Update on age and growth of bigeye tuna in the WCPO

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Western and Central Pacific Fisheries Commission

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Outline

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Introduction

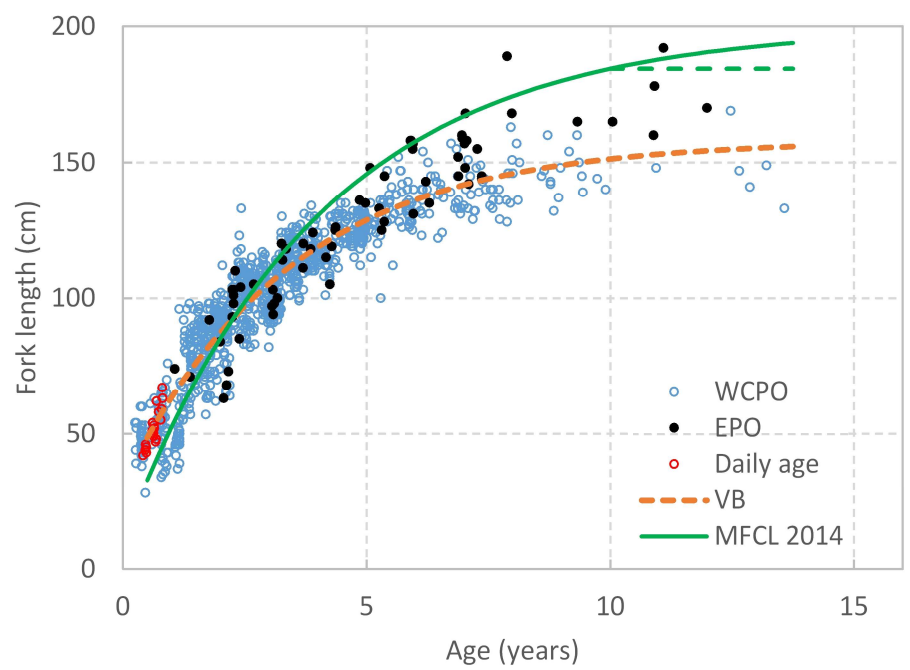
2007 - SC4 recommended a bigeye growth project

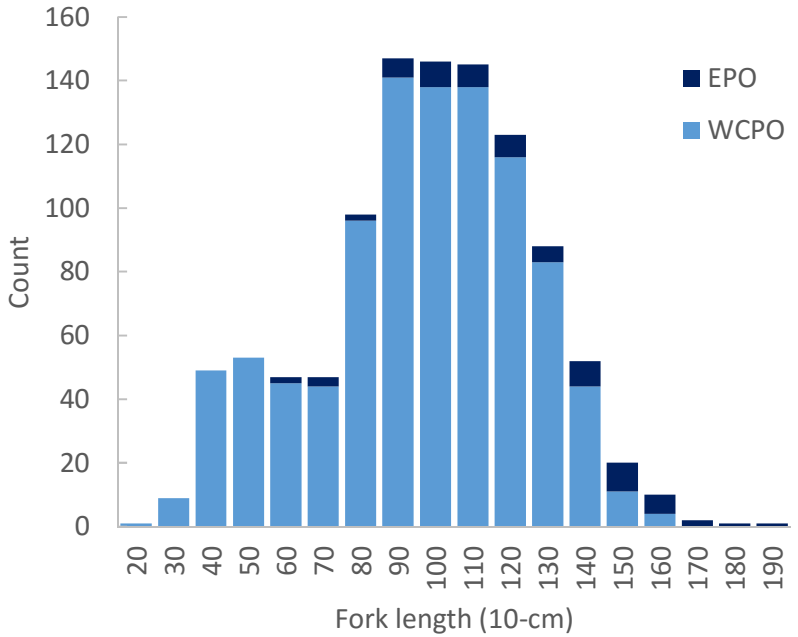
2011 - **Pilot project completed** - preliminary growth curve

2017 - **Final project completed** - presented at SC13 (Project 35)

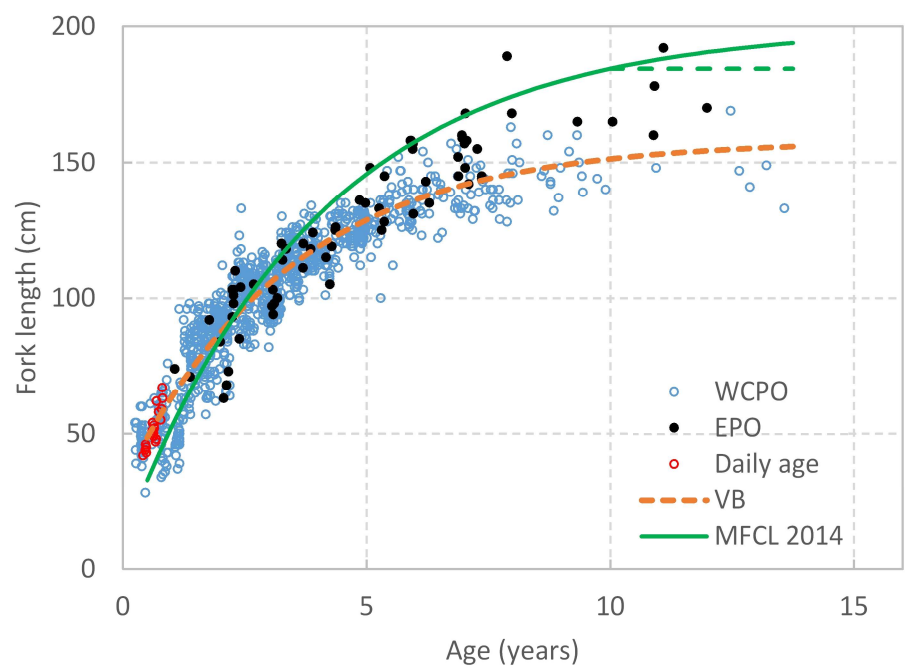
- 1,039 annual age estimates (included 68 BET from EPO)
- Estimate growth parameters
  - L_{∞} = **158 cm**
  - Ln (L2) = **152 cm**; smaller than **184 cm** used in previous assessments
- Contributed to more optimistic view of stock status
  (not in an overfished state, not experiencing overfishing)
- But concern at SC13 that large fish may be underrepresented in data
- Additional otoliths identified by NRIFSF and SPC
- SC13 requested further work = Project 81

Introduction

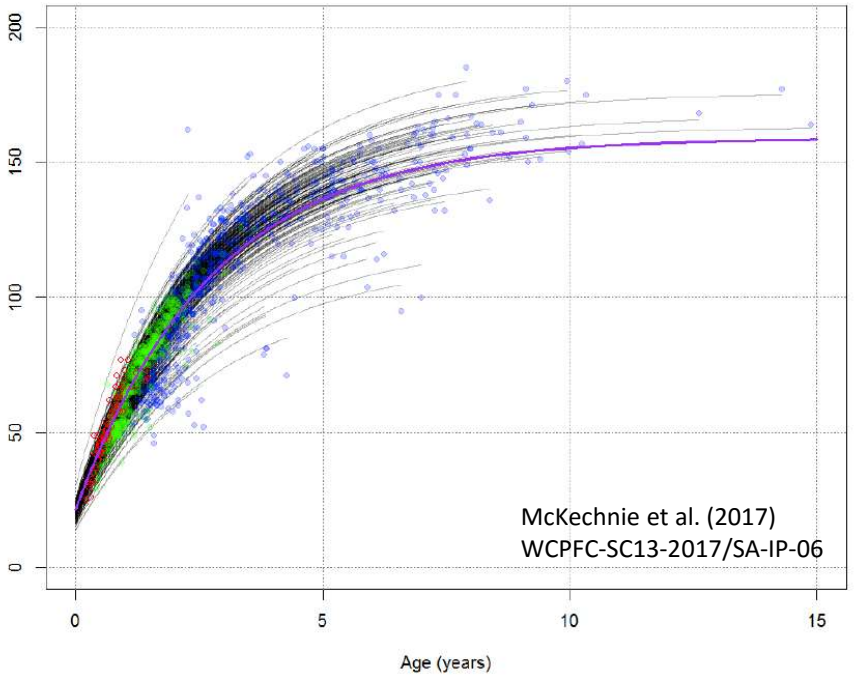




Introduction



Daily-integrated-VB (daily age & tag data)



Objectives

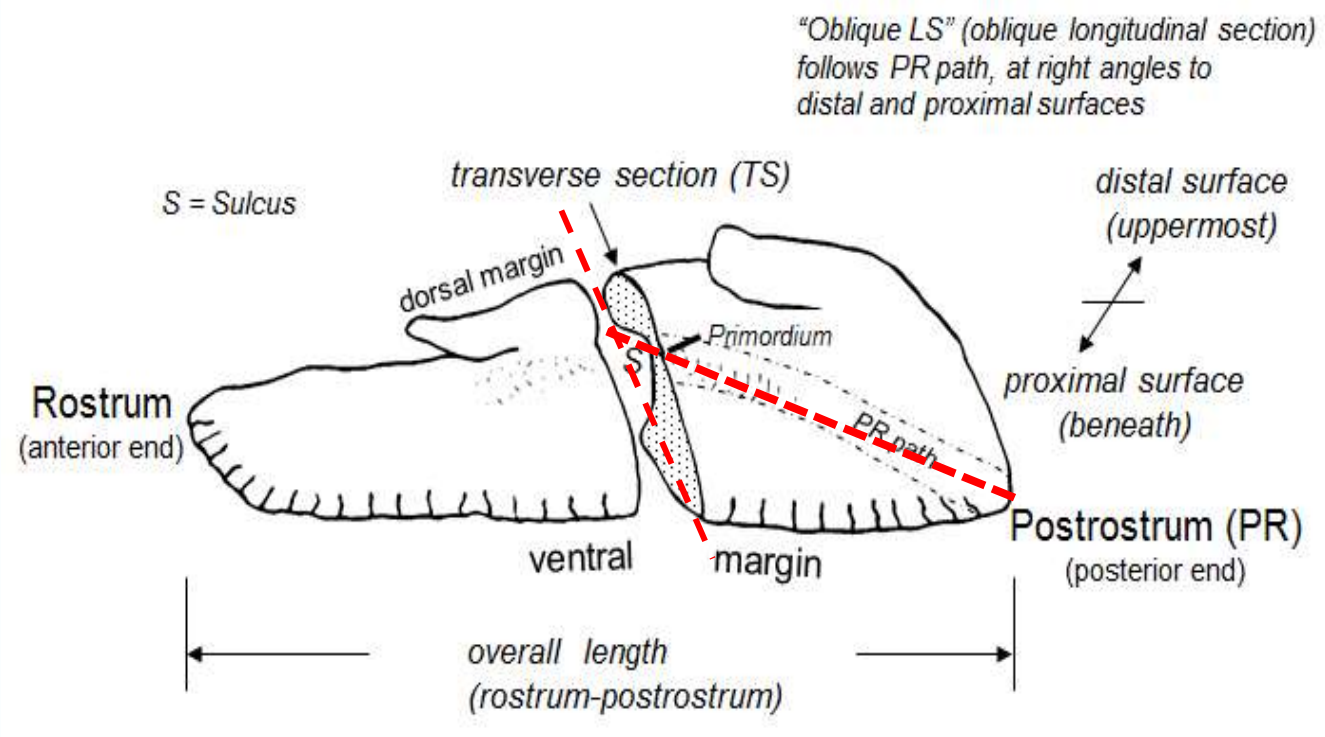
- Prepare and read an additional 125 otoliths from bigeye tuna >130 cm FL using the annual increment method identified in Farley et al. (2017).

- Revise and update the Farley et al. (2017) age and growth estimates based on the additional new data.

Background:

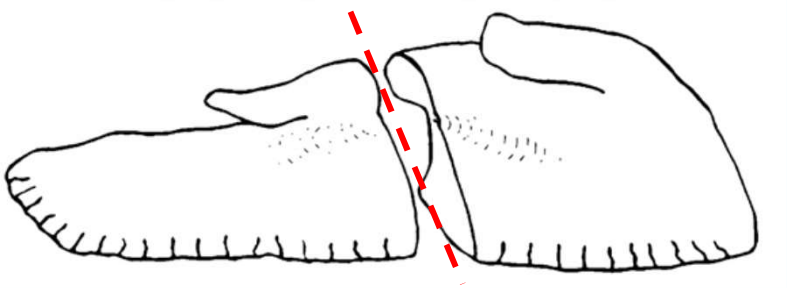
1) Ageing methods - annual & daily

Otolith sectioning plane



Annual ageing

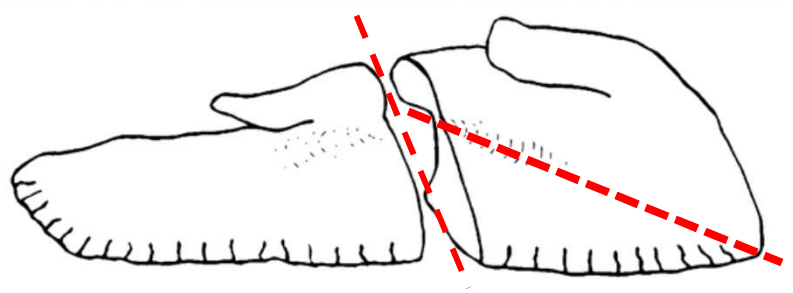
- Fish Ageing Services (FAS)
- Transverse plane
- 4 serial sections
- Alternate opaque/translucent zones
- Count opaque zones
- Readability score
- Edge type
  - Narrow T, wide T or opaque
  - Used to estimate decimal age



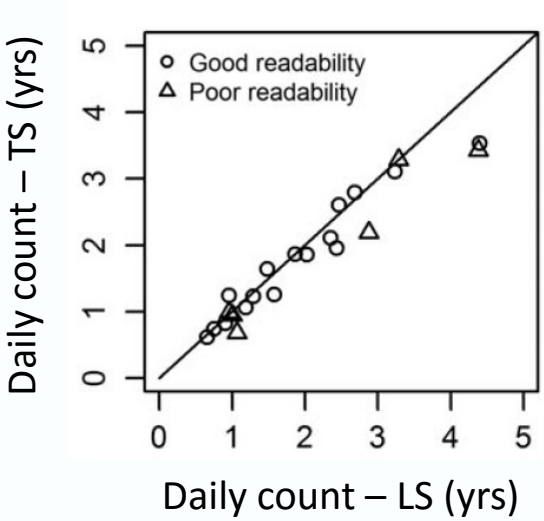
4 zones (130 cm FL)

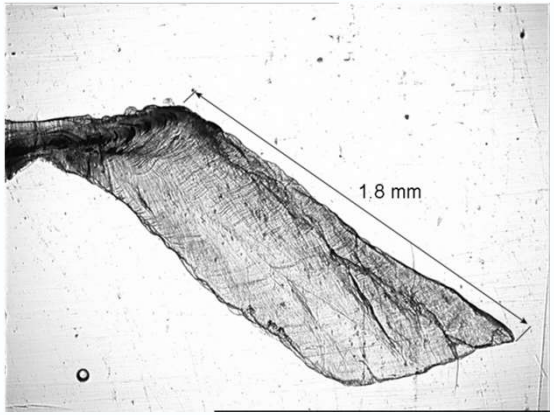
12 zones (169 cm FL)

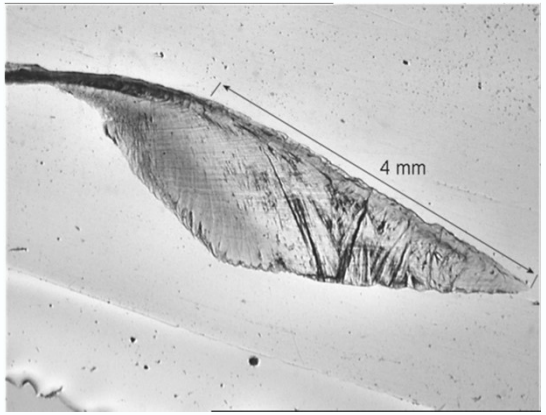
Daily ageing



- Fish Ageing Services (FAS)
- Transverse or longitudinal plane
- Count microincrements
- Readability score
- Confident up to age 300 days only

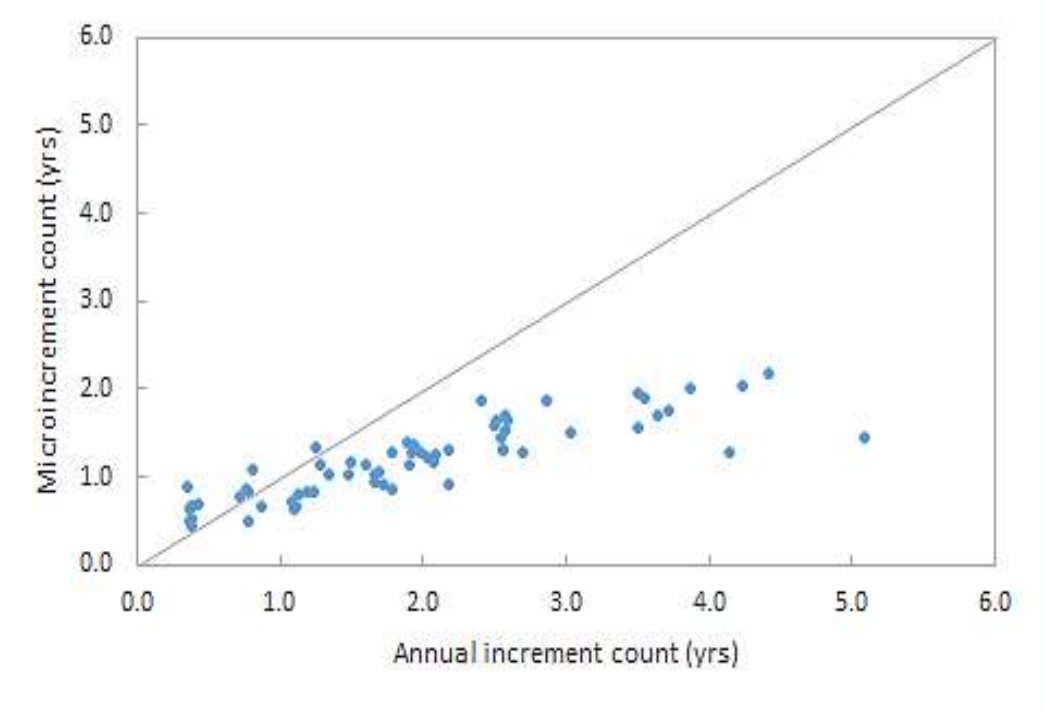






From Williams et al. (2013).

Daily vs annual age



Background:

2) Age validation – annual & daily

Mark-recapture experiment

- 1990s SPC / CSIRO tagging program
- Coral Sea
- BET caught - injected with $SrCl_2$ - released
- 34 recaptured
- 11 analysed
- At liberty 207 days to >6 years
- $SrCl_2$ mark examined under SEM

Annual age validation

Fish number	Release Date	Release fork length (cm)	Recapture Date	Recapture fork length (cm)	Growth (cm)	Days at Liberty	
591	9/10/1995	80	2/11/1998	139	59	1120	
37	13/11/1992	72	31/07/1993	85	13	260	
57	6/10/1995	75	14/08/1997	128	53	678	
59	12/11/1992	96	15/07/1998	159	63	2071	5.7 y
62	9/10/1995	109	3/05/1996	123	14	207	
63	6/10/1995	83	10/06/1996	94	11	248	
64	6/10/1995	79	unknown	unknown			
65	9/10/1995	78	26/01/1998	128	50	840	
66	9/10/1995	84	18/12/1997	129	45	801	
67	9/10/1995	78	4/11/1997			757	
2820	9/10/1995	125	25/5/2002	157	32	2420	6.6 y

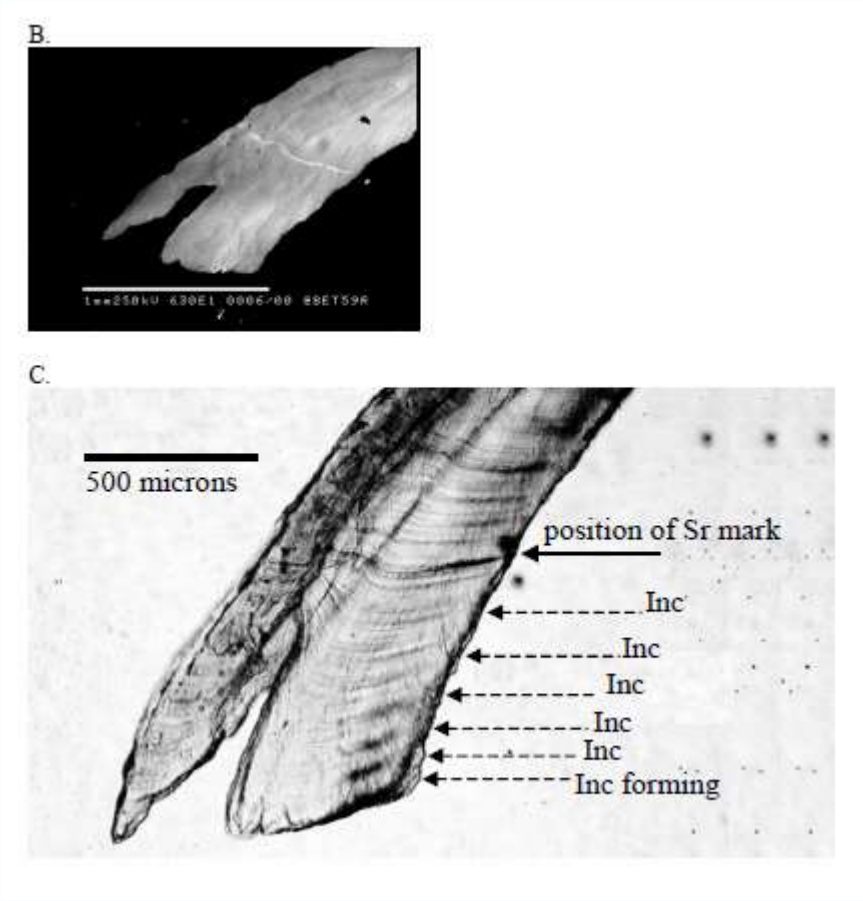
Annual age validation

Fish number		37	57	59	62	63	64	65	66	67	591	2820
FL at tagging (cm)		72	75	96	109	83	79	78	84	78	80	125
FL at recapture (cm)		85	128	159	123	94	-	128	129	-	139	157
Time at liberty after tagging (days)		260 (8.5 mths)	678 (1 yr 10 mths)	2071 (5 yrs 8 mths)	207 (7 mths)	248 (8 mths)	recap. details not known	840 (2 yrs 3 mths)	801 (2 yrs 2 mths)	757 (2 yrs 1 mth)	1120 (3 yrs 1 mth)	2420 (6 yrs 7 mths)
Number of increments after Sr mark	**expected**	**0 or 1**	**1 or 2**	**5 or 6**	**0 or 1**	**0 or 1**		**2**	**2**	**2**	**3**	**6 or 7**
	observed	**1**	**1**	**5**	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**6**
Age estimate (this study) *		2	3	8	3	2	2	3	3	3	4	9
Age at tagging **		1.2	1.3	2.1	2.7	1.6	1.5	1.4	1.6	1.4	1.5	3.18
Age at recapture **		1.7	3.8	8.6	3.5	2.0	-	3.8	3.9	-	4.8	7.87
Month of recapture		July	Aug	July	May	June		Jan	Dec	Nov	Feb	May
distance from Sr mark to margin (cm)	Sr (O) -O	0.36	0.74	1.06	0.25	0.27	0.30	0.72	0.77	0.81	0.67	0.49
	Sr (I) -I	0.26	0.56	0.80	0.15	0.16	0.25	0.54	0.63	0.77	0.50	0.43

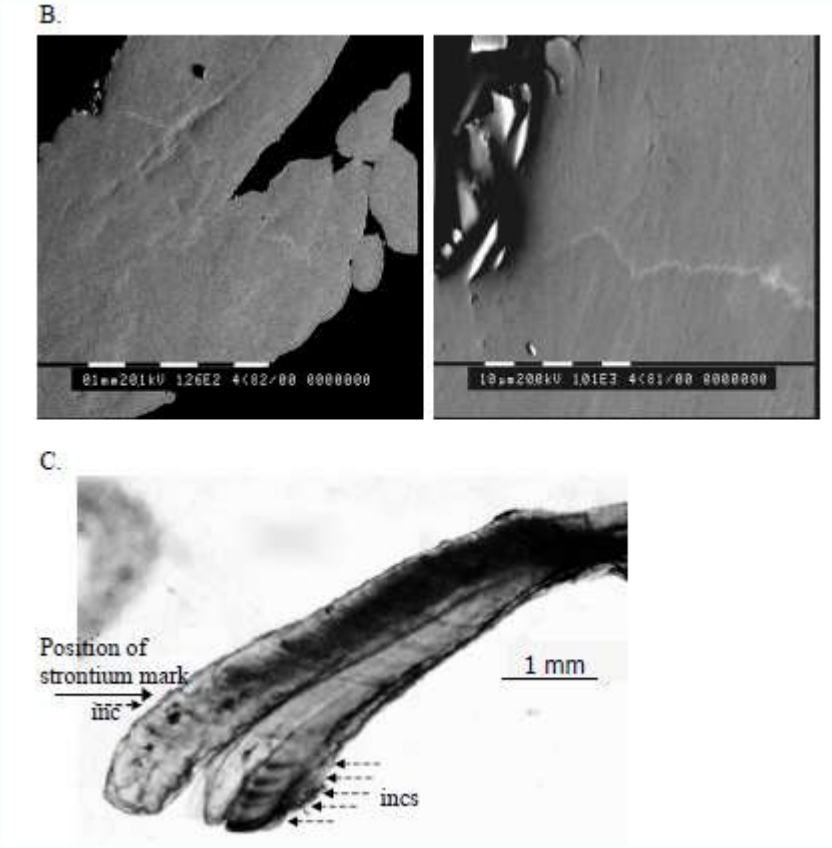
* Estimated by counting annual increments on sectioned sagittal otoliths.

** Estimated using results from a study of otolith microincrements and tagging data (Hampton et al. 1998).

Examples – validated annual age



BET 59 - at liberty 5 years, 8 months
5 opaque zones



BET 2820 - at liberty 6 years, 7 months
6 opaque zones

Daily age validation

Fish no.	Release FL (cm)	Recapture FL (cm)	Days at Liberty	Otolith analysed in the SEM				Sister Otolith			
				Count 1	Count 2	Reading Score	% mean difference from days at liberty	Count 1	Count 2	Reading Score	% mean difference from days at liberty
37	72	85	260	218	216	A	-16.5				
57	75	128	678	587	570	B	-14.7	530	560	C	-19.6
62	109	123	207	155	137	C	-29.4	144	146	A	-30.0
63	83	94	248	230	228	B	-7.7	184	200	C	-22.6
65	78	128	840	597	666	B-	-24.7				
66	84	129	801			broken		567	582	C	-28.3
67	78	unknown	757					570	532	B	-27.2

A= count with high confidence, all areas have visible microincrements
B= count with medium confidence, most areas have visible microincrements but a few areas are unreadable
C= count with low confidence, many areas along the section are unreadable

Conclusions – WCPO BET

- Annual periodicity of increments directly validated for age range 2 to 9 years.
- Age estimates in days for BET 72 - 129 cm FL are not reliable

Background:

3) Biological (decimal) age

Biological age from annual counts

- The number of opaque zones counted in otoliths is not necessarily the fish's biological age
- Convert counts to decimal age using an algorithm that accounts for:
  - Birth date
  - Timing of year that opaque zones form
  - Otolith edge type
  - Catch date

Age algorithm $a = (n + b) + r/365$

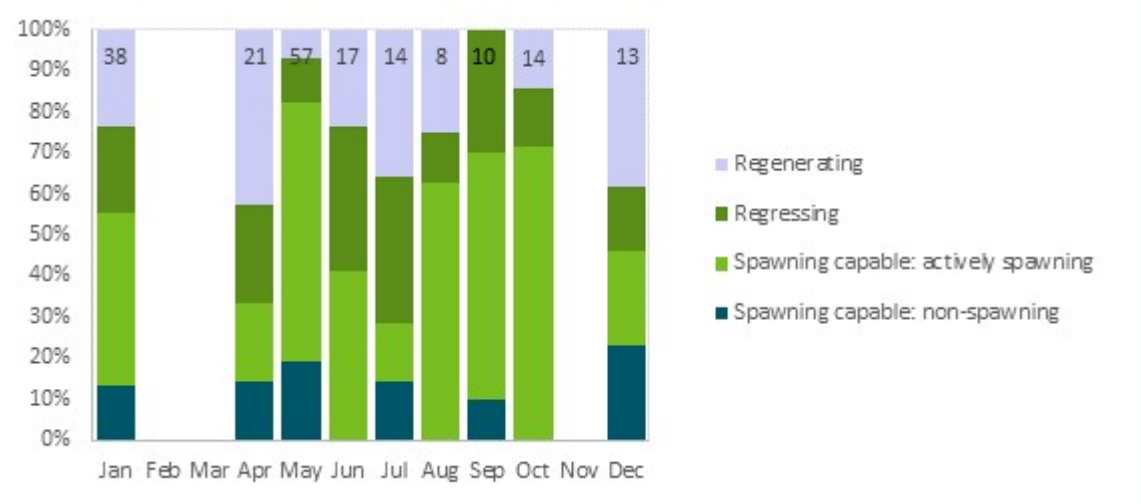
- *a* = decimal age
- *n* = count opaque zones
- b = “adjustment” (criteria in table below)
- *r* = capture date (days since last birthday; **July 1**)

Opaque zones completed Apr-Sep (**July 1** as midpoint)

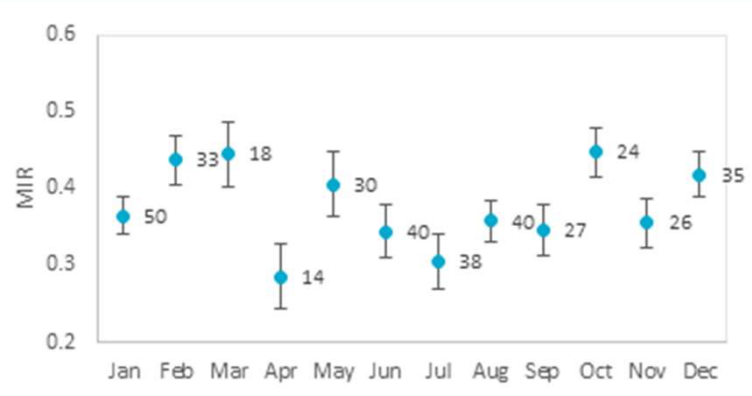
- need to adjust depending if zone has been deposited & counted, or not
- Use edge type to decide

	OCTOBER TO MARCH	APRIL TO JUNE	JULY TO SEPTEMBER
Wide or Intermediate	0	0	+1
Narrow	0	-1	0

Birth date & increment formation period



July 1



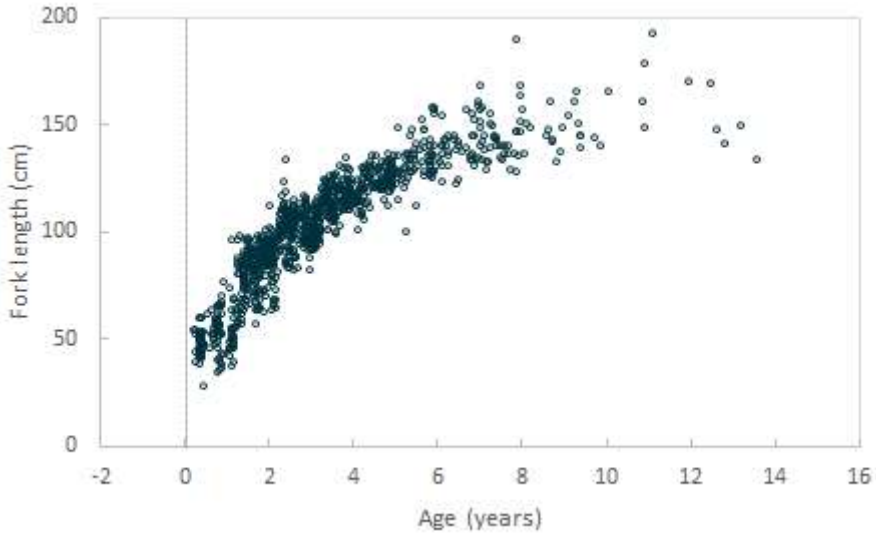
July 1

Examples of age calculation

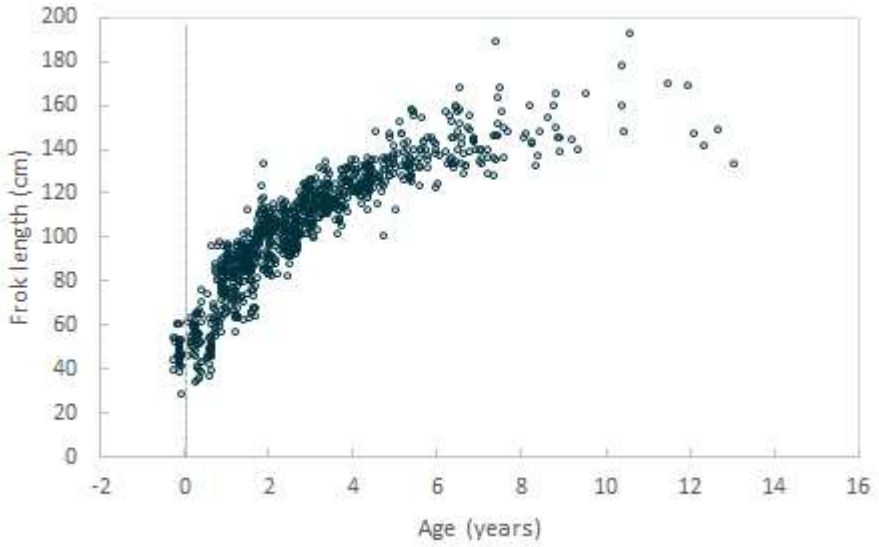
Fish	1	2	3	4
Nominal birth date	1 July 2010	1 July 2010	1 July 2010	1 July 2010
Last birthday	1 July 2011	1 July 2011	1 July 2012	1 July 2012
Date caught	1 June 2012	1 June 2012	1 Aug 2012	1 Aug 2012
Day of capture after last birthday *(r)*	336	336	31	31
Zone count (*n*)	1	2	1	2
Edge type	Wide	Narrow	Wide	Narrow
Count adjustment (*b*)	0	-1	+1	0
Decimal age (*a*)	1.92	1.92	2.08	2.08

Nominal birth date

July 1



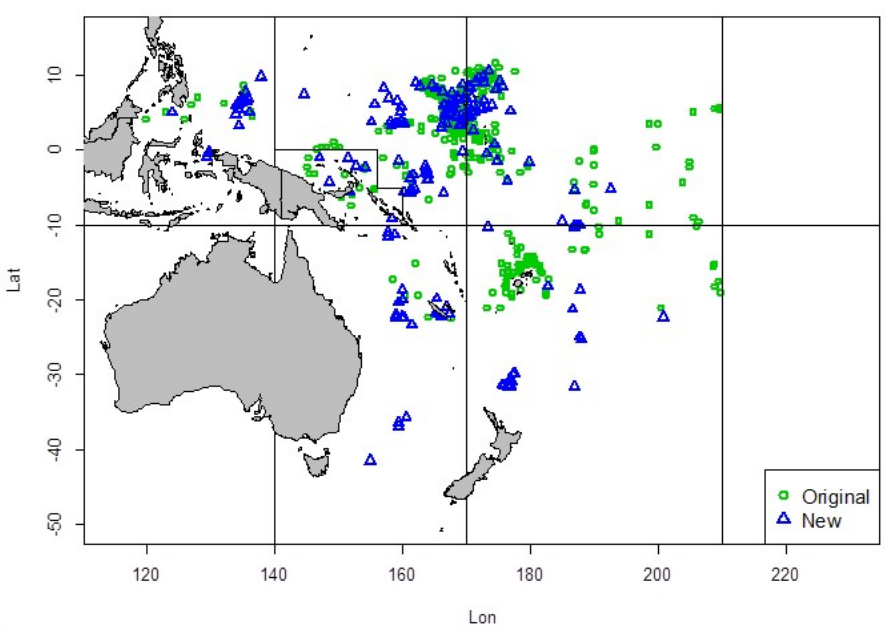
January 1



Project 81
Update on age and growth of bigeye tuna in the WCPO

Methods

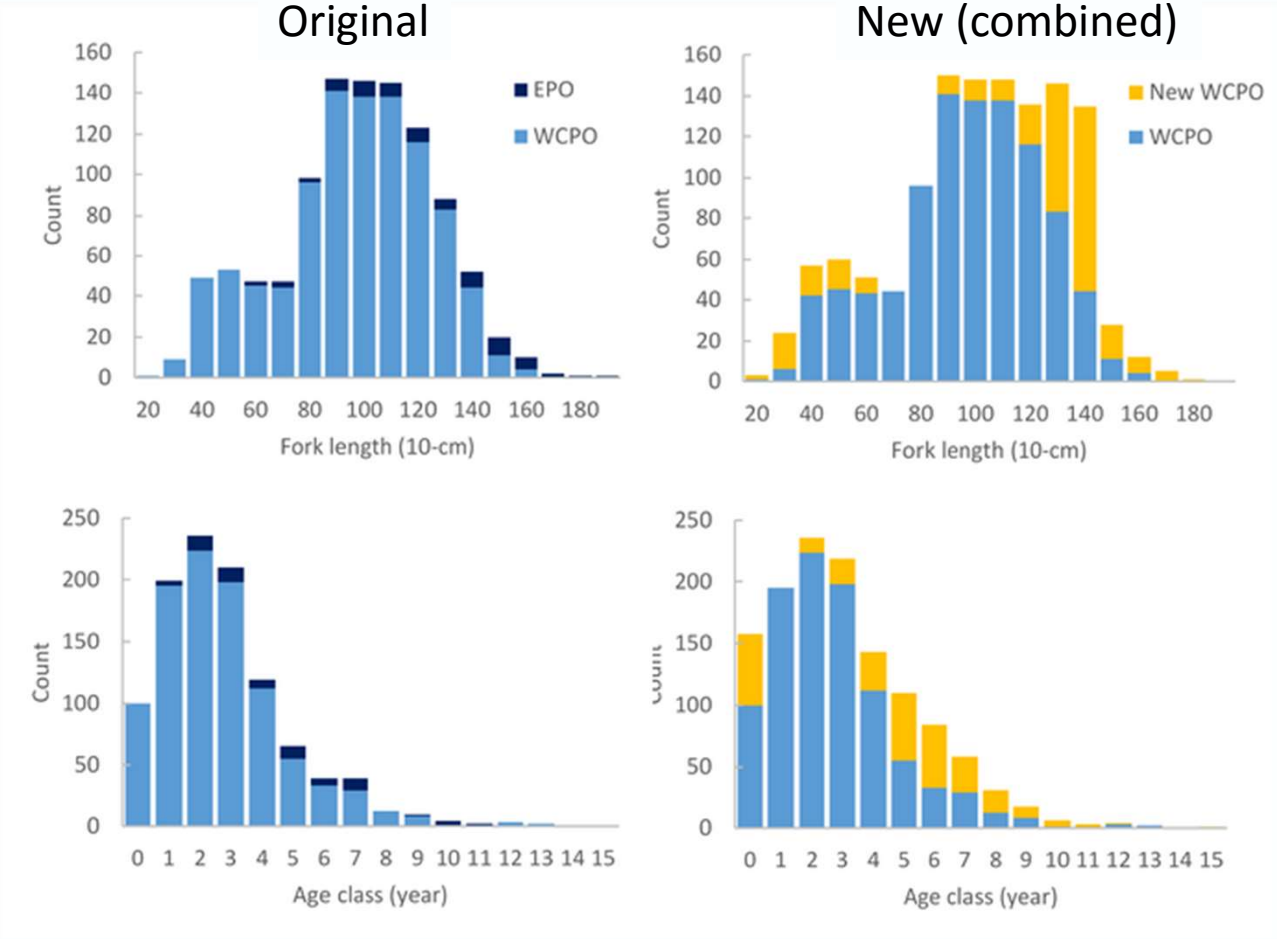
- n = 136 >130 cm
- n = 49 - 90-129 cm
- n = 52 >130 cm from pilot study
- n = 12 daily ageing 31-39 cm



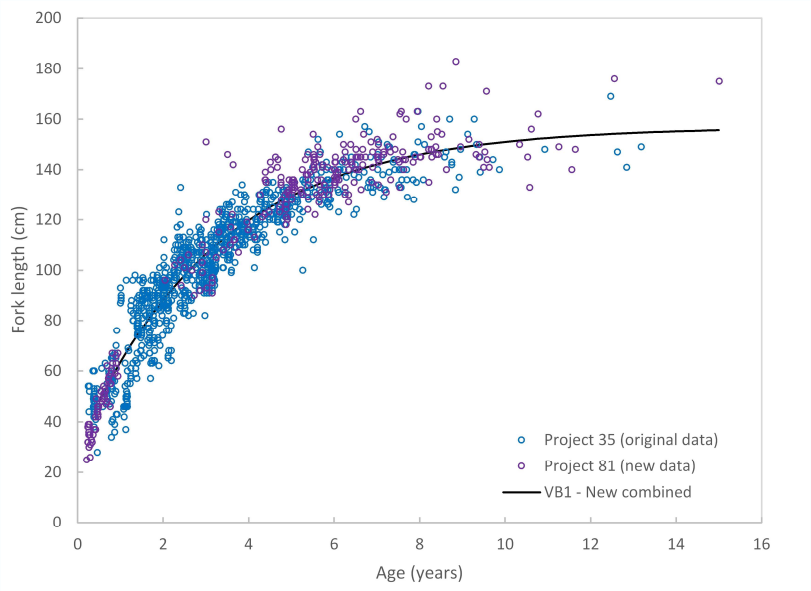
- Removed EPO ages
- Included all daily ages <300 days (no doubles)
- Included SPC daily ages (n = 28 <1 yr)

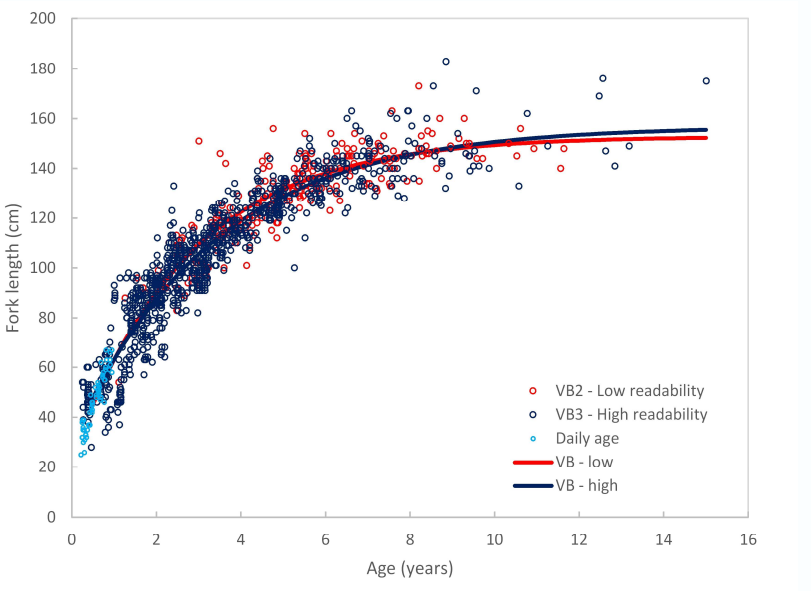
- Total = 1244 age estimates

Length/age frequency of BET aged



Length-at-age & VB curves

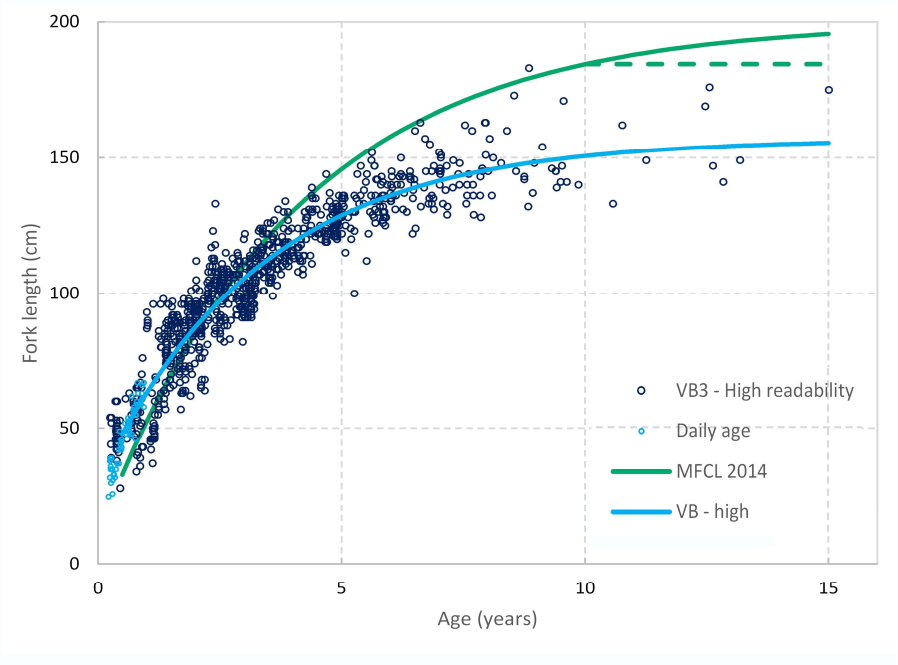




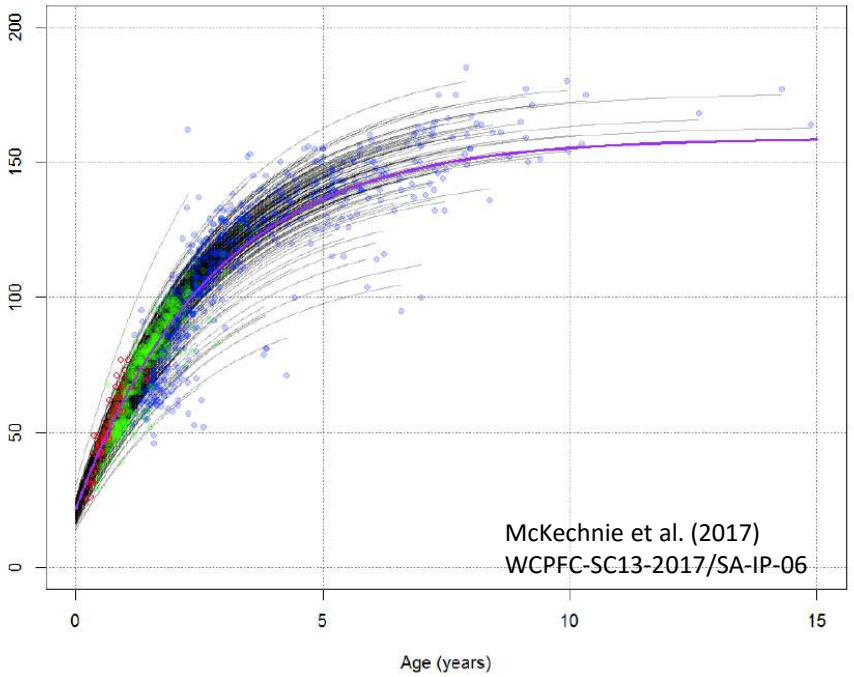
MODEL	Data	n	L_∞	k	t_0	σ
VB1	Project 81	1244	156.9 (1.7)	0.307 (0.010)	-0.69 (0.04)	9.3 (0.22)
VB2	Project 81 low readability	318	152.9 (1.6)	0.361 (0.015)	-0.47 (0.05)	8.0 (0.32)
VB3	Project 81 high readability	984	156.9 (1.7)	0.301 (0.010)	-0.71 (0.04)	9.4 (0.21)
VB4	Project 35	1039	158.1 (1.8)	0.292 (0.011)	-0.75 (0.05)	9.7 (0.21)

Comparing growth curves

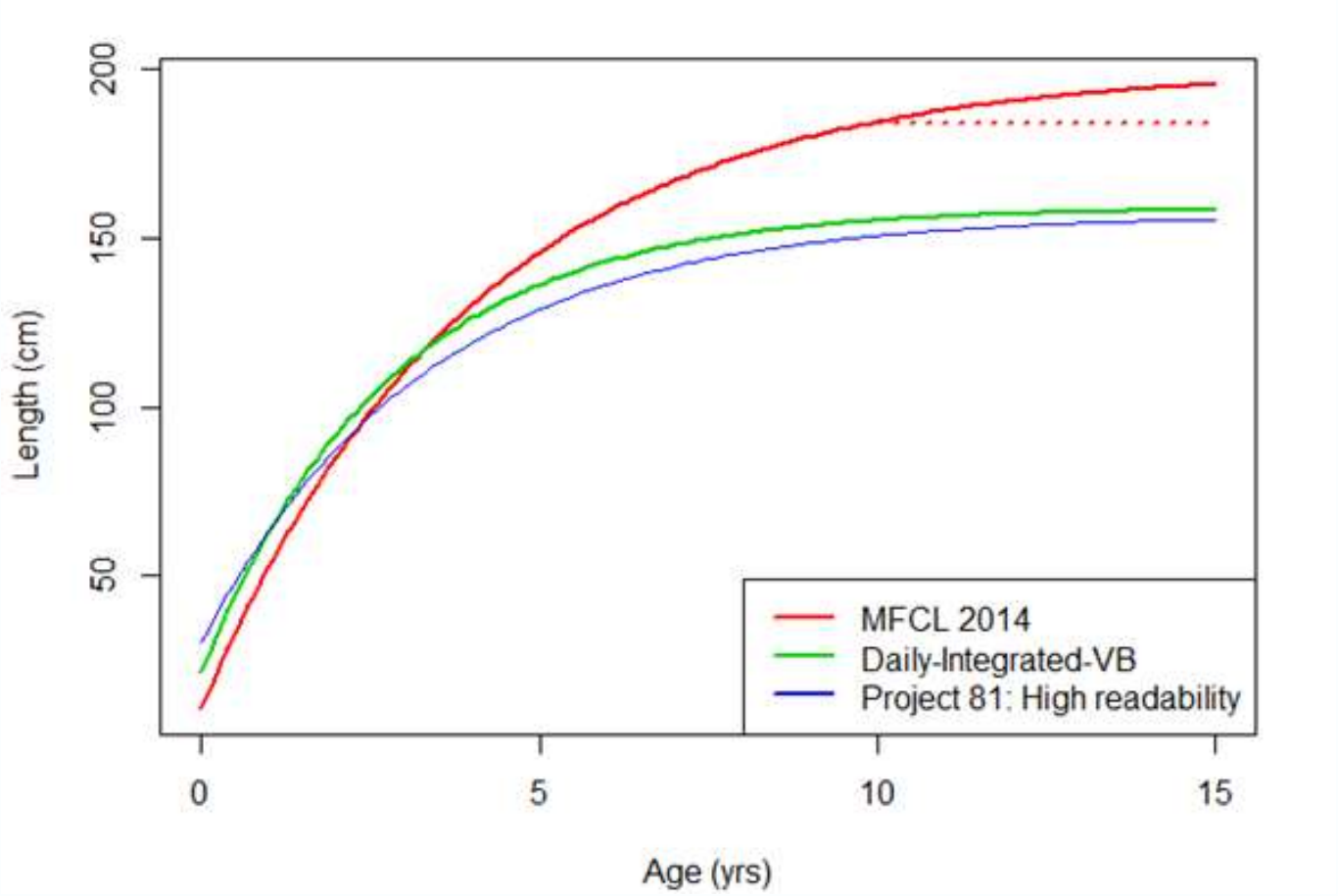
New ‘high readability’ curve & MFCL 2014



Daily-integrated-VB (daily age & tag)

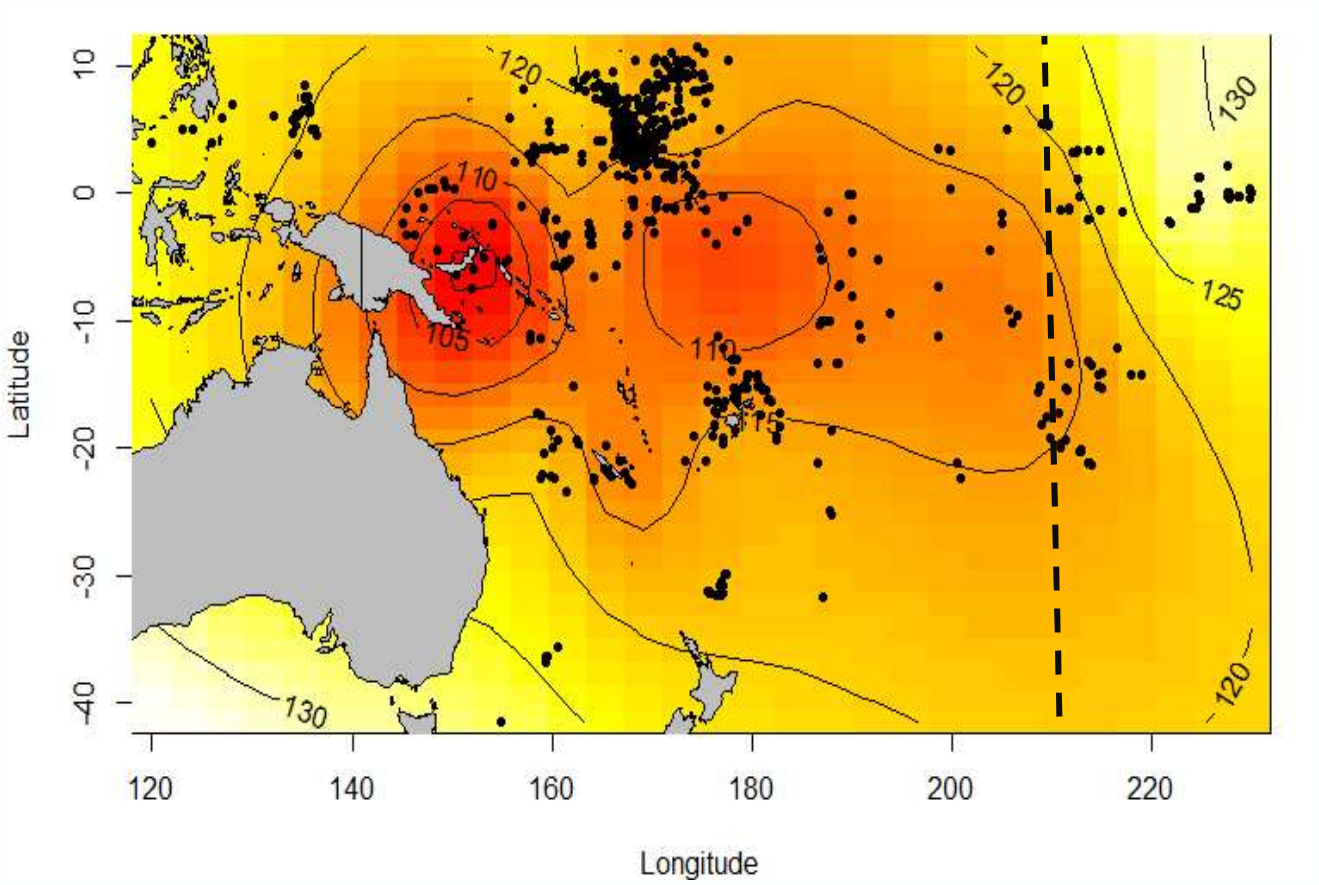


Comparing growth curves



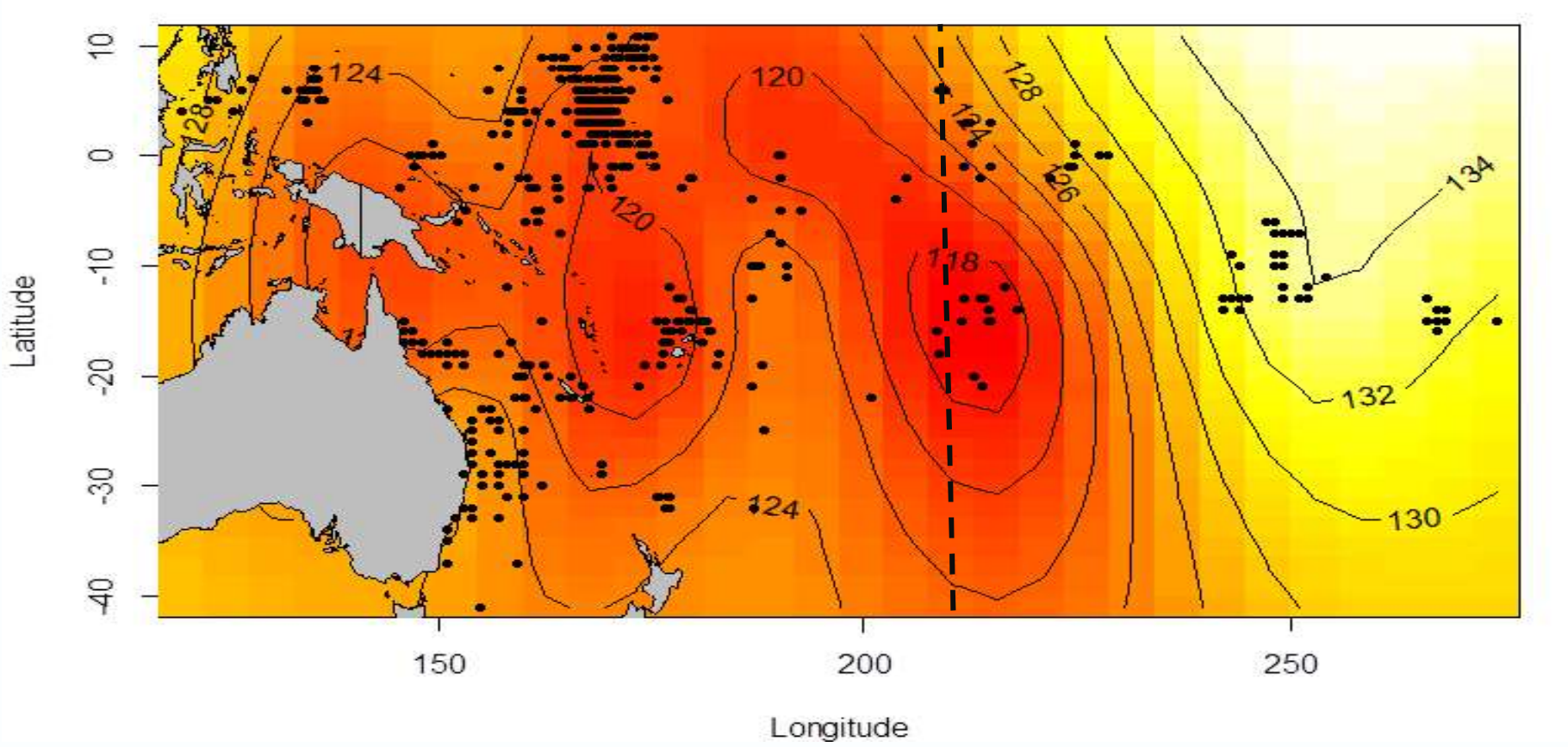
Fitting GAM to investigate spatial effects

Predict length at **age** 3.3 years



Fitting GAM to investigate spatial effects

Predict length at **otolith weight** 0.6 g



Summary & recommendations

- Annual ageing = counts of opaque zones
  - Use algorithm to account for birth date, catch date, edge type etc
- Daily ageing = confident up to 300 day
- Annual periodicity of increments validated for age range 2-9 years
- Age estimates in days for fish 72 - 129 cm FL are not reliable
- New growth curve using high confident age data
  - L_{∞} = 156.9 cm FL
  - Consistent with daily-integrated-VB growth curve
- PAW recommendations
  - Inter-lab ageing workshop in Pacific (daily/annual ageing methods)
  - Further improve tagging data for integrated growth curve

Acknowledgements

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