Review of Life History Parameters for Blue Marlin *Makaira nigricans*[1]

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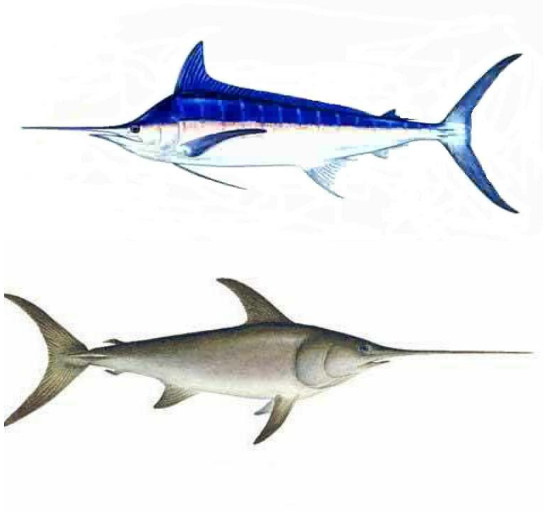

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Abstract

The objective of this working paper (ISC/13/BILLWG-1/12) is to summarize life history parameters for blue marlin (*Makaira nigricans*) for the January 16-23, 2013 ISC Billfish Working Group Intercessional Workshop in Honolulu, HI. This paper will provide a summary of life history information in an accessible format that may be used by stock assessment scientists as input for the upcoming blue marlin stock assessment conducted by the ISC BILLWG. We hope this paper will also help scientists identify gaps in blue marlin life history information. Life history information provided by Uchiyama and Humphreys 2007 and Sun et al. 2012 was included. Additional information found in peer-reviewed articles and gray literature was also included. The life history parameters presented in this review include length-length relationships, length-weight relationships, growth rates, mortality rates, fecundity, and proportion mature at size for blue marlin. The life history parameter compilations are drawn from several widely separated locales in the Pacific Ocean. We have taken this approach because blue marlin is believed to compromise a single stock in the Pacific Ocean (Graves and McDowell 2003).

Table 1: A compliation of weight (kg) on length (cm) and length on weight relationships for Pacific blue marlin (*Makaira nigricans*). **W**= body weight, **GW**= body weight after gilled and gutted, **PW** =body weight without bill, caudal fin, gills, and viscera. **EFL**= eye to fork length, **SFL**= anterior tip of bill to fork of tail length, **LJFL**= lower jaw to fork length.

Weight (kg) on length (cm) relationship	Sex	n	Size range (cm)	r^2	Reference	Region
$\mathbf{W} = 1 \times 10^{-5}\mathbf{EFL}^{2.996}$	female	926	100 - 275	0.945	Chen 2002	western Pacific
$\mathbf{W} = 2 \times 10^{-5}\ \mathbf{EFL}^{2.883}$	male	666	100 - 220	0.900	Chen 2002	western Pacific
$\mathbf{W} = 6 \times 10^{-5}\ \mathbf{EFL}^{2.7002}$	female	257	110 - 250	0.864	Dai 2002	western Pacific
$\mathbf{W} = 1 \times 10^{-5}\ \mathbf{EFL}^{2.9763}$	male	418	100 - 195	0.890	Dai 2002	western Pacific
$\mathbf{W} = 7.129\ \mathbf{e}^{0.013\mathbf{EFL}}$	female	105	120 - 350	0.872	Hill 1986	central Pacific
$\mathbf{W} = 4.354\mathbf{e}^{0.016\mathbf{EFL}}$	male	213	80 - 230	0.884	Hill 1986	central Pacific
$\mathbf{W} = 5.5565 \times 10^{-6}\mathbf{EFL}^{3.0888}$	combined	11	167 - 270	-	Kume and Joseph 1969	eastern Pacific
$\mathbf{GW} = 1.0242 \times 10^{-5}\mathbf{EFL}^{2.9749}$	combined	24	98 - 234	-	Kume and Joseph 1969	eastern Pacific
$\mathbf{W} = 1.9034 \times 10^{-6} \times \mathbf{LJFL}^{3.2842}$	female	3,267	23 - 378.5	0.930	Prager et al. 1994	north Atlantic
$\mathbf{W} = 2.4682 \times 10^{-6} \times \mathbf{LJFL}^{3.2243}$	male	1,978	23-277	0.910	Prager et al. 1994	north Atlantic
$\mathbf{W} = 1.955 \times 10^{-6} \times \mathbf{LJFL}^{3.3663}$	combined	5,245	23-378.5	0.940	Prager et al. 1994	north Atlantic
$\mathbf{PW} = 4.70 \times 10^{-6}\ \mathbf{LJFL}^{3.11}$	combined	1305	155-352	0.936	Shimose 2009	western Pacific
$\mathbf{W} = 5.0048 \times 10^{-6}\ \mathbf{TL}^{3.0214}$	combined	453	135 - 457	0.950	Skillman and Young 1974	central Pacific
$\mathbf{SFL} = 65.4502\ \mathbf{W}^{0.3030}$	female			-	Skillman and Young 1976	central Pacific
$\mathbf{SFL} = 56.8780\ \mathbf{W}^{0.3218}$	male			-	Skillman and Young 1976	central Pacific
$\mathbf{W} = 1.3 \times 10^{-6}\mathbf{EFL}^{3.43}$	combined	32	110 - 303	0.985	Uchiyama and Kazama 2003	central North Pacific
$\mathbf{EFL} = 52.0203\ \mathbf{W}^{0.28337}$	combined	154	10.4 - 381.1 (kg)	0.929	Uchiyama and Kazama 2003	central North Pacific
$\mathbf{W} = 0.00000272228\mathbf{EFL}^{3.30967}$	combined	154	109.2 - 269.2	0.933	Uchiyama and Kazama 2003	central North Pacific
$\log_{10}\mathbf{W} = -5.690 + 3.318(\log_{10}\mathbf{EFL})$	female	57	154 - 265.1	0.948	Wares and Sakagawa 1974	eastern North Pacific
$\log_{10}\mathbf{W} = -7.543 + 3.905(\log_{10}\mathbf{LJFL})$	female	20	221.1 - 347.3	0.954	Wares and Sakagawa 1974	eastern North Pacific
$\mathbf{W} = 0.0000708\mathbf{LJFJ}^{2.60}$	male	102	127 - 234	-	Wilson et al. 1991	central North Pacific
$\mathbf{W} = 0.0000001\mathbf{LJFL}^{3.81}$	female	55	131 - 342	-	Wilson et al. 1991	central North Pacific
$\mathbf{W} = 2.79 \times 10^{-6}\mathbf{LJFL}^{3.24}$	combined	2548	150 - 280		Wang et al. 2006	Taiwan waters
$\mathbf{W} = 1.427 \times 10^{-5}\mathbf{EFL}^{2.996}$	female	717	100 - 311	0.871	Su et al. 2013	northwest Pacific Ocean
$\mathbf{W} = 1.116 \times 10^{-5}\mathbf{EFL}^{3.033}$	male	1043	100 - 236	0.983	Su et al. 2013	northwest Pacific Ocean

Table 2: Length (cm) on length (cm) relationships for Pacific blue marlin (*Makaira nigricans*). **EFL=** eye to fork length, **LJFL=** lower jaw to fork length, and **SFL**= anterior tip of bill to fork of tail length.

Length (cm) on length (cm) relationship	Sex	n	Size range (cm)	r^2	Reference
LJFL = 1.071 X **EFL** + 11.767	female	64	-	0.952	Dai 2002
LFJFL = 1.088 X **EFL** + 8.895	male	65	-	0.985	Dai 2002
TL = 1.353 X **EFL** - 4.836	female	52	100 - 425	0.987	Hill 1986
TL = 1.353 X **EFL** - 4.836	male	120	125 - 240	0.929	Hill 1986
LFFL = 1.094 X **EFL** +9.512	female	52	100 - 425	0.997	Hill 1986
LJFL = 1.080 X **EFL** + 11.780	male	120	125 - 240	0.975	Hill 1986
LJFL = 0.800 X **SFL** + 15.964	female	52	110 - 570	0.989	Hill 1986
LJFL = 0.786 X **SFL** + 18.951	male	119	160 - 320	0.940	Hill 1986
LJFL = 1.0831 **EFL** + 9.0296	female	213	112 - 299	0.970	Su et al. 2005
LJFL = 1.0899 X **EFL** +7.3668	male	209	107.8- 245	0.980	Su et al. 2005
LJFL = 1.0915 X **EFL** + 7.2158	combined	422	107.8 - 299	0.990	Su et al. 2005
EFL= **SFL** X 0.810 - 15.785	combined	21	221 - 347	0.997	Wares and Sakagawa 1974
EFL = **LJFL** X 0.893 - 5.5105	combined	22	194 - 297	0.979	Wares and Sakagawa 1974
LJFL = 9.550 + 1.080 X **EFL**	combined	312	100 - 311	0.986	Su et al. 2013

Table 3: Summary of age and growth studies of the Pacific blue marlin (*Makaira nigricans*). **EFL=** eye to fork length**, LJFL=** lower jaw to fork length, and **SFL=** anterior tip of bill to fork of tail length. **M=** male, **F=** female, and **C=** combined sexes.

Von Bertalanffy Growth function (VBGF)				Sex	Fitting method	Reference
L_{inf} (cm)	K (yr^{-1})	t_0	Length type (cm)			
371.1	0.285	0.106	SFL	M	Modal analysis of length frequency and nonlinear least squares	Skillman and Yong 1976
659.1	0.116	-0.161	SFL	F		
338.0	0.040	-10.42	EFL	M	VBGF; linear function for back-calculation	Chen 2001
229.7	0.110	-5.21	EFL	M	VBGF; power function for back-calculation	
420.7	0.030	-9.92	EFL	F	VBGF; linear function for back-calculation	
283.2	0.090	-4.65	EFL	F	VBGF; power function for back-calculation	
232.8	0.130	-3.58	EFL	M	Multifan	Dai 2002
312.5	0.110	-2.42	EFL	F	Mulifan	
263.0	0.483	-1.43	LJFL	F	Back calculation data	Shimose 2008
201.0	0.387	-3.21	LJFL	M	Back calculation data	
210.0	0.004	-54.93	LJFL	C	2- stage growth model (later stage VBGF for individuals >110 days old)	Prince et al. 1991

Table 4: Summary of age and growth studies of the Pacific blue marlin (*Makaira nigricans*). **EFL=** eye to fork length in cm, **NLS=** non-linear least squares, **Case 1=** linear function for back-calculation, and **Case 2=** power function for back-calculation.

Reference	Richard Growth Model Coefficients					Fitting method	Sex
	L_{inf} (cm)	K (yr^{-1})	t_0	*m*	Length type (cm)		
Chen 2001	346.9	0.02	-6.96	-0.56	EFL	NLS; Case 1	M
Chen 2001	333.4	0.01	-1.78	-1.65	EFL	NLS; Case 2	M
Chen 2001	501.8	0.03	-9.11	-0.11	EFL	NLS; Case 1	F
Chen 2001	421.8	0.01	-1.76	-1.15	EFL	NLS; Case 2	F

Table 5: Reported size at 1st maturity and 50% maturity for the Pacific blue marlin (*Makaira nigricans*). Size at maturity appears to vary across region. The relationship between the fraction of mature individuals at size is reported by Sun et al. (2009) as: $P_f = 1/\{1+e^{-\ln(19)[(EFL-179.76)/(194.2-179.76)]}\}$ for females and $P_m = 1/\{1+e^{-\ln(19)[(EFL-130)/(130.13-130)]}\}$ for males.

Reported size at 50% maturity (EFL, in cm)		**Location**	**Reference**
male	**female**		
131.00	179.76	Taiwan	Sun et al.2009
No data	178.80	Yonaguni Island	Shimose et al. 2009

Table 6: Natural mortality estimates for Pacific blue marlin (*Makaira nigricans).* **EFL=** eye to fork length, **LJFL=** lower jaw to fork length, and **SFL=** anterior tip of bill to fork of tail length. **M=** male, **F=** female, and **C=** combined sexes. Model 1= fit of the von Bertalanffy growth model by the least squares method to lengths of fish of assumed age and Model 2= fit of the von Bertalanffy growth model by the least squares method to observed lengths, using data on growth increment in known time intervals but making no assumptions about absolute age.

Natural mortality estimate (yr^{-1})	Sex	Method	L_{inf} (cm)	K (yr^{-1})	Mean SST °C	Model as described in Skillman & Yong (1976)	Age Groups Included	Reference
0.53	M	Murphy and Sakagawa (1977)	276.0 (EFL)	0.285	Not applicable	Not applicable	Unspecified	Boggs (1989)
0.21	F	Murphy and Sakagawa (1977)	505.0 (EFL)	0.116	Not applicable	Not applicable	Unspecified	Boggs (1989)
0.38	M	Pauly (1980)	371.1 (SFL)	0.285	26	Model 1	All age groups	Hinton (2001)
0.81	M	Pauly (1980)	282.3 (SFL)	0.815	26	Model 2	All age groups	Hinton (2001)
0.41	M	Pauly (1980)	368.0 (SFL)	0.315	26	Model 1	All age groups with more than 2 individuals	Hinton (2001)
0.63	M	Pauly (1980)	298.8 (SFL)	0.560	26	Model 2	All age groups with more than 2 individuals	Hinton (2001)
0.18	F	Pauly (1980)	659.1 (SFL)	0.116	26	Model 1	All age groups	Hinton (2001)
0.14	F	Pauly (1980)	807.8 (SFL)	0.091	26	Model 2	All age groups	Hinton (2001)
0.19	F	Pauly (1980)	626.6 (SFL)	0.123	26	Model 1	All age groups with more than 2 individuals	Hinton (2001)
0.25	F	Pauly (1980)	540.2 (SFL)	0.175	26	Model 2	All age groups with more than 2 individuals	Hinton (2001)
0.08	F	Pauly (1980)	1248.1 (SFL)	0.048	26	Model 1	Same age groups as males with more than 2 individuals	Hinton (2001)
0.14	F	Pauly (1980)	875.2 (SFL)	0.086	26	Model 2	Same age groups as males with more than 2 individuals	Hinton (2001)
0.253	M	Pauly (1980)	232.8 (EFL)	0.131	25	Not applicable	Unspecified	Dai (2002)
0.209	F	Pauly (1980)	312.5 (EFL)	0.111	25	Not applicable	Unspecified	Dai (2002)
0.38	C	MULTIFAN-CL				Not applicable	Unspecified	Kleiber et al. (2003)
0.41	C	Pauly (1980)	244.0 (LJFL)	0.28	26	Not applicable	Unspecified	Pine et al. (2008)

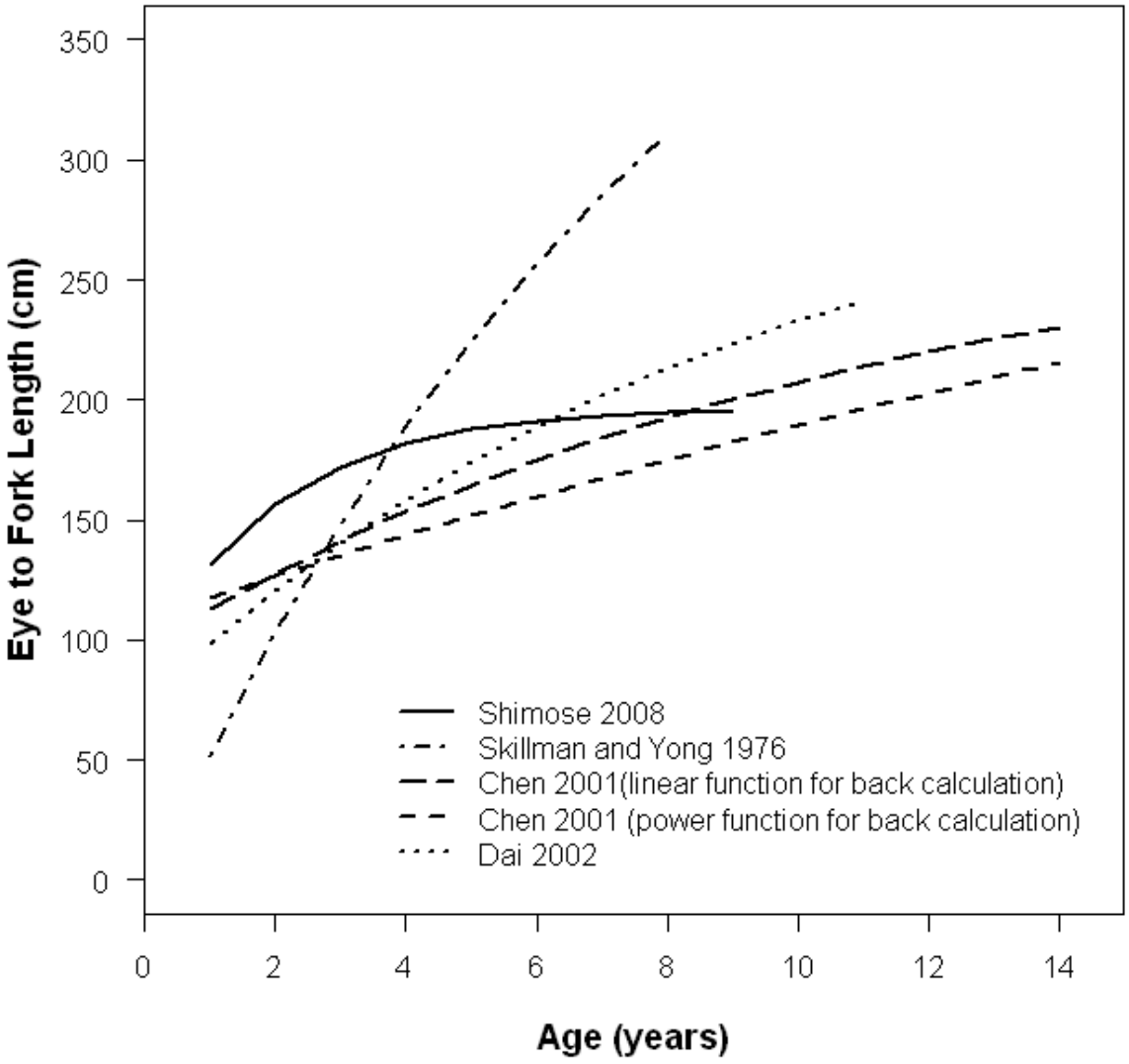

Figure 1: Standard von Bertalanffy growth curves for female Pacific blue marlin (*Makaira nigricans*) as estimated by different studies. Chen 2001 used both the linear function and power function for back calculation (both are shown).

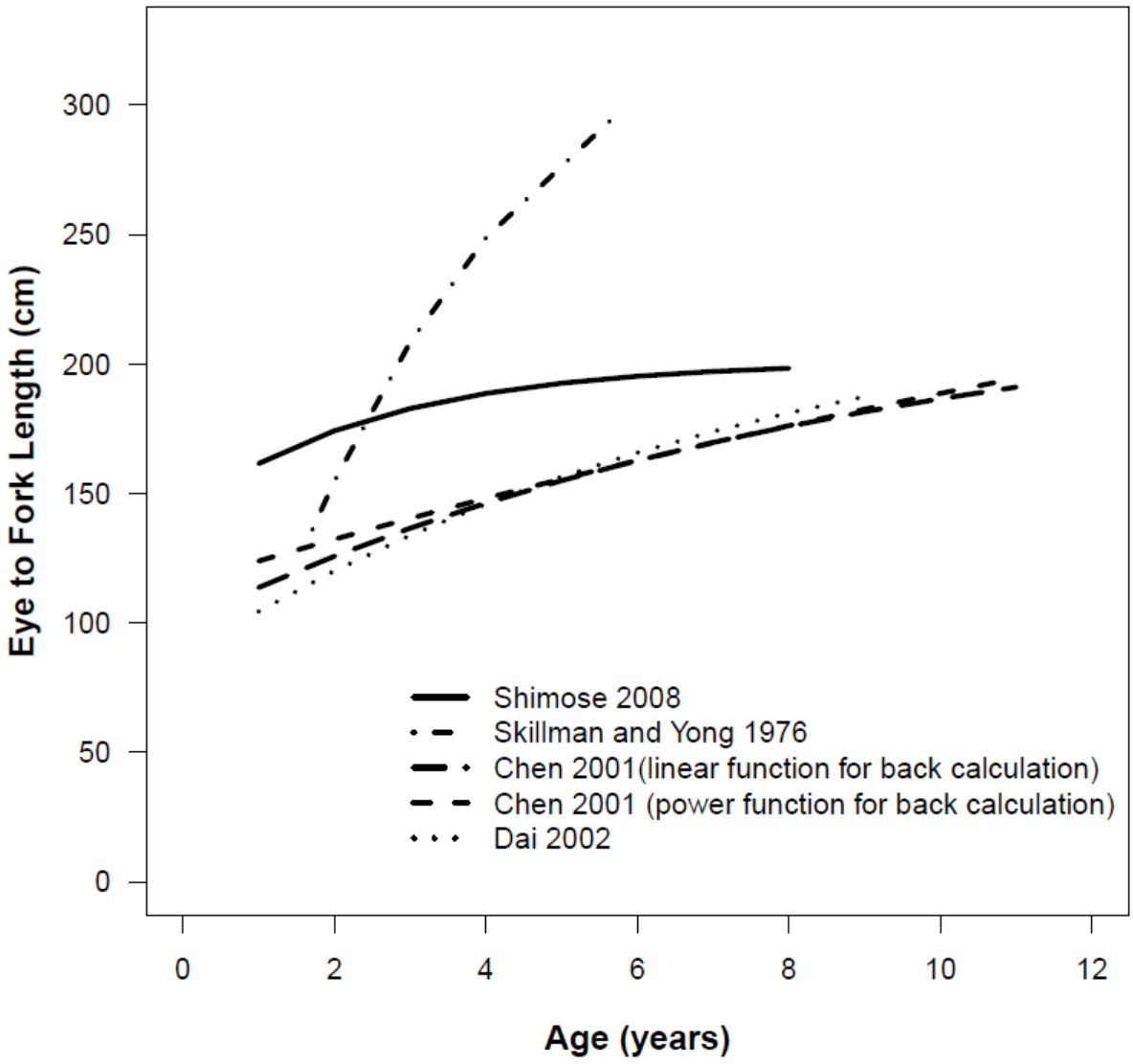

Figure 2: Standard von Bertalanffy growth curves for male Pacific blue marlin (*Makaira nigricans*) as estimated by different studies. Chen 2001 used both the linear function and power function for back calculation (both are shown).

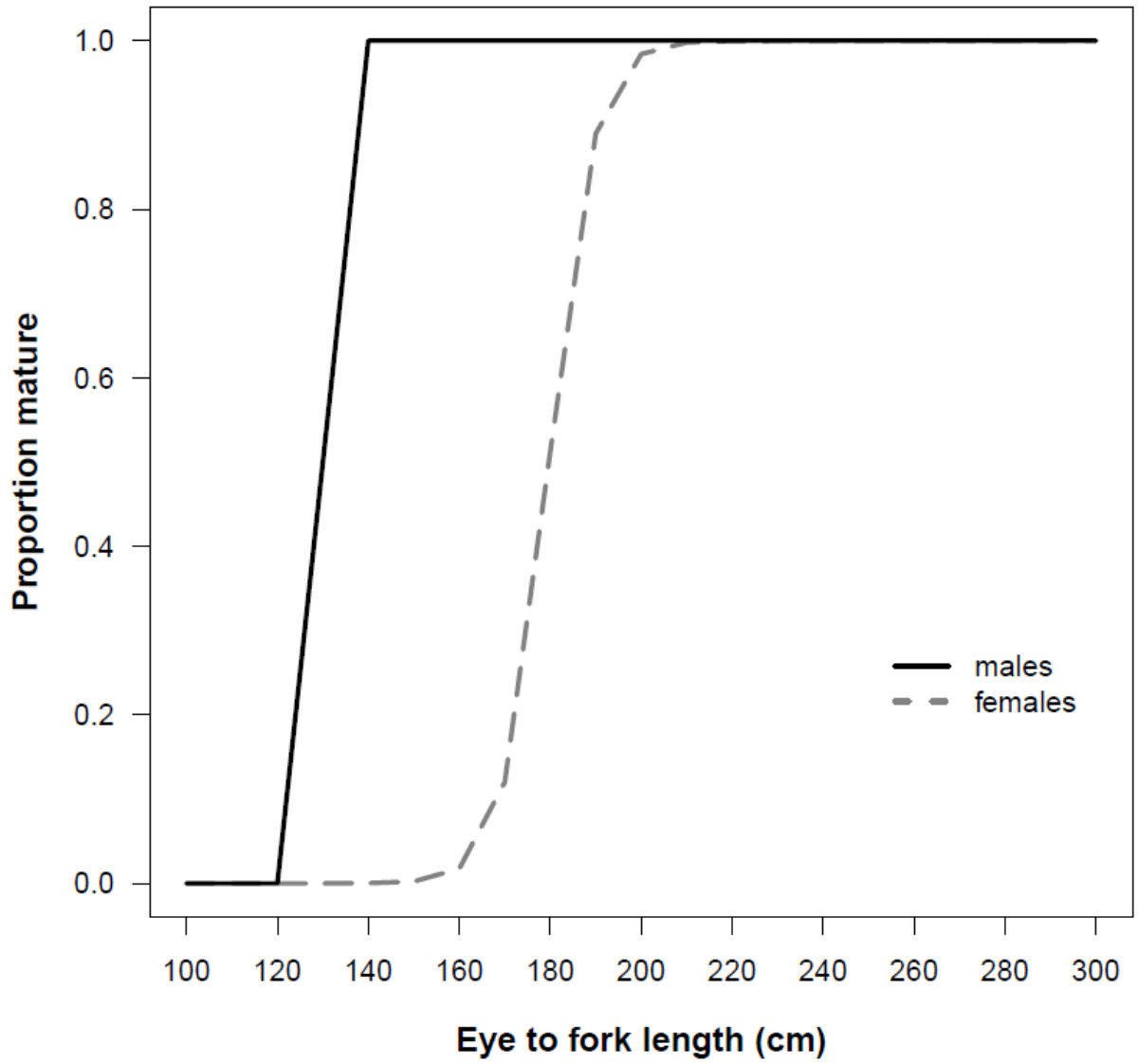

Figure 3: The proportion of male and female Pacific blue marlin (*Makaira nigricans*) that are mature as a function of eye to fork length as estimated by Sun et al. 2009. The circles represent estimated age at maturity for males and females at various locations. The size at first maturity at Yonguni Island was reported by Shimose et al. 2009, in Taiwan it was reported by Sun et al. 2009, in the eastern Pacific it was reported by Nakano and Bayliff 1992, and in the western Pacific reported by Nakamura 1985.

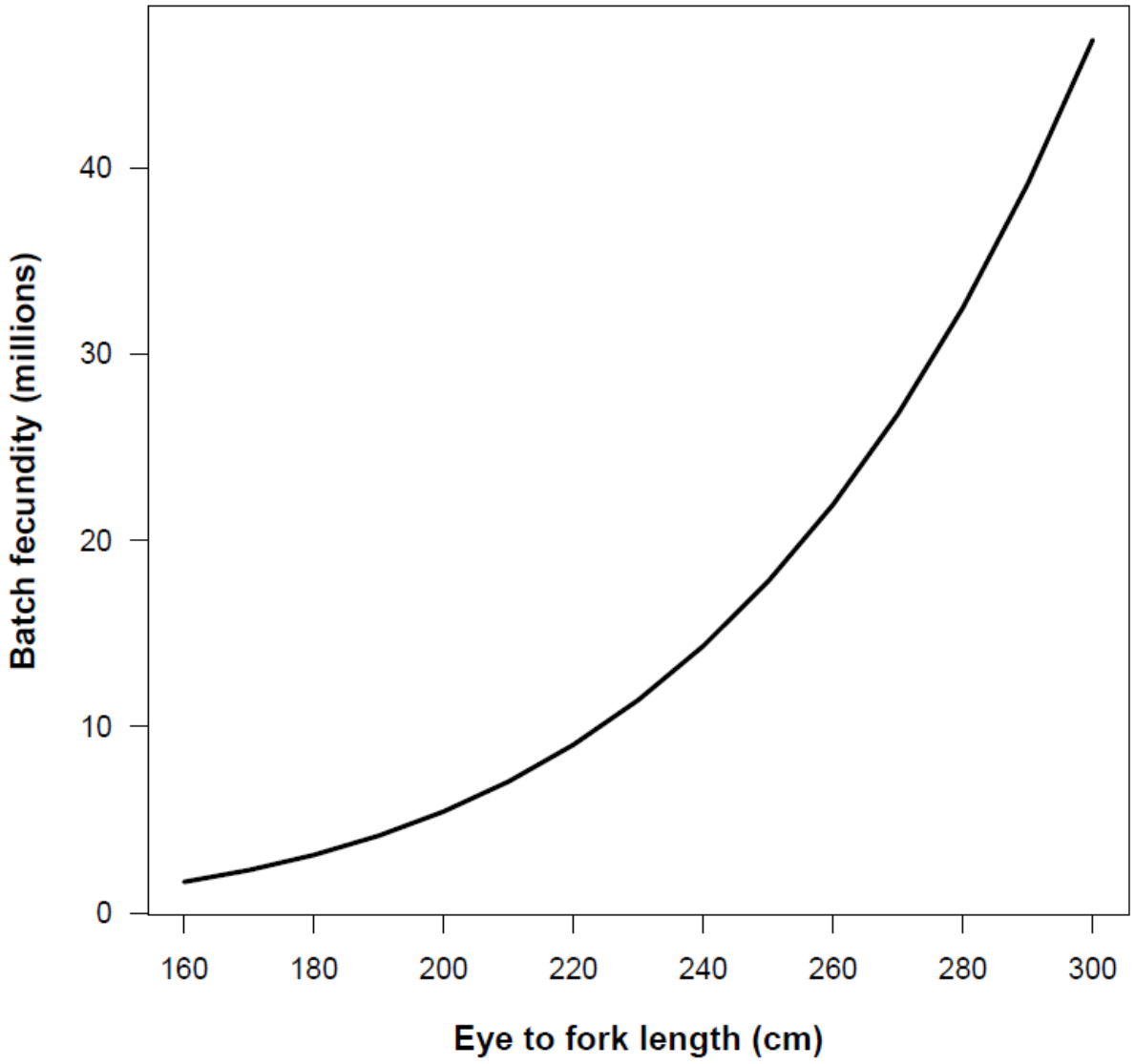

Figure 4: Predicted fecundity as a function of eye to fork length for the Pacific blue marlin (*Makaira nigricans*) reported by Sun et al. 2009; batch fecundity = $3.29 \times 10^{-12} EFL^{5.31}$.

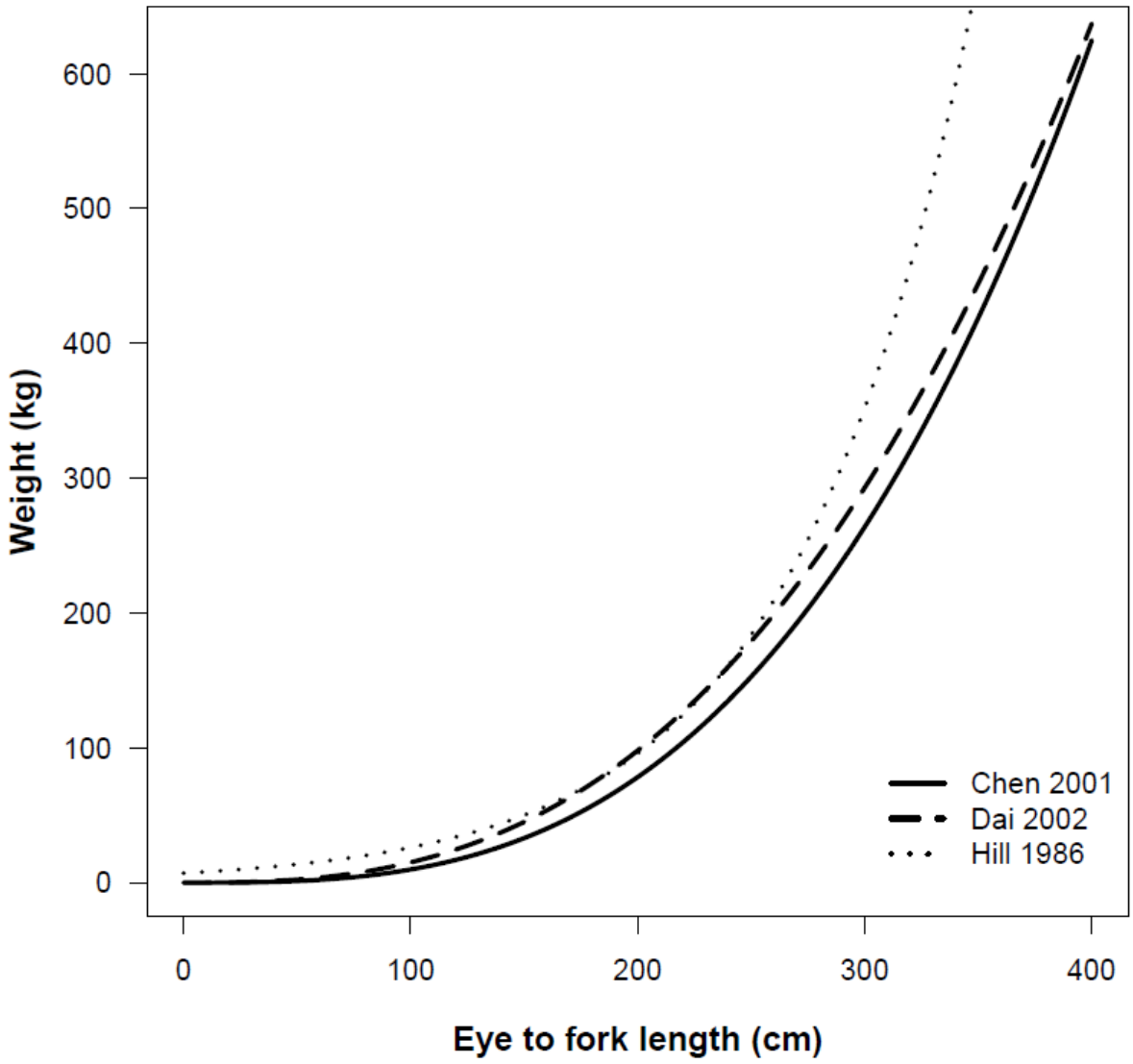

Figure 5: Relationship of eye fork length (EFL in cm) to weight (W in kg) for female Pacific Blue marlin (*Makaira nigricans*). Length-weight relationships reported by Chen 2002, Dai 2002, and Hill 1986. For equations see Table 1.

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