Sablefish Growth

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Background

"Consider including time-varying or cohort-specific maturity curves, and/or **weight-at-age relationships** if supported by data.“

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Background

- Last update to growth in the assessment was in 2008 (Hanselman et al. 2007)
  - Updated growth information was divided into 2 time periods *based on a change in sampling design*: 1981-1993 and 1996 - 2004

Parameter name	Value		Source
Time period	1960 - 1995	1996 - current	
Maturity-at-length – females	$m_a = 1/(1+e^{-0.4*(L-65)})$		Sasaki (1985)
Maturity-at-length – males	$m_a = 1/(1+e^{-0.4*(L-57)})$		Sasaki (1985)
Maturity-at-age – females	$m_a = 1/(1+e^{-0.84*(a-6.60)})$		Sasaki (1985)
Length-at-age – females	$\overline{L}_a = 75.6(1-e^{-0.208(a+3.63)})$	$\overline{L}_a = 80.2(1-e^{-0.222(a+1.95)})$	Hanselman et al. (2007)
Length-at-age – males	$\overline{L}_a = 65.3(1-e^{-0.227(a+4.09)})$	$\overline{L}_a = 67.8(1-e^{-0.290(a+2.27)})$	Hanselman et al. (2007)
Weight-at-age – females	$\ln \hat{W}_a = \ln(5.47) + 3.02 \ln(1-e^{-0.238(a+1.39)})$		Hanselman et al. (2007)
Weight-at-age – males	$\ln \hat{W}_a = \ln(3.16) + 2.96 \ln(1-e^{-0.356(a+1.13)})$		Hanselman et al. (2007)

- Several above avg. year classes (density dependence?) and warming conditions have occurred since last update of growth

Objectives

- ➢Have there been temporal changes in sablefish growth?
- ➢If so, are they significant and should they be accounted for in the assessment?

Temporal Change: Annual LVB growth curves

1. Fit to randomly collected age-weight-length data from 1996-2019 LL surveys, using non linear least squares.

Length at age

$$L_a = L_\infty\left(1 - e^{-K(a-t_0)}\right) + \varepsilon_a$$

Length-weight

$$\widehat{W} = \alpha L^{\beta}\varepsilon$$

Weight at age

$$\ln\widehat{W}_a = \ln W_\infty + \beta\ln\left(1 - e^{-K(a-t_0)}\right) + \varepsilon_a$$

(Von Bertalanffy 1938)

Temporal Change: *K*-means cluster analysis

2. Perform *K*- means cluster analysis on annual growth parameters (Kaufman and Rousseeuw 1990).

Years that are clustered in the same group have similar growth.

Temporal Change: *K*-means cluster analysis

Step 1. *Determine the recommended number of clusters* to be used by calculating the average silhouette width.

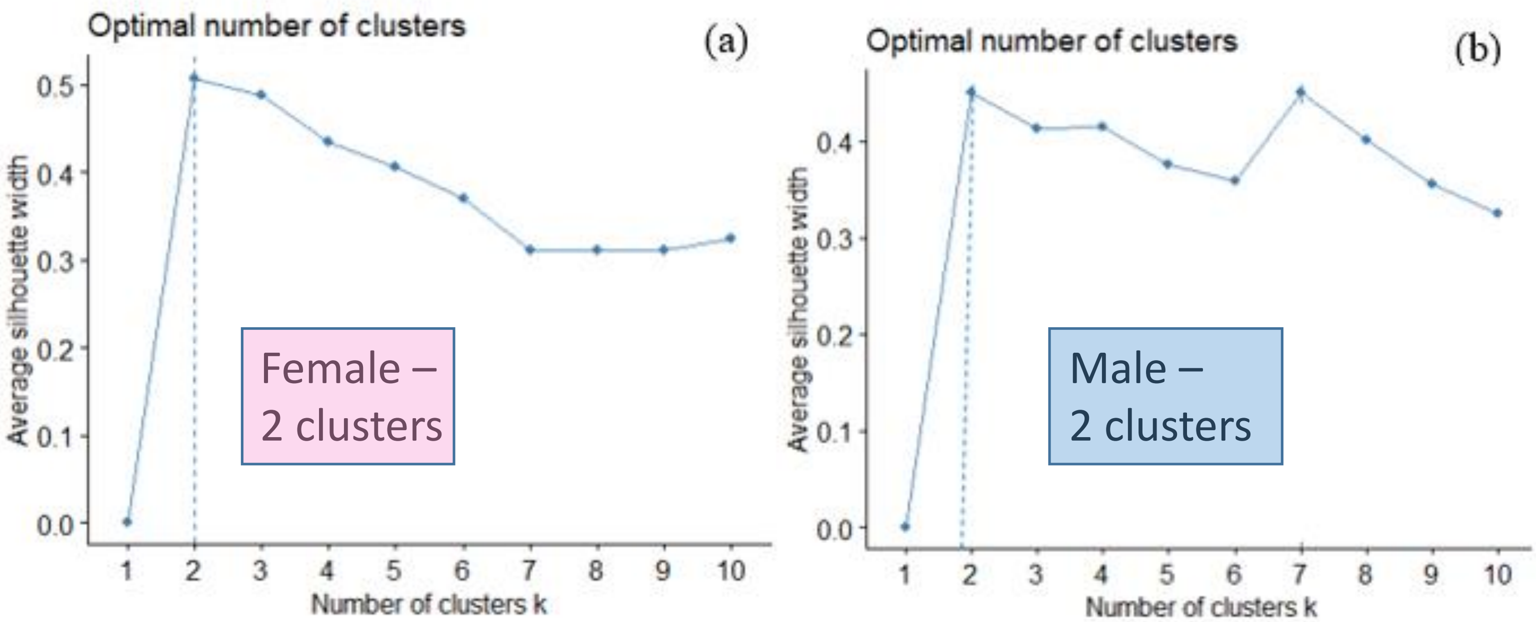


Figure 1.1. Calculated average silhouette width (y axis) per number of clusters (x axis) for females (a) and males (b). Dotted lines represent recommended number of clusters.

Temporal Change: *K*-means cluster analysis

Step 2. *Define the clusters* using the Hartigan-Wong algorithm (1979)

$$W\ (C_k) = \sum_{x_{i \in C_k}} (x_i - \mu_k)^2 \qquad (4)$$

Each observation (x_i) is assigned to a given cluster C_k such that the sum of squares distance of the observation to their assigned cluster centers (μ_k) is minimized

Temporal Change: *K*-means cluster analysis

Figure 1.2. Final cluster groupings of annual growth curves for female (a) and male (b) sablefish in Alaska waters. 1996 = 1, 1997 = 2, 1998 = 3, and so on.

<u>Female:</u>
Cluster 1: 1996-2004
Cluster 2: 2005-2019

<u>Male:</u>
Cluster 1:1996-1999, 2001-2003, **2010**, **2017-2019**
Cluster 2: **2000**, 2004-2009, 2011-2016

Temporal Change: Results

The following were the time periods tested for significant growth changes for both males and females.

2 CLUSTERS/TIME PERIODS

- 1996 – 2004
- 2005 – 2019

Growth Model Testing

General Model: Separate parameter estimates for each time period.

$$L_a = L_\infty[Year](1 - e^{-K[Year](t - t_0[Year])})$$

One parameter in common between time periods:

Common L_∞ Model

Common K Model

Common t_0 Model

Two parameters in common between time periods:

Common L_∞ and K Model

Common L_{inf} and t_0 Model

Common K and t_0 Model

Common Model: Same parameter estimates for all time periods:

$$L_a = L_\infty(1 - e^{-K(t - t_0)})$$

Galucci and Quinn II, Ritz and Streibig 2008

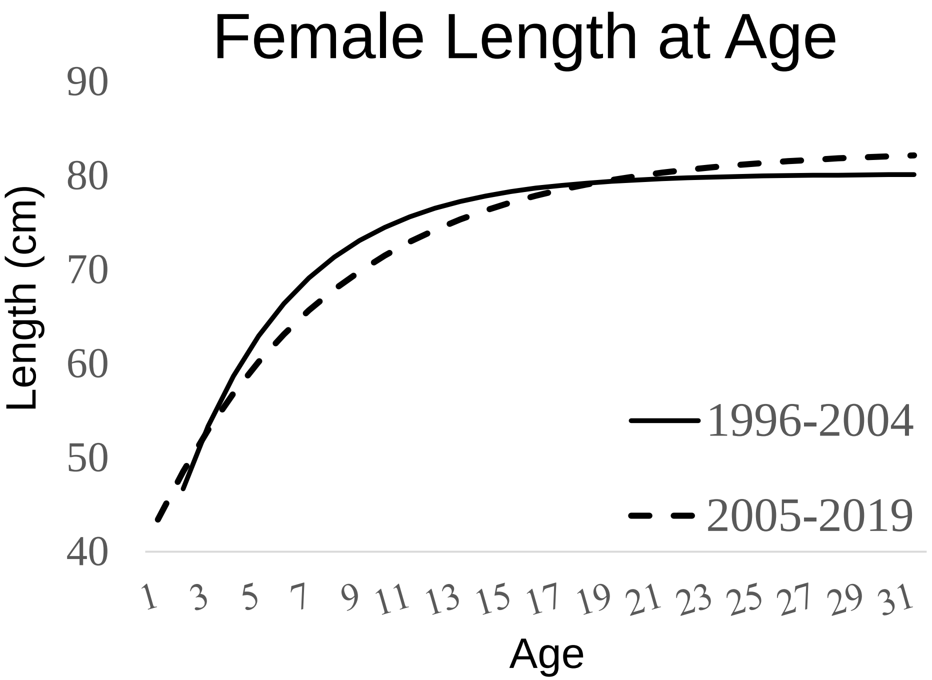
Length Model Results

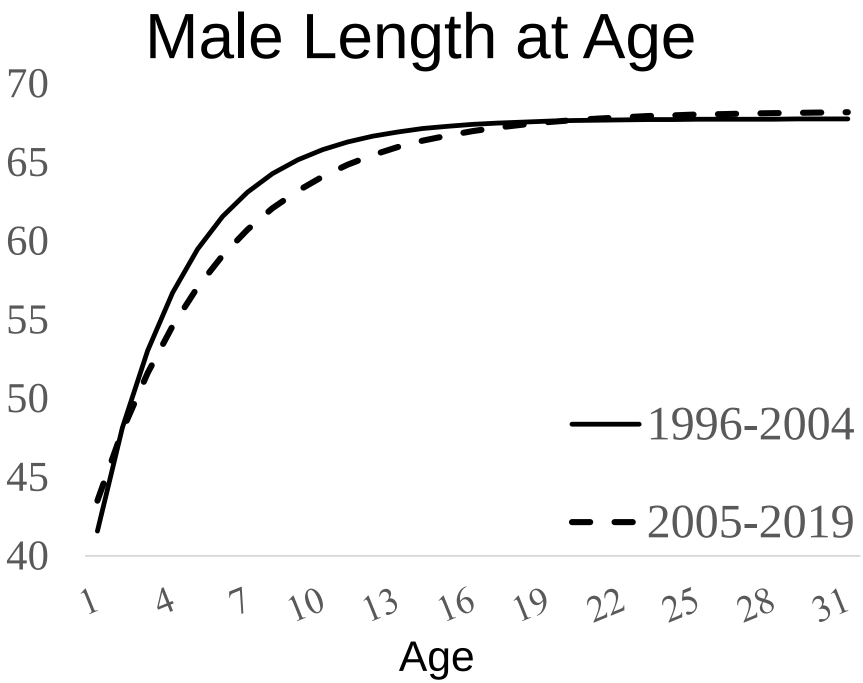
Model	df	AIC: Female	AIC: Male
General Model	7	**99,457***	**77,213***
Common L_∞ Model	6	99,504	77,218
Common t_0 Model	6	99,615	77,265
Common K Model	6	99,668	77,305
Common L_∞ and K Model	5	99,747	77,350
Common L_∞ and t_0 Model	5	99,617	77,268
Common K and t_0 Model	5	99,684	77,375
Common Model	4	100,158	77,739

Length Model Results

	Females			Males	
	1996-2004	**2005-2019**		**1996-2004**	**2005-2019**
L_∞	80.2 (0.221)	82.8 (0.29)		67.8 (0.12)	68.3 (0.13)
k	0.22 (0.005)	0.14 (0.002)		0.29 (0.008)	0.20 (0.004)
t_o	-1.9 (0.119)	-4.3 (0.13)		-2.3 (0.16)	-4.1 (0.15)
n	5,767	9,591		4,889	8,503

Length Model Results





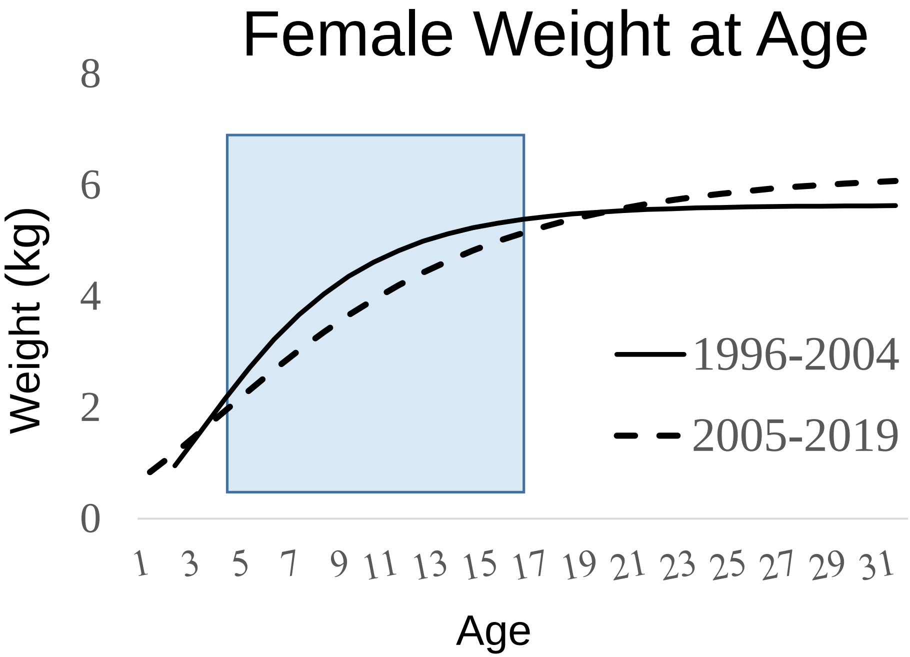
Weight Model Results

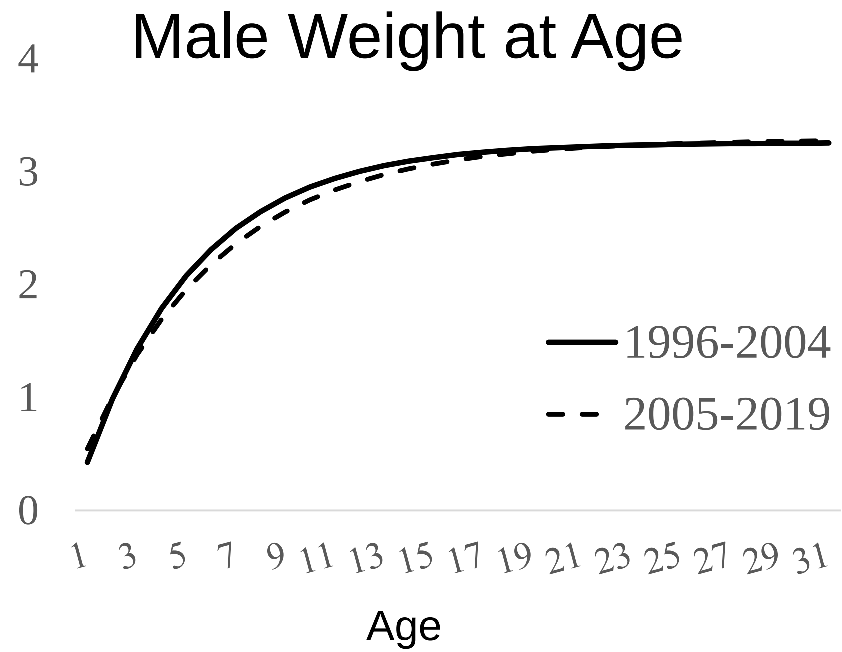
Model	df	AIC: Female	AIC: Male
General Model	7	**44,475***	24,359
Common W_∞ Model	6	44,566	**24,358***
Common t_0 Model	6	44,570	24,378
Common K Model	6	44,740	24,445
Common W_∞ and K Model	5	44,820	24,534
Common W_∞ and t_0 Model	5	44,595	24,830
Common K and t_0 Model	5	44,795	24,531
Common Model	4	45,264	24,962

Weight Model Results

	Females			Males	
	1996-2004	2005-2019		1996-2004	2005-2019
W_∞	5.6 (0.05)	6.2 (0.08)		3.3 (0.02)	3.2 (0.02)
k	0.24 (0.005)	0.14 (0.003)		0.34 (0.01)	0.23 (0.005)
t_o	-1.34 (0.07)	-4.23 (0.08)		-1.53 (0.09)	-3.25 (0.15)
n	5,767	9,591		4,889	8,503

Weight Model Results





Results

- There have been temporal changes in the growth of both male and female sablefish: an obvious change occurred after 2004 for females, and a less obvious change around this time for males.

- Sablefish are growing to a larger maximum size, but at a slower rate, which translates to smaller sized fish during the critical early ages when fish are reaching maturity.

However….Final Recommendation

Recommend updating size at age parameters with all available post-1996 data:

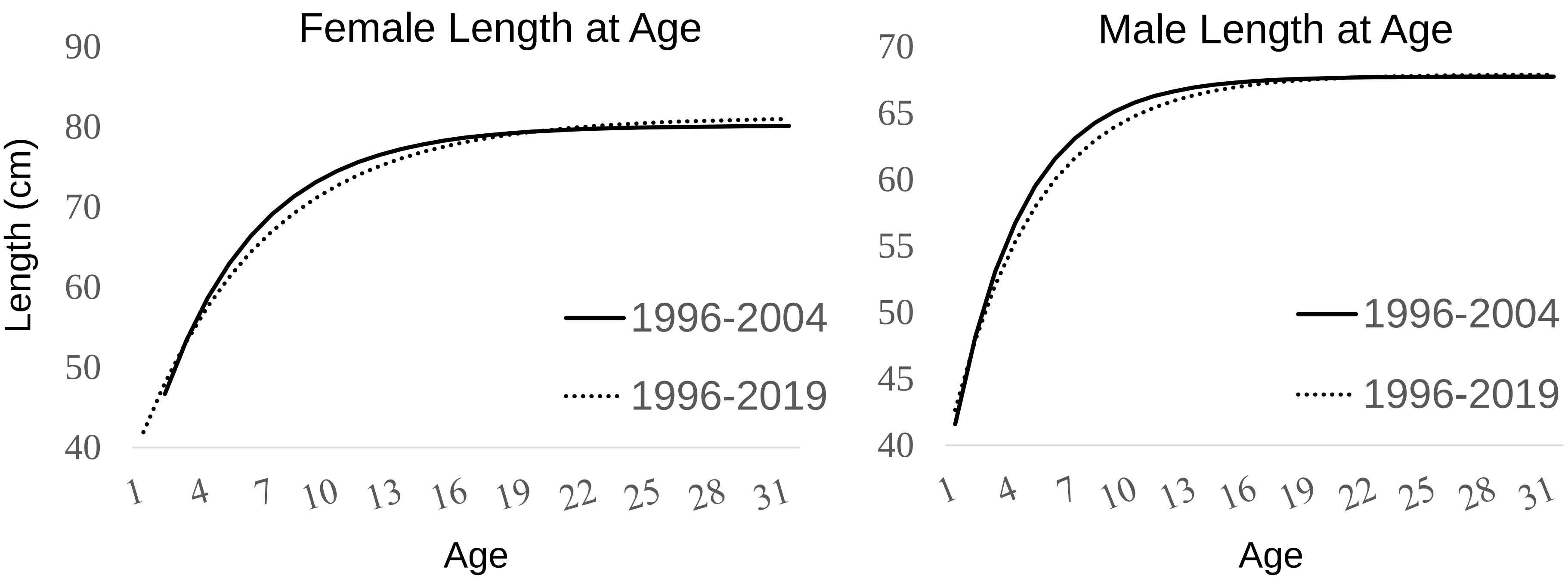
1981-1993

1996-2019

Final Recommendation – Length at Age

		1981-1993		1996-2004	2005-2019		1996-2019
Female	L_∞	75.5 (0.460)		80.2 (0.221)	82.8 (0.29)		81.2 (0.19)
	k	0.208 (0.018)		0.22 (0.005)	0.14 (0.002)		0.17 (0.003)
	t_o	-3.62 (0.523)		-1.9 (0.119)	-4.3 (0.13)		-3.28 (0.09)
	n	31		5,767	9,591		15,358
Male	L_∞	65.2 (0.341)		67.8 (0.12)	68.3 (0.13)		67.9 (0.09)
	k	0.2 (0.029)		0.29 (0.008)	0.20 (0.004)		0.23 (0.003)
	t_o	-4.09 (0.936)		-2.3 (0.16)	-4.1 (0.15)		-3.3 (0.11)
	n	30		4,889	8,503		13,392

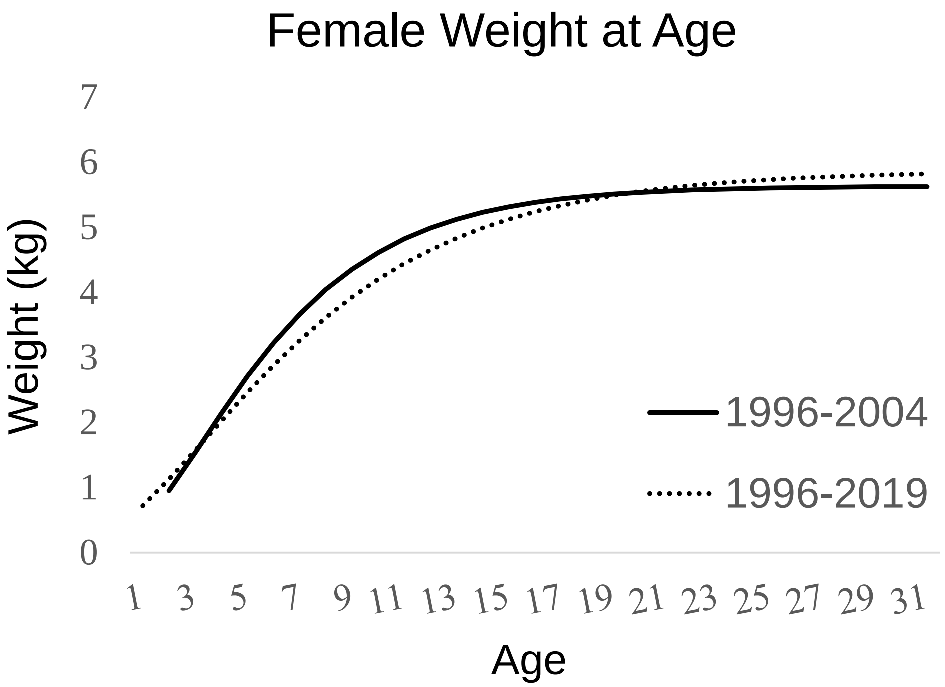
Final Recommendation – Length at Age

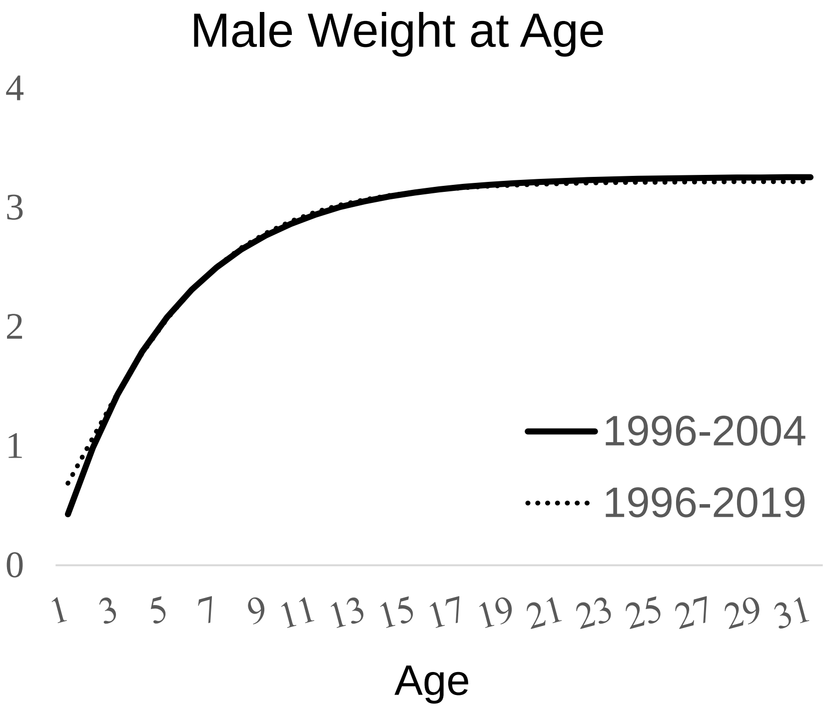


Final Recommendation – Weight at Age

		1996-2004	2005-2019		1996-2019
Female	W_∞	5.6 (0.05)	6.2 (0.08)		5.87 (0.04)
	k	0.24 (0.005)	0.14 (0.003)		0.17 (0.002)
	t_o	-1.34 (0.07)	-4.23 (0.08)		-2.98 (0.06)
	n	5,767	9,591		15,358
Male	W_∞	3.3 (0.02)	3.2 (0.02)		3.2 (0.01)
	k	0.34 (0.01)	0.23 (0.005)		0.27 (0.002)
	t_o	-1.53 (0.09)	-3.25 (0.15)		-2.41 (0.07)
	n	4,889	8,503		13,392

Final Recommendation – Weight at Age





Final Recommendation

1981 - 1993 | 1996 - 2019

Length-at-Age: Female

$$L_a = 75.5\left(1 - e^{-0.208(a+3.62)}\right) + \varepsilon_a$$

$$L_a = 81.2\left(1 - e^{-0.17(a+3.28)}\right) + \varepsilon_a$$

Length-at-Age: Male

$$L_a = 65.2\left(1 - e^{-0.2(a+4.09)}\right) + \varepsilon_a$$

$$L_a = 67.9\left(1 - e^{-0.23(a+3.3)}\right) + \varepsilon_a$$

Weight-at-Age: Female

$$\ln\widehat{W}_a = \ln(5.87) + 3.02\ln\left(1 - e^{-0.17(a+2.98)}\right) + \varepsilon_a$$

Weight-at-Age: Male

$$\ln\widehat{W}_a = \ln(3.2) + 3.02\ln\left(1 - e^{-0.27(a+2.41)}\right) + \varepsilon_a$$

Questions?