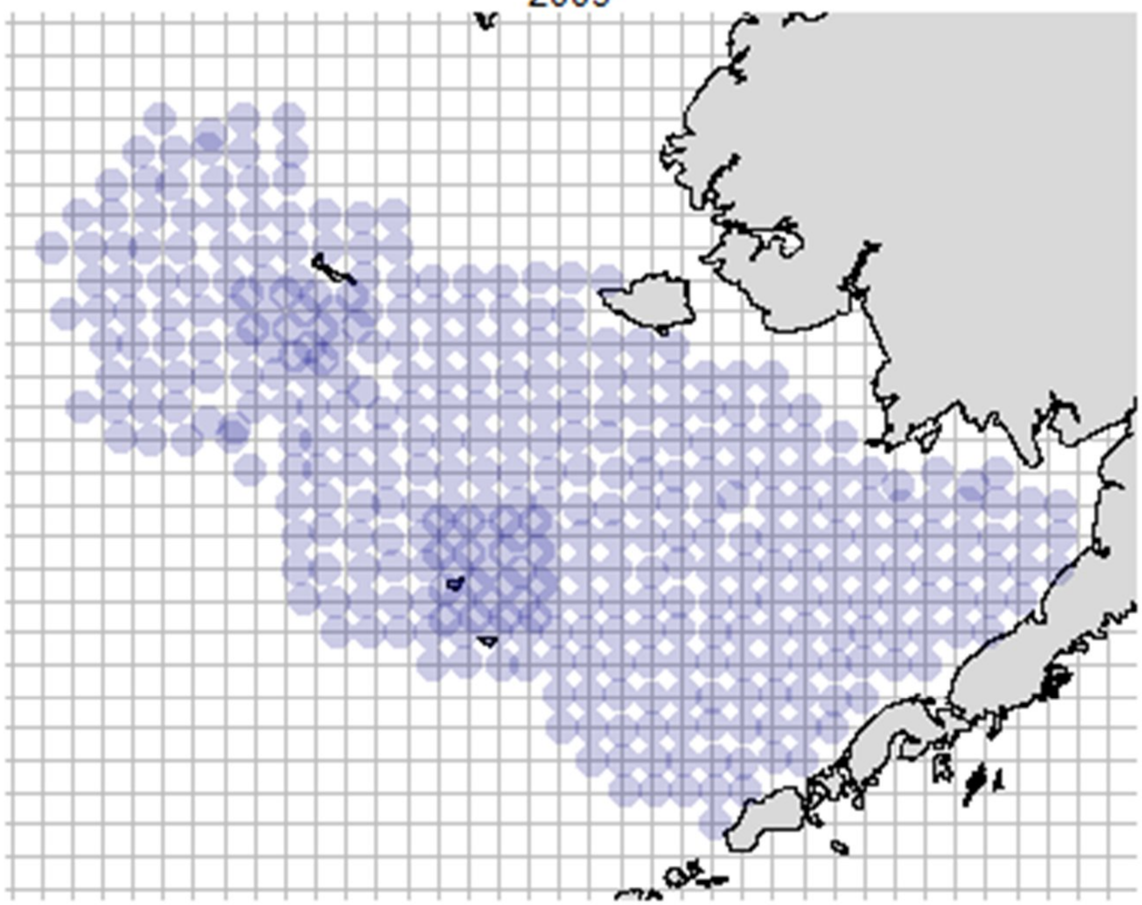
2007



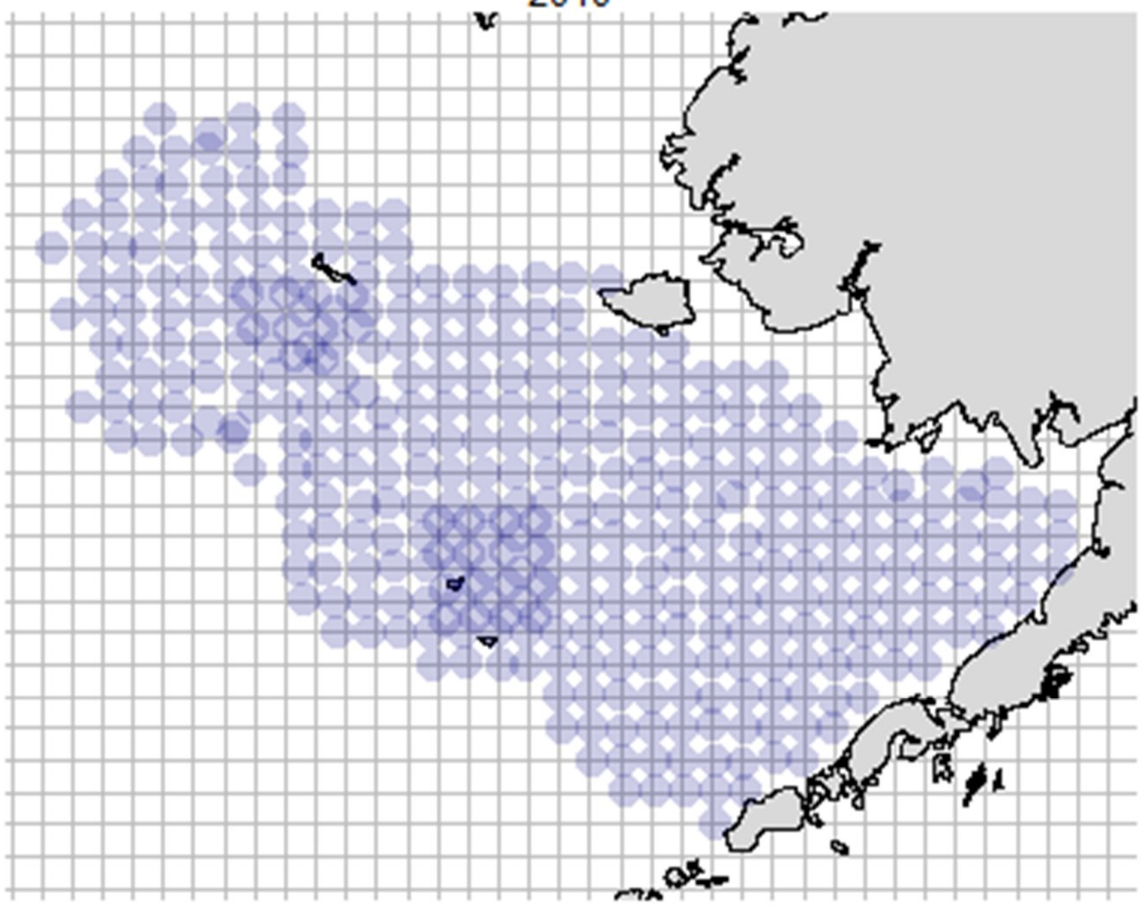
2008

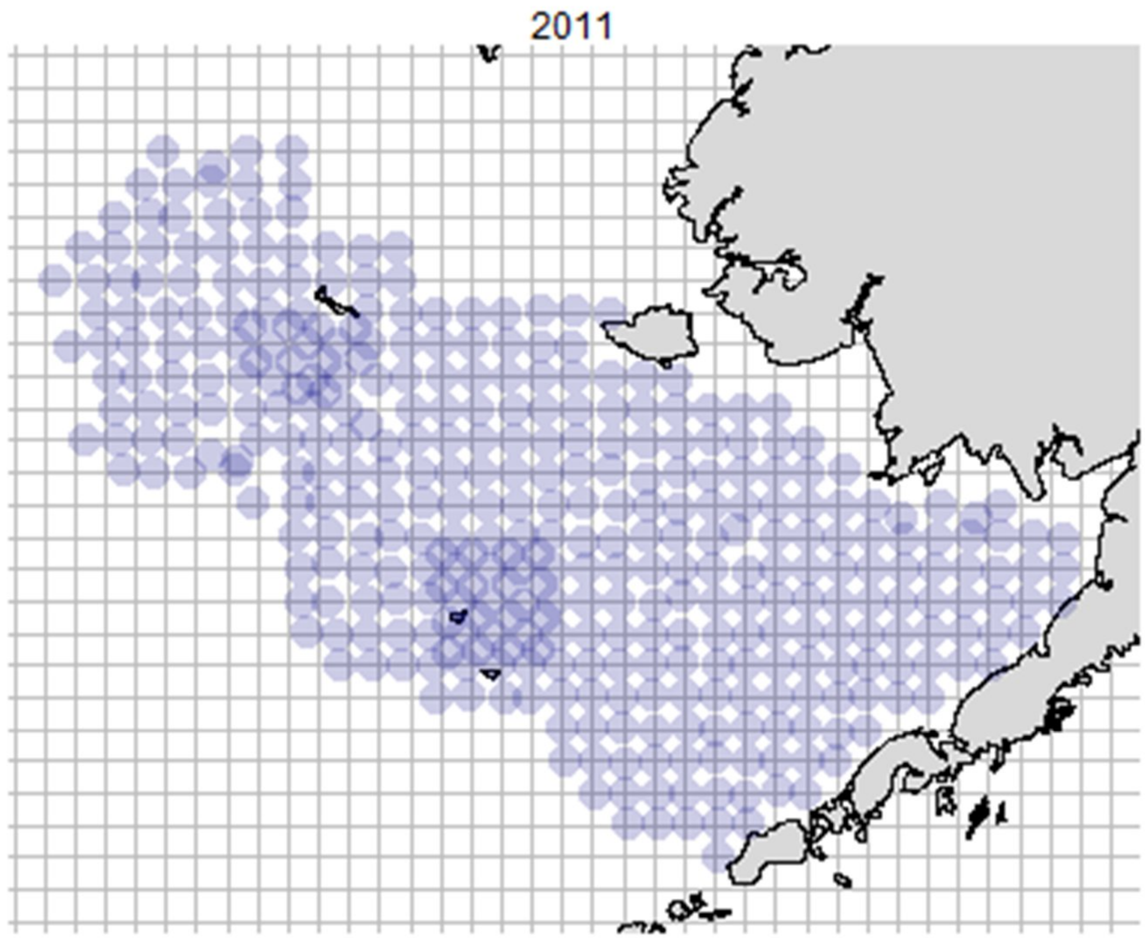


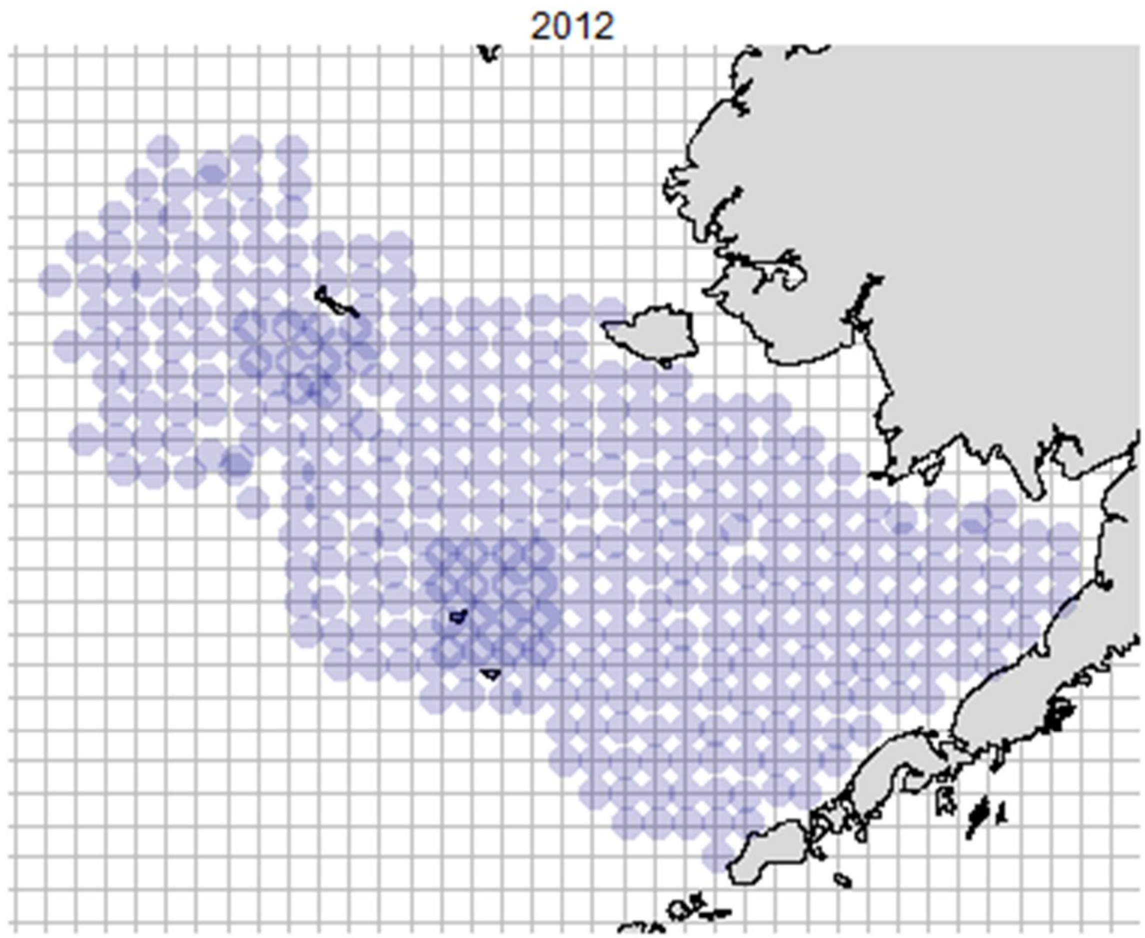
2009

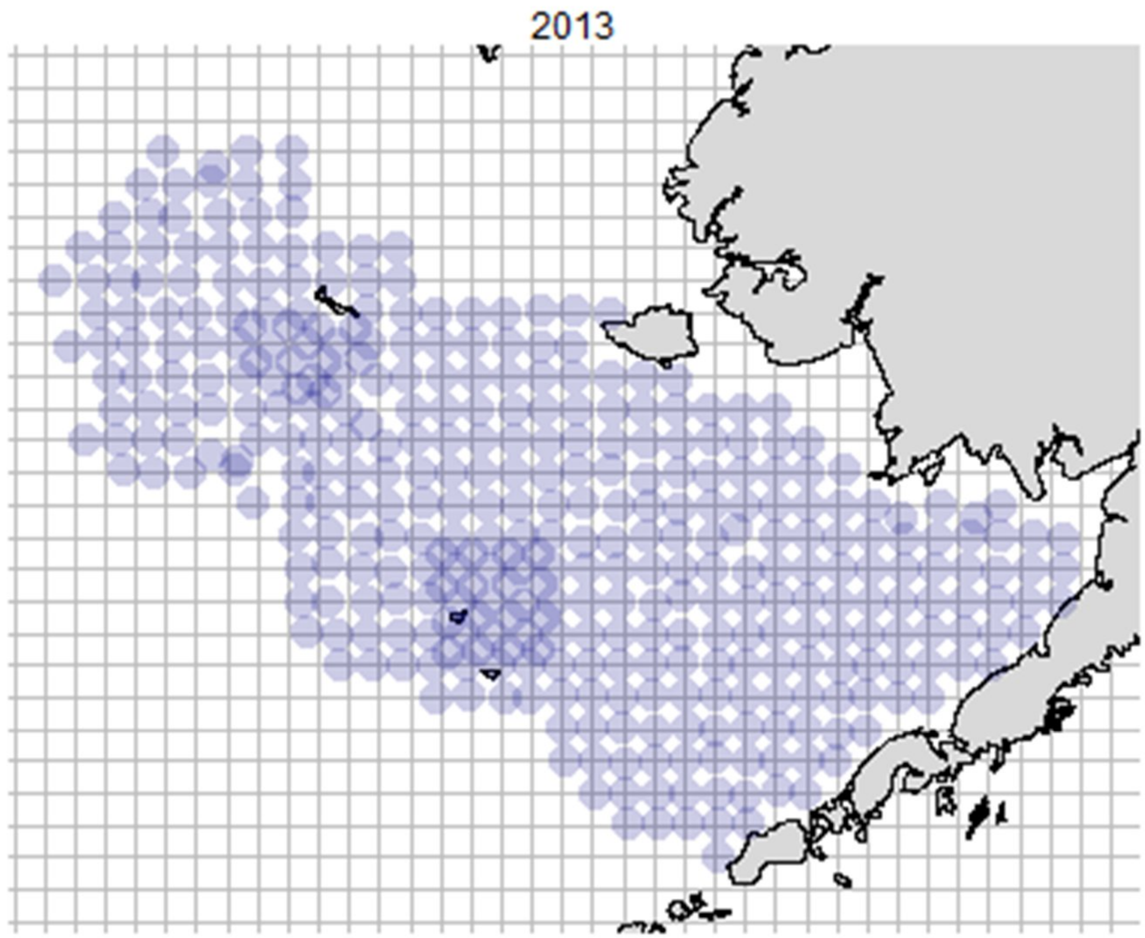


2010

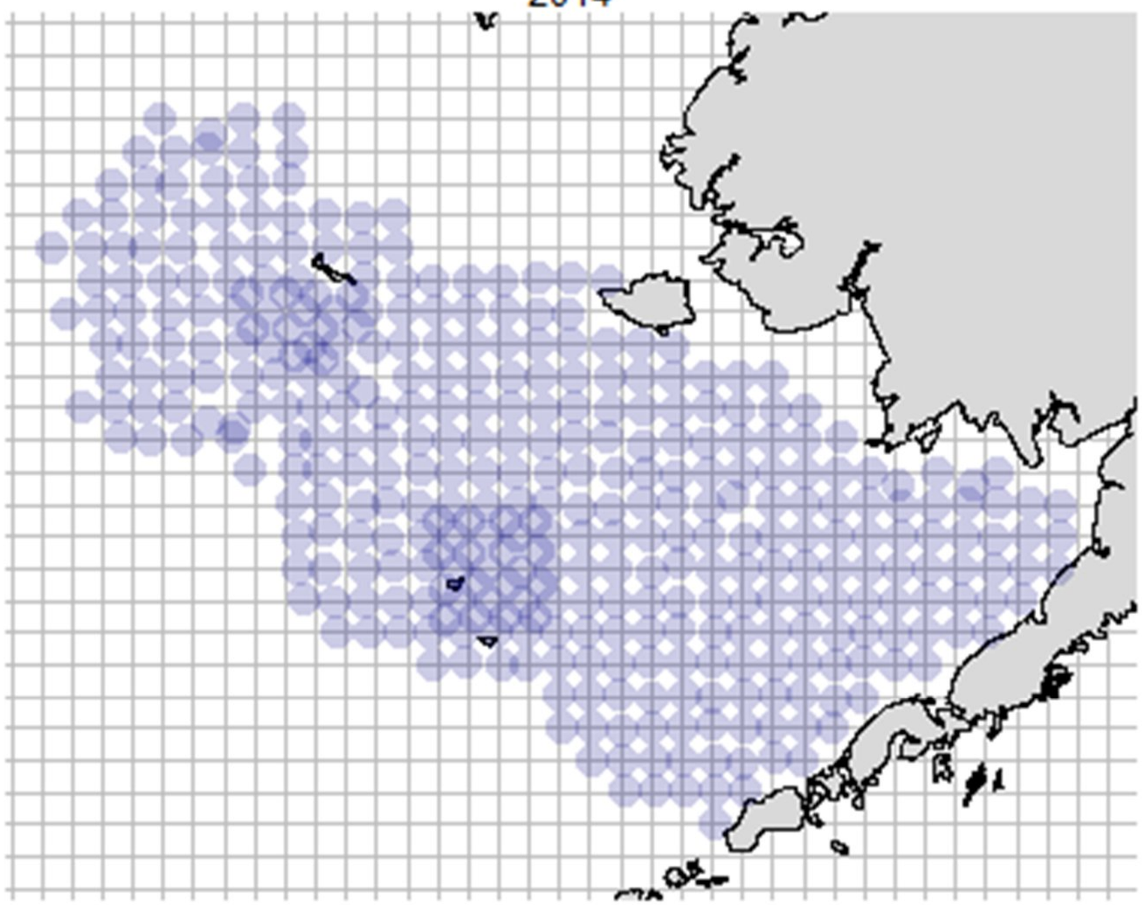



2011

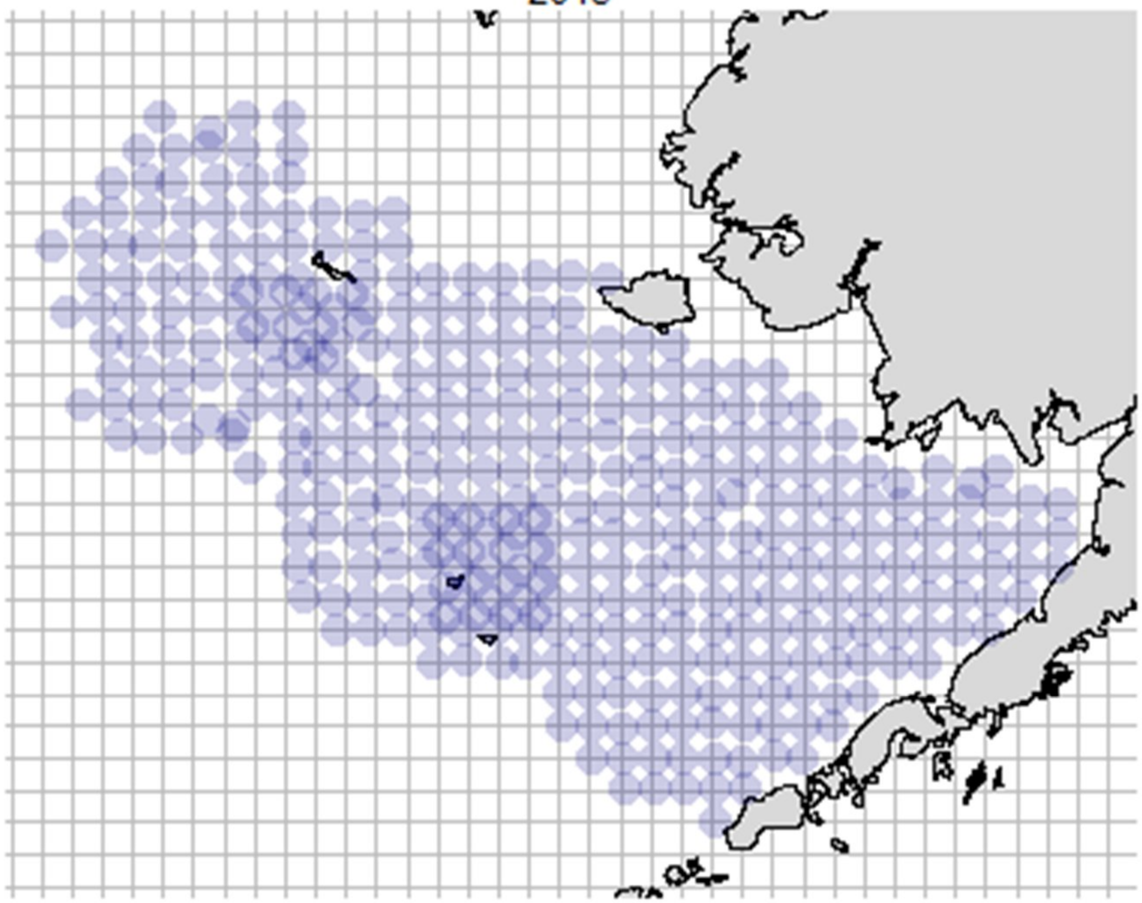

2012


2013

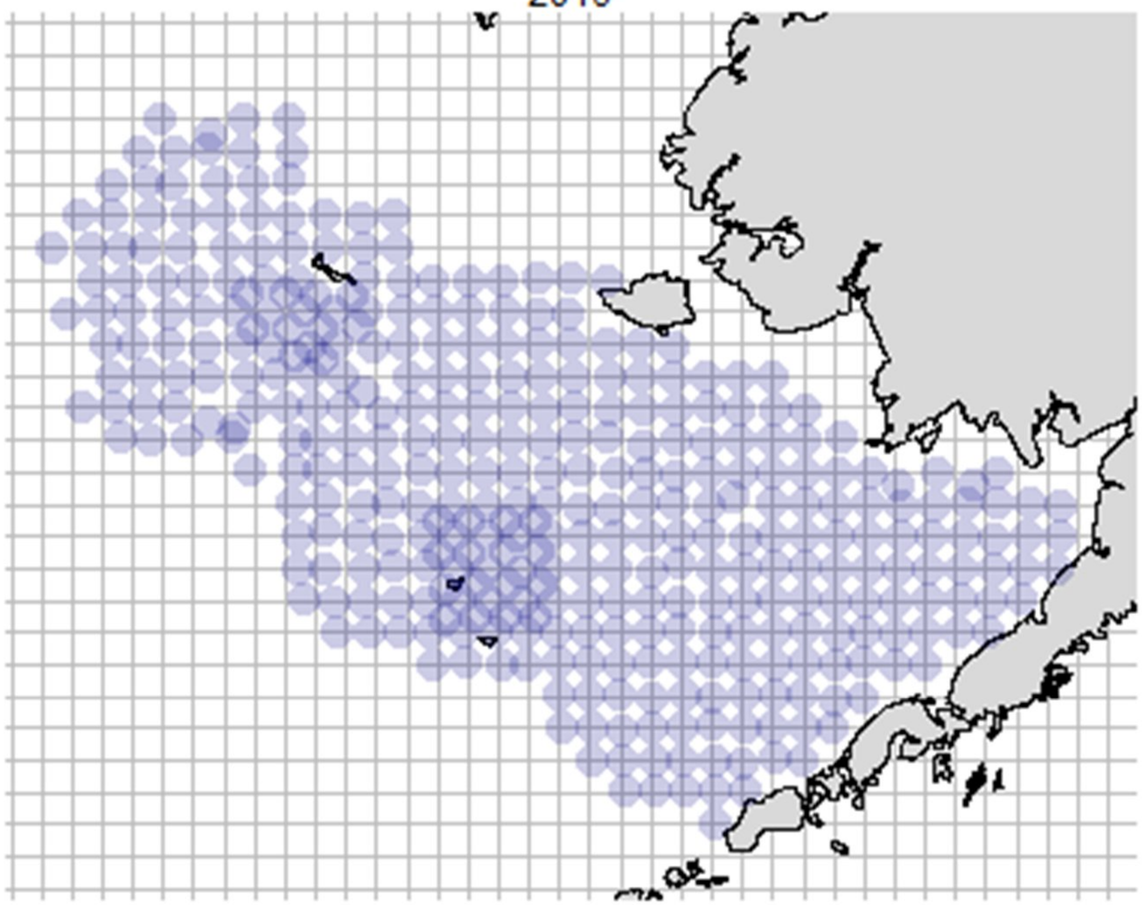
2014

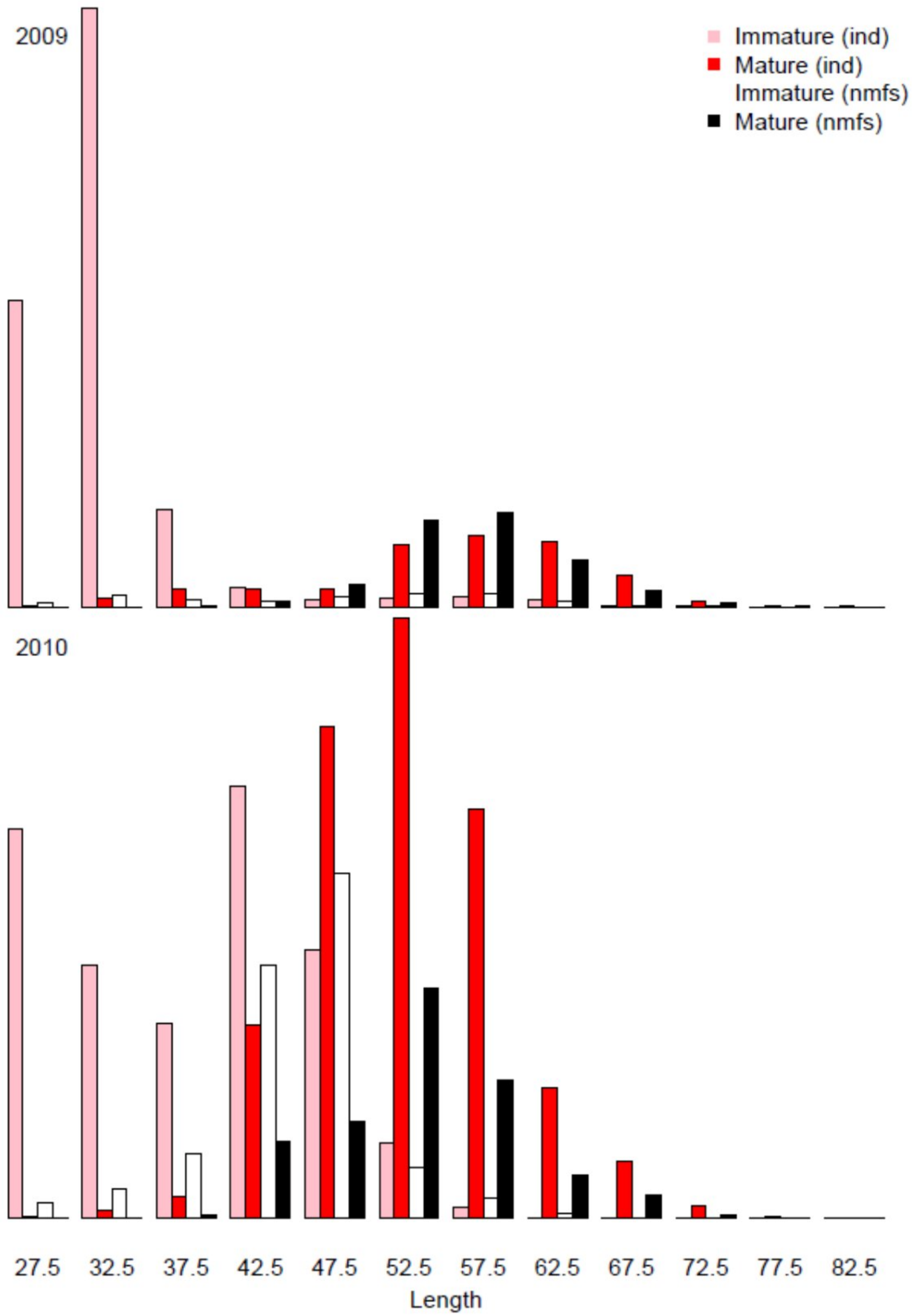


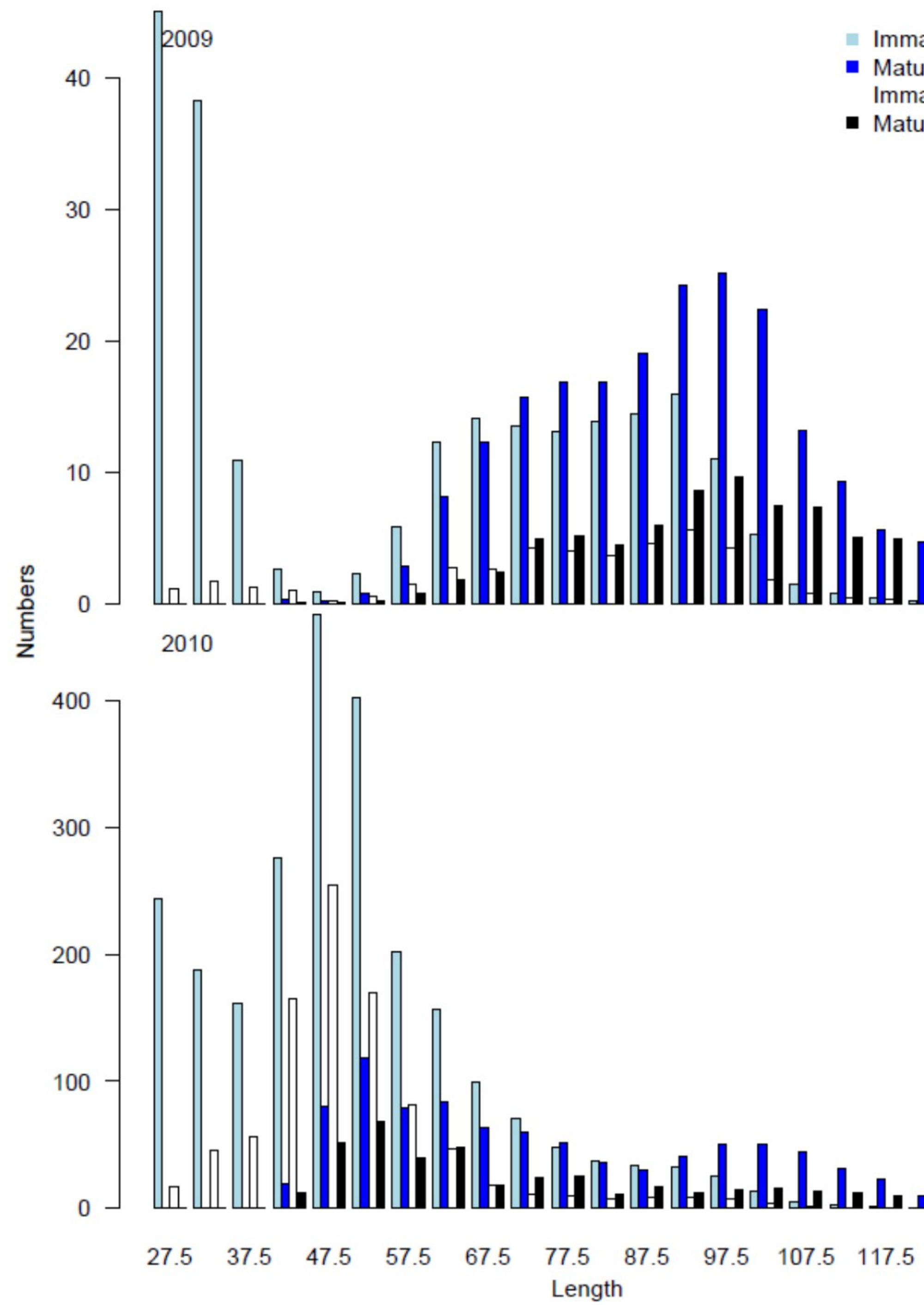
2015

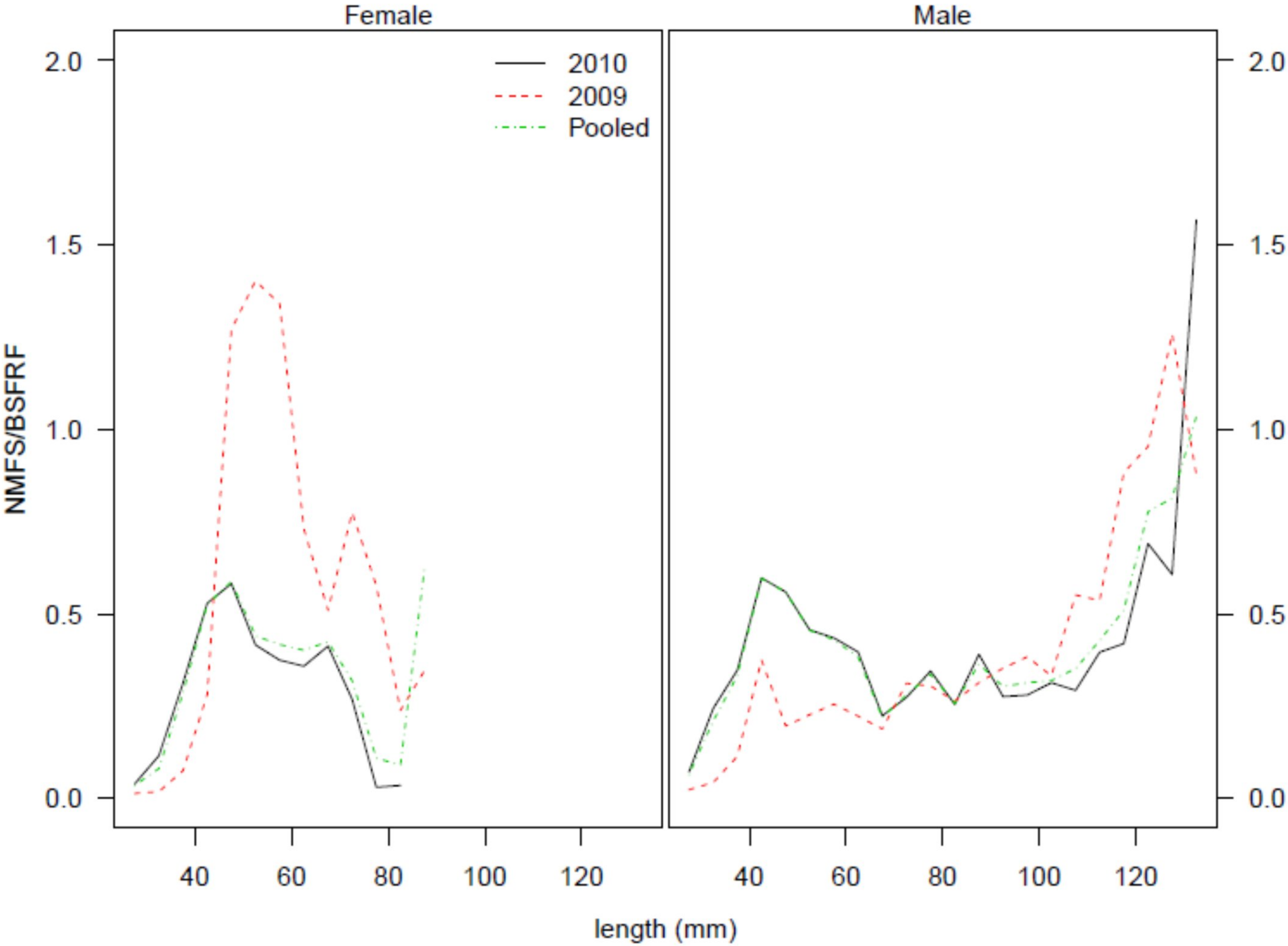


2016




2009
Immature (ind)
Mature (ind)
Immature (nmfs)
Mature (nmfs)
2010
27.5
32.5
37.5
42.5
47.5
52.5
57.5
62.5
67.5
72.5
77.5
82.5
Length

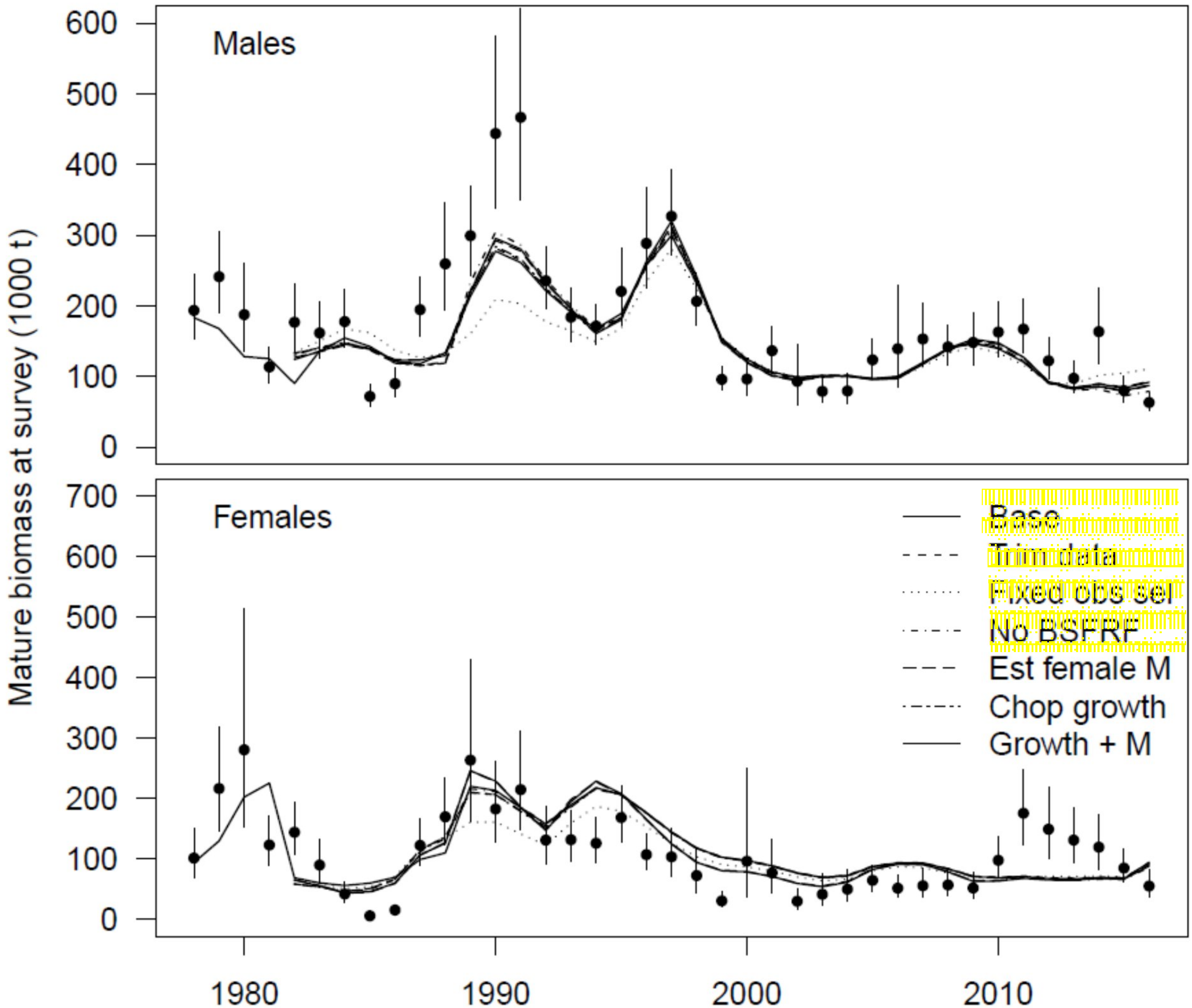

2009
Numbers
0
10
20
30
40
2010
0
100
200
300
400
27.5
37.5
47.5
57.5
67.5
77.5
87.5
97.5
107.5
117.5
Length



Female
Male
2010
2009
Pooled
NMFS/BSFRF
0.0
0.5
1.0
1.5
2.0
40
60
80
100
120
length (mm)

del runs

- im data'
  - Excludes all data from 1978-1981, start model in 1982
  - Explores problem of anchoring of q and bound hitting parameters
- xed obs sel'
  - 'Trim data' + fixing survey selectivity in era 2 and era 3 to selectivity inferred from BSFRF data
  - Explores implications of BSFRF data
- o BSFRF'
  - 'Trim data' + setting the weights for the BSFRF likelihood components to 0
  - Explores the impact of the BSFRF data on model output


Males
Females
Mature biomass at survey (1000 t)
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
0
100
200
300
400
500
600
700
1980
1990
2000
2010

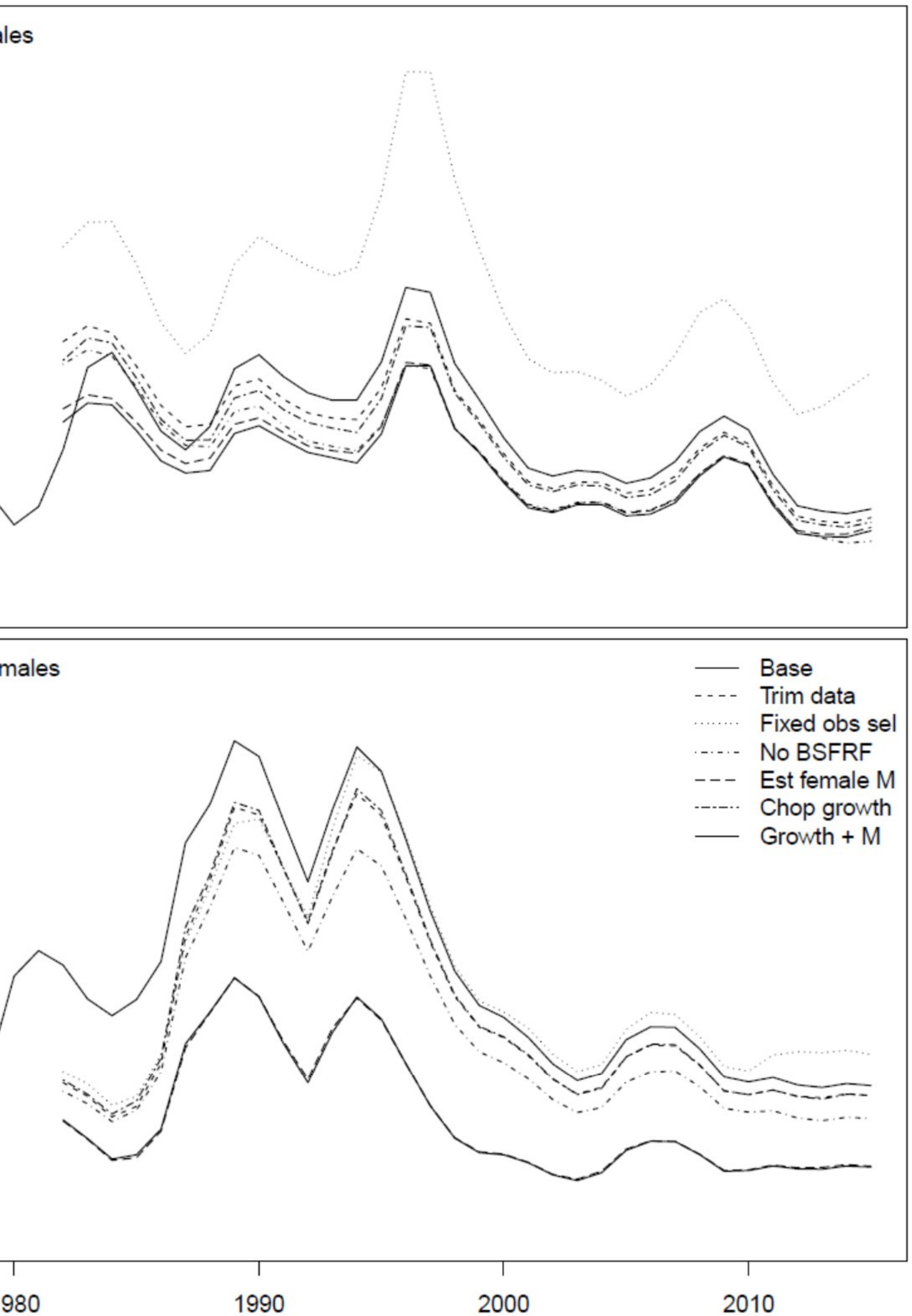
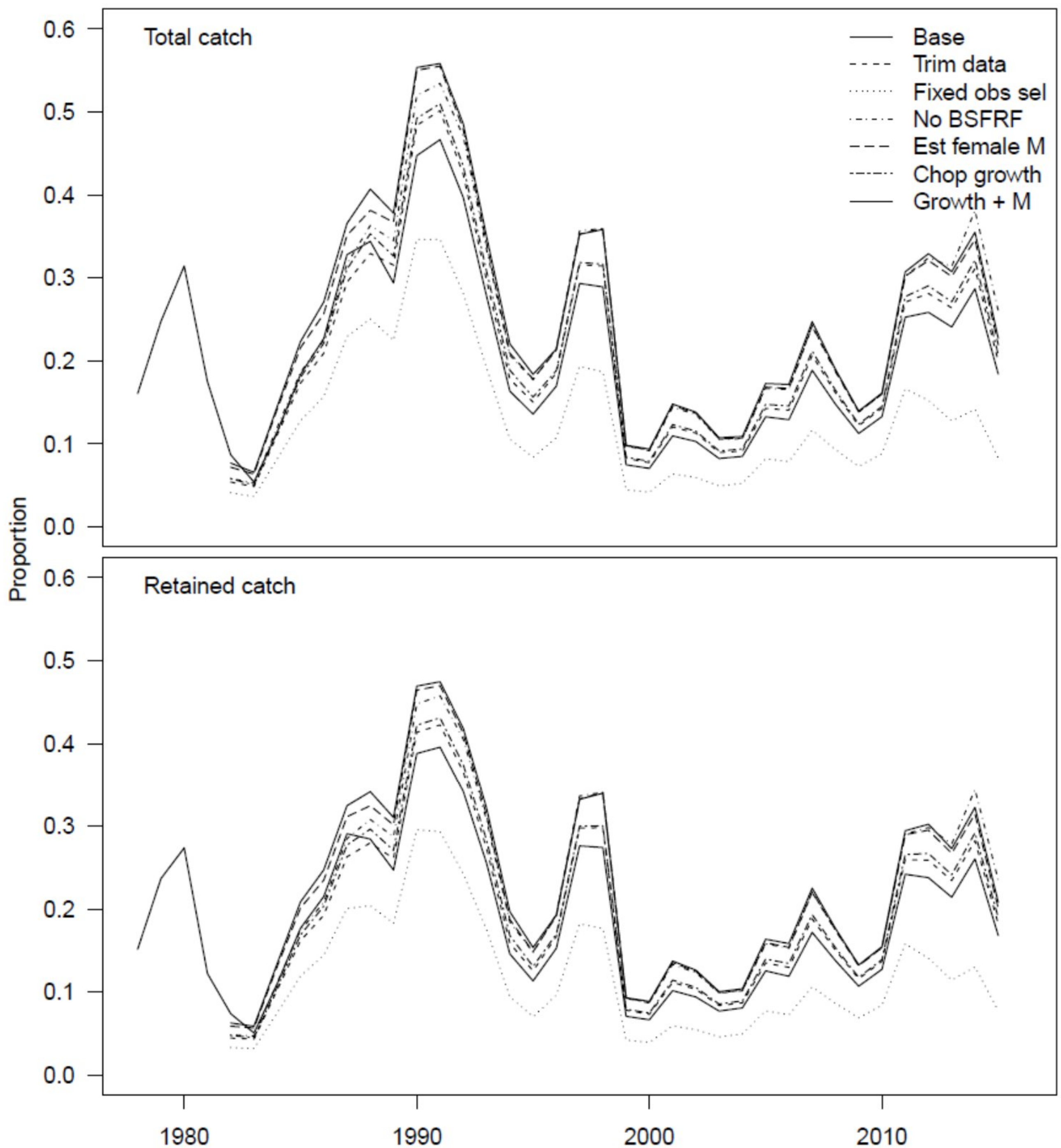
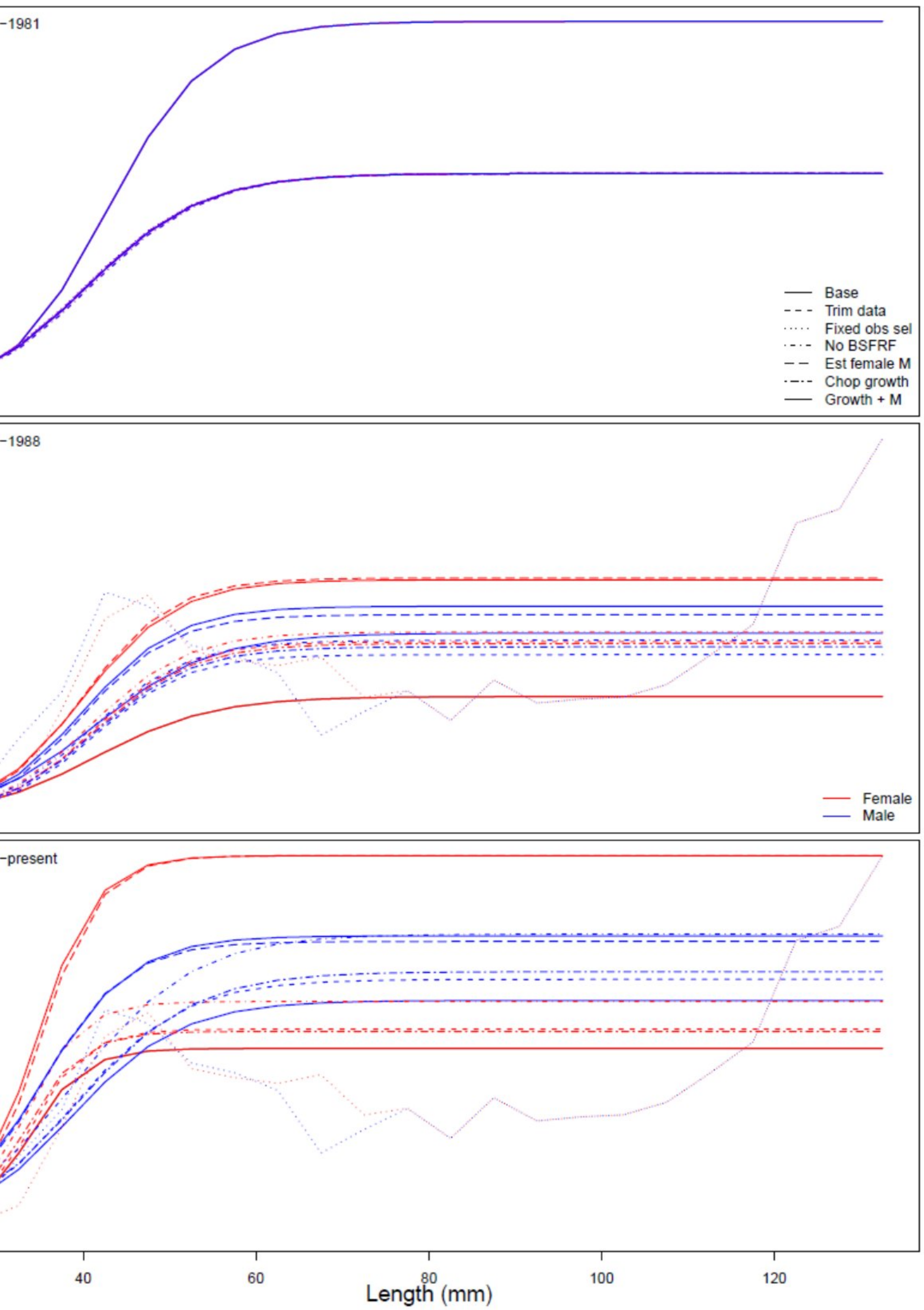


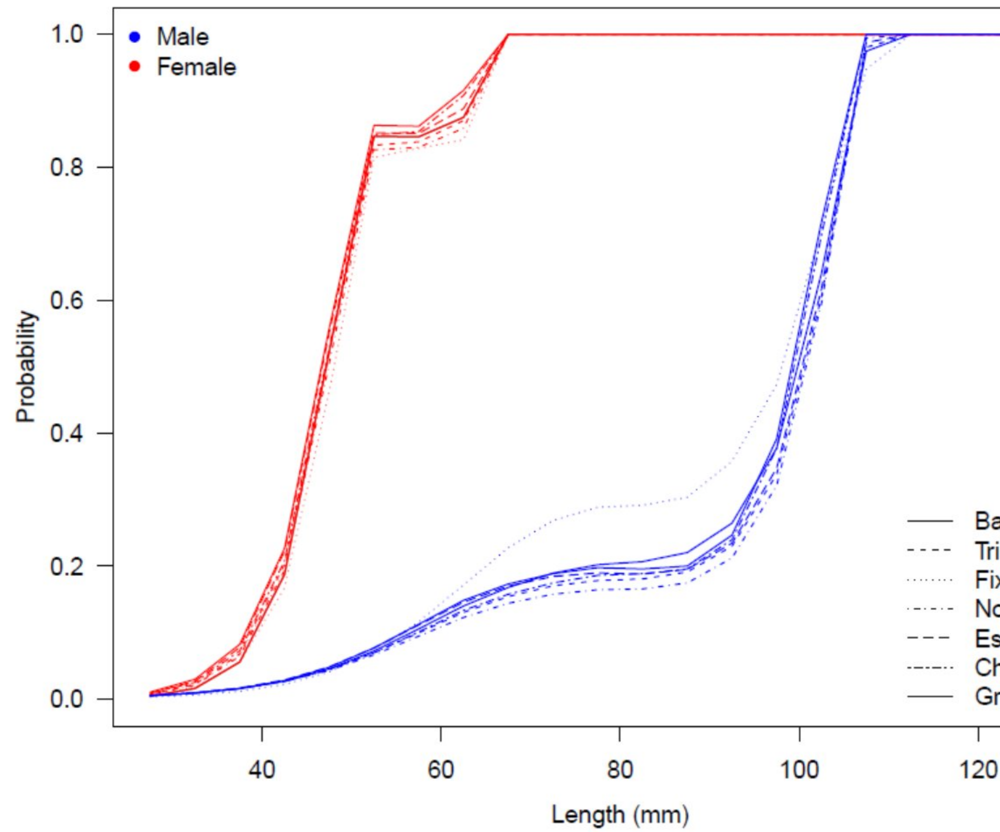
Table 1: Changes in management quantities for each scenar
sidered. Reported quantites are the MLEs because running M
for every model was prohibitively time-consuming. The MI
scenarios in which MCMCs were performed are very close
medians of the posterior distributions.

Model	MMB	B35	F35	FOFL
Base	92.09	152.3	1.91	1.14
Trim data	83.8	152.3	1.42	0.81
Fixed obs sel	221.6	215.3	3.49	2.62
No BSFRF	60.86	142.3	1.17	0.56
Est female M	74.29	139.6	1.21	0.68
Chop growth	79.57	149.8	1.34	0.75
Growth + M	70.89	137.4	1.17	0.64



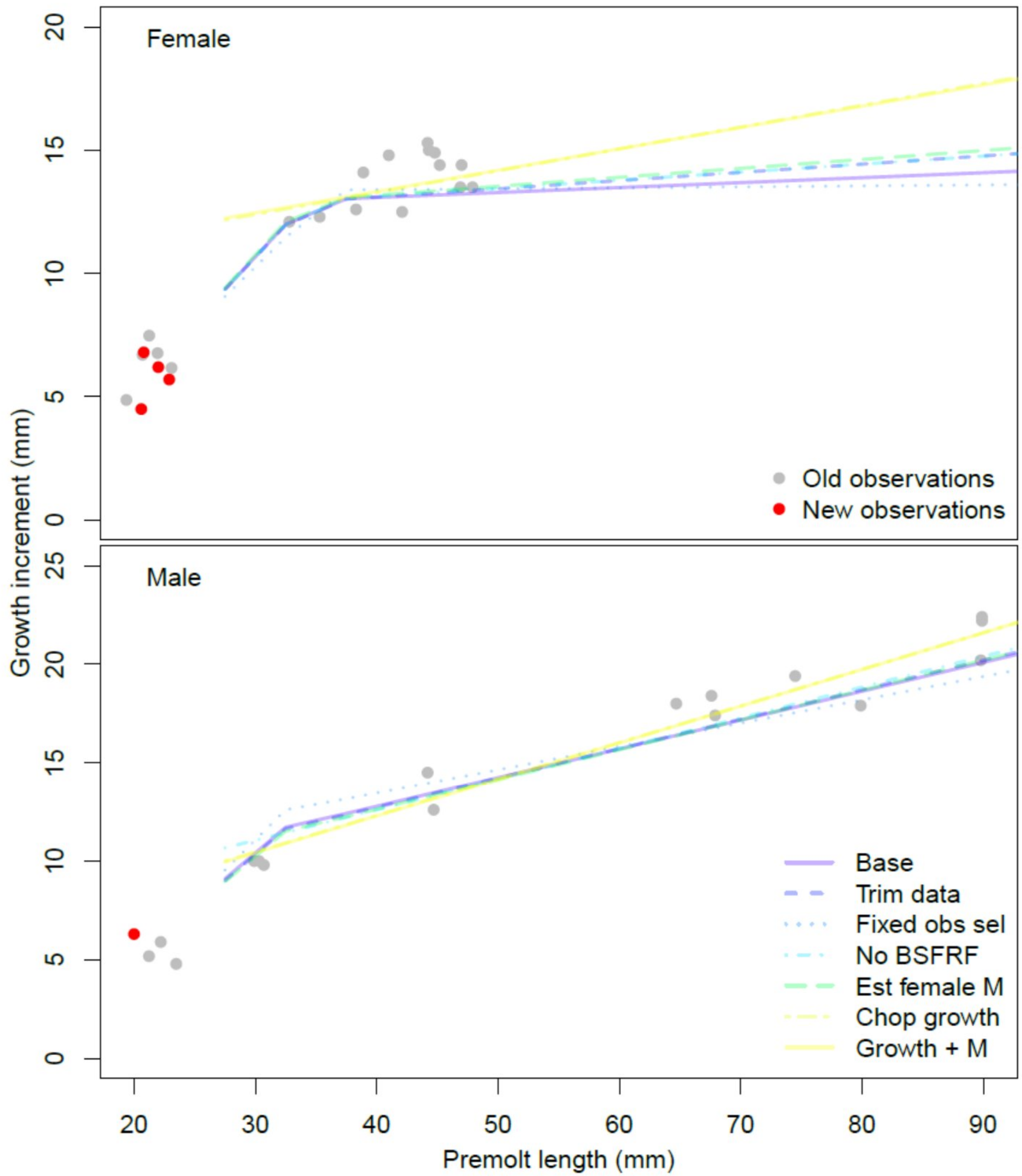
Total catch
Retained catch
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
Proportion
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1980
1990
2000
2010


-1981
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
-1988
Female
Male
-present
40
60
80
100
120
Length (mm)

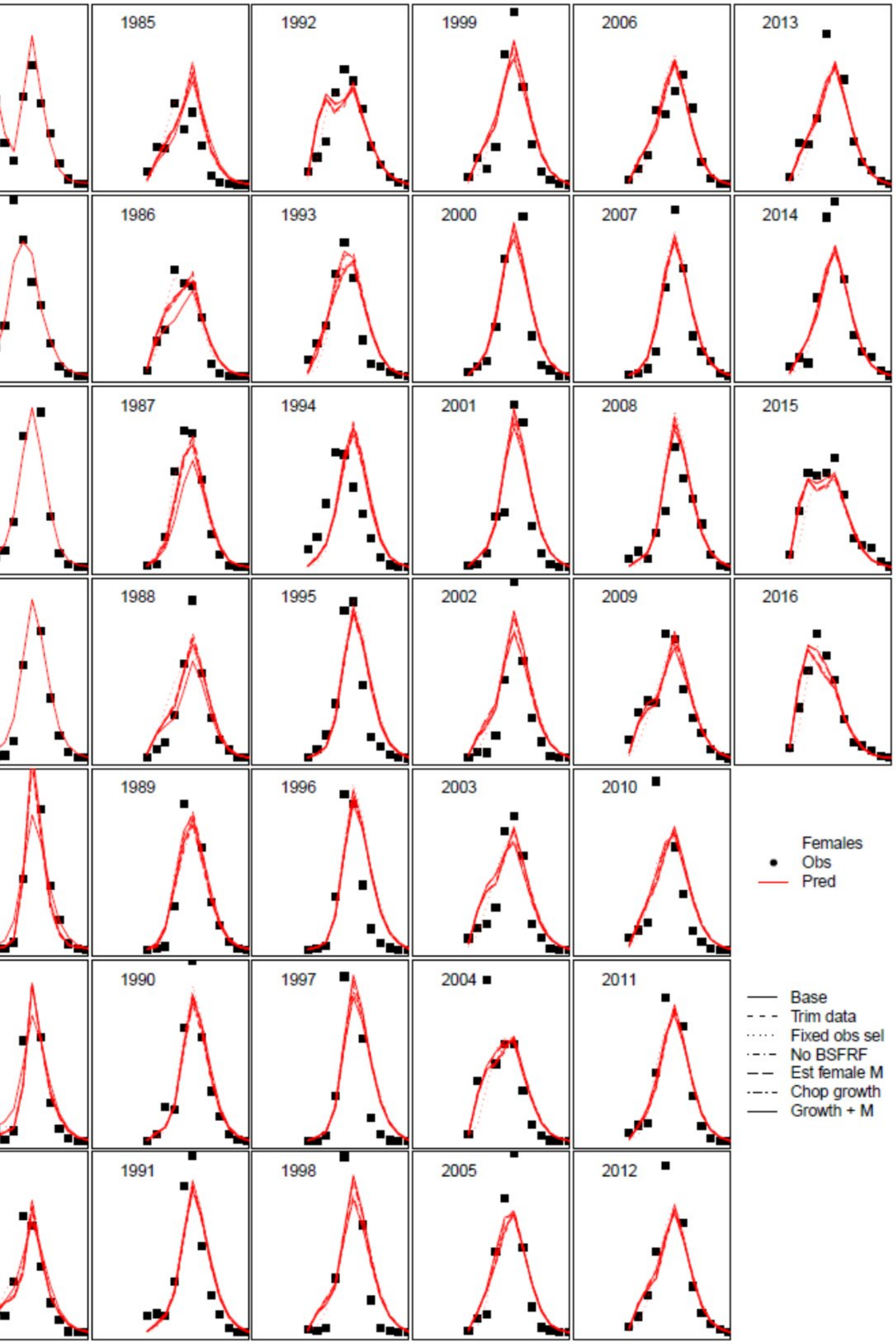

Male
Female
Probability
1.0
0.8
0.6
0.4
0.2
0.0
40
60
80
100
120
Length (mm)

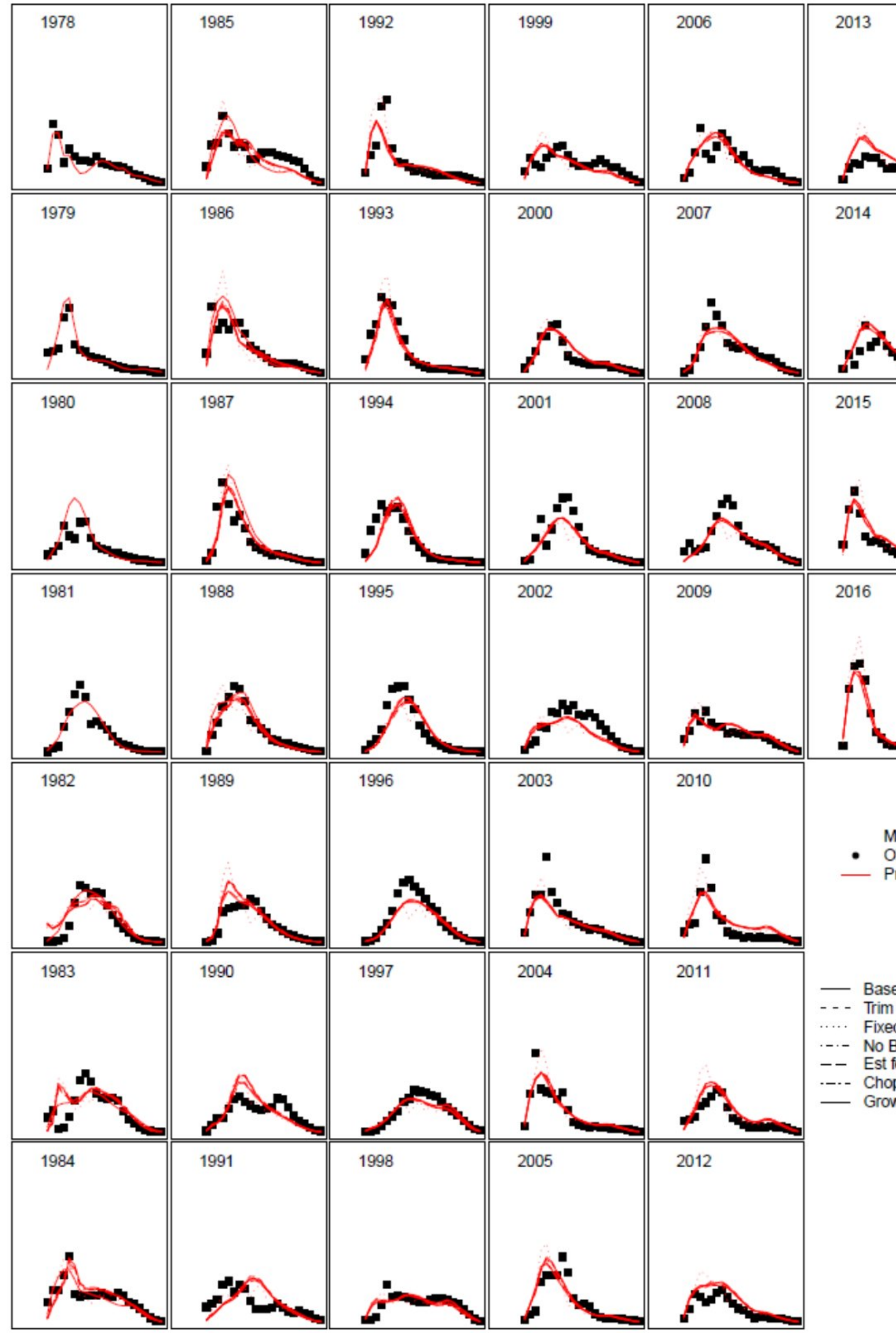
Parameter	Base	Trim data	Fixed obs sel	No BSFRF	Est female M	Chop growth	Growth + M
srv1_q	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_q_f	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel95	59.89	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel50	42.66	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv2_q	0.49	0.43	[redacted]	0.47	0.54	0.45	0.56
srv2_q_f	0.32	0.46	[redacted]	0.49	0.63	0.46	0.63
srv2_sel95	61.3	57.05	[redacted]	57.32	55.24	53.35	56.91
srv2_sel50	41.32	41.18	[redacted]	40.84	39.82	41.55	39.36
srv3_q	0.62	0.68	[redacted]	0.79	0.77	0.7	0.79
srv3_sel95	57.24	57.63	[redacted]	59.43	49.53	59.37	50.62
srv3_sel50	38.42	38.59	[redacted]	38.78	34.78	39.15	34.94
srv3_q_f	0.49	0.54	[redacted]	0.62	1	0.54	1
srv3_sel95_f	43.09	43.42	[redacted]	42.85	45.23	42.34	44.8
srv3_sel50_f	33.27	33.47	[redacted]	32.97	31.53	32.94	34.27

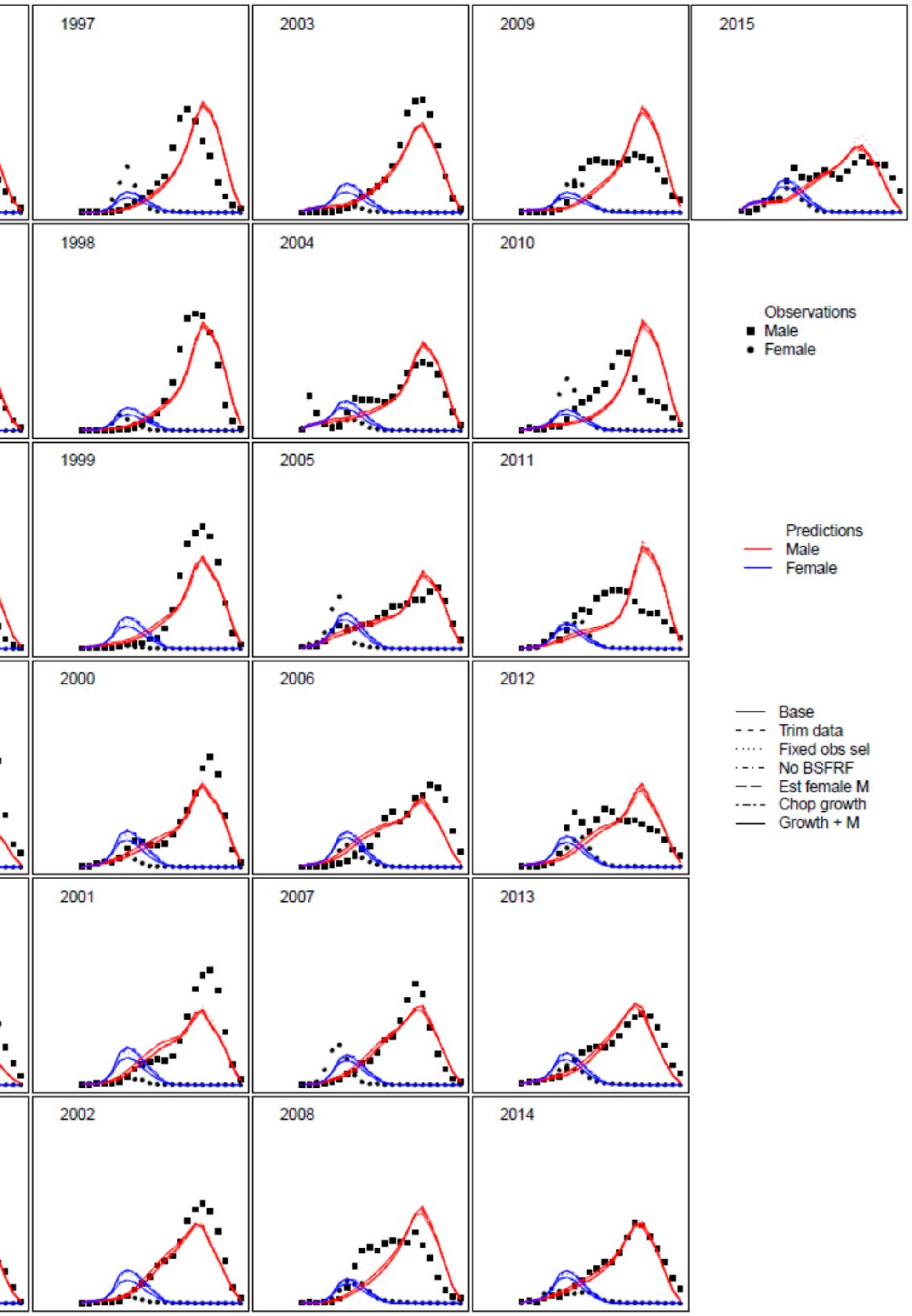
Parameter	Base	Trim data	Fixed obs sel	No BSFRF	Est female M	Chop growth	Growth + M
Mmult_imat	1.8	1.81	1.22	1.74	1.28	1.81	1.27
Mmult	1.13	1.08	1.13	1.06	1.15	1.09	1.16
Mmultf	[redacted]				1.41	[redacted]	1.42

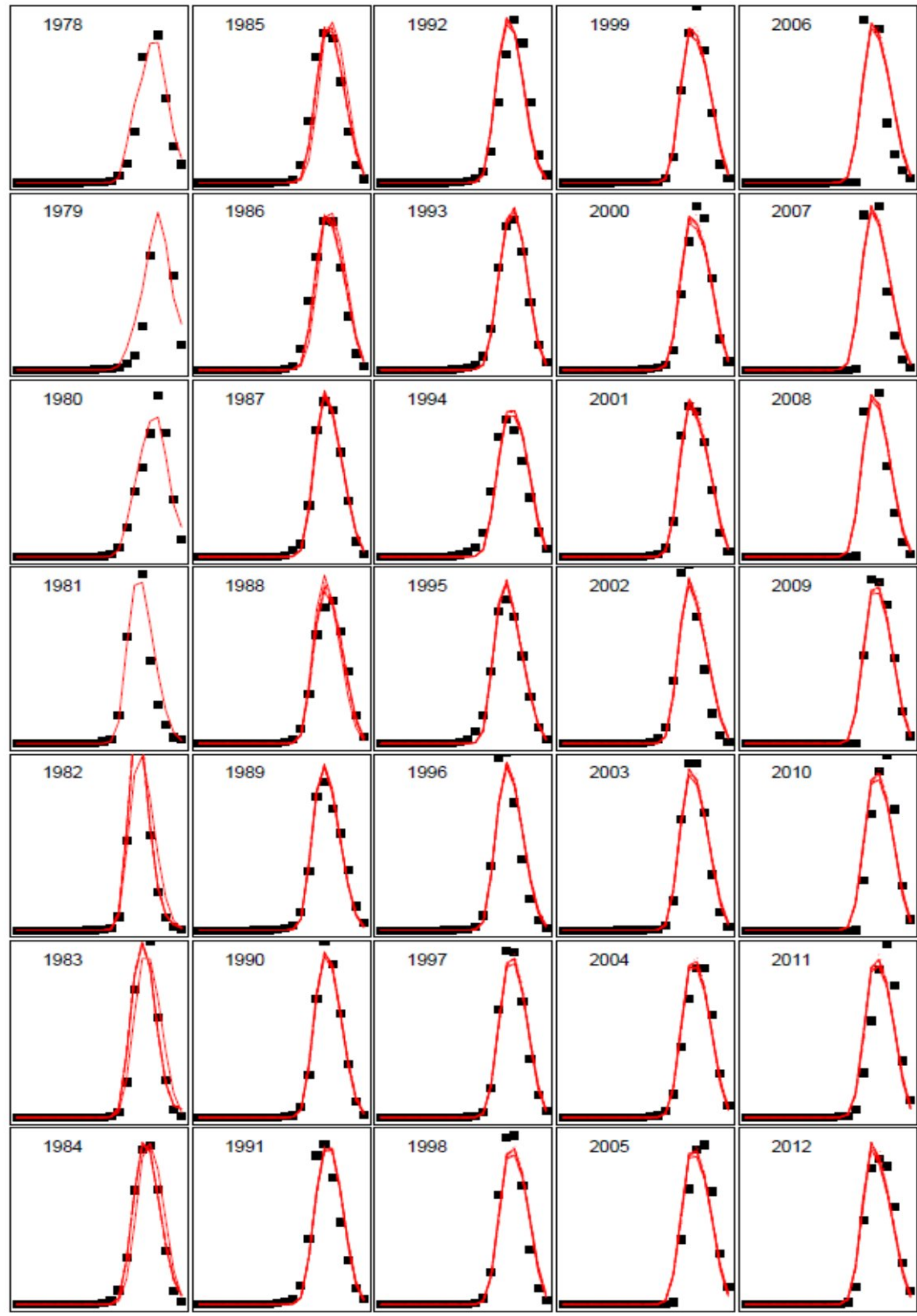

Female
Old observations
New observations
Male
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
Growth increment (mm)
Premolt length (mm)
0
5
10
15
20
25
30
40
50
60
70
80
90

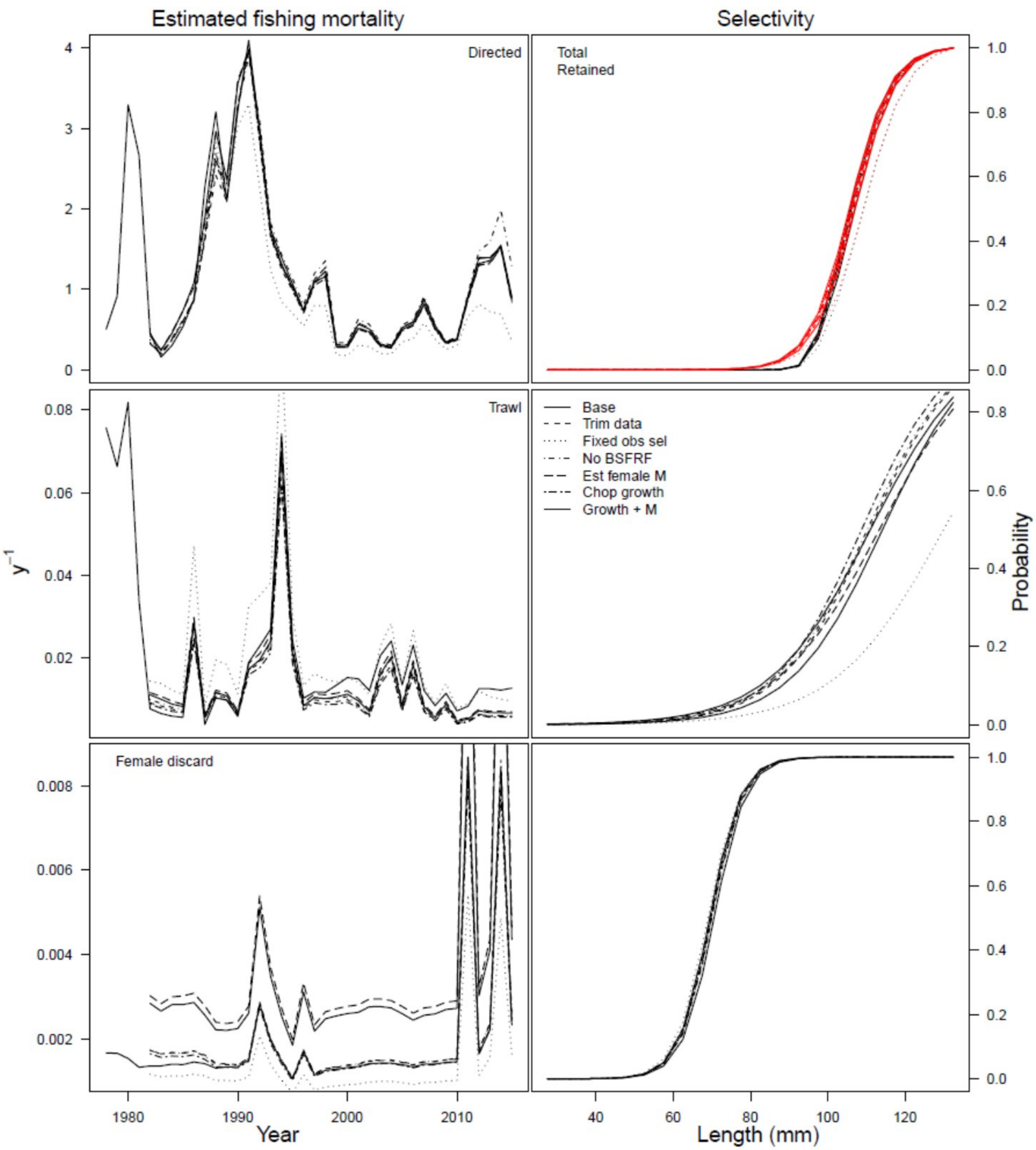
Parameter	Base	Trim data	Fixed obs sel	No BSFRF	Est female M	Chop growth	Growth + M
af	-5.08	-5.06	-4.1	-5.08	[illegible]	[illegible]	[illegible]
am	-5.74	-5.83	-7.48	-12.2	-5.61	4.89	4.64
bf	1.53	1.52	1.48	1.53	1.53	1.09	1.09
bm	1.54	1.54	1.62	1.83	1.53	1.19	1.19
b1	1.15	1.15	1.12	1.16	1.15	1.25	1.25
bf1	1.02	1.03	1	1.03	1.04	1.5	1.5
deltam	32.2	32.25	32.37	27.47	32.1?	[illegible]	[illegible]
deltaf	34.37	34.29	36.51	34.33	34.13	[illegible]	[illegible]


1985
1992
1999
2006
2013
1986
1993
2000
2007
2014
1987
1994
2001
2008
2015
1988
1995
2002
2009
2016
1989
1996
2003
2010
1990
1997
2004
2011
1991
1998
2005
2012
Females
Obs
Pred
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M

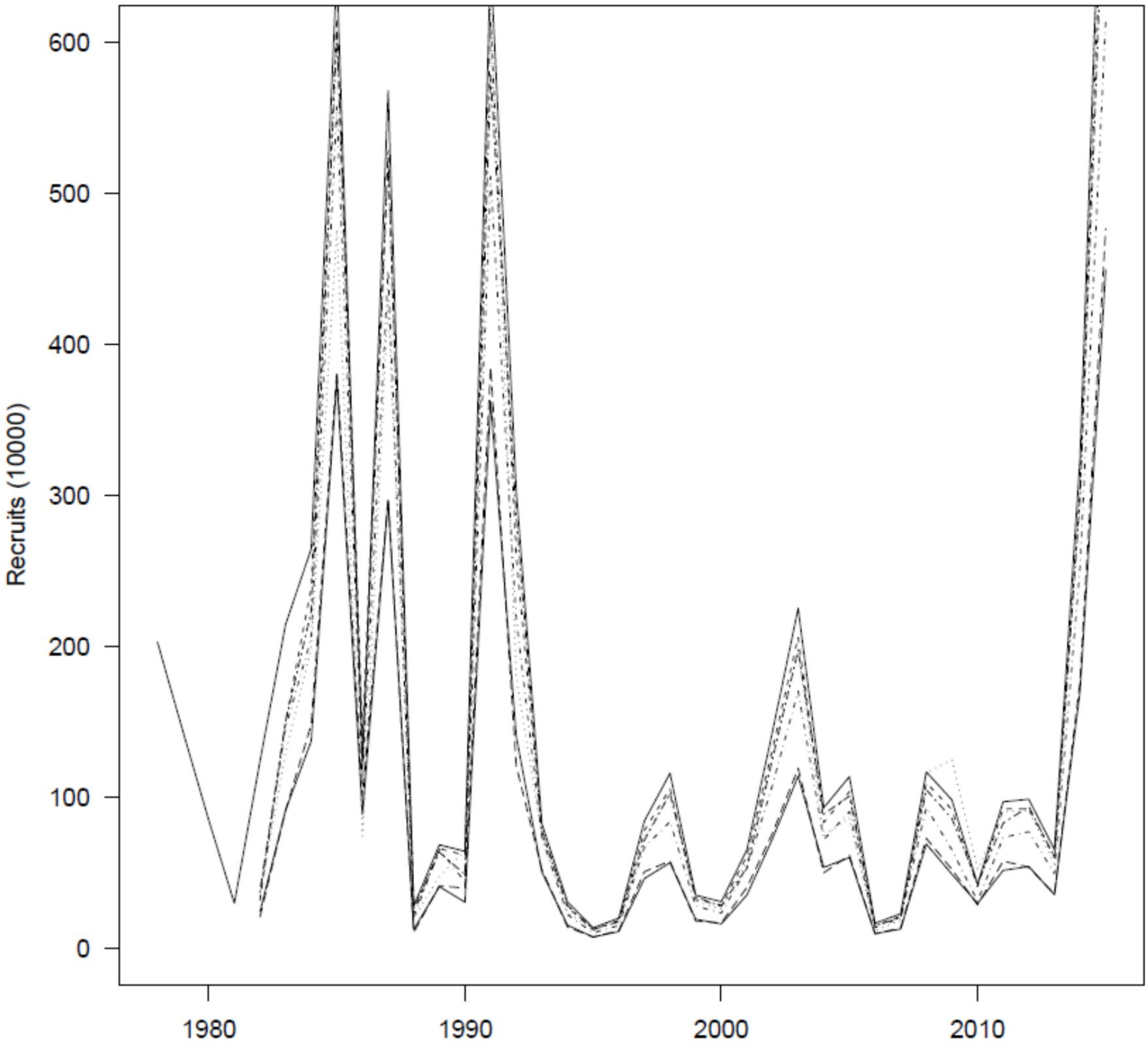

1978
1985
1992
1999
2006
2013
1979
1986
1993
2000
2007
2014
1980
1987
1994
2001
2008
2015
1981
1988
1995
2002
2009
2016
1982
1989
1996
2003
2010
1983
1990
1997
2004
2011
1984
1991
1998
2005
2012

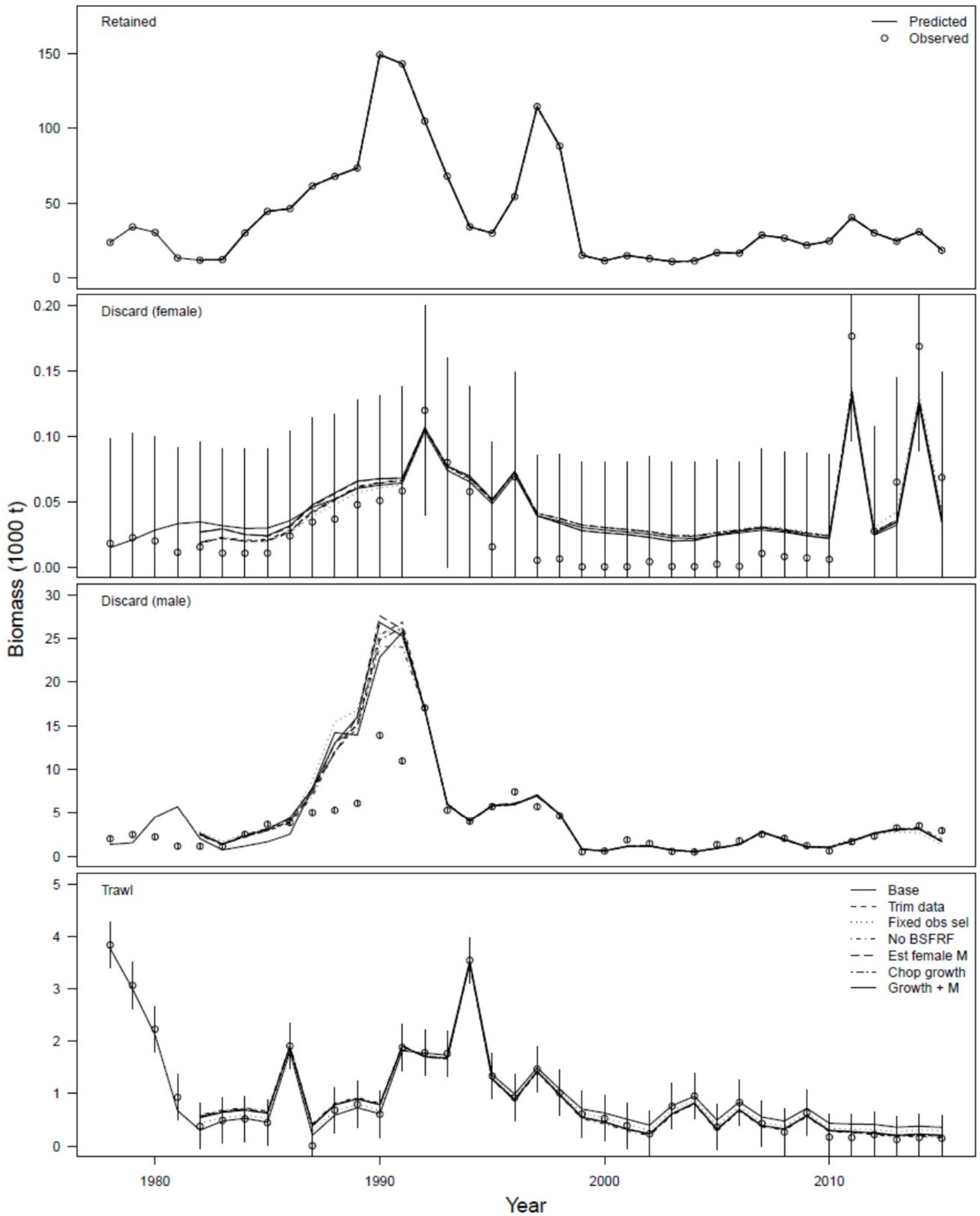

1997
2003
2009
2015
1998
2004
2010
1999
2005
2011
2000
2006
2012
2001
2007
2013
2002
2008
2014
Observations
Male
Female
Predictions
Male
Female
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M


1978
1985
1992
1999
2006
1979
1986
1993
2000
2007
1980
1987
1994
2001
2008
1981
1988
1995
2002
2009
1982
1989
1996
2003
2010
1983
1990
1997
2004
2011
1984
1991
1998
2005
2012



Estimated fishing mortality
Selectivity
Directed
Total
Retained
Trawl
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
Female discard
y^{-1}
Probability
Year
Length (mm)


Recruits (10000)
0
100
200
300
400
500
600
1980
1990
2000
2010



Retained
Predicted
Observed
Discard (female)
Discard (male)
Trawl
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
Biomass (1000 t)
Year

del results

im data'

- OFL decreased compared to 'Base', primarily because q in era 3 increased
- Decrease in estimated probability of maturing and natural mortality for brought down F35%

ed obs sel'

- OFL increased (a lot) compared to 'Base' from a decrease in q, probability of maturing, and growth
- Much worse fits to survey MMB, survey selectivity much lower than any of the estimated scenarios

 BSFRF'

- OFL decreased compared to 'Base', primarily because q in era 3 increased
- Shifts breakpoint in growth
- F35% decreases relative to 'Base' due to decreases in natural mortality and probability of maturing

Table 1: Changes in management quantities for each sce
sidered. Reported quantites are the MLEs because runnin
for every model was prohibitively time-consuming. The
scenarios in which MCMCs were performed are very clo
medians of the posterior distributions.

Model	MMB	B35	F35	FOFL
Base	92.09	152.3	1.91	1.14
Trim data	83.8	152.3	1.42	0.81
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Chop growth	79.57	149.8	1.34	0.75
Growth + M	70.89	137.4	1.17	0.64

ommendations

- im data'
  - Adopt exclusion of all data from 1978-1981, start model in 1982
  - Rationale: Including this era artificially anchors catchability at 1. Given the uncertainties around expected changes under different survey gear and the potential for catch to be missing in the early years, the risks outweigh the benefits
  - Era 3 should start in 1988 instead of 1989
- xed obs sel' & "No BSFRF"
  - Neither of these should be adopted, but were used illustratively
  - Think harder about how to do incorporate extra survey
  - Issues:
    - problems with variables hitting bounds
    - Large disconnect between 'observed' selectivity and estimated
    - Stock is at it's lowest, in spite of an assumption of a higher q than implied by the industry surveys—changing this assumption to the 'observed' would have exacerbated the decline in MMB

ural mortality

- urrent:
  - Immature M (male and female):
    - 0.41 (estimated)
    - Prior = N(0.23, 0.154)
  - Mature female M:
    - 0.23 (fixed)
  - Mature male M:
    - 0.26 (estimated)
    - Prior = N(0.23,0.054)
- sues
  - Mature male M was higher than female, which was biologically questionable
  - No natural mortality specific data (e.g. tagging data)
  - Has a large impact on reference points
  - Poorly documented rationale

del runs

- t female M’
  - ‘Trim data’ + estimating mature female M + setting the prior for immature crab equal to prior for mature crab
  - Potentially corrects for flip-flop of M between sexes and corrects the prior to conform to the rationale of M being based on longevity

del results

- rim data'
  - Immature M (male and female):
    - 0.29 (estimated, decreased from 0.41)
    - Prior = N(0.23, 0.054) [sd decreased from 0.154]
  - Mature female M:
    - 0.32 (estimated, increased from 0.23)
    - Prior = N(0.23,0.054)
  - Mature male M:
    - 0.26 (estimated; did not change)
    - Prior = N(0.23,0.054)
  - Survey catchability is pegged at 1 for females when estimating mature M
  - OFL decreased compared to 'Base', primarily because q in era 3 increased
  - Decrease in estimated probability of maturing for brought down F35%

Parameter	Base	Trim data	Fixed obs sel	No BSFRF	Est female M	Chop growth	Growth + M
srv1_q	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_q_f	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel95	59.89	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel50	42.66	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv2_q	0.49	0.43	[redacted]	0.47	0.54	0.45	0.56
srv2_q_f	0.32	0.46	[redacted]	0.49	0.63	0.46	0.63
srv2_sel95	61.3	57.05	[redacted]	57.32	55.24	58.05	56.01
srv2_sel50	41.32	41.18	[redacted]	40.84	39.82	41.35	39.86
srv3_q	0.62	0.68	[redacted]	0.79	0.77	0.7	0.79
srv3_sel95	57.24	57.63	[redacted]	59.43	49.53	59.37	50.62
srv3_sel50	38.42	38.59	[redacted]	38.78	34.78	39.15	34.94
srv3_q_f	0.49	0.54	[redacted]	0.62	1	0.54	1
srv3_sel95_f	43.09	43.42	[redacted]	42.85	45.23	42.84	44.8
srv3_sel50_f	33.27	33.47	[redacted]	32.97	34.73	32.94	34.27

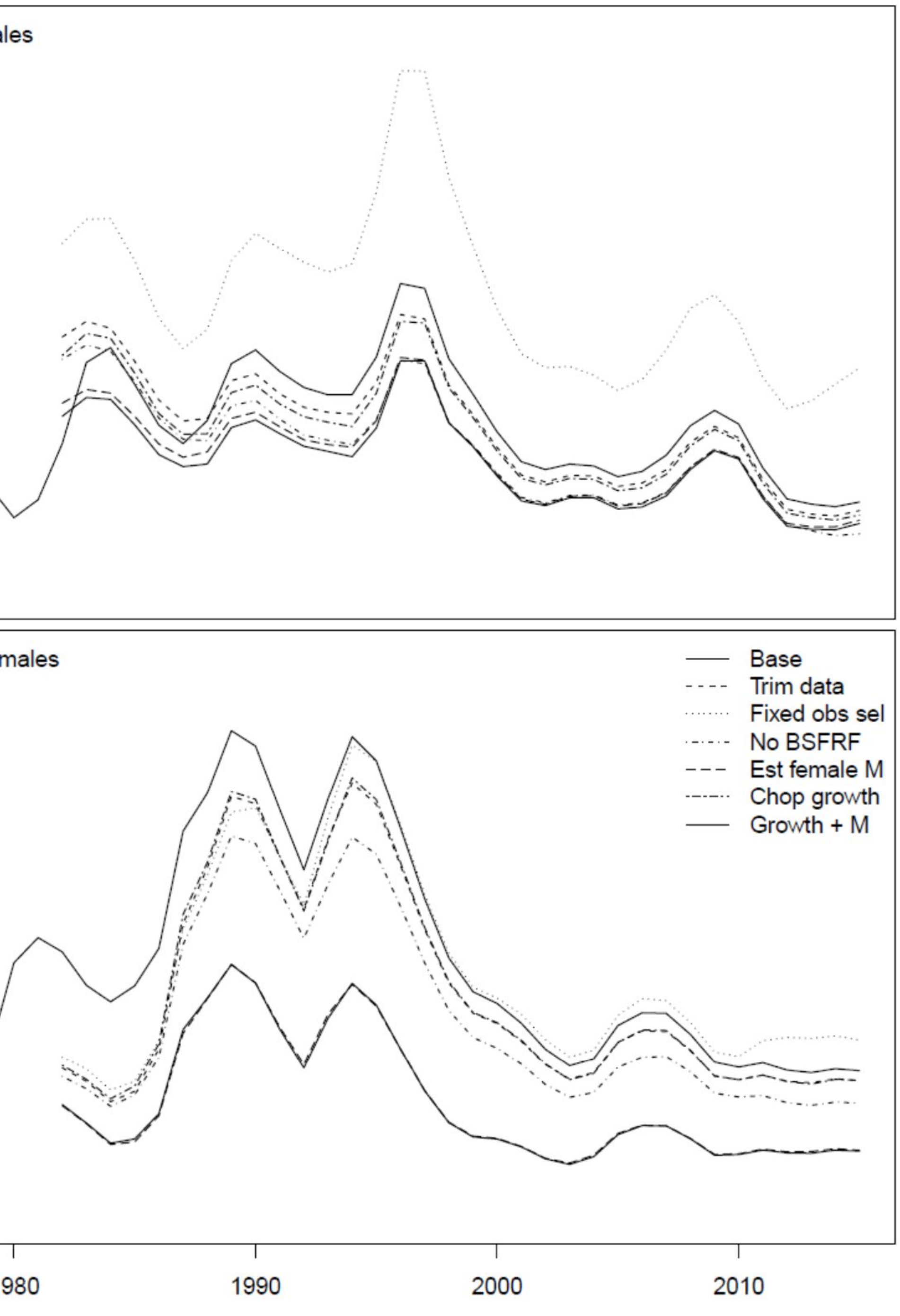

Table 1: Changes in management quantities for each scenar
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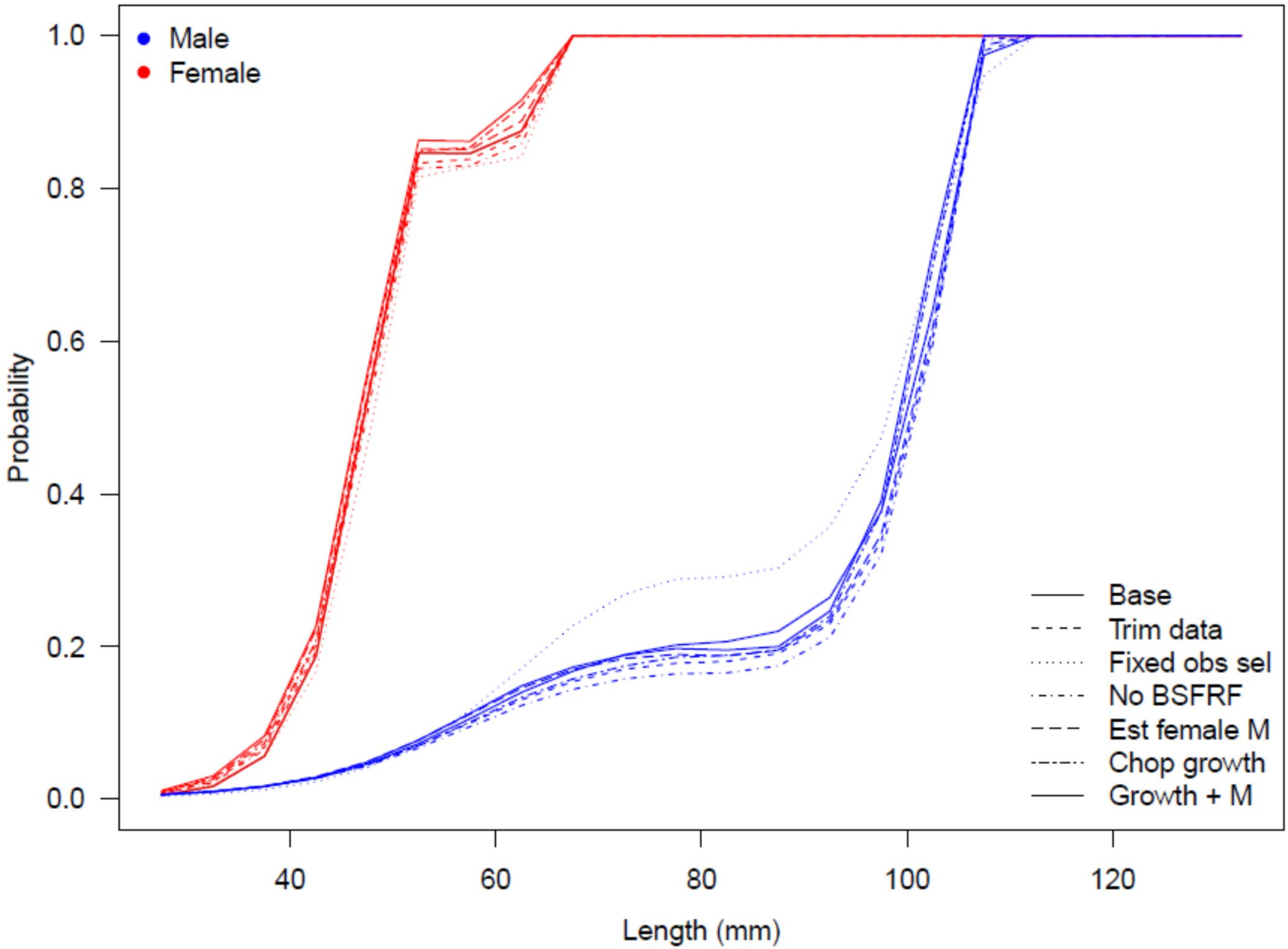


Male
Female
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M
Probability
Length (mm)
0.0
0.2
0.4
0.6
0.8
1.0
40
60
80
100
120

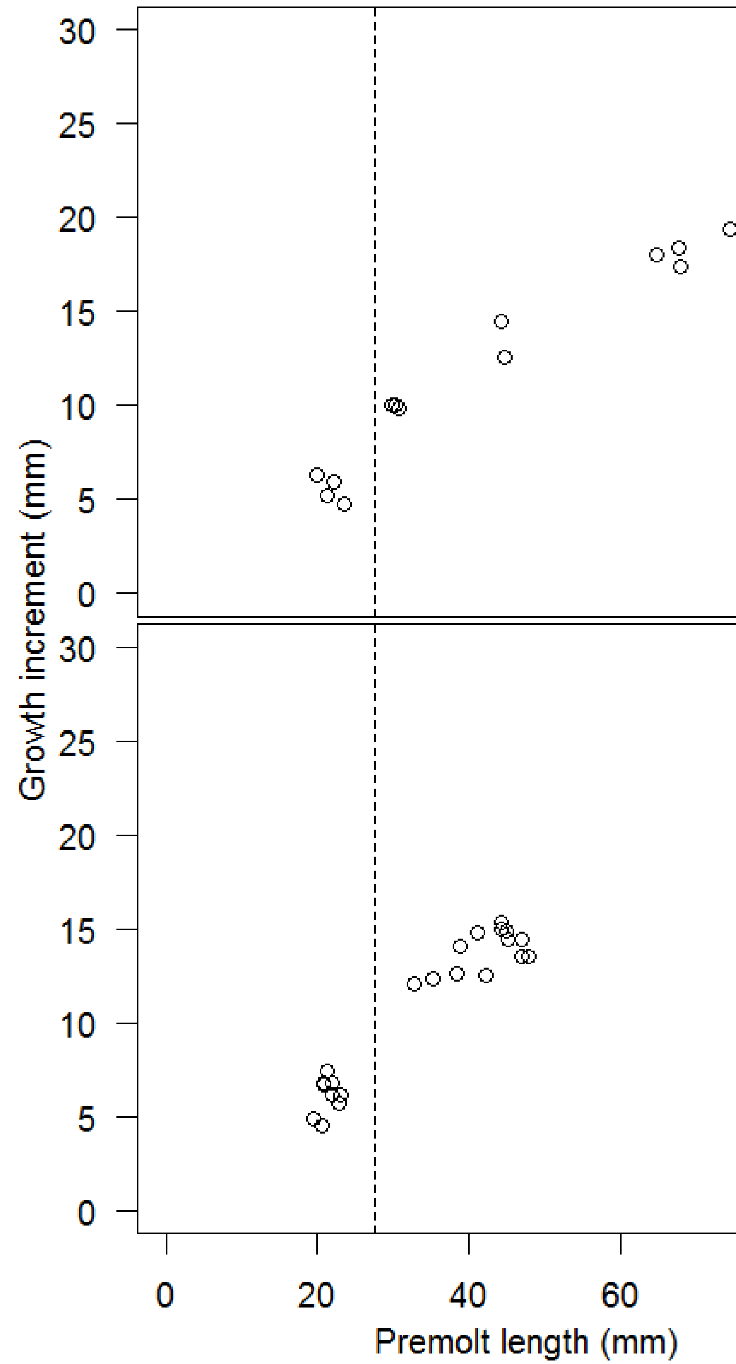
ommendations

makes sense to estimate mature female natural mortality and corrects lationship between mature male and mature female M, but now surve a 3 for females hits its bound of 1.

mature natural mortality is now flipped, but this is a result of placing t me prior on immature M that is placed on mature M.

wth model and available data

- rrent: Piece-wise linear model
- estimated parameters
- data points
- ues
  - No data where the breakpoint, resulting in poor estimation
  - Data beneath the breakpoint impacts the model little
  - Growth parameters hit bounds and are generally poorly behaved
- hat model should be used for growth?



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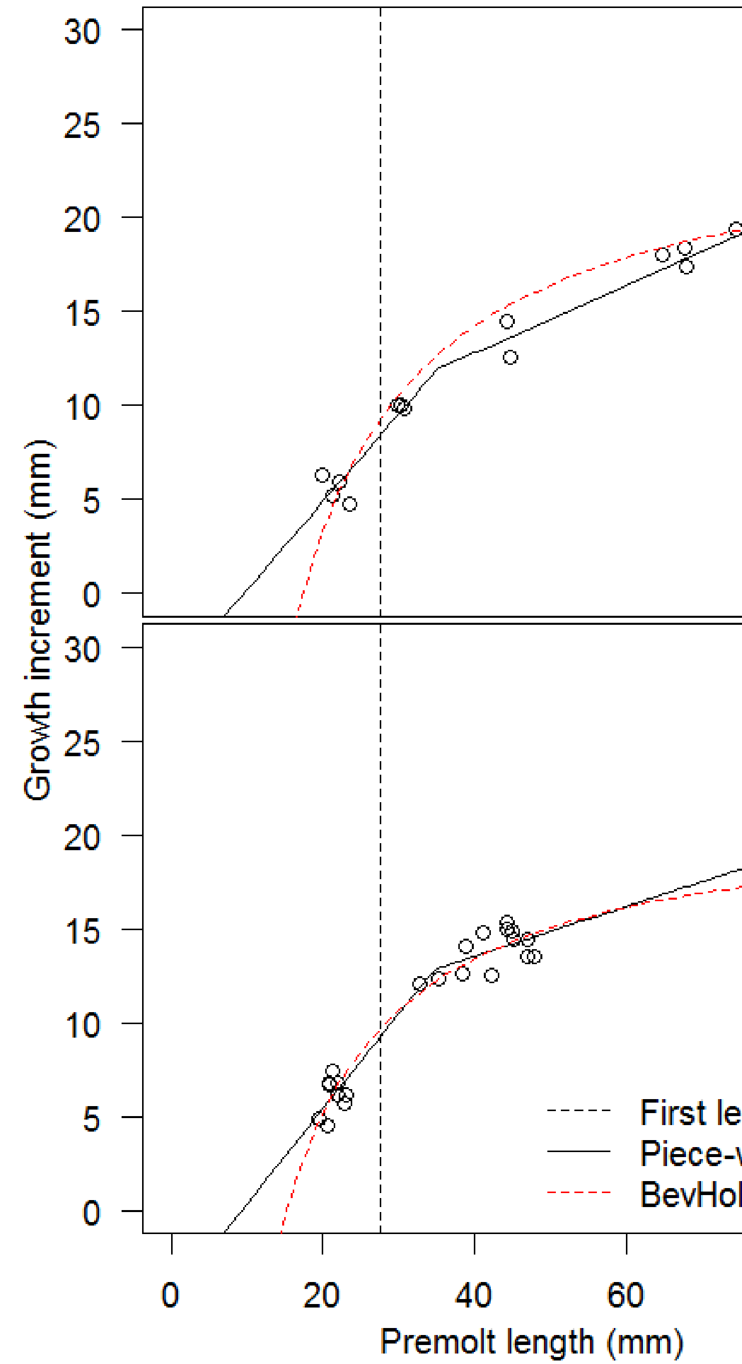

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- data points
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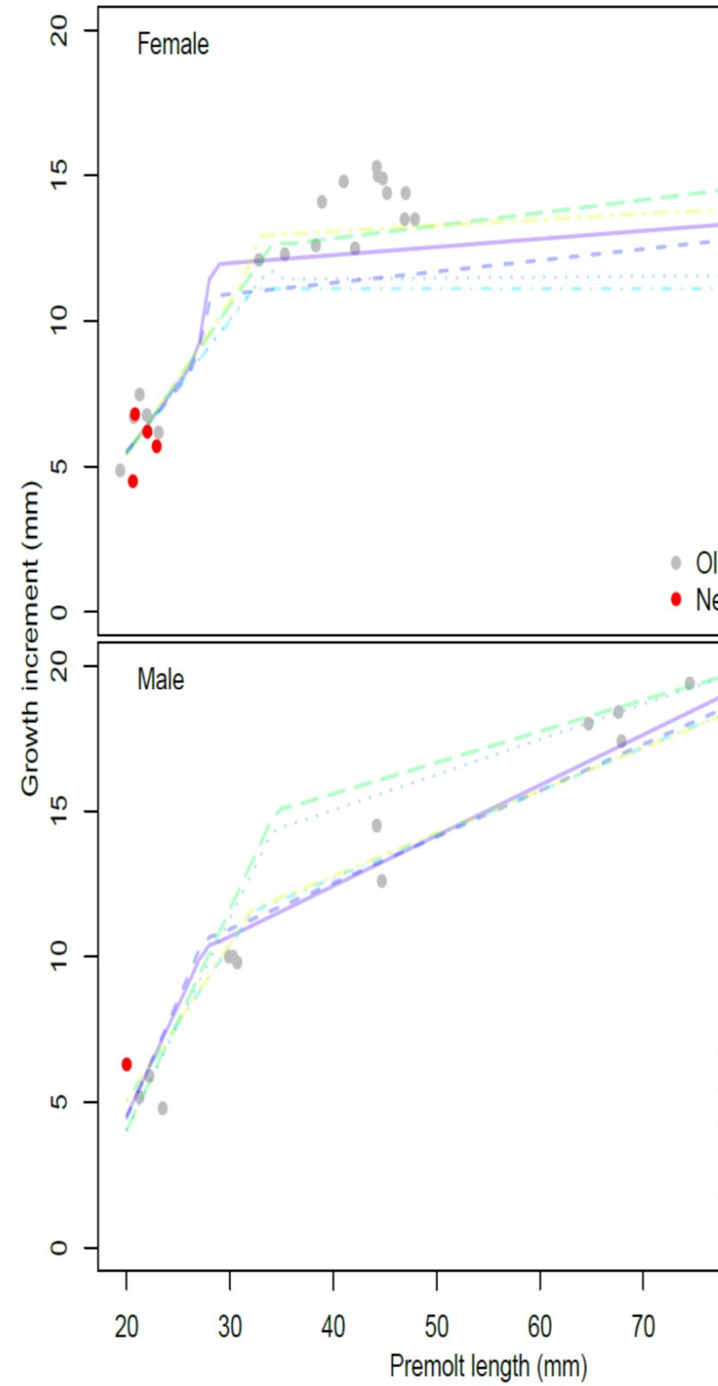
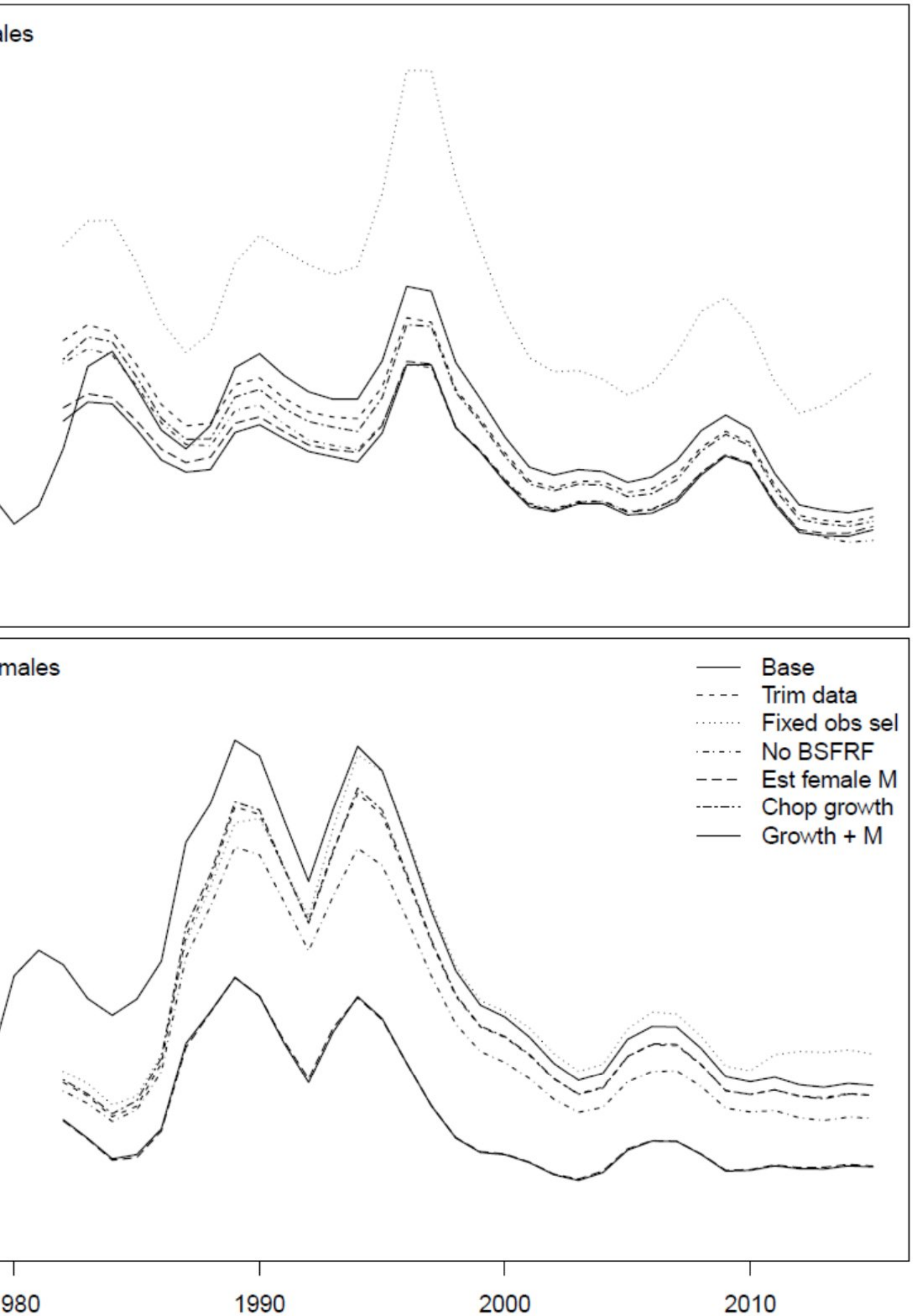


del runs

- hop growth’
  - “Trim data” + excludes all growth data with a premolt size of <27.5 mm, then estimates only a linear model for both males and females
  - Explores problem of bound hitting and poorly estimated growth parameters
- rowth + M’
  - ‘Chop growth’ + estimating mature female M
  - Growth and natural mortality are somewhat confounded



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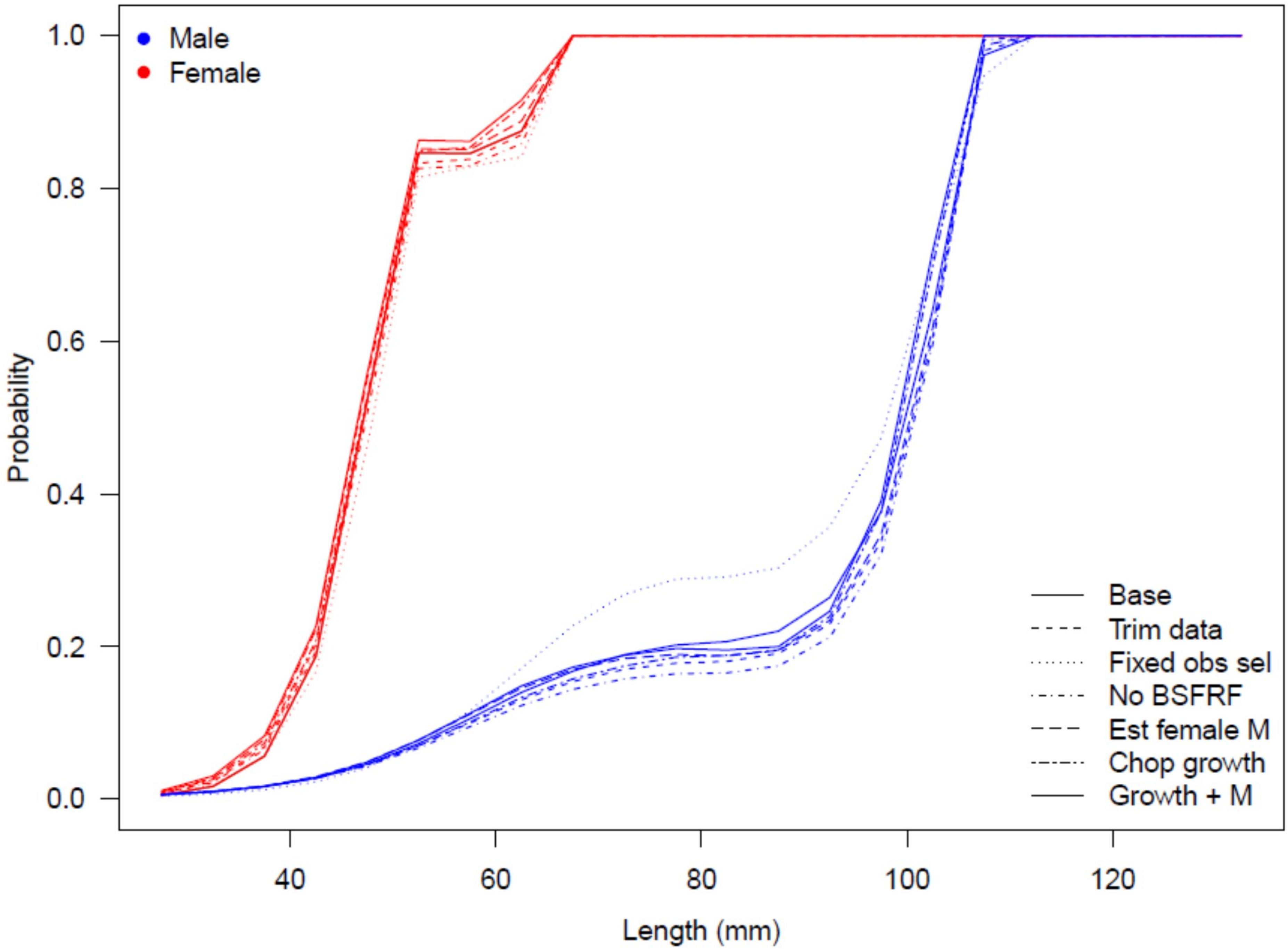
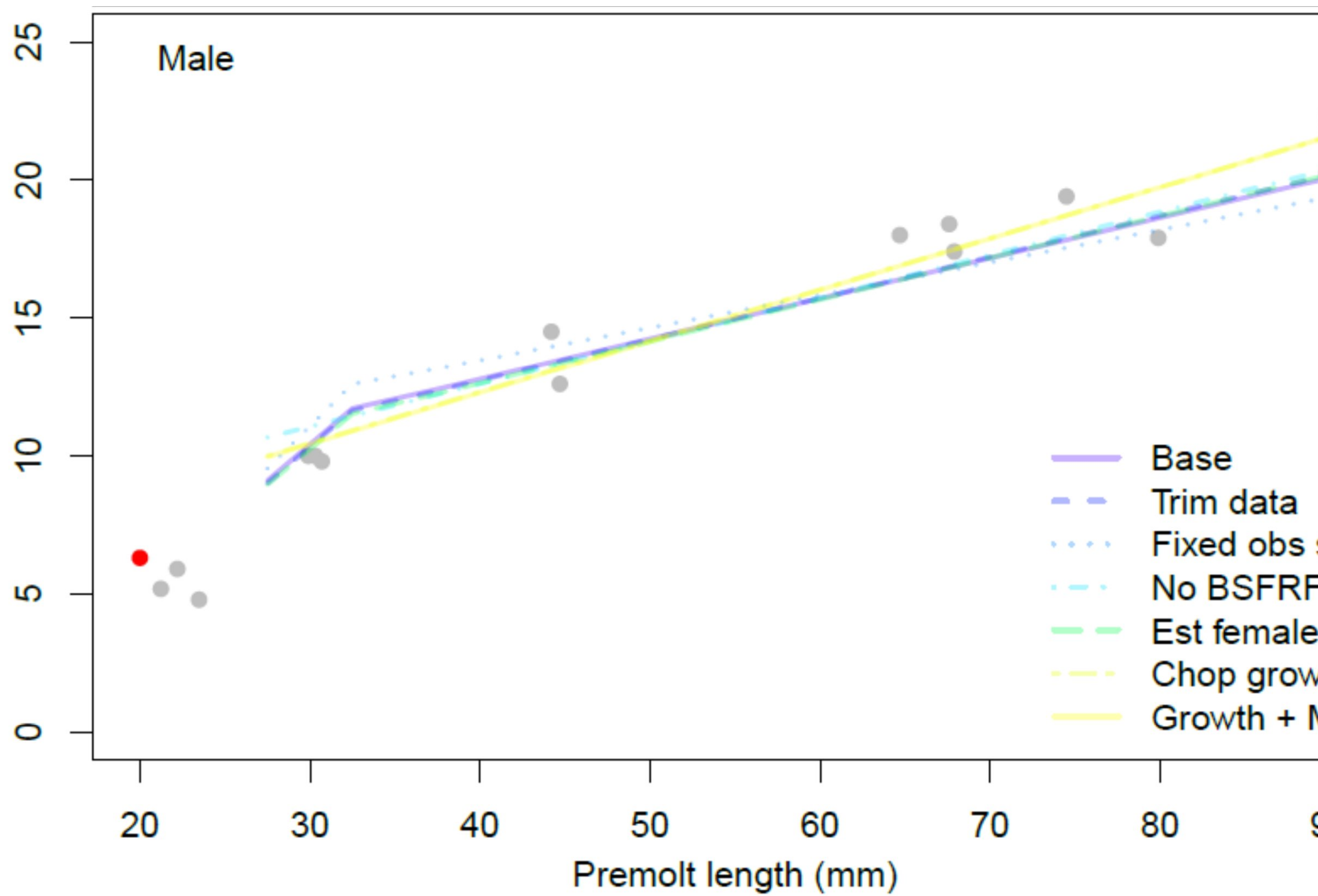
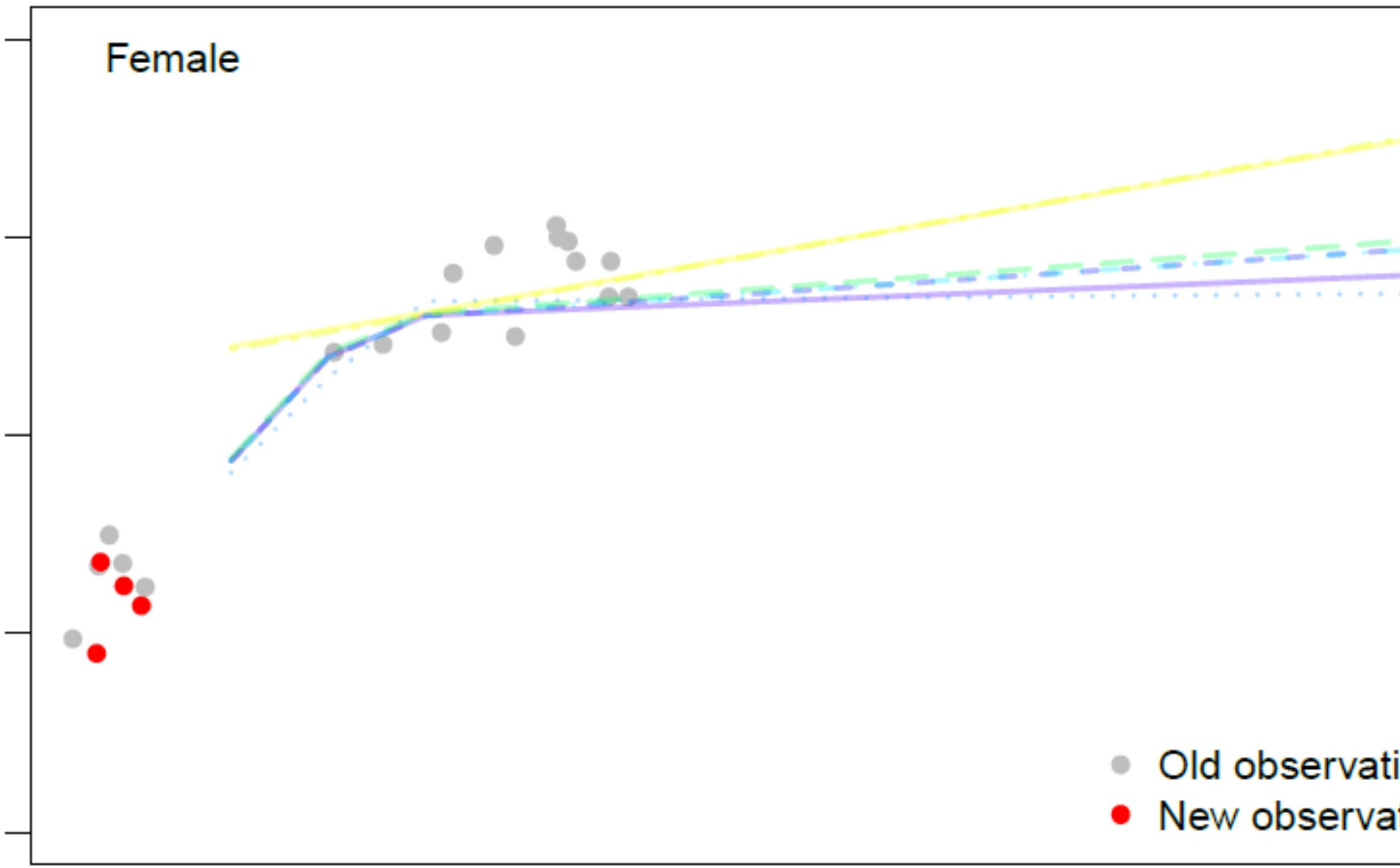
Growth + M	70.89	137.4	1.17	0.64

Parameter	Base	Trim data	Fixed obs sel	No BSFRF	Est female M	Chop growth	Growth + M
srv1_q	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_q_f	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel95	59.89	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv1_sel50	42.66	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
srv2_q	0.49	0.43	[redacted]	0.47	0.54	0.45	0.56
srv2_q_f	0.32	0.46	[redacted]	0.49	0.63	0.46	0.63
srv2_sel95	61.3	57.05	[redacted]	57.32	55.24	58.05	56.01
srv2_sel50	41.32	41.18	[redacted]	40.84	39.82	41.35	39.86
srv3_q	0.62	0.68	[redacted]	0.79	0.77	0.7	0.79
srv3_sel95	57.24	57.63	[redacted]	59.43	49.53	59.37	50.62
srv3_sel50	38.42	38.59	[redacted]	38.78	34.78	39.15	34.94
srv3_q_f	0.49	0.54	[redacted]	0.62	1	0.54	1
srv3_sel95_f	43.09	43.42	[redacted]	42.85	45.23	42.84	44.8
srv3_sel50_f	33.27	33.47	[redacted]	32.97	34.73	32.94	34.27


Male
Female
Probability
1.0
0.8
0.6
0.4
0.2
0.0
40
60
80
100
120
Length (mm)
Base
Trim data
Fixed obs sel
No BSFRF
Est female M
Chop growth
Growth + M



Male
0
5
10
15
20
25
20
30
40
50
60
70
80
Premolt length (mm)
Base
Trim data
Fixed obs
No BSFR
Est female
Chop grow
Growth + M


Female
Old observati
New observat

del results

rowth + M'

- 'Growth + M' is the 'synthesis' of all the changes—excludes 1978-1981 data, estimates mature female M, eliminates problem parameters from growth
- BUT, new problems arise:
  - Survey q (females era 3) is now estimated at 1
  - Survey q (males era 3) is now estimated at 0.79, which is a large increase over the 'Base'

ommendations summary

- ect a method for computing a distribution of the OFL based on certainty in the data and parameter estimates
- op 1978-1981 data
- art era 3 in 1988
- e a model selection approach to identify a model other than the ece-wise linear models for growth?
- timate mature female M, but whack-a-mole era 3 survey q?