Review of the Ross Sea region stock assessment

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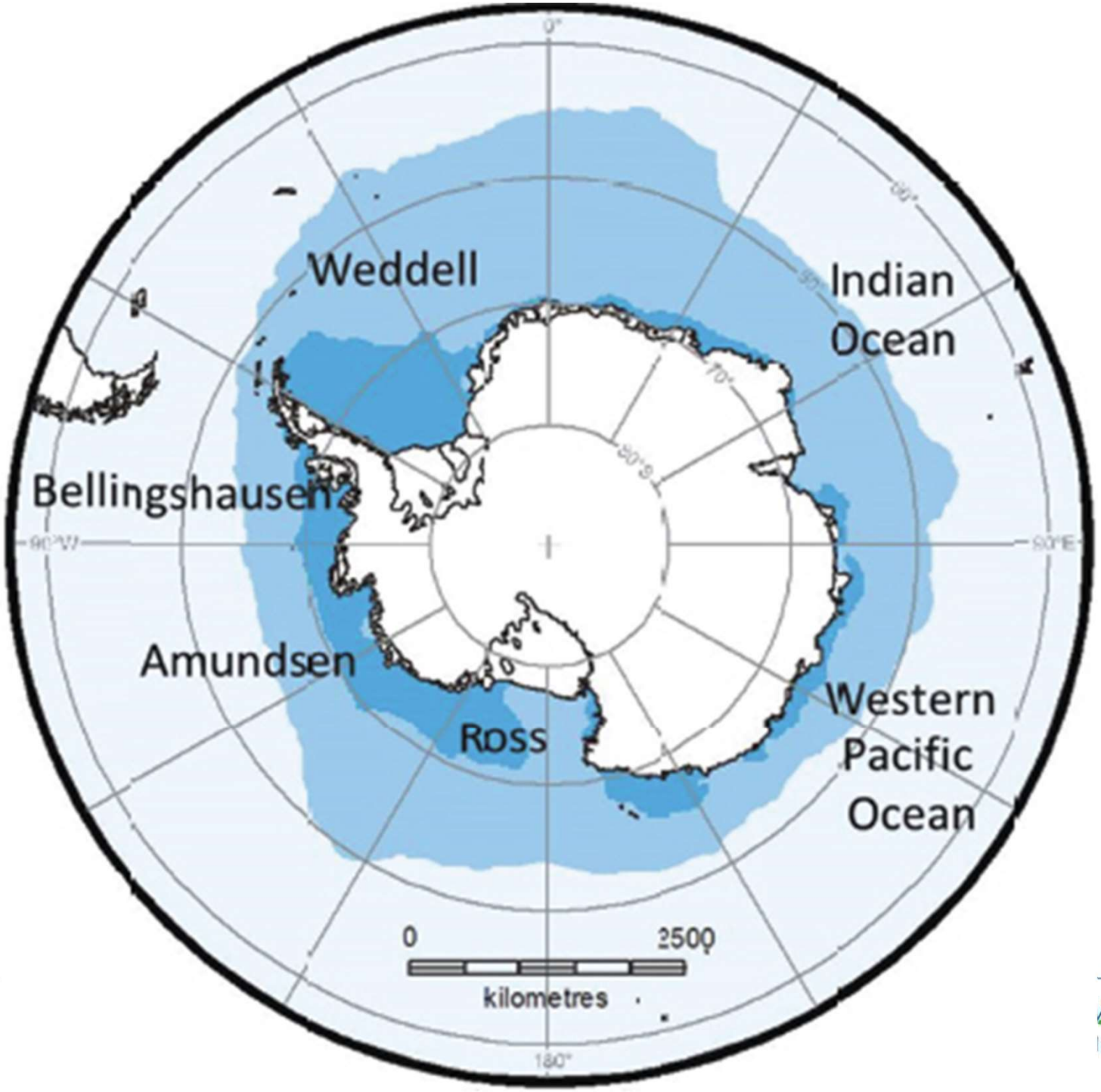
- Stock hypothesis and model structure
- Data inputs and clean up
- Model results
- Issues and challenges
- Effect of the MPA


Weddell
Indian Ocean
Bellingshausen
Amundsen
Ross
Western Pacific Ocean
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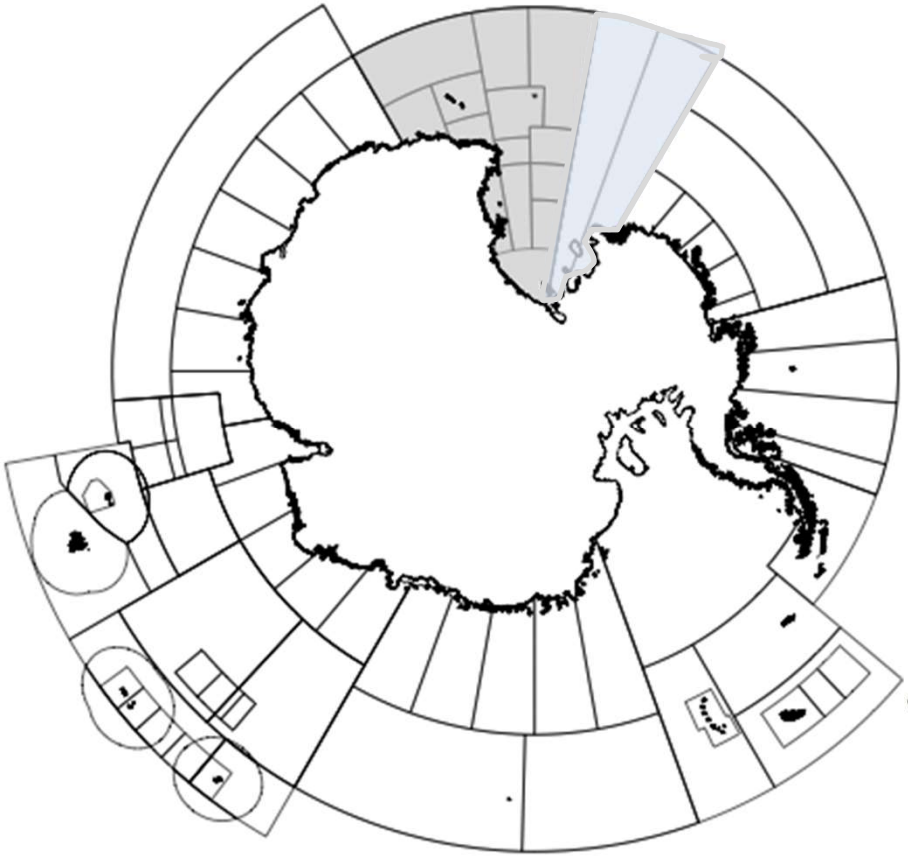
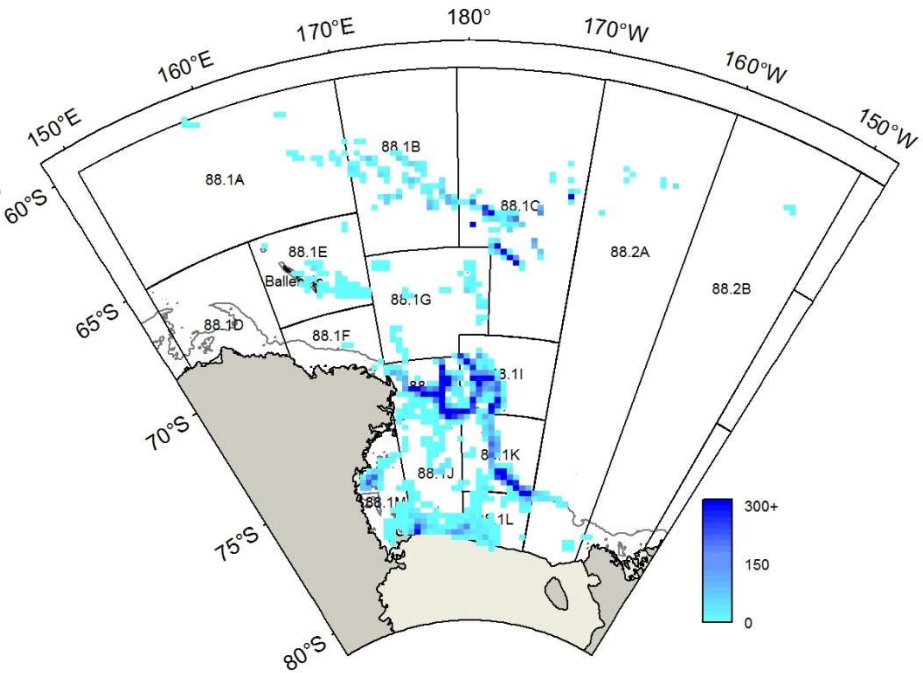
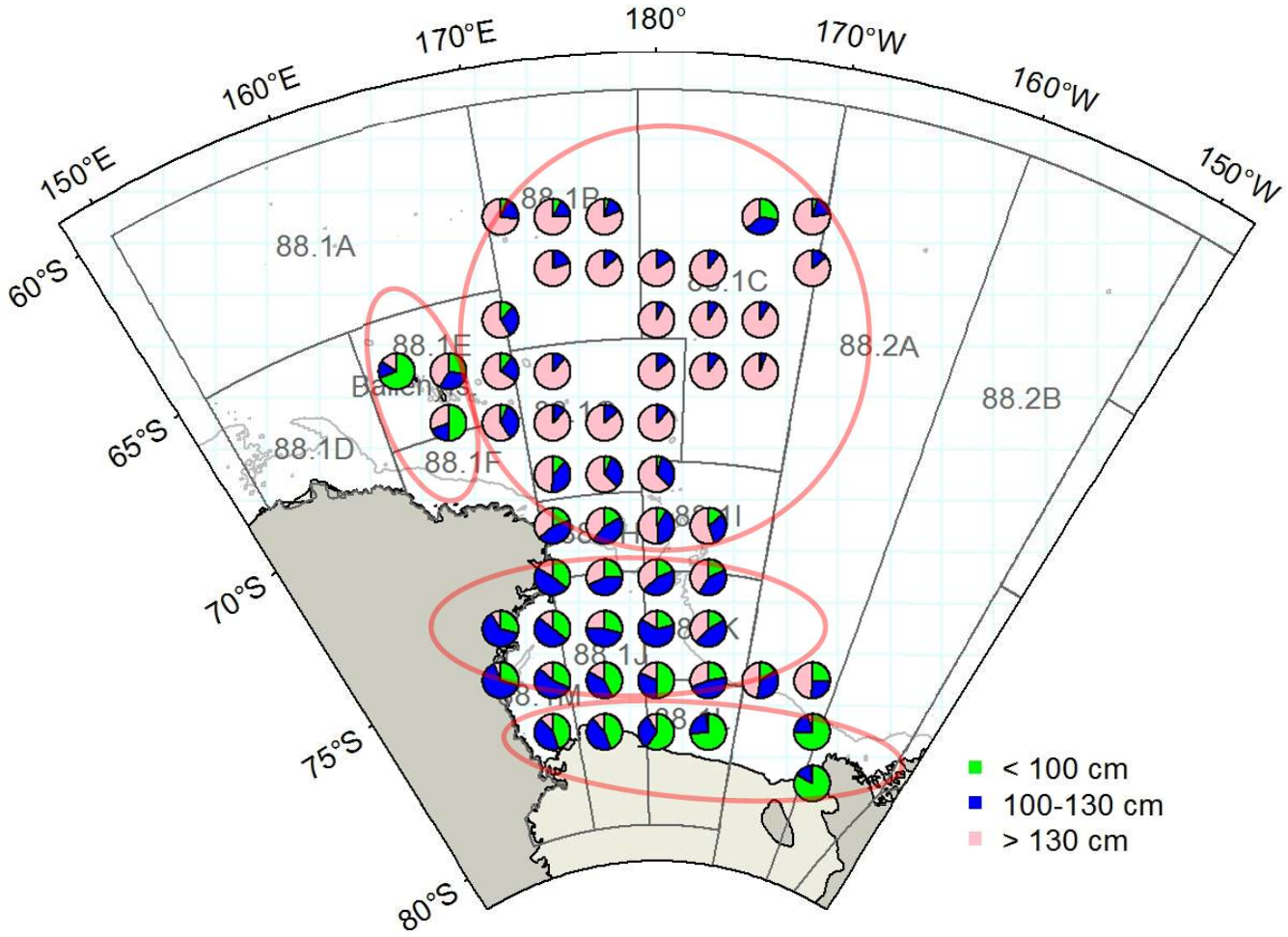
2500
kilometres




150°E
160°E
170°E
180°
170°W
160°W
150°W
60°S
65°S
70°S
75°S
80°S
88.1A
88.1B
88.1C
88.1D
88.1E
88.1F
88.1G
88.1I
88.1J
88.1K
88.1L
88.2A
88.2B
300+
150
0

Stock hypothesis
&
Model structure

Proportion of toothfish by length class in catch in RSR



Hanchet et al. (2015) Hydrobiologia. **761**

- Immature fish (<100 cm) on southern shelf and at Balleny Islands
- Maturing fish (100-130 cm) in western and central Ross Sea
- Mature fish (>130 cm) on northern hills

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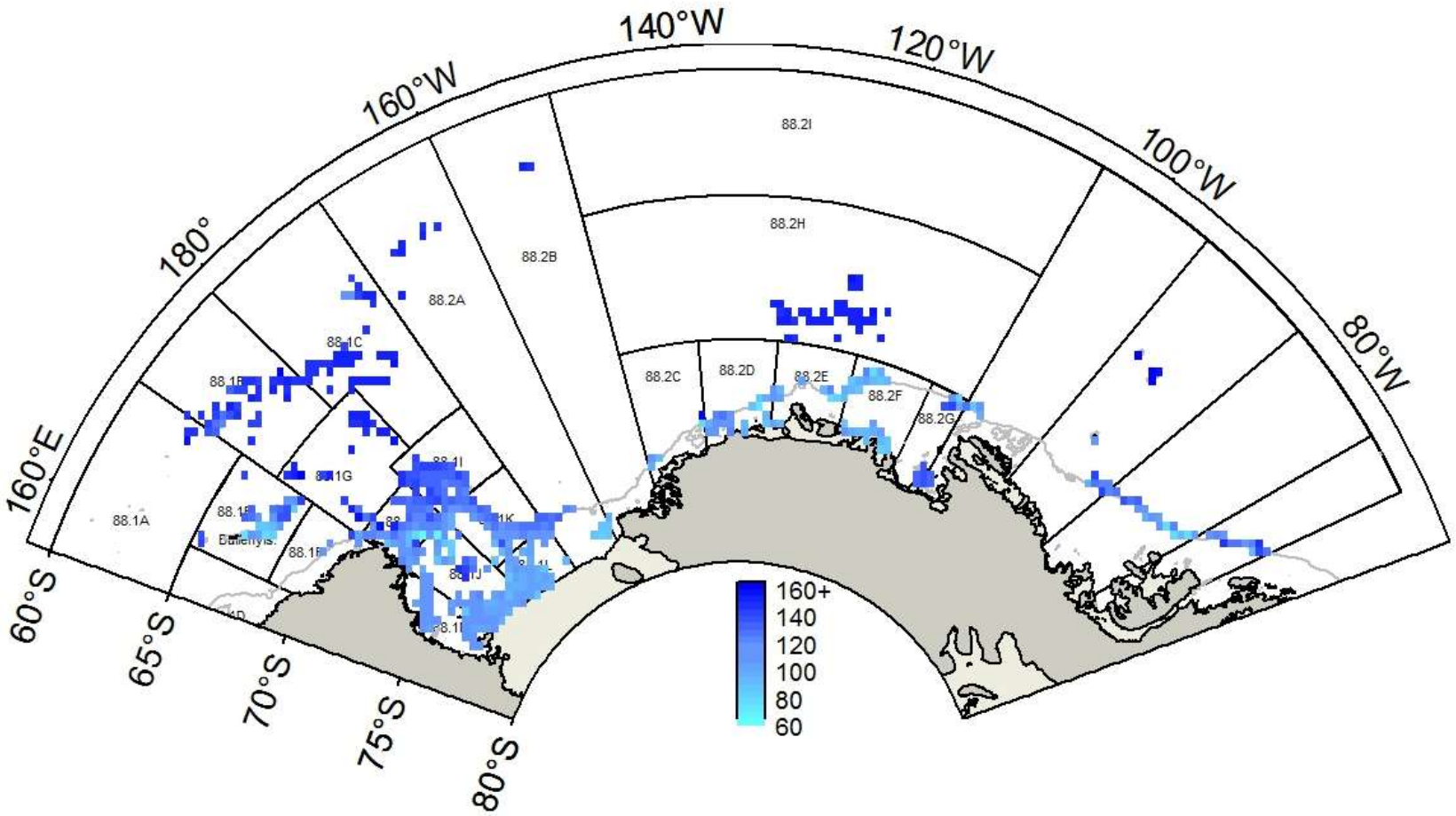
Median length frequency in 88.1-88.3



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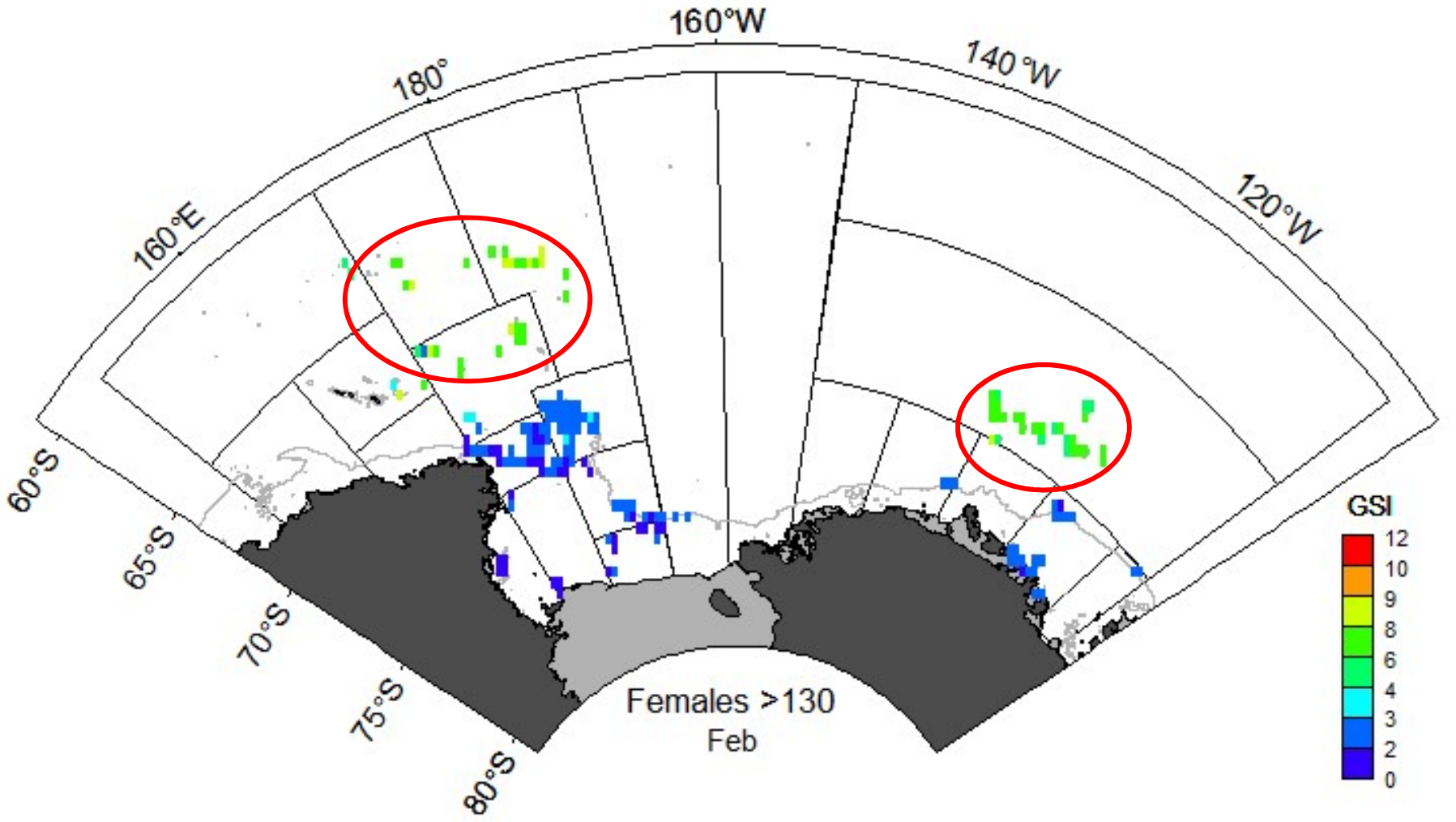
Likely spawning locations



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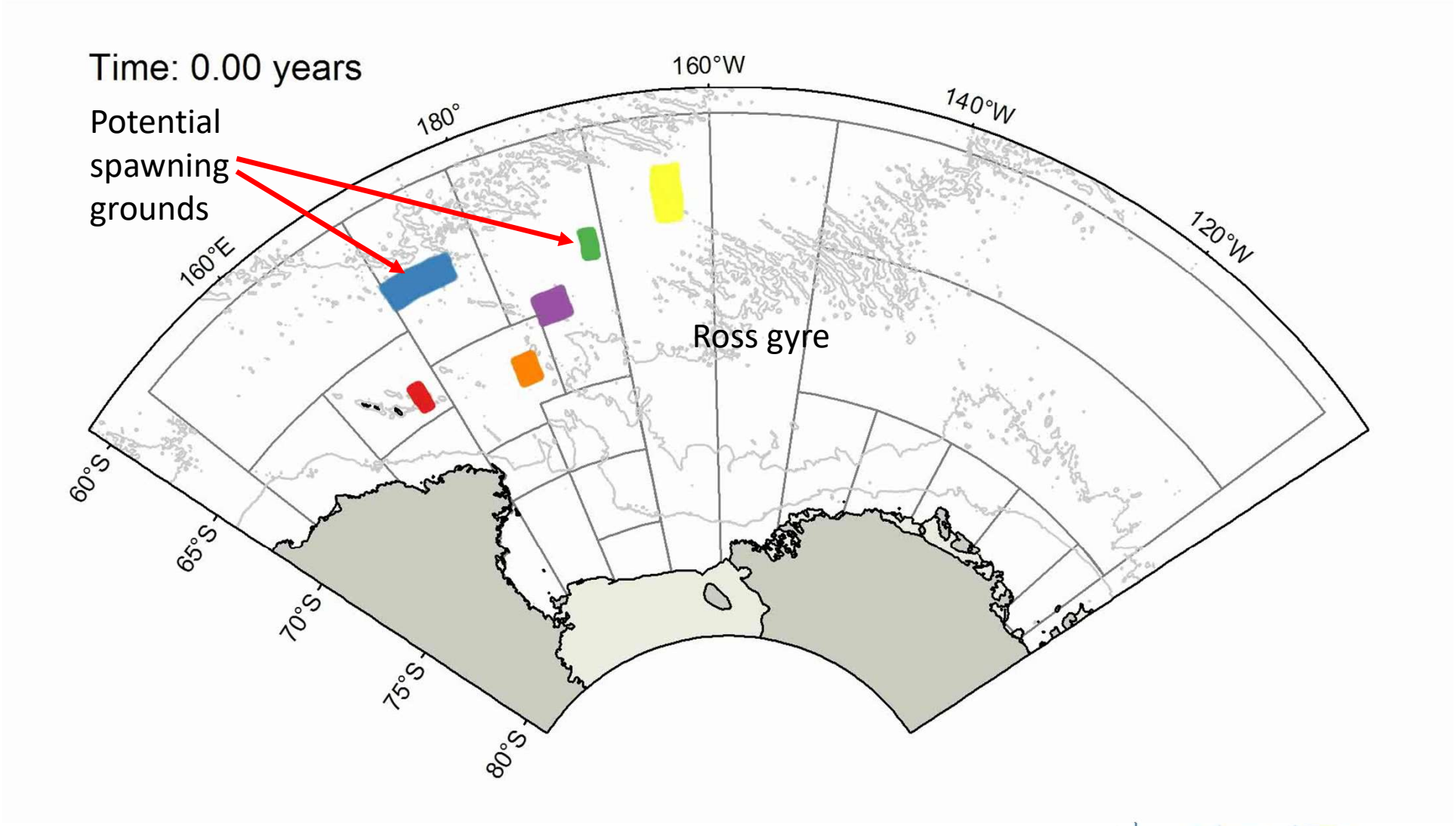
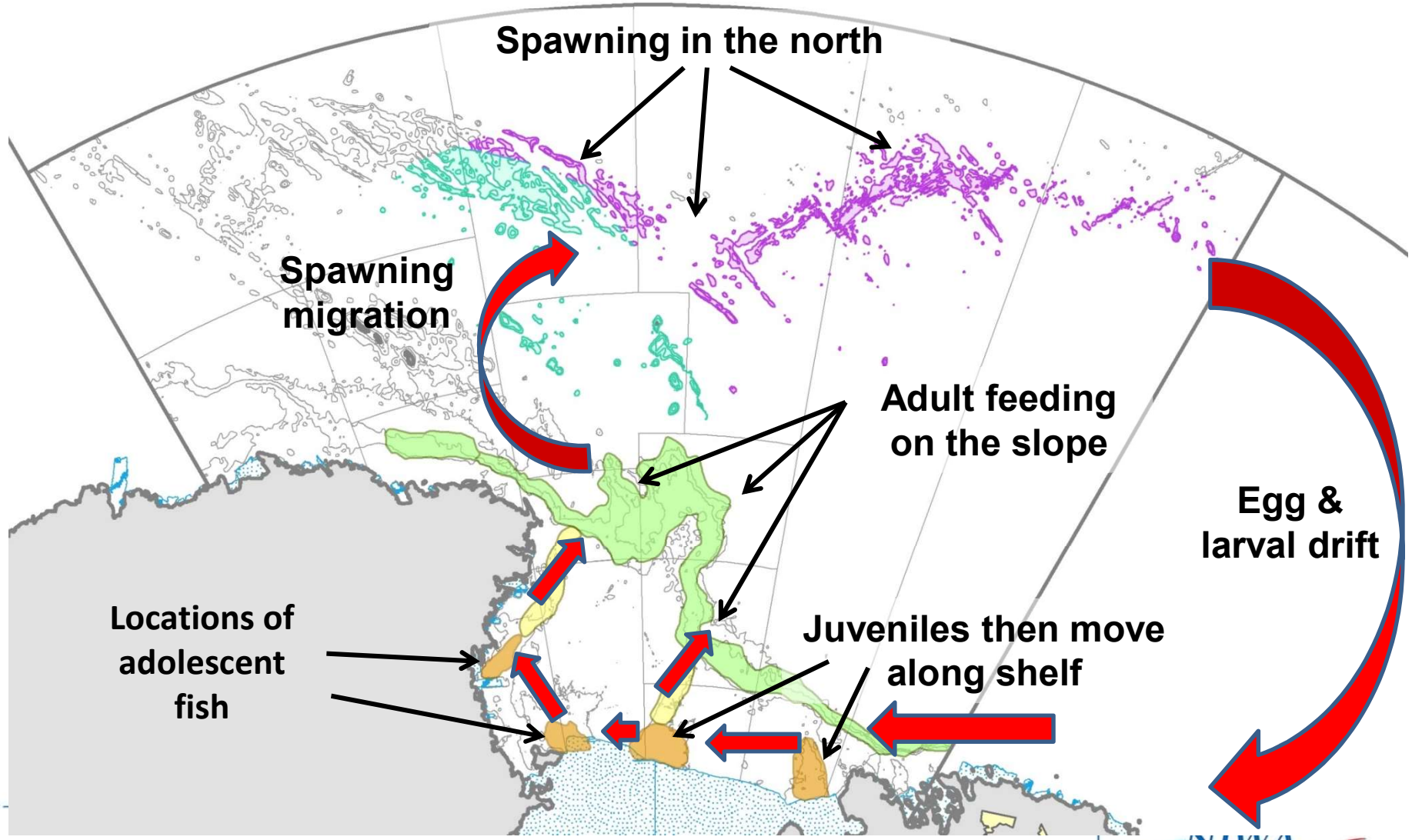
Egg and larval dispersal simulations to help understand life cycle



Life cycle of Antarctic toothfish in the Ross Sea region



Hanchet et al. (2008)
CCAMLR Sci. **15**

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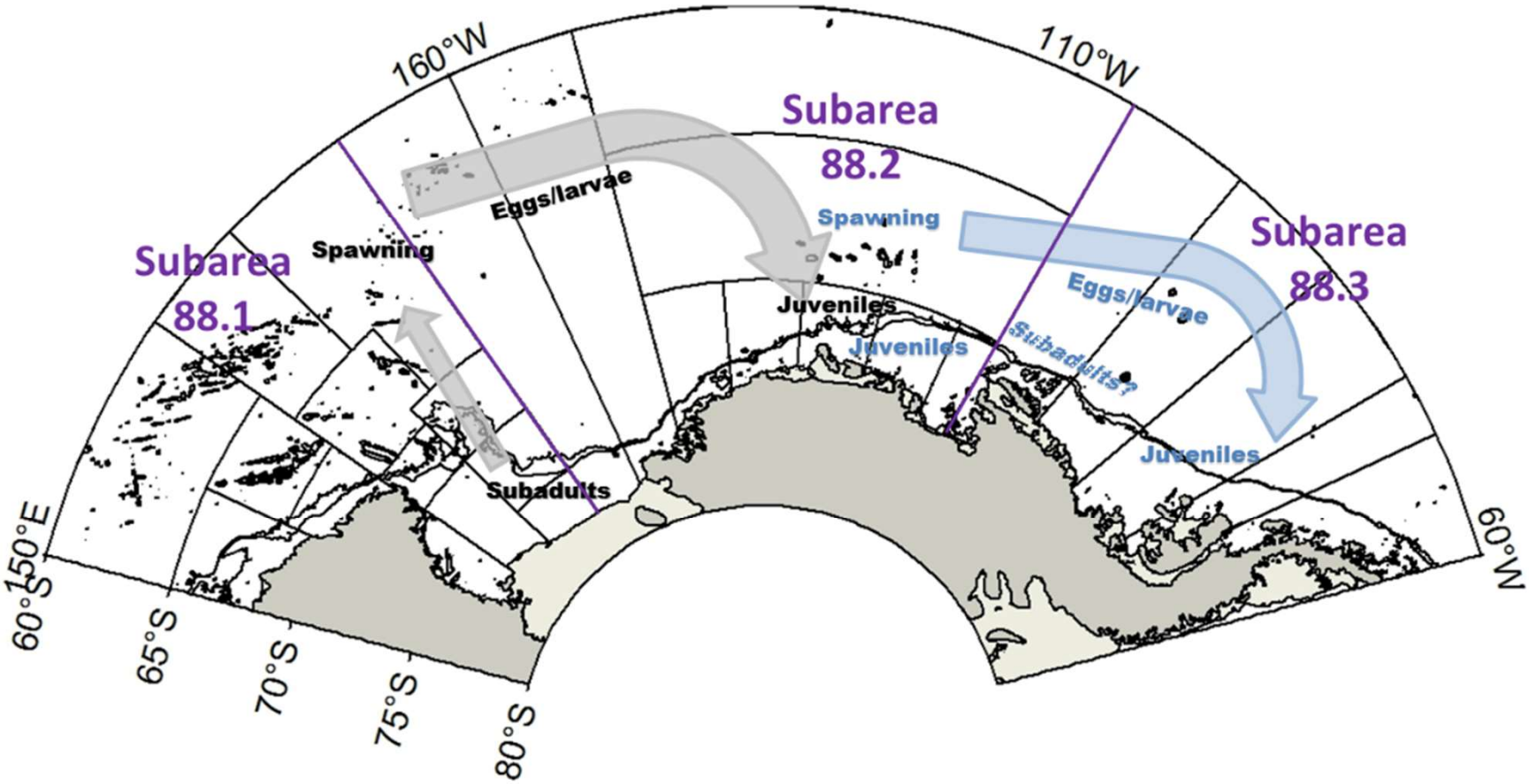
Hypothetical stock structure in Area 88



Population model

- Single stock (88.1 + SSRUs 88.2A-B)
- Areas as fisheries
  - Shelf, slope and north separate with different fishing selectivities (constant over time)
  - These areas are re-examined every year using tree regression on mean length by set
  - Tagged fish released by area to account for potential differences in sex ratio of tagged fish

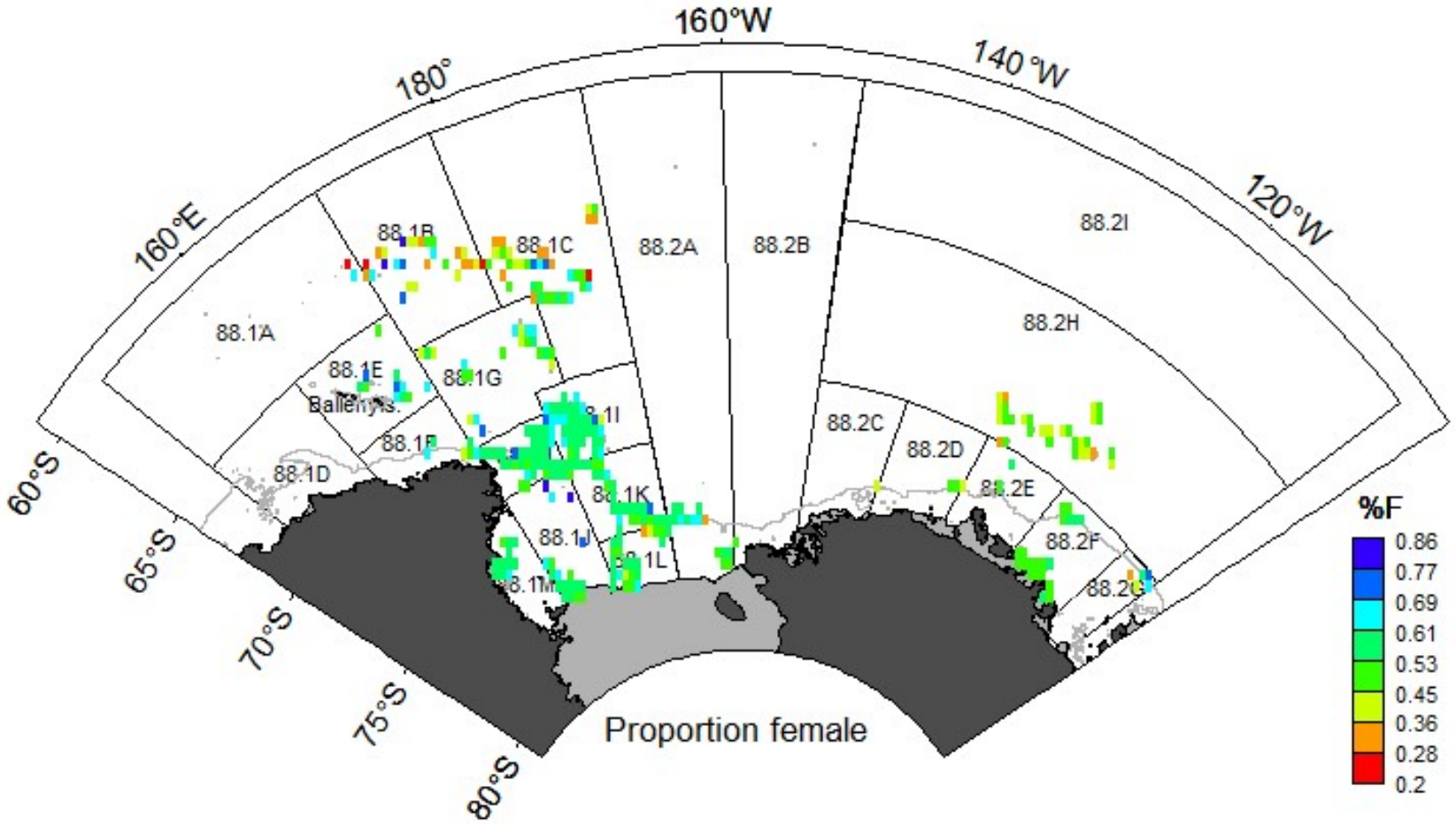
Annual model process

- Summer
  - Recruitment of fish aged 1
  - Fishing mortality
  - Half of natural mortality
- Winter
  - Spawning
  - Half of natural mortality
- Instantaneous step
  - Ageing

Biological parameters

- Ages 1-50
- Males and females separately
  - Size-weight and von Bertalanffy length at age
  - Data from the Ross Sea region
  - Ageing validated with tetracycline, radio isotopes, and tagging
  - Age interpretation calibrated annually with reference set
- Maturity ogive for each sex (logistic)
  - Based on histological gonad analyses from the Ross Sea slope
- Natural mortality 0.13 based on catch at age data analysis and literature review

Proportion of females



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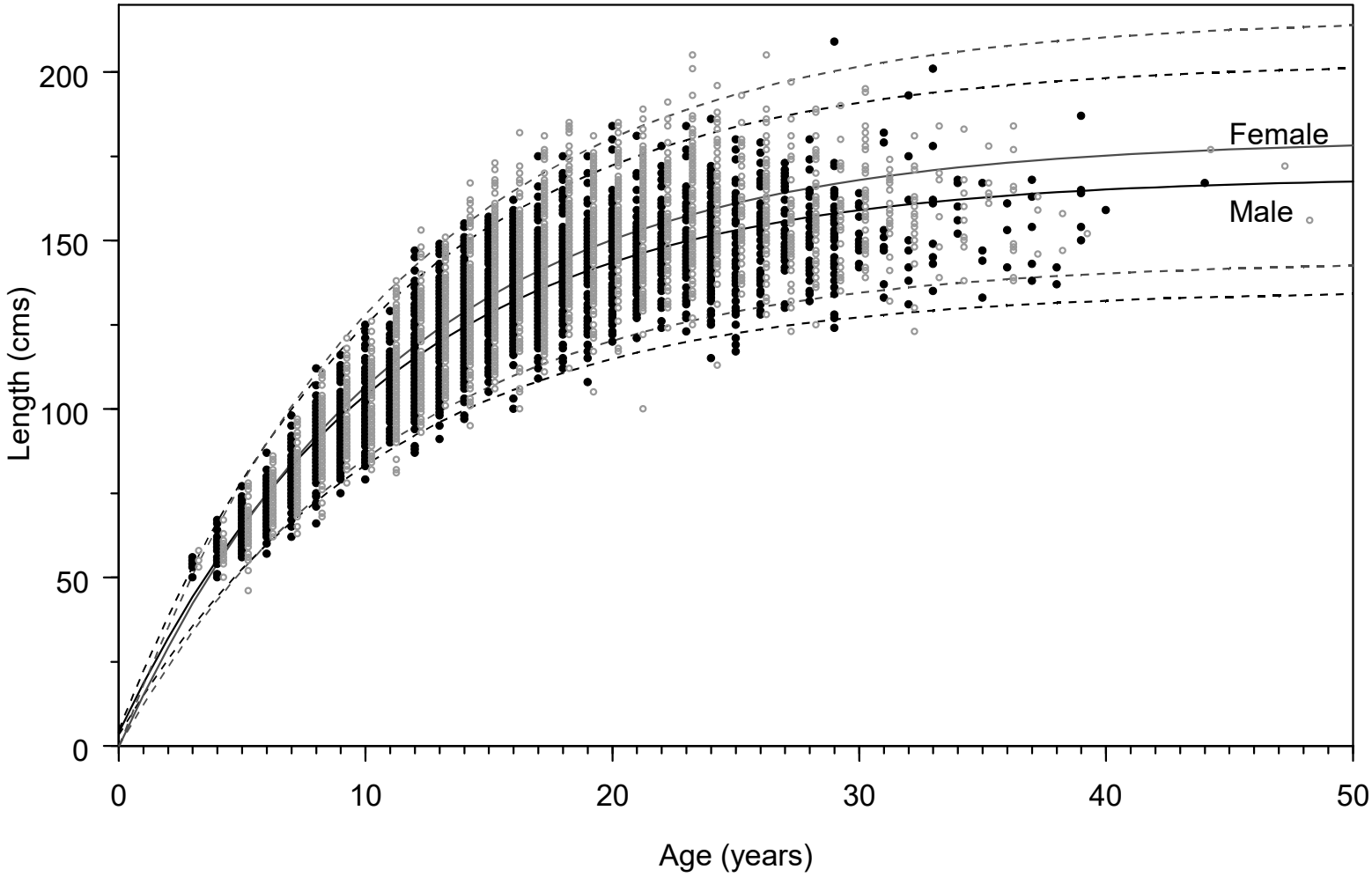
Mormede et al. (2014)
CCAMLR Sci. **21**



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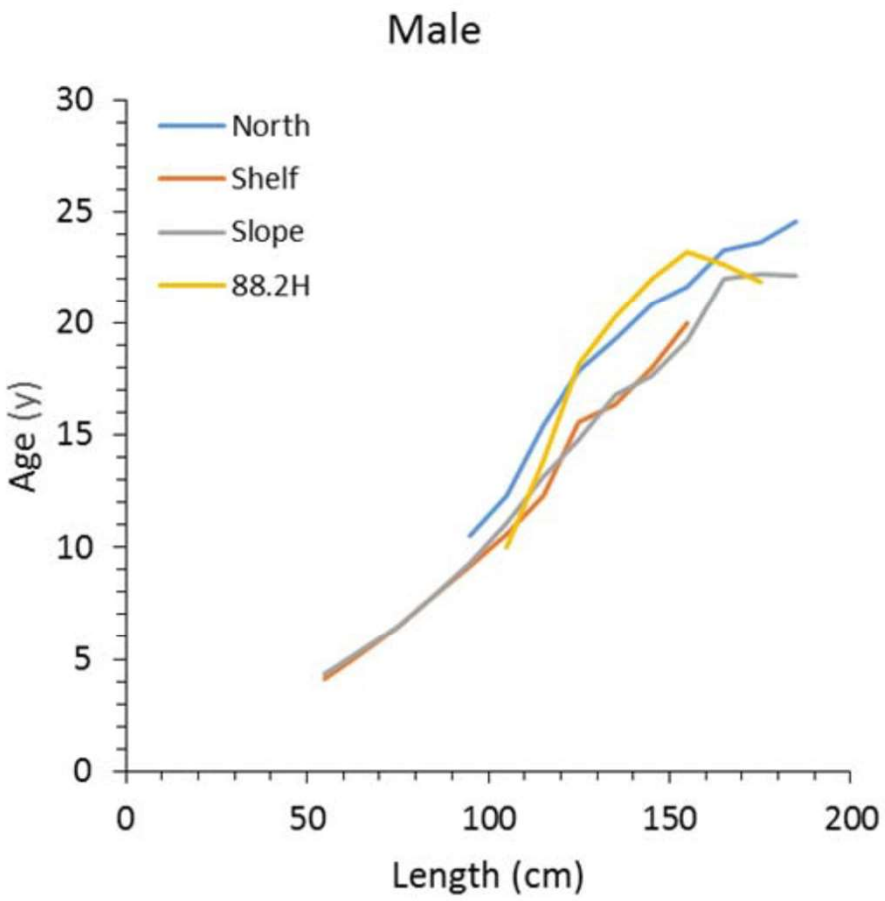
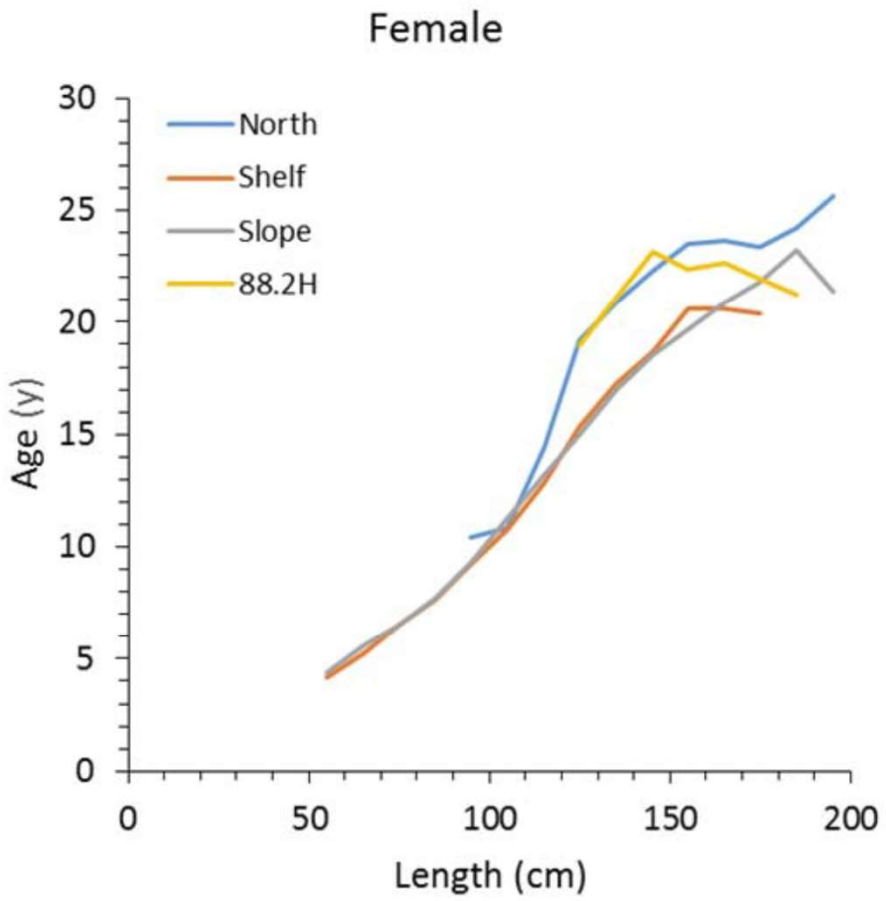
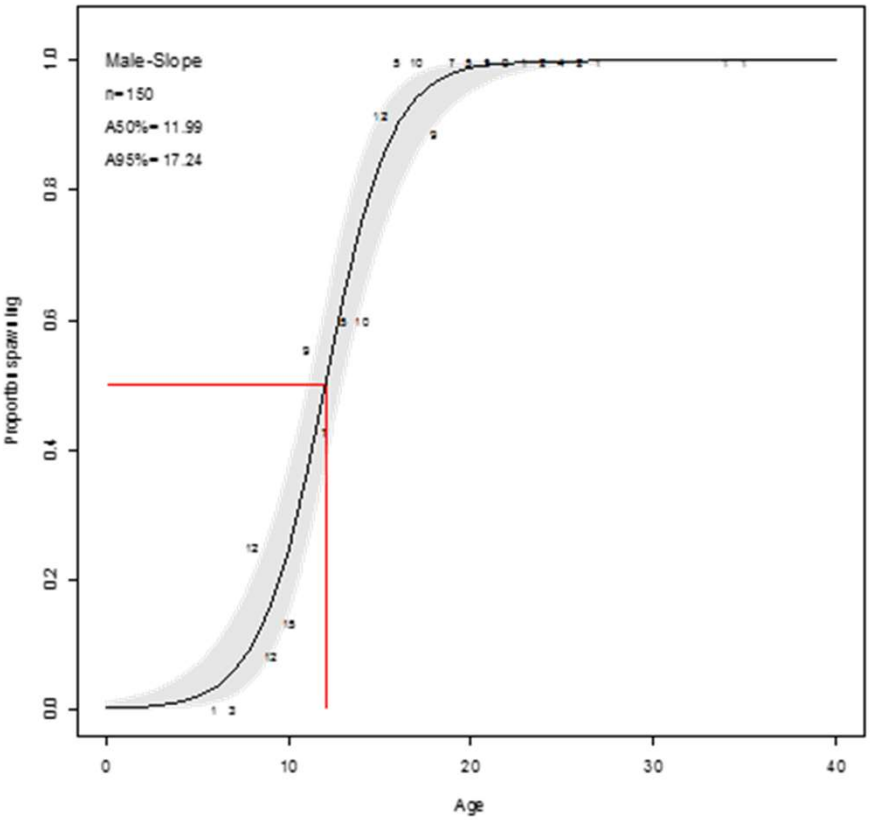
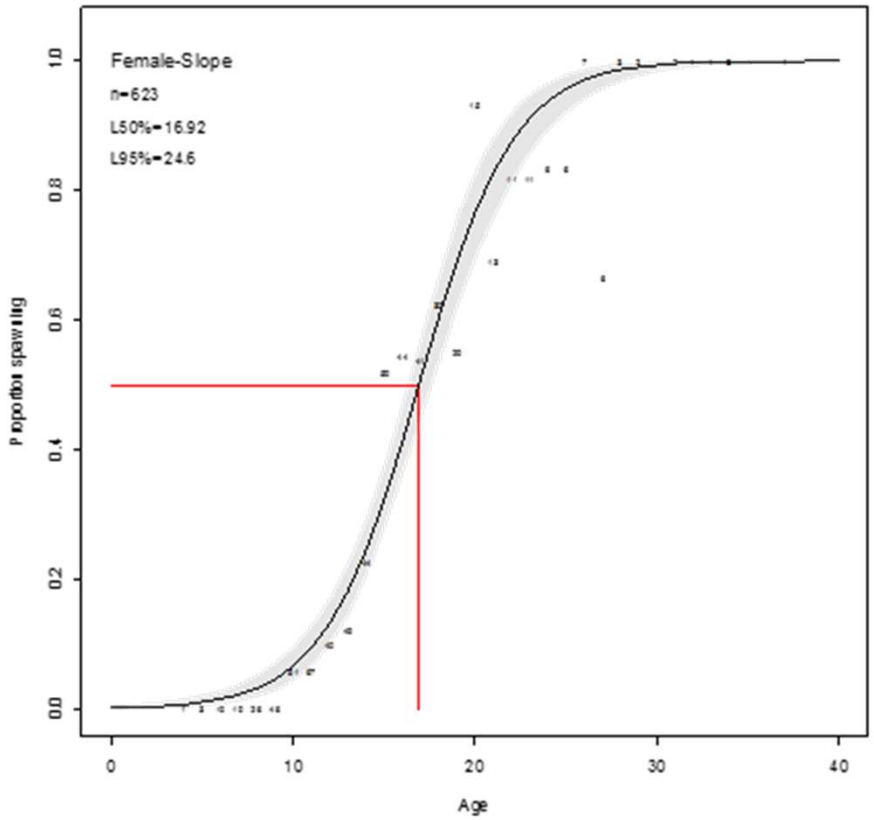
Age length keys for North and shelf/slope





Age at maturity - slope





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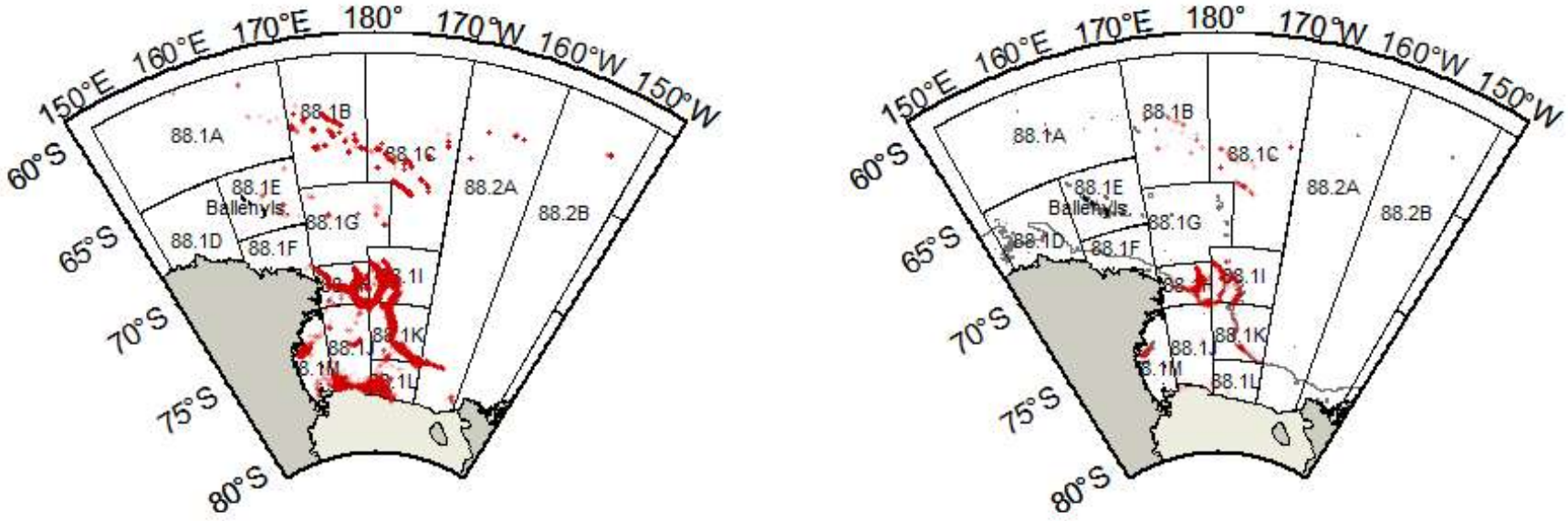
Toothfish tagging programme

- Became a CCAMLR requirement in 2004
- All fish in Ross Sea region must be double tagged at the rate of 1 fish tagged per tonne of toothfish caught (~1 in 30 fish in north)
- Fish are tagged by size proportional to the catch length frequency (since 2009; FSA para 5.13)
- Tag reward programme – 1st prize $1000
- Now, more than 45, 000 tags released & 2,300 recaptured in Ross Sea

Locations of all released (left) and recaptured (right) toothfish in the Ross Sea region



	Shelf	Slope	North	882 Slope	882 North	Total
Shelf	20	75	3	0	1	99
Slope	70	2 006	31	0	0	2 107
North	0	7	168	0	0	175
882Slope	0	3	0	47	0	50
882North	0	1	0	0	499	500
Total	90	2 092	202	47	500	2 931

Tag movement / mixing

Median movement (km) of recaptured Antarctic toothfish by time at liberty and size at release for recaptured toothfish (shaded cells indicate a sample size of less than five fish).

Time at liberty	Size class (cm)					
	< 80	81–100	101–120	121–140	141–160	160–180
<1 season	22	14	11	3	3	3
1 season	17	31	21	9	6	16
2 seasons	63	35	16	18	9	26
3 seasons	52	33	27	16	49	-
4 seasons	74	41	34	69	45	-
5 seasons	65	36	46	43	15	919
6 seasons	105	33	21	400	-	1
7 seasons	140	38	39	25	630	-
8 seasons	132	55	73	-	-	-
9 seasons	90	61	23	114	-	-
10 seasons	118	73	42	7	-	-
11 seasons	18	80	763	-	-	-
12 seasons	83	89	-	-	-	-

Tagging parameters

- Initial mortality (Agnew et al, 2006) (5% *2)
- Initial and ongoing tag loss based on Ross Sea data using double-tagged fish (Dunn et al 2011)
- Tag detection rate accounts for recaptured tags that could not be linked to a release (but see the select)
- Tag growth retardation based on length data of Ross Sea fish recaptured with time at liberty (Parker et al 2013,2015)

Model fixed parameters

Table 1: Biological parameters assumed for the modelling.

Relationship	Parameter	Value	
		Male	Female
Natural mortality	M (y^{-1})	0.13	0.13
Von Bertalanffy	t_0 (y)	-0.256	0.021
	k (y^{-1})	0.093	0.090
	L_∞ (cm)	169.07	180.20
	c.v.	0.1	0.1
Length-weight	a	1.387e-08	7.153e-09
	b	2.965	3.108
	$c.v.$	0.1	0.1
Maturity	A_{50} ($\pm A_{to95}$)	11.99 (±5.25)	16.92 (± 7.68)
Stock recruit steepness (Beverton-Holt)	h	0.75	
Recruitment variability	σ_R	0.6	
Ageing error (CV)	$c.v.$	0.1	
Initial tagging mortality		10%	
Initial tag loss (per tag)		3.3%	
Instantaneous tag loss rate (per tag)		$0.062y^{-1}$	
Tag detection rate		98.8%	
Tag related growth retardation		0.5 y	

Parameters estimated

- Spawning stock biomass B_0 (sum of biomass at age * maturity ogives)
  - Uniform-log prior
- Selectivity for each fishery and the survey
  - All are dome-shaped with uniform prior (logistic is tested for the north)
  - Used to have a selectivity shift each year that was removed from the model in 2015
- Year Class Strengths: 2003 -2011
  - Lognormal prior between 0.001 and 100, $\mu = 1$; cv = 1.1
- Survey biomass q
  - Uniform-log prior

Data weighting procedure

- Used the Francis (2011) method
  - AFs with initial multinomial weight calculated
  - Tagging data have the number of scanned fish and no dispersion
  - Survey biomass has annual cv and no process error

1. Run the model with no additional weighting
2. Calculate the weight on AFs and rerun the model
3. Calculate tagging dispersion (all years together) and rerun the model
4. Calculate the survey biomass cv and rerun the model

Data input

Time series data available

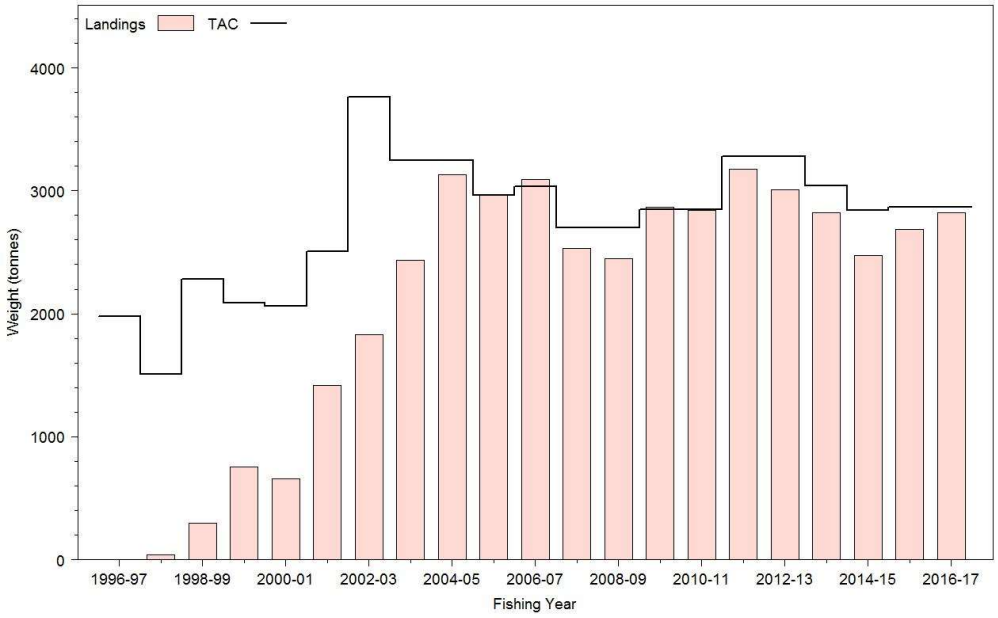
- Catch, effort, mark-recapture data from vessels (C2)
- Length/age, weight from observers (observer logbook)
- Standardised Ross Sea shelf survey data (C2 and observer logbook)
- Age-length keys by year: North vs Slope/shelf

Data clean-up

- Detailed in FSA-13/56
- Main steps carried out each year
  - Check total weights and weight vs length vs number of fish caught
  - Check for position errors in all the data
  - Check for errors in vessel type, date etc
  - Match tag recapture events with tag released events

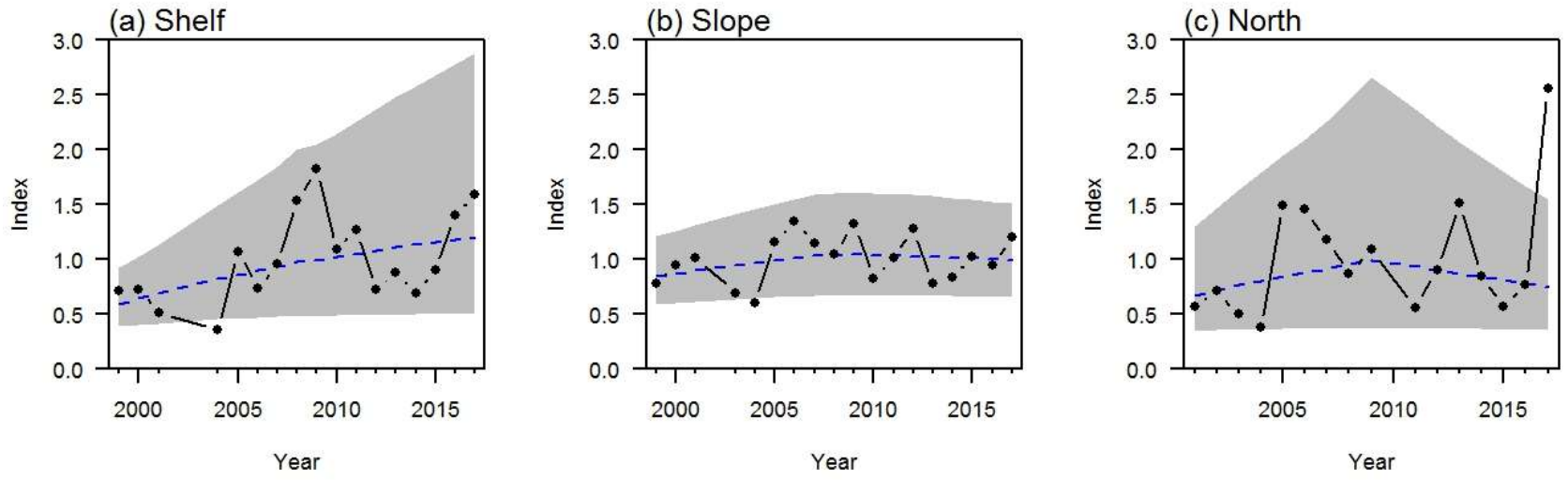
Catches

- Split by area and year
- Includes
  - Catches from quarantined data
  - Catches from the SPRFMO area just north of the Ross Sea region



Catch rates

- Removed from the stock assessment in 2007 as not expected to represent an index of abundance (standardised showed below)



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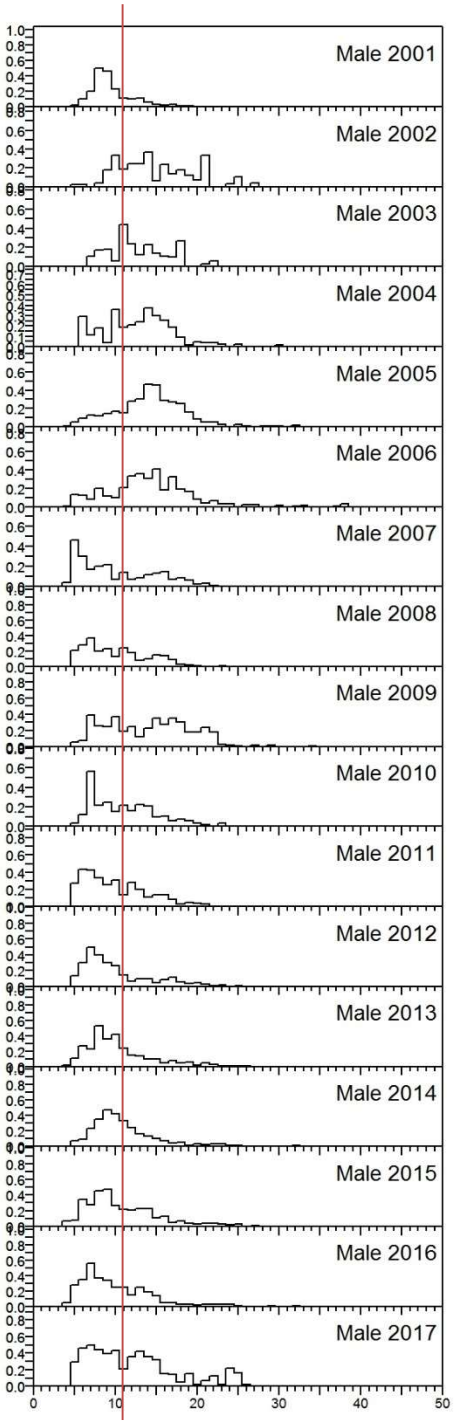
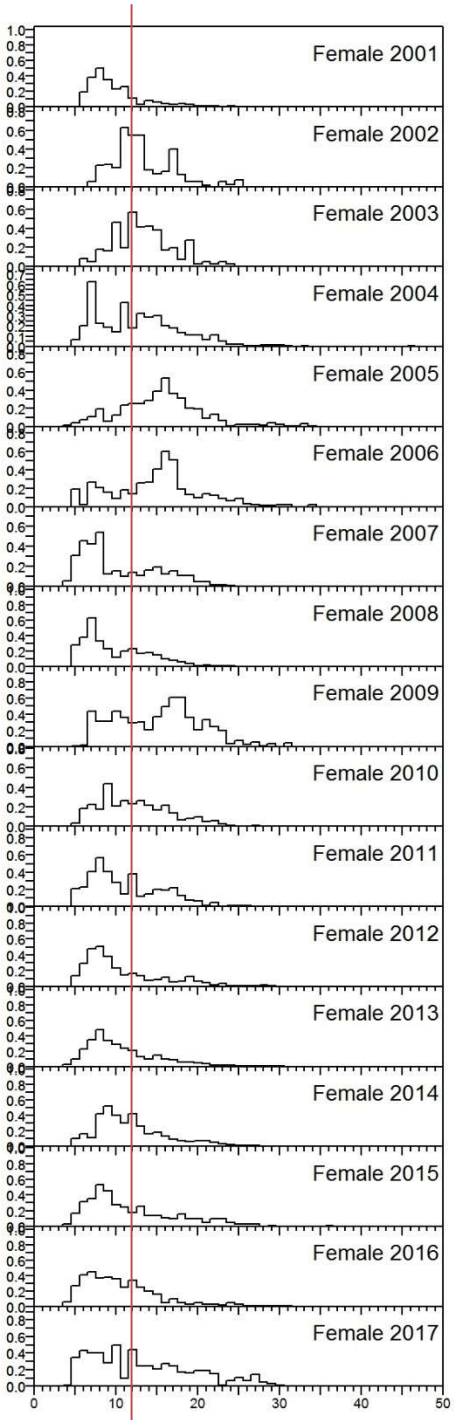
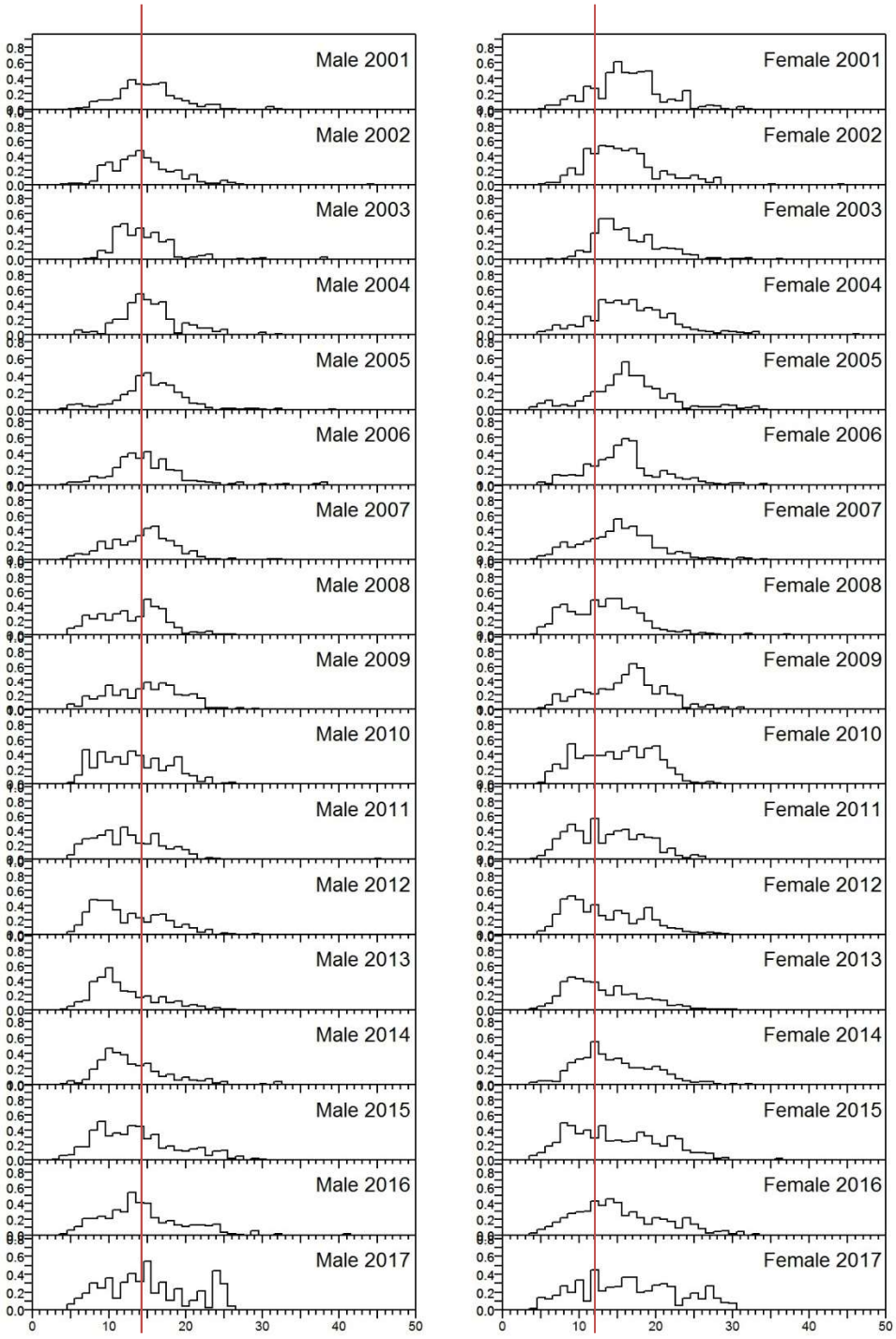
Age Frequency Shelf

- Use annual age length keys for shelf-slope and for north separately
- Exclude quarantined data
- Red line ~ mean age for all years

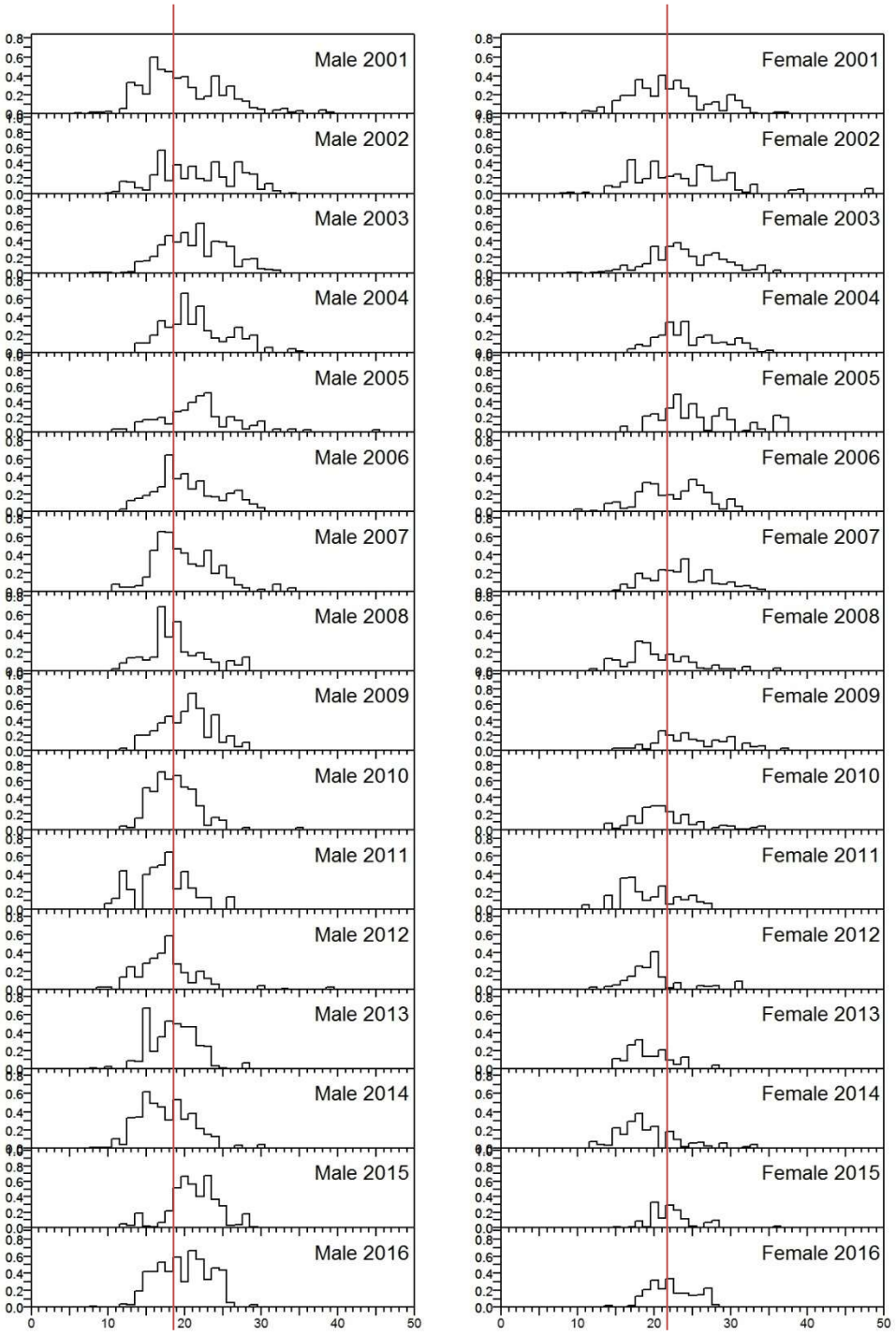




AF Slope


Male 2001
Male 2002
Male 2003
Male 2004
Male 2005
Male 2006
Male 2007
Male 2008
Male 2009
Male 2010
Male 2011
Male 2012
Male 2013
Male 2014
Male 2015
Male 2016
Male 2017
Female 2001
Female 2002
Female 2003
Female 2004
Female 2005
Female 2006
Female 2007
Female 2008
Female 2009
Female 2010
Female 2011
Female 2012
Female 2013
Female 2014
Female 2015
Female 2016
Female 2017
0.0
0.2
0.4
0.6
0.8
0
10
20
30
40
50

AF North


Male 2001
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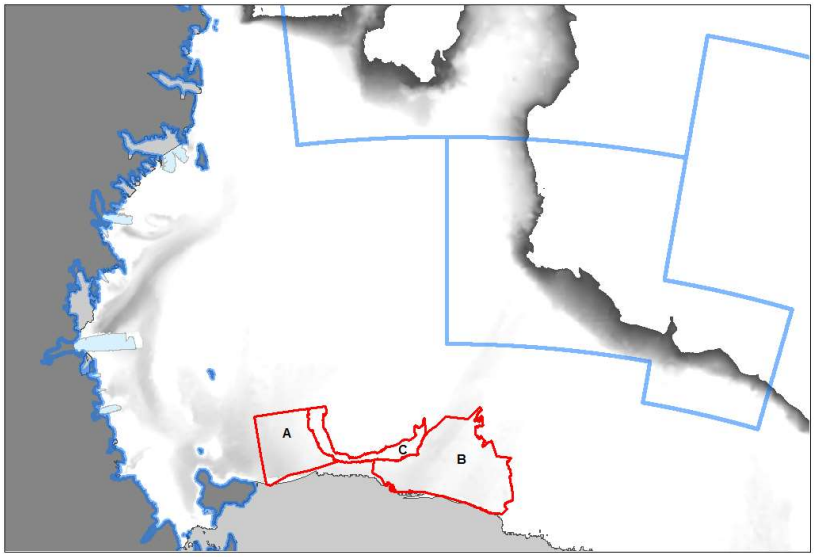
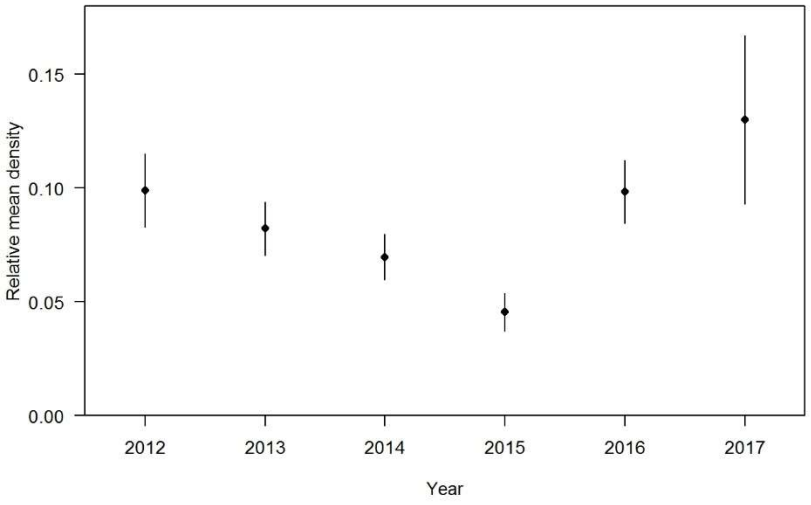
Female 2012
Female 2013
Female 2014
Female 2015
Female 2016
0.0
0.2
0.4
0.6
0.8
0
10
20
30
40
50

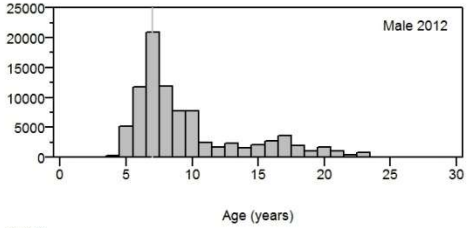
Survey information

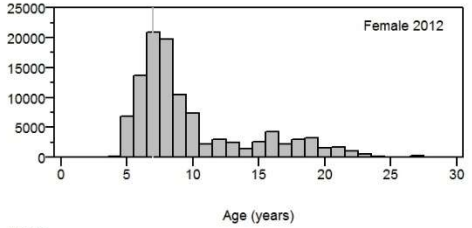
Ross Sea shelf survey: an index of the juvenile portion of the stock (~ ages 5-12)

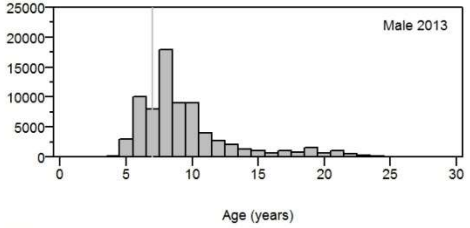
- Biomass estimates
  - Standardised for soak time
- Age frequencies
  - Annual age-length keys

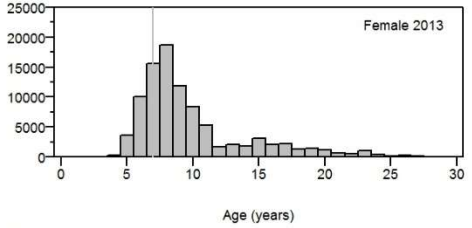

A
C
B

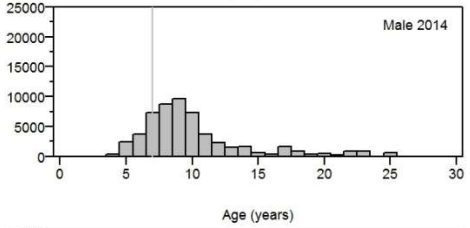

Relative mean density
0.00
0.05
0.10
0.15
2012
2013
2014
2015
2016
2017
Year

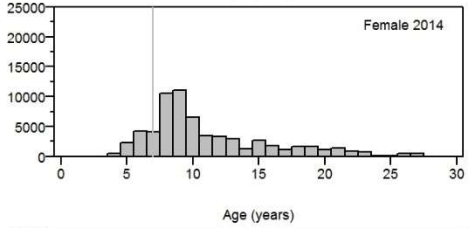

Male 2012
Age (years)

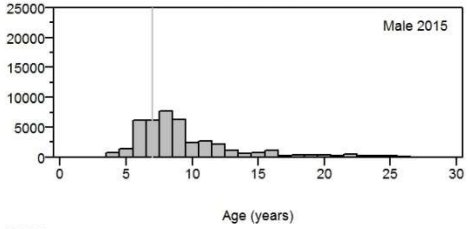

Female 2012
Age (years)

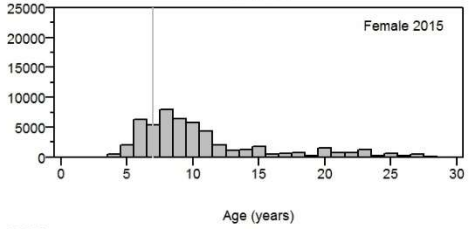

Male 2013
Age (years)

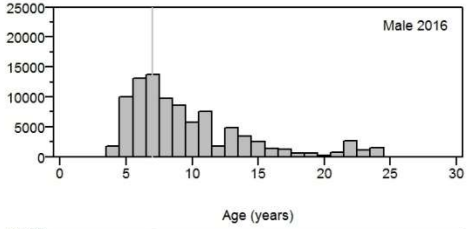

Female 2013
Age (years)

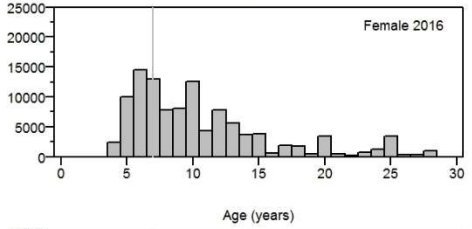

Male 2014
Age (years)

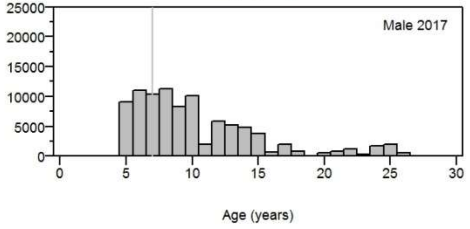

Female 2014
Age (years)

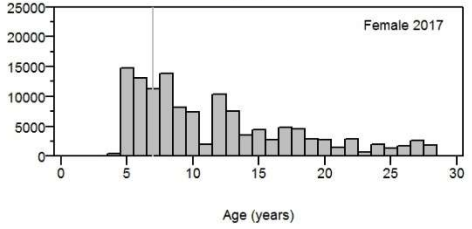

Male 2015
Age (years)


Female 2015
Age (years)


Male 2016
Age (years)


Female 2016
Age (years)


Male 2017
Age (years)


Female 2017
Age (years)

Mark-recapture data

- Use up to 6 years at liberty in the model
  - After 6 years at liberty the estimated biomass biased high

	Number released	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
2001	259	1	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0	6
2002	683	2	9	4	9	9	13	6	5	2	5	0	3	5	0	0	0	72
2003	862	-	6	13	9	2	9	2	2	2	2	1	1	3	1	0	0	53
2004	2 032	-	-	9	22	18	33	27	12	15	10	13	13	6	1	1	4	184
2005	3 277	-	-	-	8	25	28	29	11	47	15	13	18	11	11	9	3	228
2006	3 035	-	-	-	-	11	89	68	15	28	20	4	13	12	3	8	4	275
2007	3 535	-	-	-	-	-	18	62	22	50	26	12	20	38	6	18	7	279
2008	2 507	-	-	-	-	-	-	14	19	36	18	9	23	19	12	11	10	171
2009	2 829	-	-	-	-	-	-	-	9	41	37	11	20	28	9	10	5	170
2010	3 064	-	-	-	-	-	-	-	-	27	57	21	31	41	19	12	16	224
2011	3 035	-	-	-	-	-	-	-	-	-	13	36	42	55	23	22	15	206
2012	3 827	-	-	-	-	-	-	-	-	-	-	9	15	22	17	22	26	111
2013	3 582	-	-	-	-	-	-	-	-	-	-	-	12	54	31	31	25	153
2014	3 124	-	-	-	-	-	-	-	-	-	-	-	-	18	36	43	16	113
2015	3 076	-	-	-	-	-	-	-	-	-	-	-	-	-	16	57	21	94
2016	3 138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	28	37
2017	3 161	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8
Total	45 026	3	16	26	48	65	191	209	96	248	203	130	211	312	185	253	188	2 384

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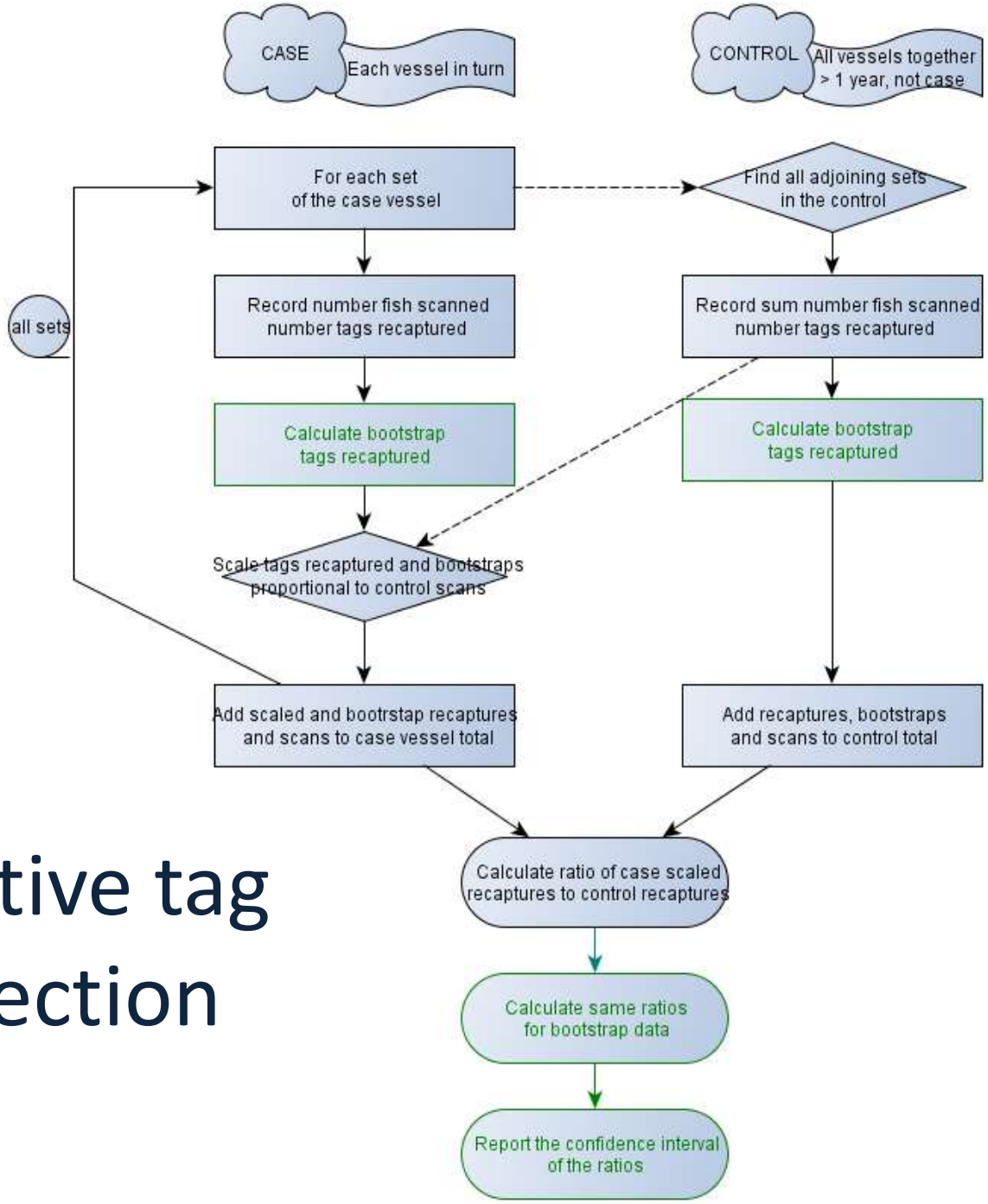
Mark-recapture ratio

	Number fish released	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2002	683			0.44	2.25	1.00	1.44	0.46	0.83	0.40	2.50	0.00	#DIV/0!	1.67	0.00	#DIV/0!	#DIV/0!
2003	862				0.69	0.22	4.50	0.22	1.00	1.00	1.00	0.50	1.00	3.00	0.33	0.00	#DIV/0!
2004	2032					0.82	1.83	0.82	0.44	1.25	0.67	1.30	1.00	0.46	0.17	1.00	4.00
2005	3277						1.12	1.04	0.38	4.27	0.32	0.87	1.38	0.61	1.00	0.82	0.33
2006	3035							0.76	0.22	1.87	0.71	0.20	3.25	0.92	0.25	2.67	0.50
2007	3535								0.35	2.27	0.52	0.46	1.67	1.90	0.16	3.00	0.39
2008	2507									1.89	0.50	0.50	2.56	0.83	0.63	0.92	0.91
2009	2829										0.90	0.30	1.82	1.40	0.32	1.11	0.50
2010	3064											0.37	1.48	1.32	0.46	0.63	1.33
2011	3035												1.17	1.31	0.42	0.96	0.68
2012	3827													1.47	0.77	1.29	1.18
2013	3582														0.57	1.00	0.81
2014	3124															1.19	0.37
2015	3076																0.37
2016	3138																
2017	3161																
Total	45026																

Use of the mark recapture data

- Large differences in the recapture rates of tagged fish between vessels
  - Includes some procedure differences between vessels
- Initial assessments used only NZL tag data
- From 2009 started developing “quality” algorithms to select mark recapture data for the assessment
- Current method is a case-control method which calculates the relative tagging survival and effective tag detection rate of vessels in the Ross Sea region (Mormede et al. 2013, CCAMLR Science)
  - Data intensive so uses all data for each vessel to calculate those rates

Effective tag detection



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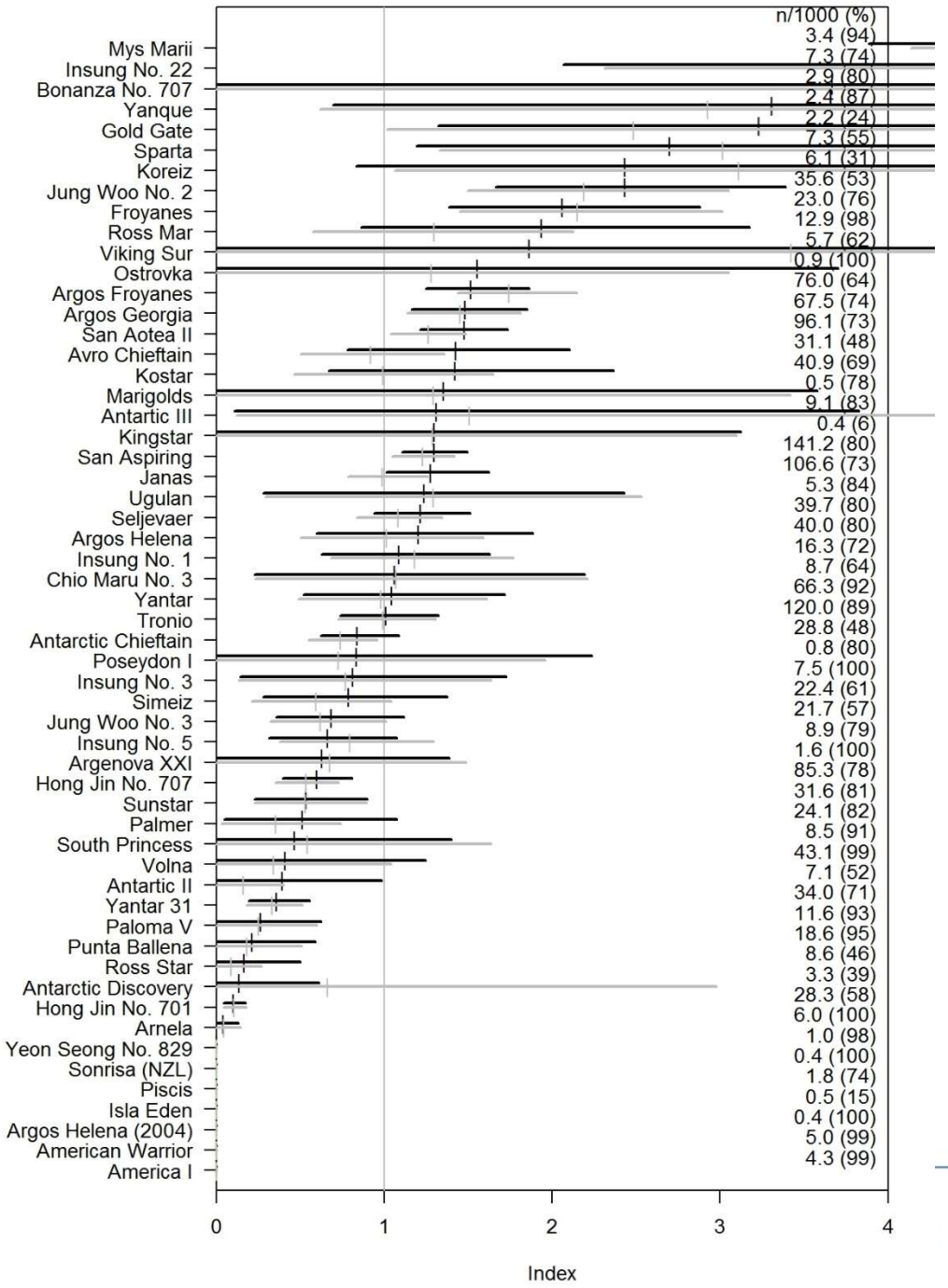

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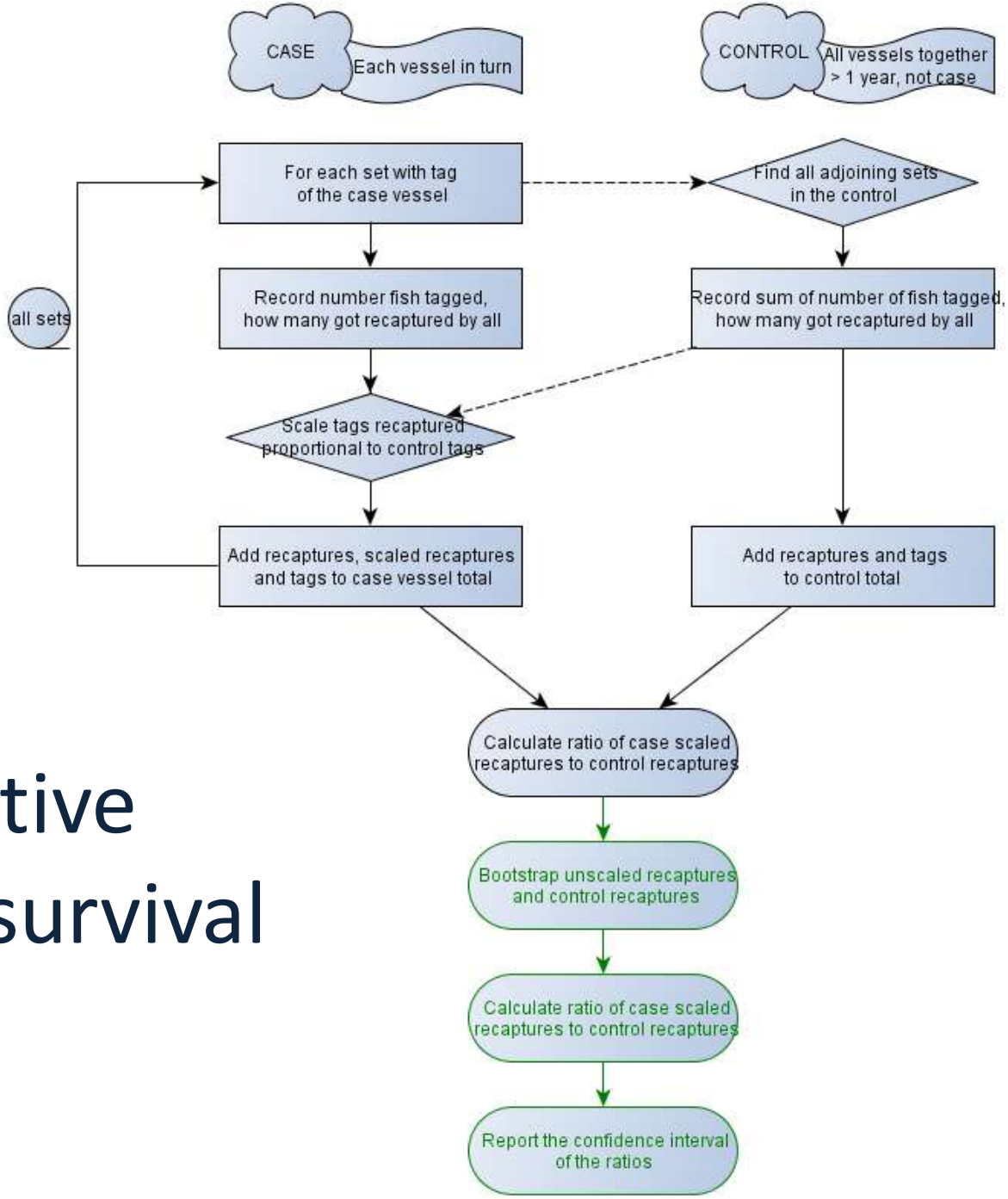
Effective tagging survival



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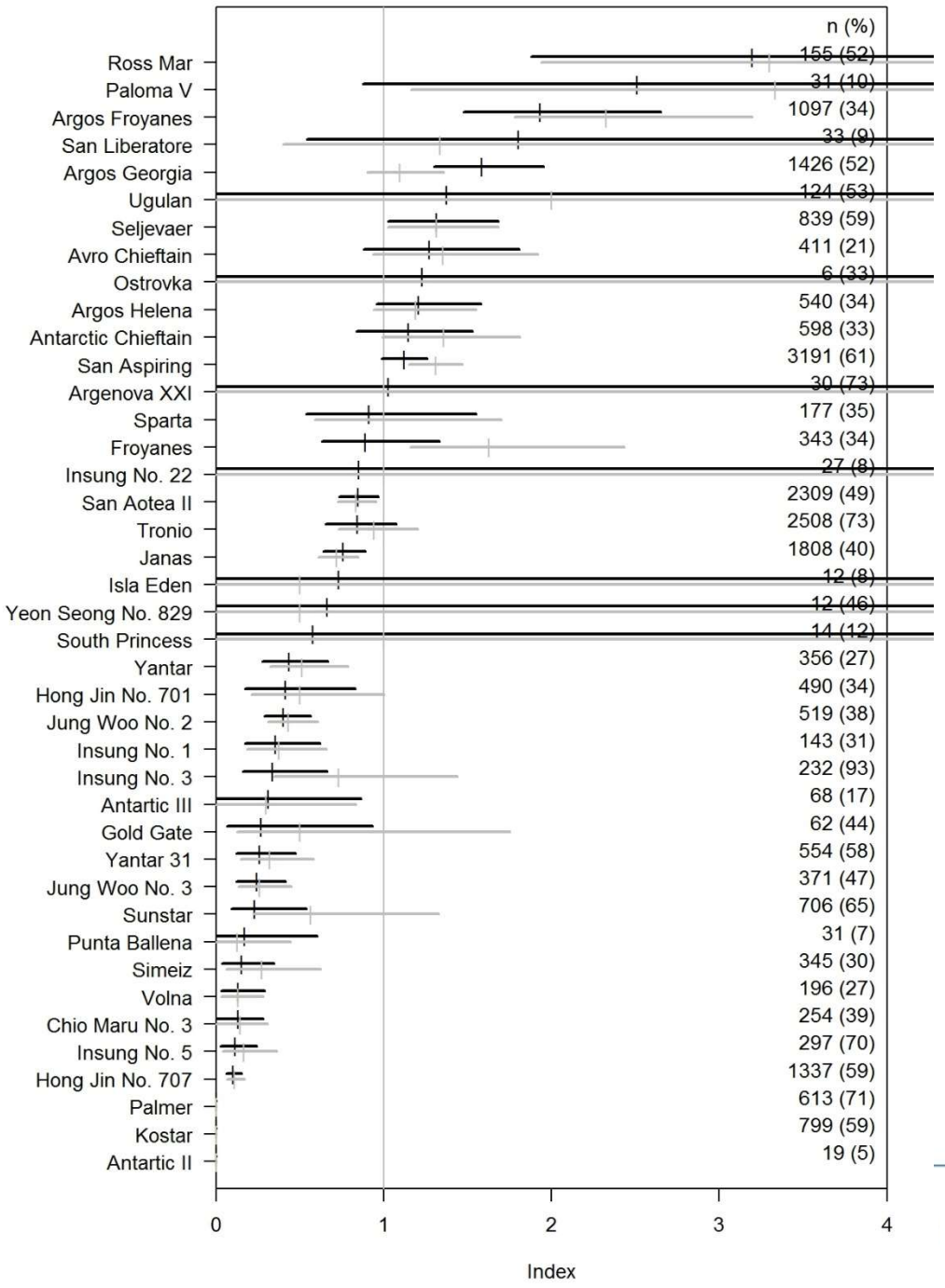

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Using effective tagging survival and effective tag detection

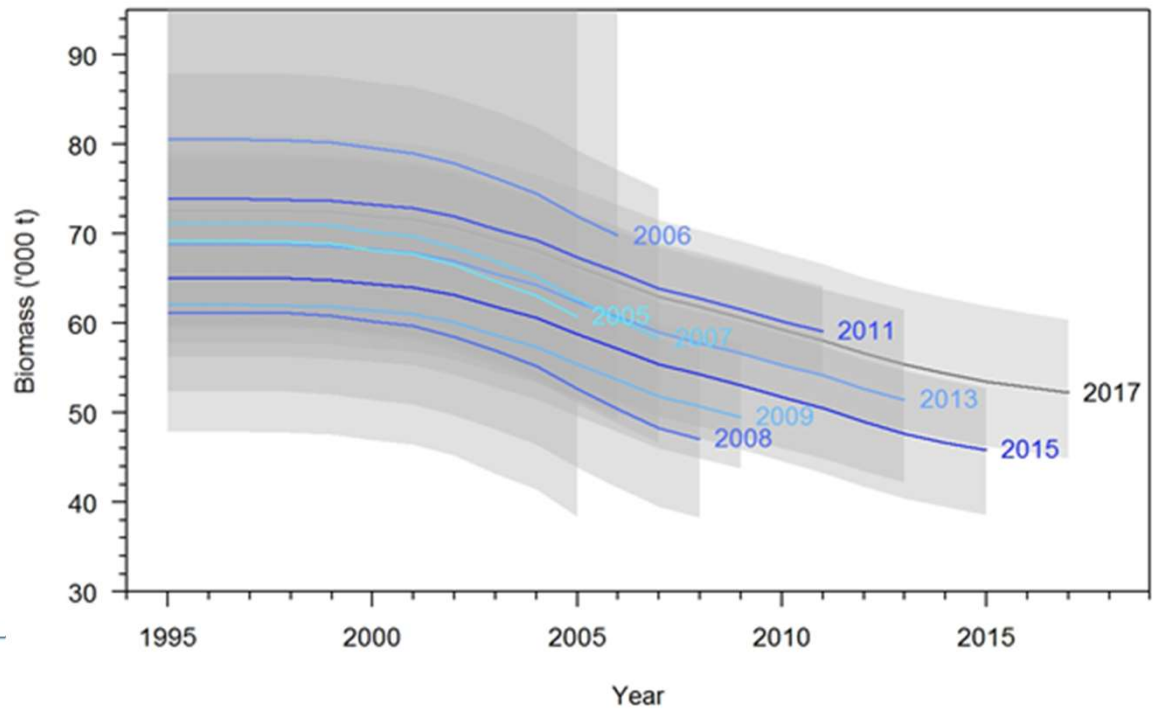
- Effective tagging survival: number of tagged fish
  - For each year and vessel a set number of tagged fish are randomly selected and removed from the data to reflect survival rates

- Effective tag detection: number of scanned fish in the tag recapture observations
  - For each year and vessel the number of fish caught is discounted by the detection rate

Model results

Summary

- Diagnostics suggest the model fits to observations were mostly adequate
- Similar trend over time from each assessments

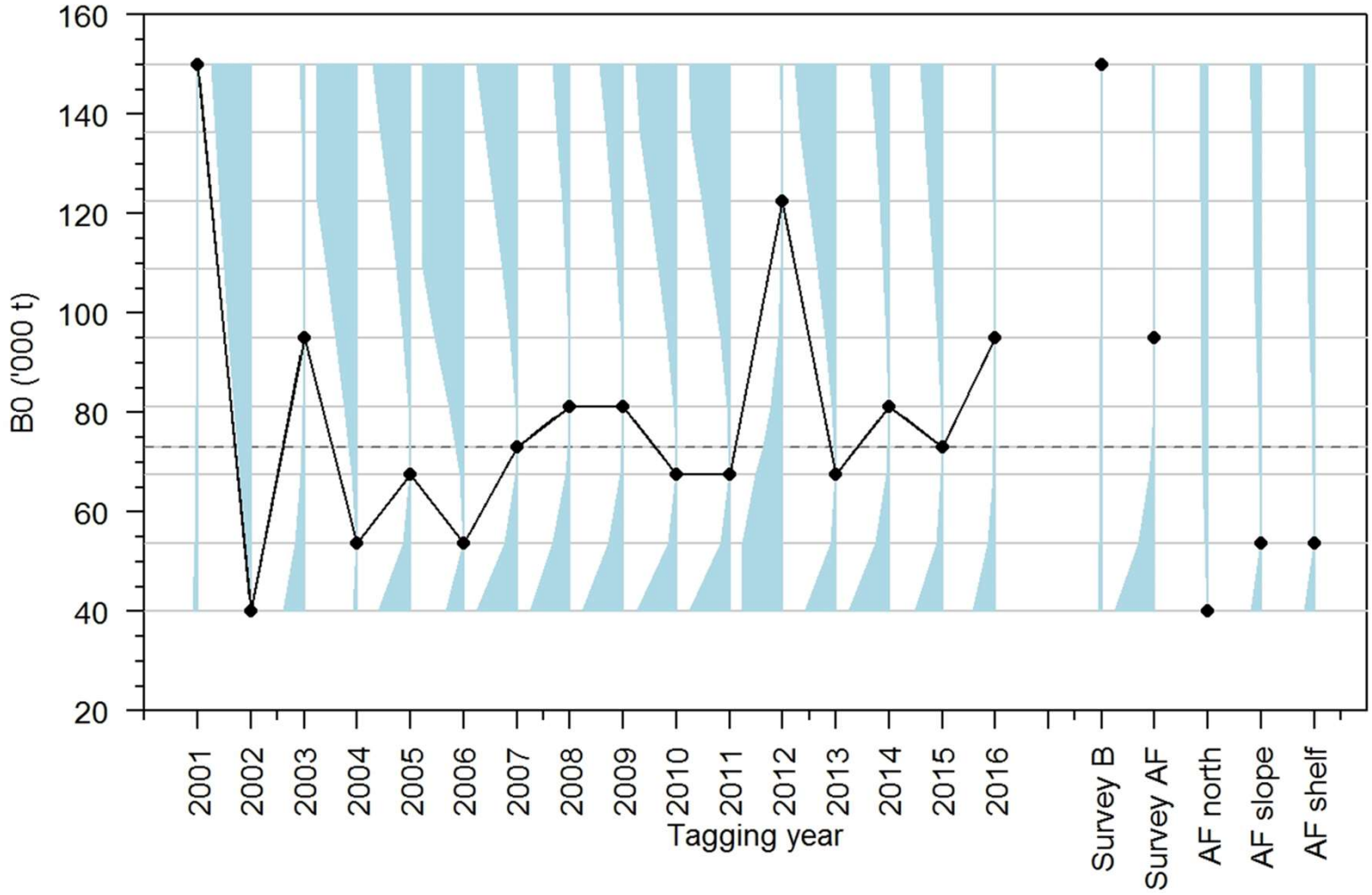


“Precautionary” catch limit

- Catch limit (R1):
  - 3234 t – 3258 t: MPA and various splits
  - Range 3213 t all slope to 3378 t all north

- CM 91-05: maximum 3157 t (don’t ask why)
  - After two years limit would be 3268 t

Likelihood profile



Bad ice years: 2001, 2008, 2015

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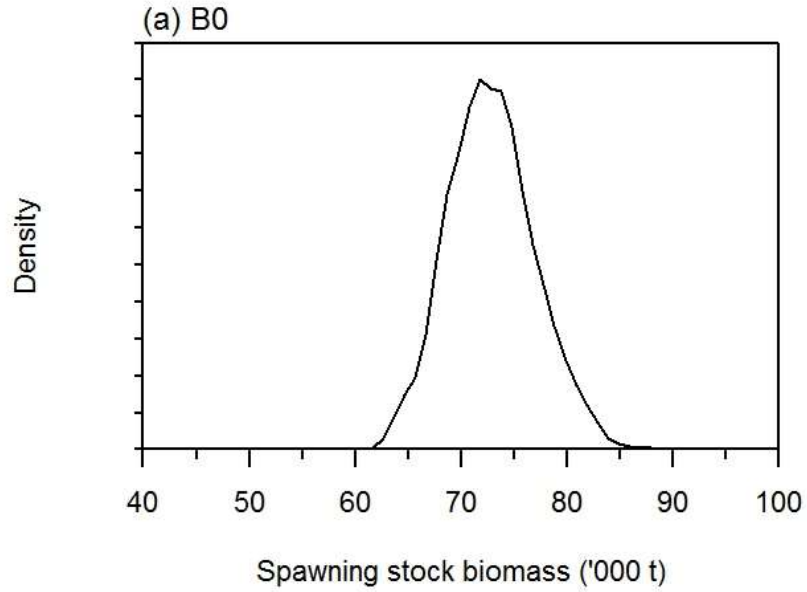
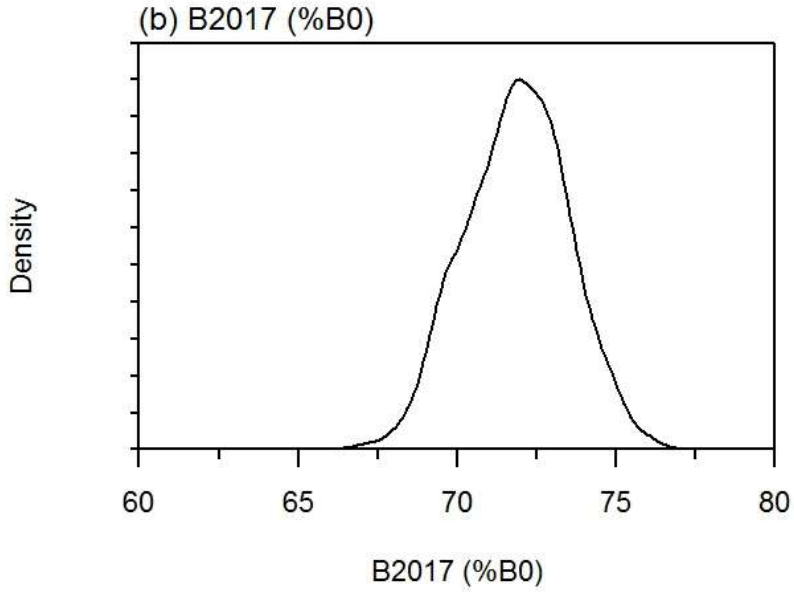
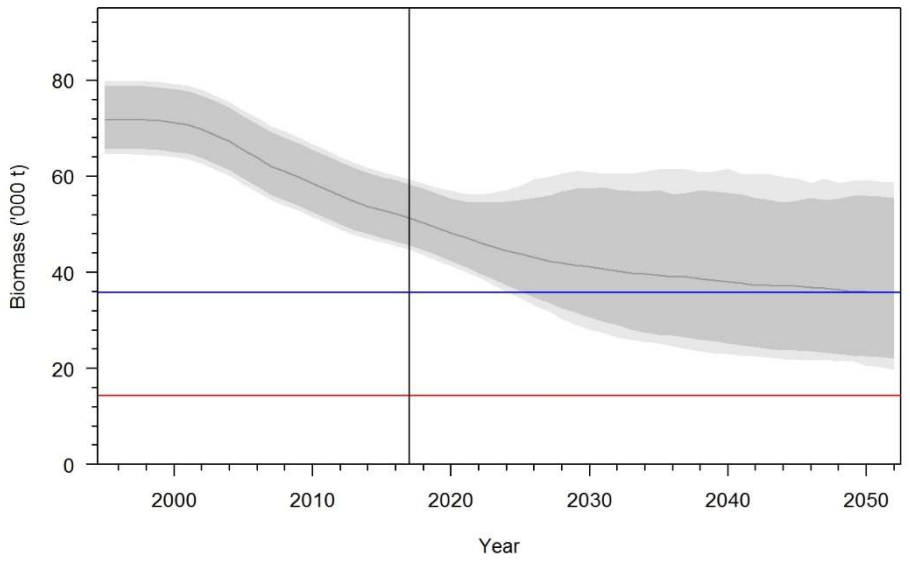
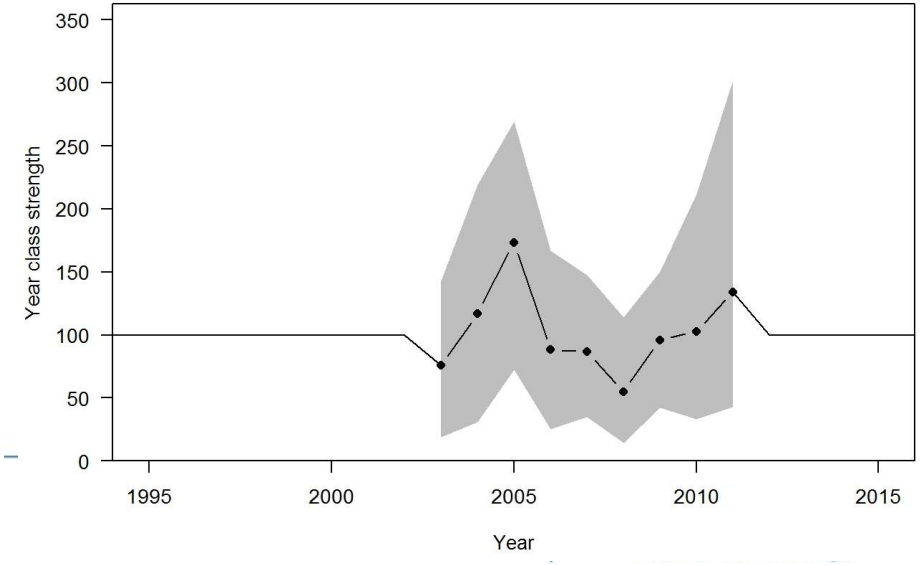
Results

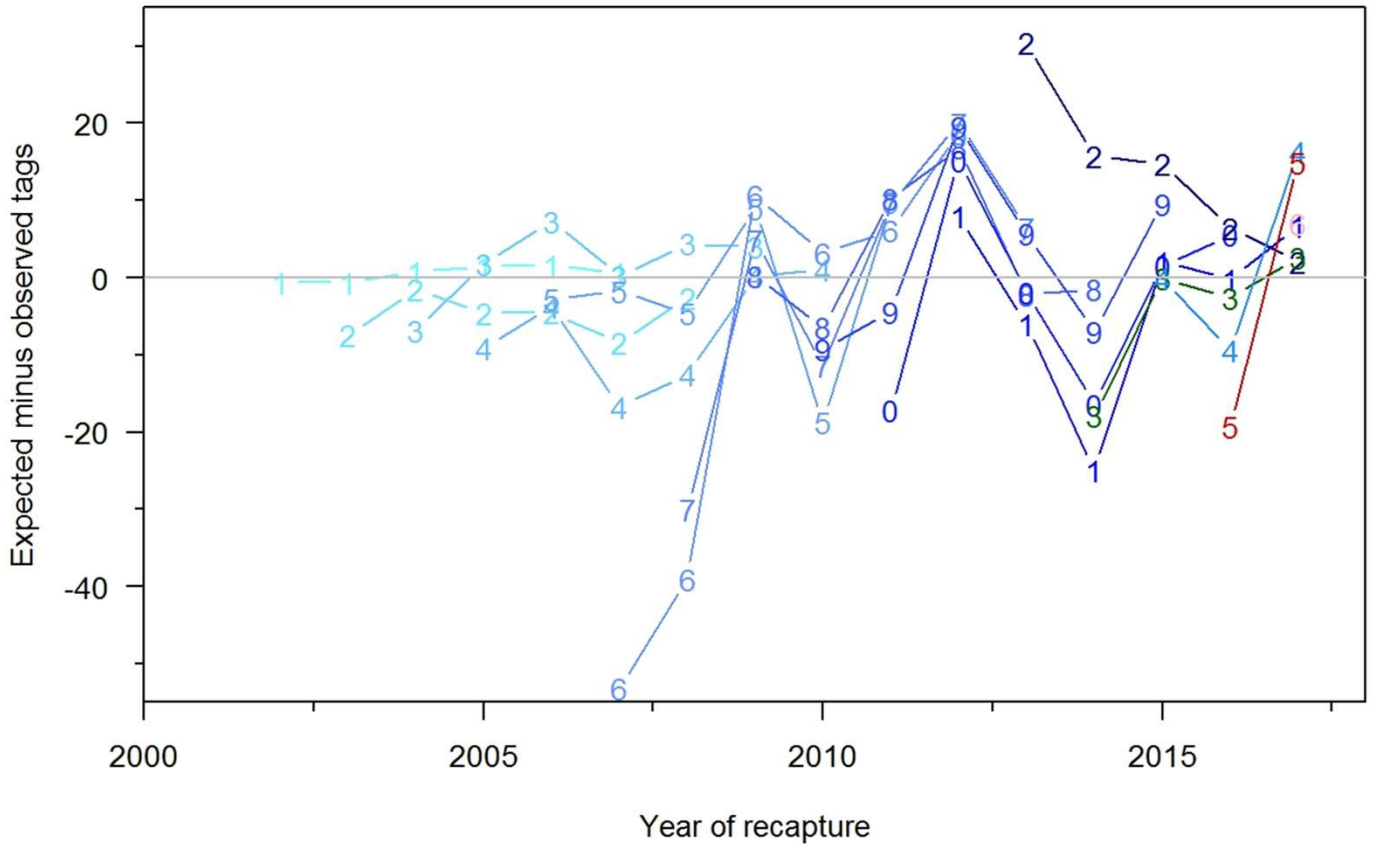

(a) B0
Density
40
50
60
70
80
90
100
Spawning stock biomass ('000 t)


(b) B2017 (%B0)
Density
60
65
70
75
80
B2017 (%B0)


Biomass ('000 t)
0
20
40
60
80
2000
2010
2020
2030
2040
2050
Year


Year class strength
0
50
100
150
200
250
300
350
1995
2000
2005
2010
2015
Year

Fits to tags



Residual pattern a function of year of recapture rather than year of release, likely linked to location of fishing.

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Sensitivity runs

- Flat-topped selectivity in the north
  - Very little difference (0.4% in MPD B_0)
- Removal of survey data
  - Without survey data, YCS was poorly estimated
- Try to fit survey biomass trend
  - biomass and AF disagree, biomass likely local processes (large fish are not always present)
- Exclude releases from one vessel where effective tagging changed a lot since the 2015 assessment
  - Some influence (B_0 3% lower than base case)

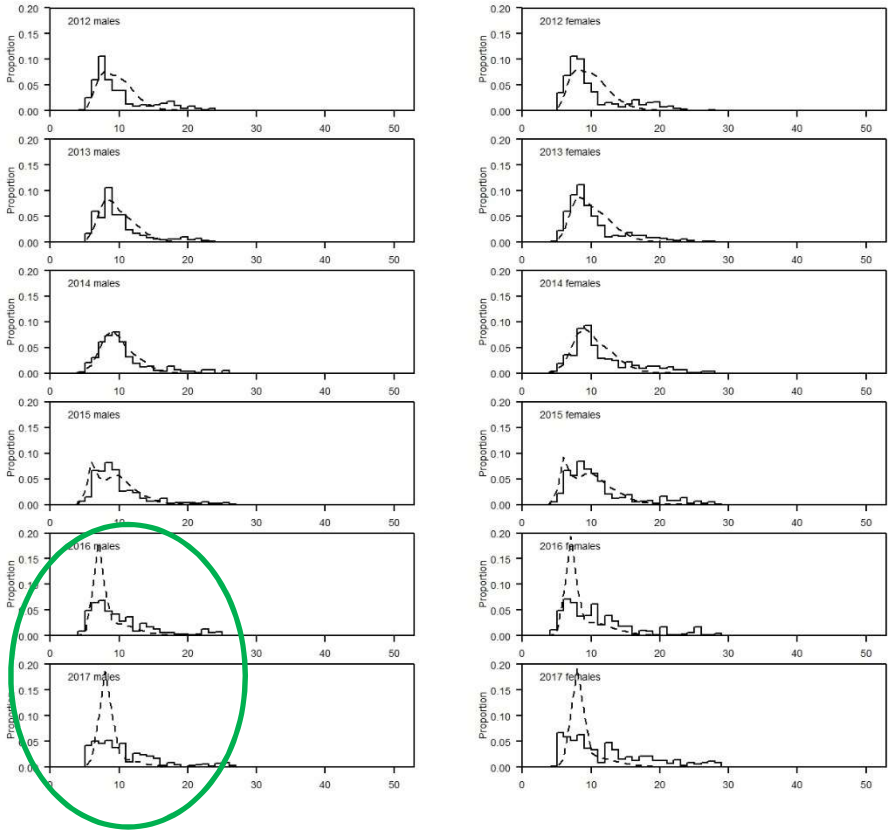
Previous model runs

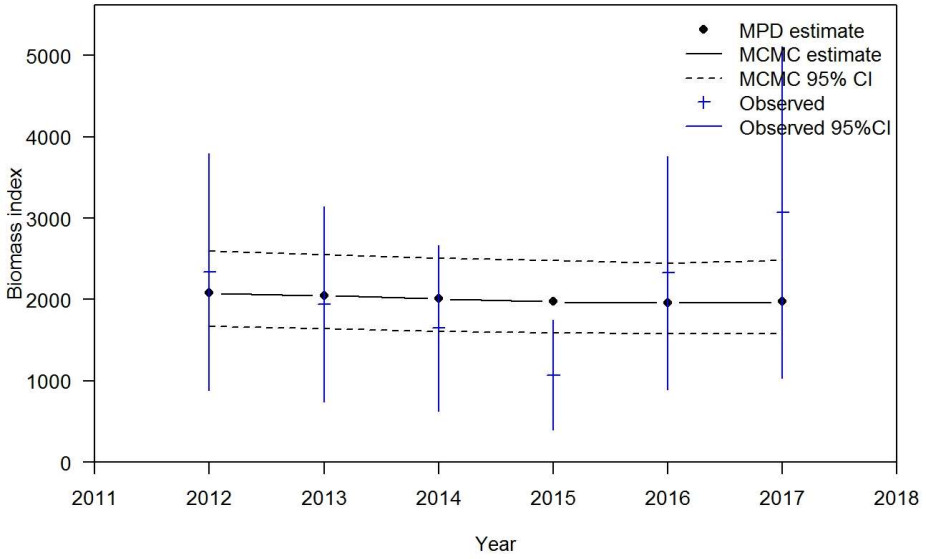
Year	Changes from previous assessment	Sensitivities
2005	First model used for management purposes. Uses proportions at age, CPUE indices, and tagging data from NZ vessels.	No tagging data, tag growth check estimated or ignored, constant or no shift in fisheries selectivities, low mortality value, single fishery, fixed fishing selectivity, 2- and 3-area models
2006	Revise length-weight and growth parameters, one additional year of data	Tagging data from all vessels, uncertainty added to natural mortality, alternative data weightings
2007	Remove CPUE indices, one additional year of data	Tagging data from all vessels, tagging data from all vessels in 2006 only, logistic north selectivity
2009	Tagging data from selected trips from all nations using new data quality method, update maturity curve, two additional years of data	Tagging data from NZ vessels only, 2007 maturity ogive
2011	Update tag data selection, update tag-loss rates based on the analysis of double-tagging data, two additional years of data	Inclusion of IUU catch, inclusion of various levels of additional mortality, tagging data from all vessels
2013	New tagging survival and tag detection calculation method using tagging data from all vessels, update maturity curve, change model data weighting to Francis (2011), two additional years of data	Logistic selectivity in the North, retrospective analysis (removing up to 210-2013 observations)
2015	Add survey age frequencies and biomass estimates and estimate YCS, remove annual selectivity shifts, update tagging survival and tag detection rates, update data weighting, two additional years of data	Logistic selectivity in the North, remove survey data, use tagging data from the last 6 years only, change the catches from quarantined data by +/- 50%,
2017	Update tagging survival and tag detection rates, update data weighting, two additional years of data	Logistic selectivity in the North, remove survey data, down-weight survey biomass estimates, exclude tag releases from a vessel with a large increase in tagging survival rates

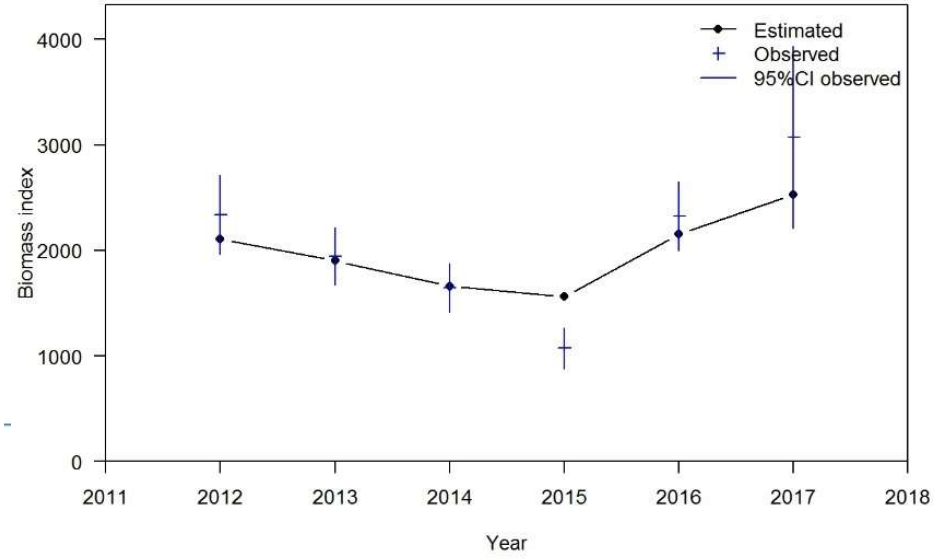
Some issues and challenges

Fits to survey biomass

- Not a good fit to the survey biomass
- Up-weighting that data doesn't fit AFs anymore
- Survey captures juveniles and a mode of older fish

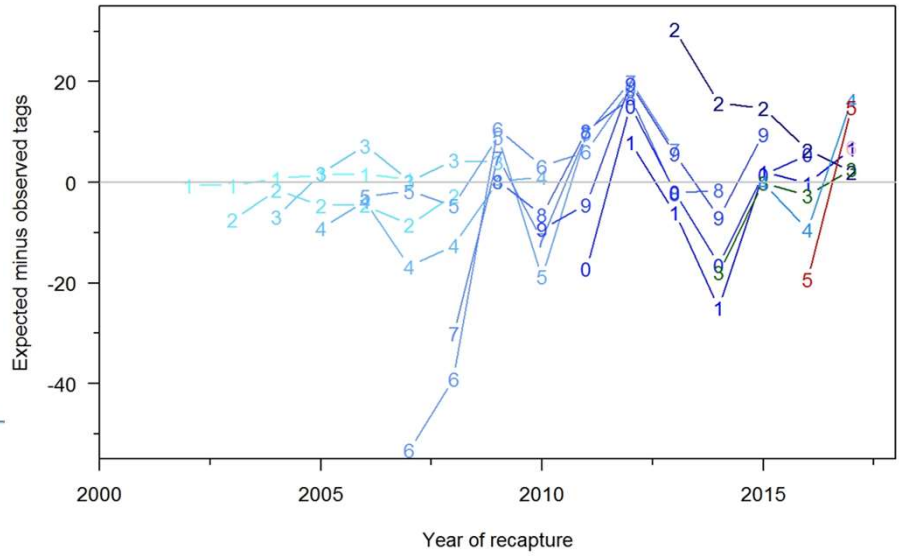


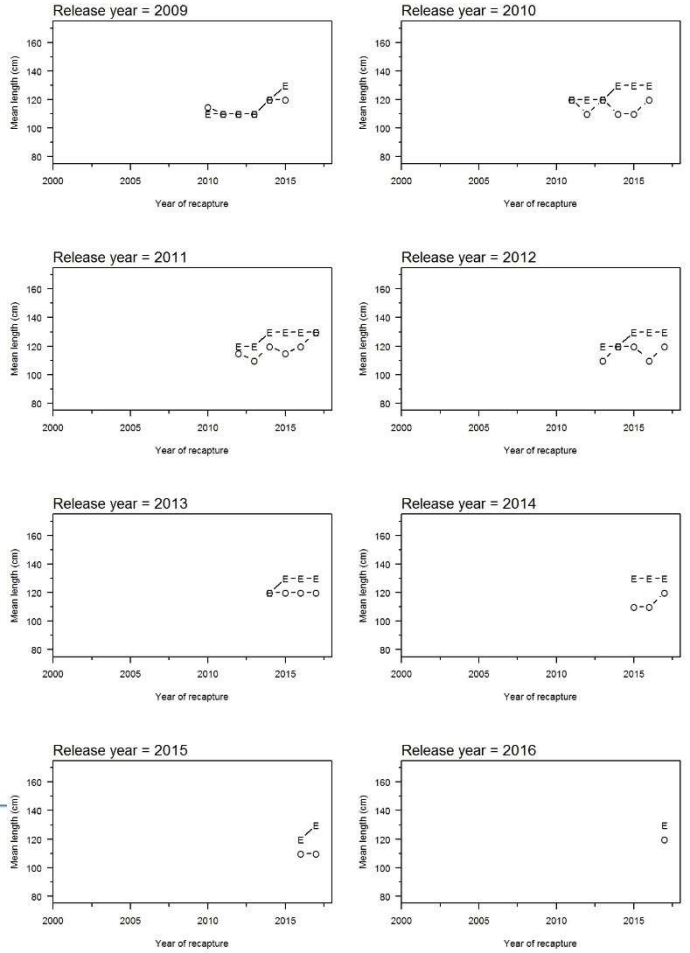




Fits to tag data

- Discrepancy between observed and expected
- Freeing tag shedding rate, initial tag loss rate did not improve fits



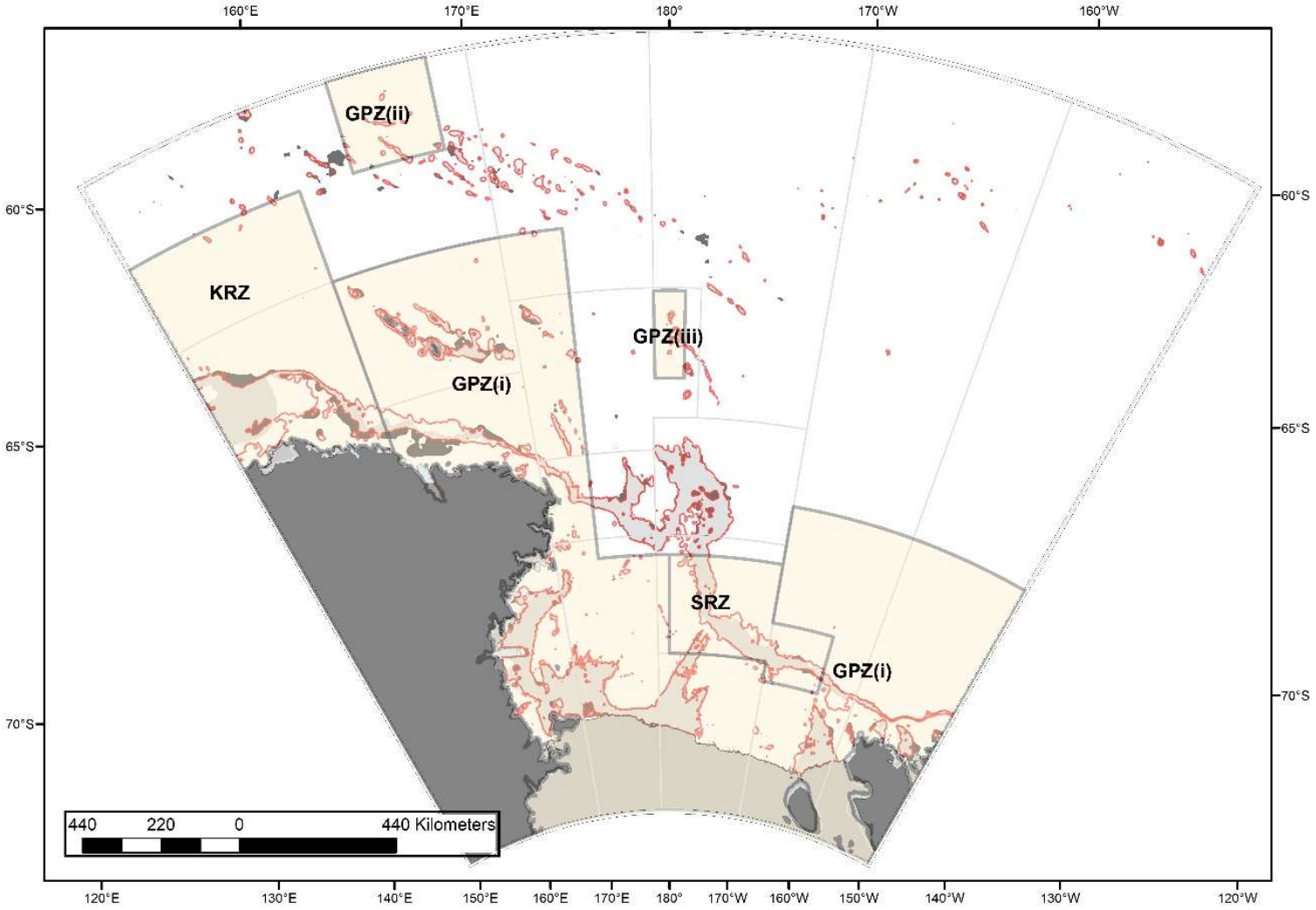


Fits

- Go through FSA-17/38

Future effects of the MPA on the assessment

The Ross Sea region MPA



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Potential impacts

- Catch split used for projections
- Location of effort and previously-released tagged fish (spatial bias)

Catch split

- 2017 assessment: assumptions on the location of future catches to estimate the catch limit

- 2019 assessment:
  - Need to assess location of catches, potential biomass in new areas and propose new catch splits
  - Might need new fisheries as areas for the model

Location of tagged fish

- 2017 assessment: no impact

- 2019 stock assessment onward:
  - Some areas with tagged fish will not be available to fish and recapture tagged fish
  - Some areas with no currently tagged fish might get fished: might create a small bias in 2019, which will increase after
  - Will need to account for the spatial heterogeneity between tagged and effort until the patterns settle

Work plan for the assessment

- Medium Term Research Plan (FSA-14/60)
  - Stock structure, in particular with 88.2C-I
  - Improve estimates of tagging mortality and tag detection
  - Performance / dashboard of key parameters
  - MSE
- Assessment papers (SAM-17/41, FSA-17/37)
  - Bias due to the change in fishing effort distribution / index of tag overlap
  - Catch split / fisheries as areas
  - Effective tagging survival and tag detection rates
  - Residuals (e.g. sex ratio, tagged fish length)

Thank you