

# Supplementary information for: Growing sabers: Mandibular shape and biomechanical evolution during the ontogeny of *Smilodon fatalis*.

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**Table S1:** Specimens used in the analyses. Institutional abbreviations: **La Brea** = La Brea Tar Pits and Museum, **MNHN** = Muséum National d’histoire Naturelle, **MVZ** = University of California Museum of Vertebrate Zoology, **MNCN** = Museo Nacional de Ciencias Naturales, **RMCA** = Royal Museum of Central Africa, **USNM** = National Museum of Natural History, **AMNH** = American Museum of Natural History. ‘NA’ in the measurements columns indicates that those measurements were not taken. **MandibleL** = Length of the mandible, **CtL** = cheek teeth length, **CoronoidH** = Coronoid process height, **DentaryH** = height of the dentary, **Diastema** = length of the diastema, **SymphysisA** = Angle of the symphysis region. See **Figure 1** for a graphical representation of the measurements taken. Not that this table is also available in a xlsx format in the ESM.

Taxa	SpecimenID	MandibleL	CtL	CoronoidH	DentaryH	Diastema	SymphysisA	Institution	Category
<i>Smilodon fatalis</i>	LACM-HC-2002-L-4	92.236	41.755	13.109	18.853	15.465	132.712	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-470	160.116	62.211	25.807	32.781	31.182	118.997	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-538	155.454	57.519	22.854	30.307	35.928	117.843	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-681	138.081	55.331	22.58	31.032	28.039	113.366	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-768	160.706	64.022	28.424	30.569	35.862	123.123	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-770	158.444	61.021	20.99	33.636	31.56	114.653	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-792	156.124	61.531	24.969	32.836	32.268	118.279	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-808	164.613	67.99	24.218	32.378	31.086	108.995	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-811	180.496	67.795	29.635	34.323	34.009	109.924	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-241	141.414	56.57	22.586	31.345	34.703	121.557	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-242	143.094	66.2	23.78	29.821	26.31	118.701	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-3	98.014	44.917	14.669	15.795	15.647	122.317	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-326	155.861	60.886	25.48	29.567	34.374	120.286	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-384	186.738	63.626	26.81	35.641	43.279	106.295	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-L-R-402	116.36	49.051	15.925	25.542	20.718	124.932	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-R-483	159.198	73.312	23.765	33.219	30.876	115.793	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-R-493	171.71	51.776	27.883	30.92	44.908	109.947	La Brea	Juv_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-HC-2002-2	208.55	58.939	33.842	46.643	68.139	108.649	La Brea	Adult_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-HC-2002-32	202.663	56.424	31.283	43.891	63.863	109.726	La Brea	Adult_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-HC-2002-44	192.841	54.114	26.504	35.846	56.056	107.926	La Brea	Adult_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-HC-2002-66	173.076	50.252	29.235	42.291	55.166	119.113	La Brea	Adult_Smilo
<i>Smilodon fatalis</i>	LACM-HC-2002-HC-2002-125	173.214	55.034	26.708	36.115	44.985	115.919	La Brea	Adult_Smilo

<i>Panthera leo</i>	MNHN-ZO-AC-1880-487	141.886	58.868	62.167	23.381	14.242	152.089	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1883-1731	154.353	65.869	43.271	28.702	19.357	133.388	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1885-701	91.564	31.088	34.332	15.966	6.855	144.282	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1898-219	109.275	33.28	45.003	24.32	10.356	116.89	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1898-295	153.507	61.462	62.365	26.477	16.981	128.5	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1908-157	106.492	31.116	44.451	22.023	11.915	149.337	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1909-391	125.402	35.092	52.948	25.959	15.49	137.243	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1926-298	155.923	41.232	63.929	35.361	14.206	135.02	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1927-582	146.928	61.194	67.398	29.204	18.494	133.272	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1932-337	95.435	30.354	37.529	20.745	10.274	128.582	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1935-343	128.156	34.205	52.884	26.498	14.822	142.666	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1945-176	163.868	68.553	73.356	31.367	13.27	139.162	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1951-15	180.921	71.761	82.155	33.52	20.747	141.269	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1951-170	152.71	61.137	64.9	26.363	14.368	141.15	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1961-617	158.043	63.301	74.441	34.729	22.327	130.81	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1962-2940	97.132	32.161	37.231	19.512	10.688	131.024	MNHN	juv_lion
<i>Panthera leo</i>	MNHN-ZO-AC-1989-272	112.333	32.278	45.148	24.423	10.429	142.053	MNHN	juv_lion
<i>Panthera leo</i>	MVZ-117851	155.775	59.052	65.867	29.517	14.393	139.926	MVZ	juv_lion
<i>Panthera leo</i>	RG6021	100.677	33.571	41.406	20.777	8.302	137.264	RMCA	juv_lion
<i>Panthera leo</i>	MNCN COMP-255	190.611	66.829	78.171	35.054	30.505	154.891	MNCN	adult_lion
<i>Panthera leo</i>	MVZ-117849	251.103	78.855	123.894	78.733	28.836	135.571	MVZ	adult_lion
<i>Panthera leo</i>	RG30674	198.647	67.827	88.583	33.714	29.276	138.684	RMCA	adult_lion
<i>Proailurus lemanensis</i>	USNM-PAL-635370	88.39	NA	NA	NA	NA	NA	USNM	Primitive
<i>Pseudaelurus intrepidus</i>	USNM-124	114.06	NA	NA	NA	NA	NA	USNM	Primitive
<i>Pseudaelurus marshi</i>	AMNH-F-AM-61808	107.15	NA	NA	NA	NA	NA	AMNH	Primitive
<i>Pseudaelurus skineri</i>	AMNH-F-AM-61812	75.19	NA	NA	NA	NA	NA	AMNH	Primitive

**Table S2:** Description of the fixed landmarks placed on the 49 mandibles from **Table S1**

Landmark #	Description
1	Posterior base of the coronoid process, serving as the first anchorage point for the curve characterizing the shape of the coronoid process.
2	Posterior extent of the tooth row, second anchorage point for the curve characterizing the shape of the coronoid process.
3	Anterior extent of the tooth row, first anchorage point for the curve characterizing the shape and size of the diastema
4	Posterior extent of the lower canine, second anchorage point for the curve characterizing the shape and size of the diastema
5	Anterior extent of the lower canine and the symphysis, first anchorage point for the curve characterizing the symphyseal region and the ventral border of the mandibular corpus
6	Posterior extent of the angular process, second anchorage point for the curve characterizing the symphyseal region and the ventral border of the mandibular corpus.

**Table S3:** Sequence of sliding landmarks for the curves on the mandibles.

slide	before	after
7	1	8
8	7	9
9	8	10
10	9	11
12	10	2
13	3	14
14	13	15
15	14	16
16	15	4
17	5	18
18	17	19
19	18	20
20	19	21
21	20	22
22	21	23
23	22	24
24	23	25
25	24	26
26	25	27
27	26	28
28	27	29
29	28	30
30	29	6

**Table S4:** List of *Smilodon fatalis* mandibles and crania used in the finite element analysis with the scaling factor used to adjust the size of the cranium when necessary.

<b>Mandible</b>	<b>Cranium</b>	<b>Scaling factor</b>
<b>LACMHC-2002-L-R-3</b>	LACM-HC-2001-104	0.63
<b>LACMHC-2002-L-R-242</b>	LACM-HC-2001-104	0.92
<b>LACMHC-2002-L-R-402</b>	LACM-HC-2001-104	0.72
<b>LACMHC-2002-2</b>	<b>LACMHC-2001-2</b>	<b>No scaling</b>
<b>LACMHC-2002-125</b>	<b>LACMHC-2001-125</b>	<b>No scaling</b>
<b>LACMHC-2002-L-4</b>	LACM-HC-2001-104	0.60
<b>LACMHC-2002-L-R-326</b>	LACM-HC-2001-104	1.2

**Table S5:** List of *Panthera leo* mandibles and crania used in the finite element analysis with the scaling factor used to adjust the size of the cranium when necessary.

<b>Mandible</b>	<b>Cranium</b>	<b>Scaling factor</b>
<b>MNHN-ZO-AC-1885-701</b>	<b>MNHN-ZO-AC-1885-701</b>	<b>No scaling</b>
<b>MNHN-ZO-AC-1961-617</b>	MNHN-ZO-AC-1880-487	1.1
<b>MNHN-ZO-AC-1908-157</b>	MNHN-ZO-AC-1885-701	1.2
<b>RG30674</b>	<b>RG30674</b>	<b>No scaling</b>
<b>MNCN-COMP-255</b>	RG30674	0.96
<b>MNHN-ZO-AC-1945-176</b>	MNHN-ZO-AC-1880-487	1.2
<b>MNHN-ZO-AC-1880-487</b>	<b>MNHN-ZO-AC-1880-487</b>	<b>No scaling</b>

**Table S6:** Exact number of triangles after decimation, reaction force (in N) in the anterior part of the mandible generated during the simulations, total input force (TIF), mechanical efficiency (ME), internal energy (IE, in mJ), Model volume (in mm<sup>3</sup>), adjusted internal energy (using the model volume), mandible length (MandibleL) and exact number of tetrahedra in volumetric meshes for each specimen. Not that this table is also available in a xlsx format in the ESM.

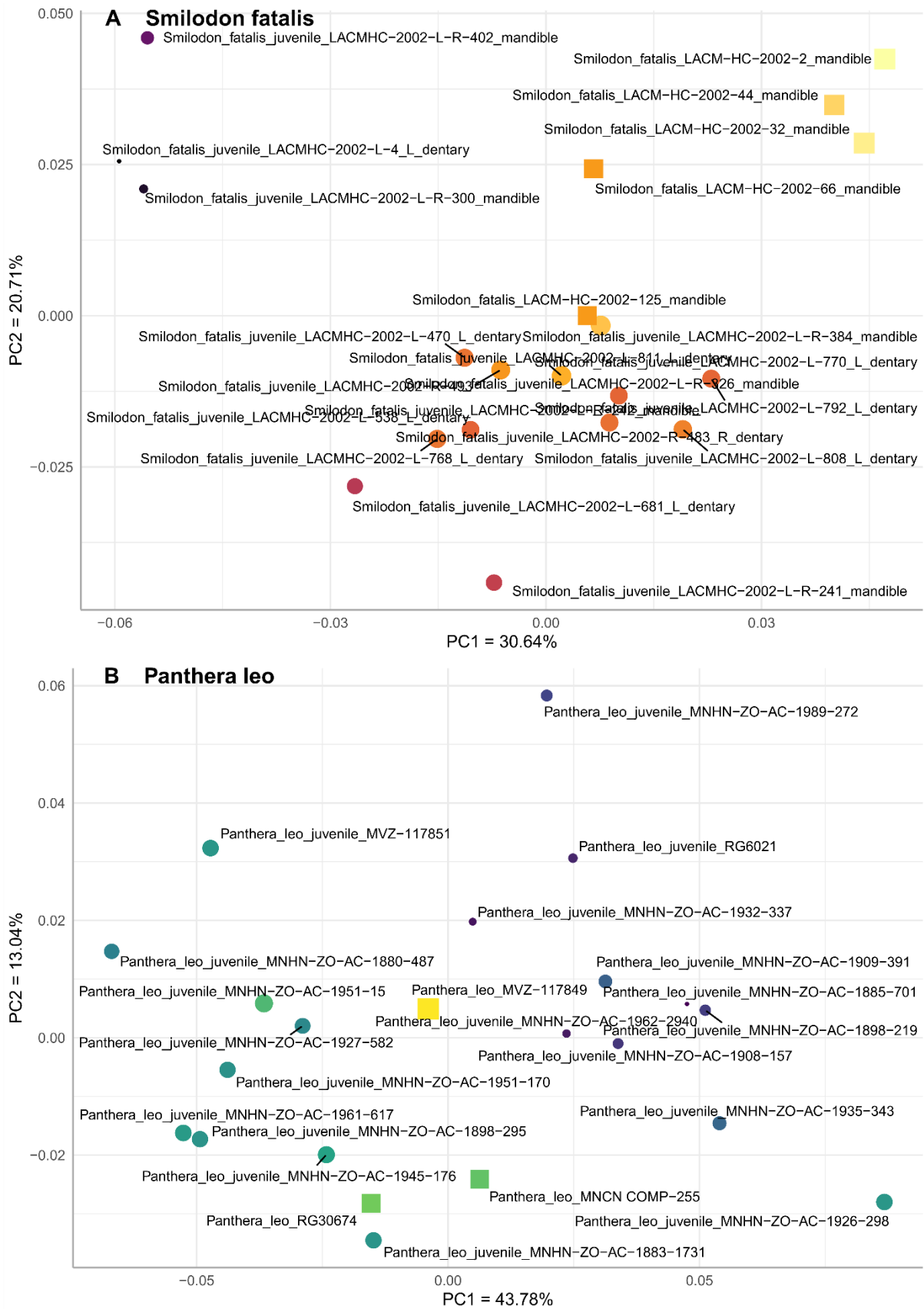
Species	Stage	Specimen number	Triangles	Reaction force	TIF	ME	IE	Model Volume	AdjustedIE	MandibleL	NumTetra
<i>S. fatalis</i>	Juvenile	LACM-HC-2002-L-R-3	99,994	45.159	349.959	0.129	12.387	39,845.471	0.0003	98.01	321,287
			199,990	47.536	349.959	0.136	17.856	39,845.471	0.0004	98.01	936,178
			299,986	46.478	349.959	0.133	17.381	39,845.471	0.0004	98.01	1,767,014
<i>S. fatalis</i>	Juvenile	LACMHC-2002-L-R-402	99,990	73.742	600.699	0.123	10.442	69,955.917	0.0001	116.36	342,967
			200,012	99.760	600.699	0.166	12.785	69,955.917	0.0002	116.36	966,527
			300,002	96.303	600.699	0.160	11.328	69,955.917	0.0002	116.36	1,770,116
<i>S. fatalis</i>	Juvenile	LACMHC-2002-L-R-242	100,000	26.424	612.996	0.043	7.917	69,954.706	0.0001	143.09	343,026
			200,000	29.136	612.996	0.048	9.711	69,954.706	0.0001	143.09	987,548
			300,002	28.202	612.996	0.046	10.341	69,954.706	0.0001	143.09	1,797,858
<i>S. fatalis</i>	Juvenile	LACM-HC-2002-L-4	100,008	31.603	322.541	0.098	4.468	35,613.372	0.0001	92.24	303,365
			200,018	33.244	322.541	0.103	4.519	35,613.372	0.0001	92.24	894,025
			299,978	31.085	322.541	0.096	4.503	35,613.372	0.0001	92.24	1,789,599
<i>S. fatalis</i>	Juvenile	LACM-HC-2002-L-R-326	99,964	145.752	1,092.537	0.133	35.249	150,417.473	0.0002	155.86	305,419
			200,058	147.613	1,092.537	0.135	38.929	150,417.473	0.0003	155.86	834,753
			300,022	146.829	1,092.537	0.134	36.776	150,417.473	0.0002	155.86	1,518,016
<i>S. fatalis</i>	Adult	LACMHC-2002-2	100,014	489.330	2,117.946	0.231	157.022	332,075.674	0.0005	208.55	307,186
			199,976	463.944	2,117.946	0.219	187.000	332,075.674	0.0006	208.55	812,118
			299,990	454.083	2,117.946	0.214	146.474	332,075.674	0.0004	208.55	1,558,688
<i>S. fatalis</i>	Adult	LACMHC-2002-125	99,994	335.397	1,494.358	0.224	120.633	190,570.939	0.0006	173.21	284,701
			199,988	332.205	1,494.358	0.222	129.518	190,570.939	0.0007	173.21	712,218

			299,984	333.486	1,494.358	0.223	132.025	190,570.939	0.0007	173.21	1,294,186
<i>P. leo</i>	Juvenile	MNHN-ZO-AC-1885-701	100,012	73.021	551.242	0.132	144.049	31,009.856	0.0046	91.564	279,082
			200,024	71.754	551.242	0.130	144.978	31,009.856	0.0047	92.564	728,712
			299,980	68.613	551.242		151.042	31,009.856	0.0049	93.564	1,363,552
<i>P. leo</i>	Juvenile	MNHN-ZO-AC-1961-617	99,988	468.519	2,481.841	0.189	226.458	190,307.078	0.0012	158.043	394,400
			203,437	453.967	2,481.841	0.183	239.800	190,307.078	0.0013	159.043	959,731
			303,523	445.034	2,481.841	0.179	236.891	190,307.078	0.0012	160.043	1,656,575
<i>P. leo</i>	Juvenile	MNHN-ZO-AC-1908-157	96,030	140.757	912.487	0.154	162.037	53,889.592	0.0030	106.492	276,323
			200,018	139.338	912.487	0.153	149.314	53,889.592	0.0028	107.492	767,217
			300,026	139.611	912.487	0.153	150.654	53,889.592	0.0028	108.492	1,415,813
<i>P. leo</i>	Juvenile	MNHN-ZO-AC-1945-176	99,980	373.899	2,266.425	0.165	353.236	192,072.318	0.0018	97.132	308,294
			172,114	413.764	2,266.425	0.183	357.912	192,072.318	0.0019	98.132	667,000
			299,998	361.751	2,266.425	0.160	421.147	192,072.318	0.0022	99.132	1,351,186
<i>P. leo</i>	Adult	RG30674	100,078	778.398	4,414.609	0.176	1,653.050	239,152.805	0.0069	198.647	253,885
			199,976	788.454	4,414.609	0.179	1,878.520	239,152.805	0.0079	199.647	601,272
			300,102	785.990	4,414.609	0.178	1,943.250	239,152.805	0.0081	200.647	1,058,353
<i>P. leo</i>	Adult	MNCN-COMP-255	99,984	497.070	3,105.239	0.160	1,592.390	196,333.760	0.0081	190.611	272,106
			197,236	503.246	3,105.239	0.162	1,658.254	196,333.760	0.0084	191.611	935,124
			299,994	499.212	3,105.239	0.161	1,672.156	196,333.760	0.0085	192.611	1,520,018

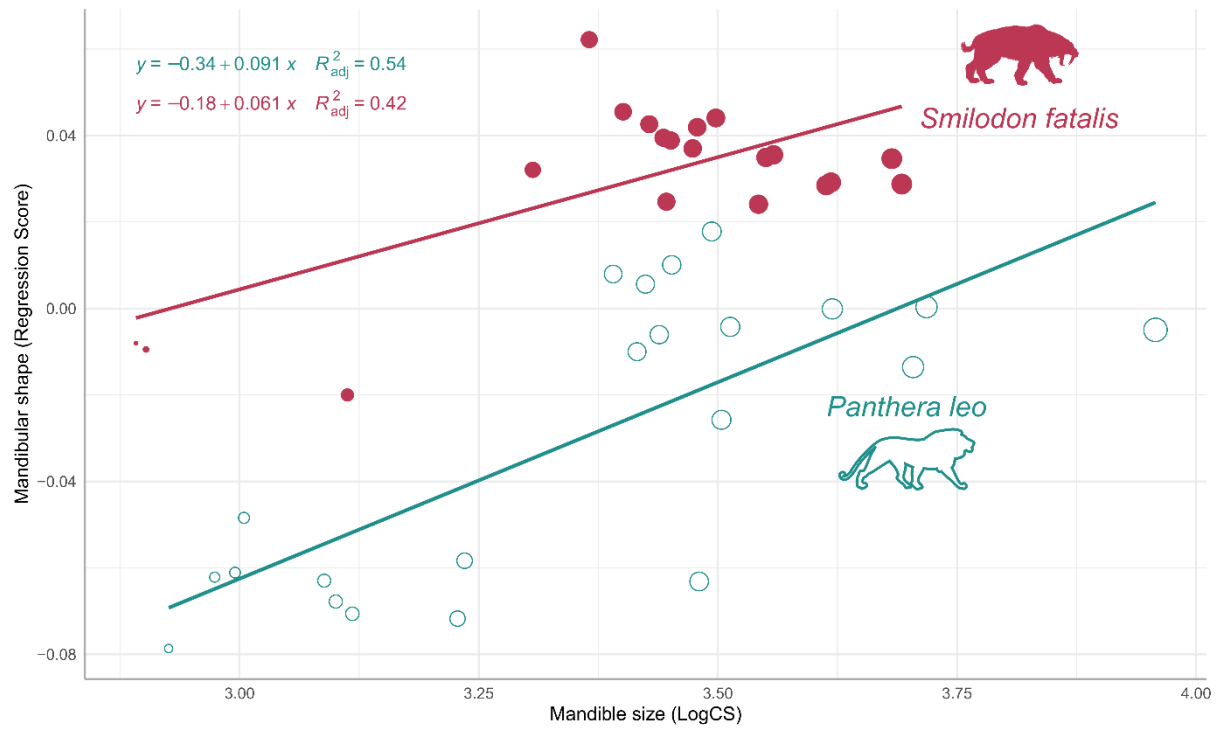
**Table S7:** Average mechanical efficiency (ME), adjusted strain energy (AdjustedIE) and their respective 95% confidence interval based on the simulations at the three different resolutions (see **Table S6**).

Species	Specimen	MandibleL	Stage	ME	AdjustedIE	ME_95CI	AdjustedIE_95CI
<i>S. fatalis</i>	LACM-HC-2002-L-R-3	98.014	Juvenile	0.13256032	0.00039841	0.00272342	6.08498E-05
	LACMHC-2002-L-R-402	116.36	Juvenile	0.14971745	0.00016465	0.01882156	1.35336E-05
	LACMHC-2002-L-R-242	143.094	Juvenile	0.04554759	0.00013328	0.00179836	1.43849E-05
	LACMHC-2002-2	208.55	Adult	0.22149715	0.00049235	0.00687001	5.06607E-05
	LACMHC-2002-125	173.214	Adult	0.22330385	0.00066848	0.00086011	2.51342E-05
	LACM-HC-2002-L-4	92.236	Juvenile	0.09914272	0.00012627	0.00279625	5.92563E-07
	LACM-HC-2002-L-R-326	155.861	Juvenile	0.13430327	0.00024588	0.00068429	9.83458E-06
<i>P. leo</i>	MNHN-ZO-AC-1885-701	91.564	Juvenile	0.13131726	0.00473042	0.00130055	9.79938E-05
	MNHN-ZO-AC-1961-617	158.043	Juvenile	0.18367012	0.0012316	0.00382176	2.94976E-05
	MNHN-ZO-AC-1908-157	106.492	Juvenile	0.15331942	0.00285772	0.00066024	0.000103804
	RG30674	198.647	Adult	0.17765576	0.00763085	0.00095001	0.000509692
	MNCN-COMP-255	190.611	Adult	0.1609675	0.00835788	0.00080807	0.000173658
	MNHN-ZO-AC-1945-176	97.132	Juvenile	0.16904947	0.00196505	0.0096062	0.000158015

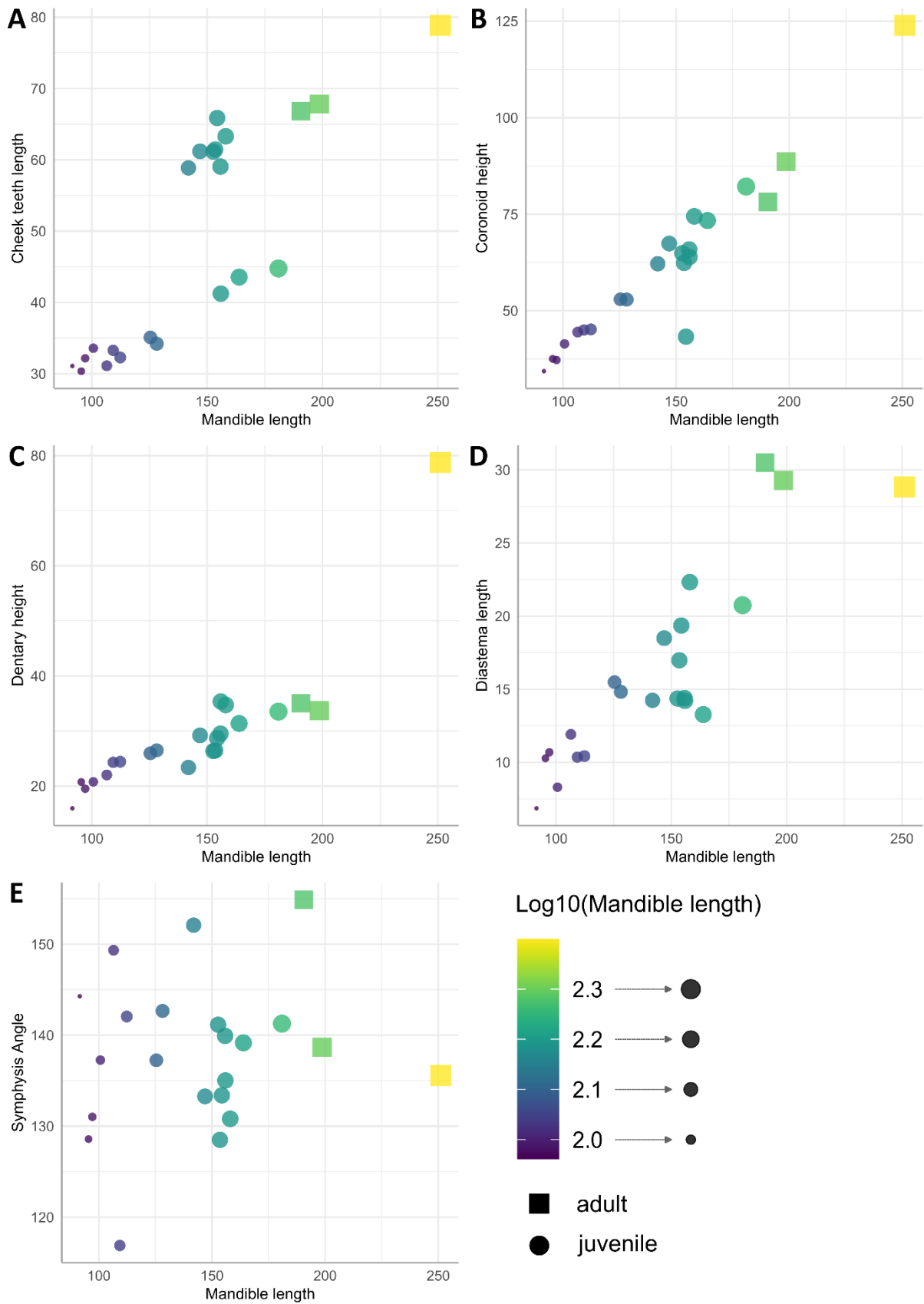




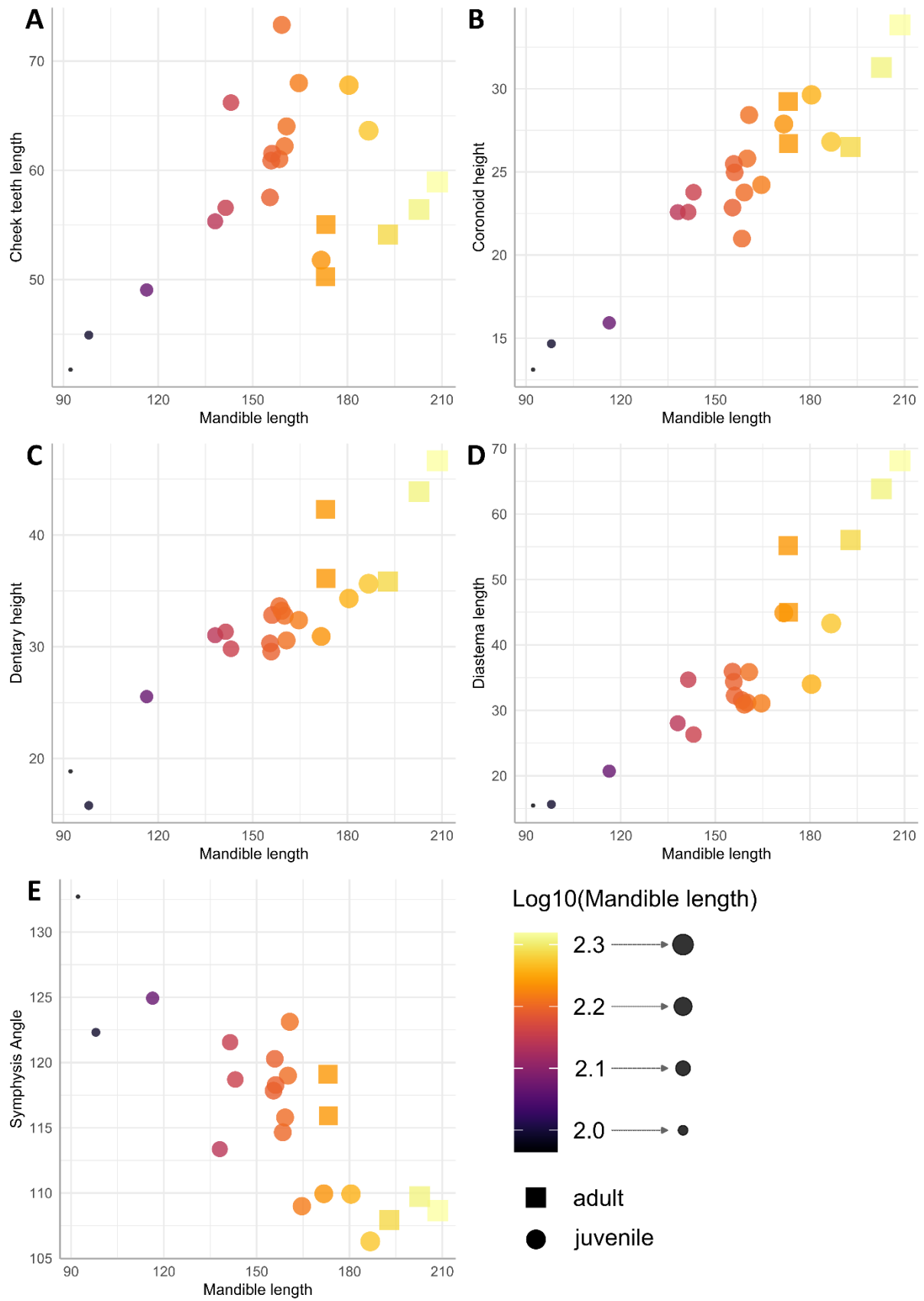
**Figure S1** : Per species morphospace occupation of **A** *Smilodon fatalis* and **B** *Panthera leo* with labels indicating specimen numbers.



**Figure S2:** Regression scores of mandibular shape plotted against the log transformed centroid size obtained from the plotAllometry function.



**Figure S3:** Ontogenetic changes of the different measurements from **Table S1** in *Panthera leo* plotted against the mandibular length. Viridis color scale is relative to the log of the centroid size of each mandible.



**Figure S4:** Ontogenetic changes of the different measurements from **Table S1** in *Smilodon fatalis* plotted against the mandibular length. Viridis color scale (option inferno) is relative to the log of the centroid size of each mandible.