Electronic Supplementary Material for

No deep diving: evidence of predation on epipelagic fish for a stem beaked whale from the late Miocene of Peru

Olivier Lambert*, Alberto Collareta, Walter Landini, Klaas Post, Benjamin Ramassamy, Claudio Di Celma, Mario Urbina, Giovanni Bianucci

*To whom correspondence should be addressed. E-mail: olivier.lambert@naturalsciences.be

Content:

1. SUPPLEMENTARY FIGURES

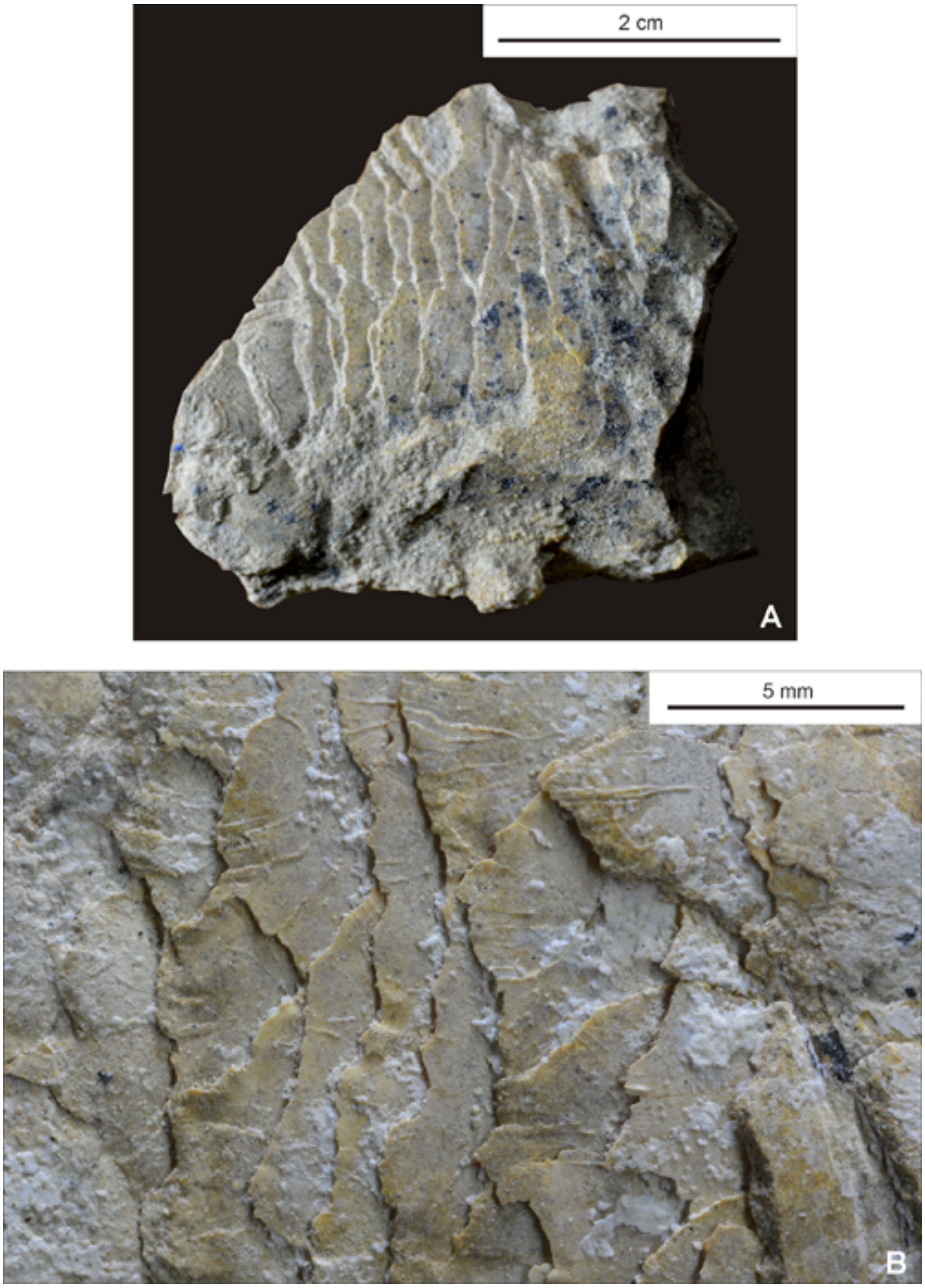

Figure S1. A, B: Two different sets of imbricated cycloid scales. Note the presence of tubercular protuberances in the centre of the scales and the curved radii-like lines in their lateral fields; nowadays, these two features are typical of large scales belonging to mature individuals of the extant Pacific pilchard (*Sardinops sagax*).

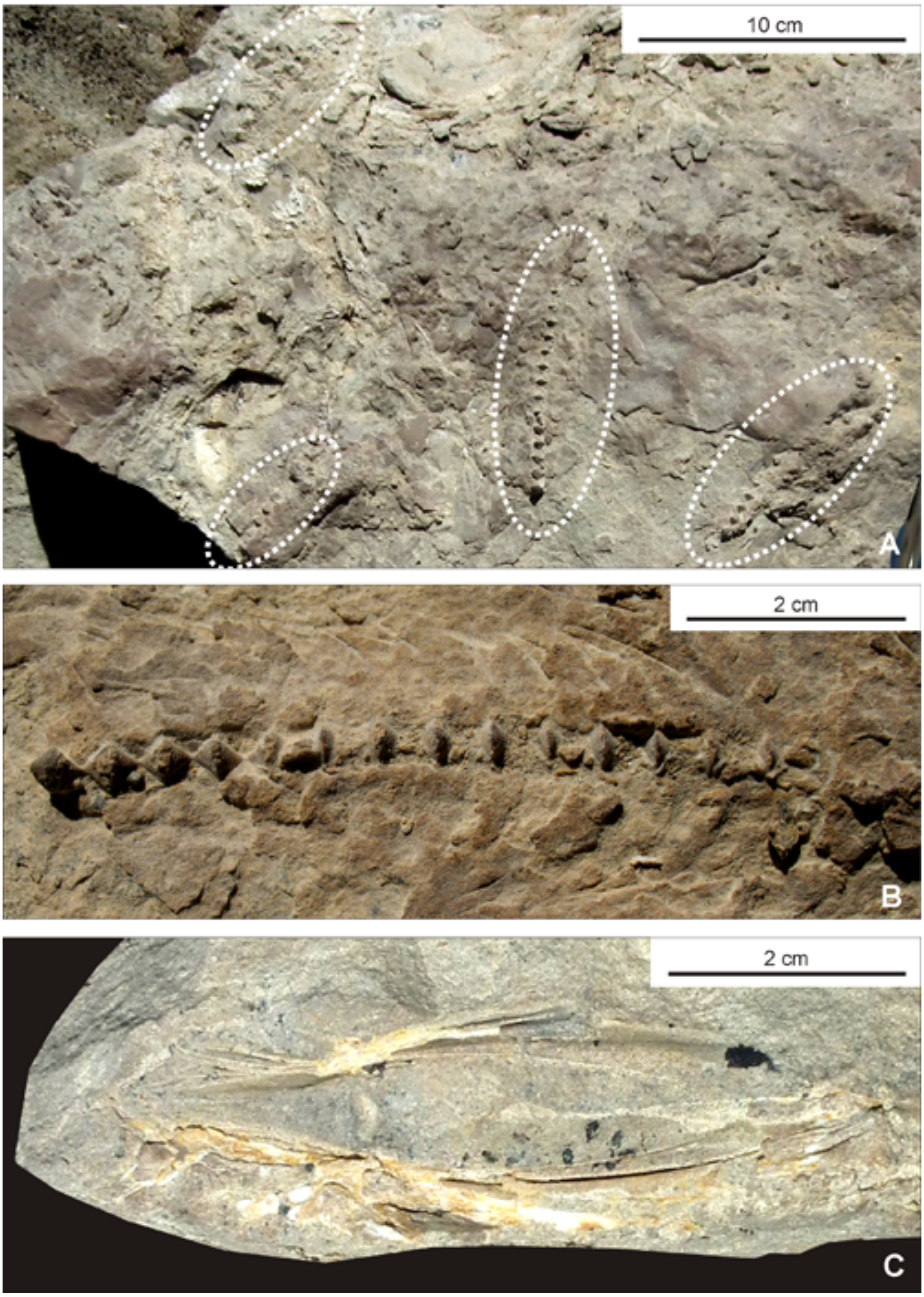

Figure S2. A: Four fully articulated fish vertebral column segments embedded in bony and dermal fish remains. B: Detail of A showing a vertebral column segment contoured by imbricated, large cycloid scales. C: Fully articulated clupeid pelvic girdle, comprising the proximal portion of some fin rays.

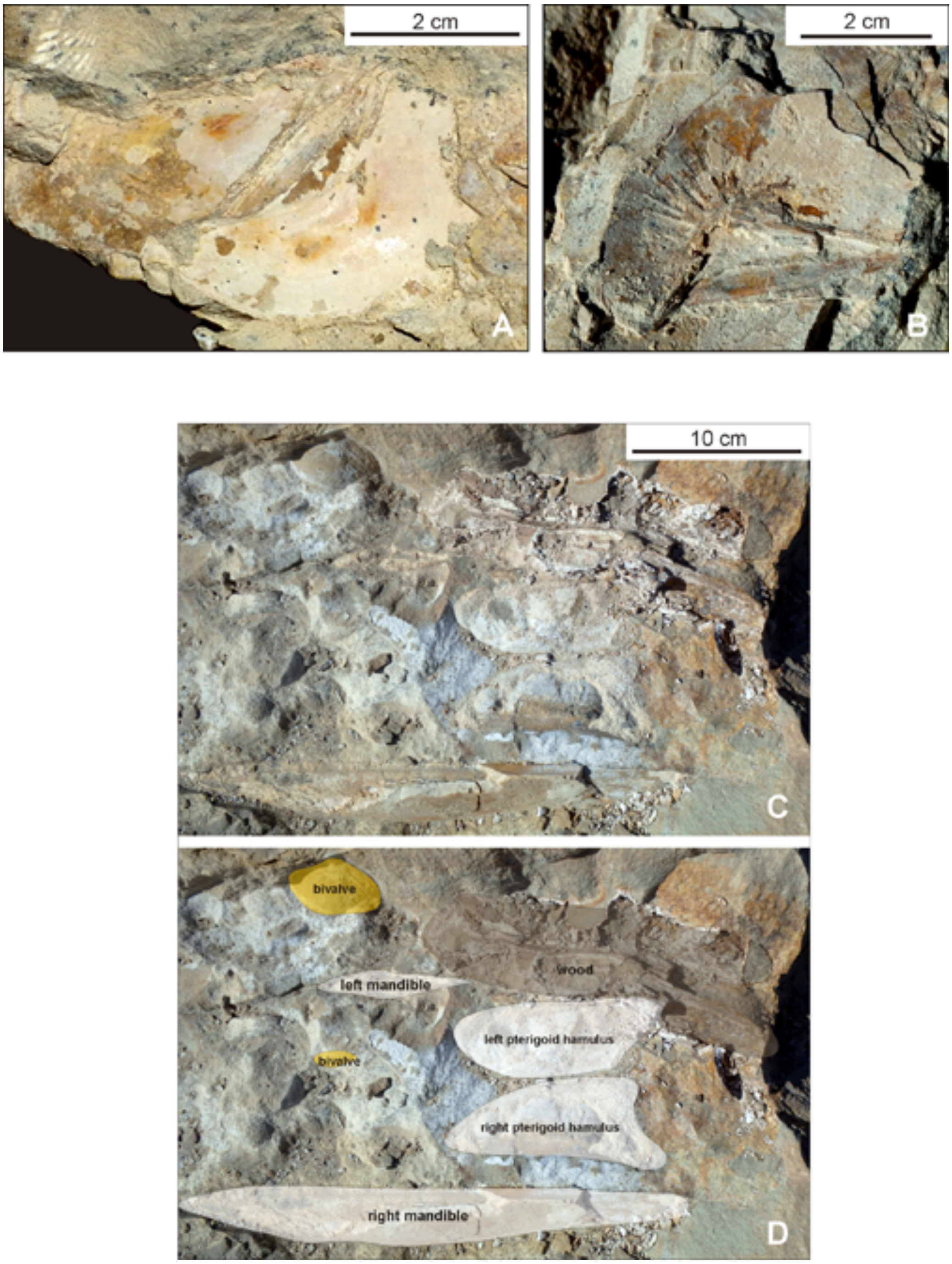

Figure S3. A, B: Two clupeid preopercles packed with other partly disarticulated, although still interconnected, collapsed skull bones. A partial bivalve shell can be seen in A, while in B some characteristic cycloid scales appear. C, D: Detail of the dolomite concretion including the skull and mandibles of *Messapicetus gregarius*, showing the hamular processes of the pterygoids, the posteroventral portions of the mandibles, two articulated bivalve shells, and a fragment of fossilized wood.

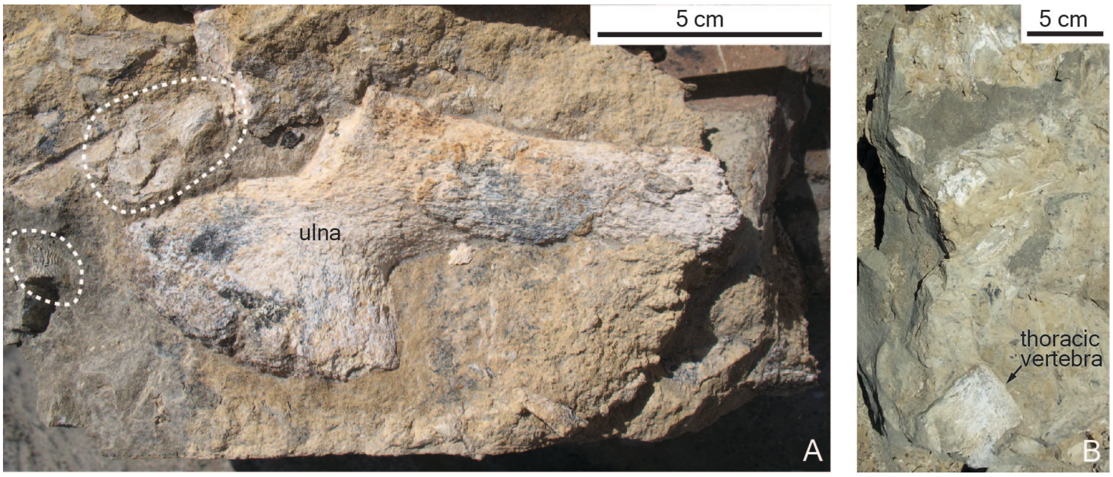

Figure S4. A, B: Postcranial remains of the *Messapicetus gregarius* specimen, seen on smaller dolomite blocks detached from the large concretion. A, proximal portion of the ulna. B, longitudinal section in a thoracic vertebra. Fish scales near the ulna are surrounded by white stippled lines.

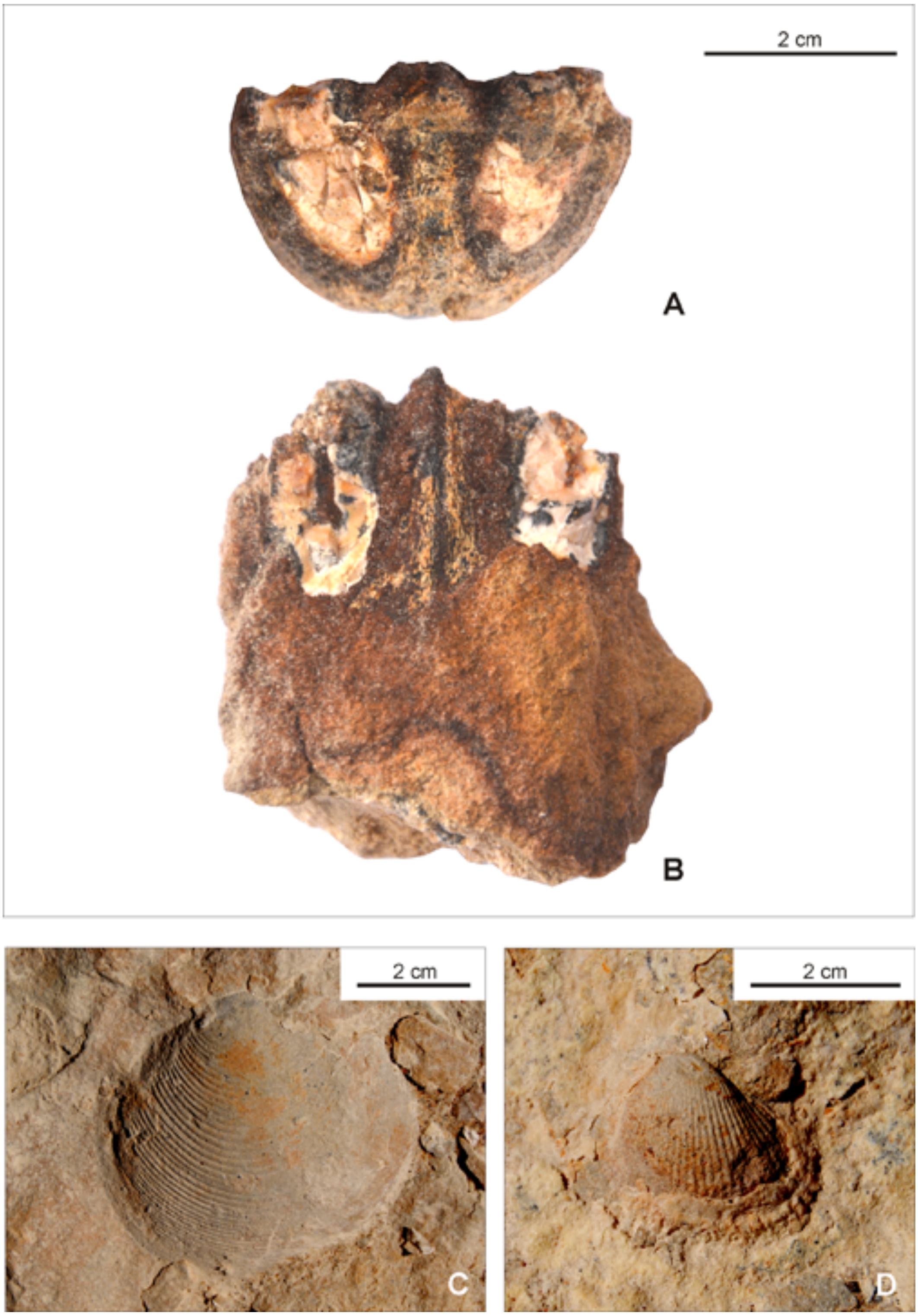

Figure S5. A, B: Anterior (A) and dorsal (B) views of the apical portion of the symphyseal region of mandibles (MUSM 2552) detached from the *Messapicetus gregarius* specimen embedded in the dolomite concretion. C, D: Bivalve shells near the skull of *M. gregarius*.

2. SIZE AND WEIGHT ESTIMATES FOR *MESSAPICETUS GREGARIUS*

To estimate the body length (BL) for specimens of *Messapicetus gregarius* from Cerro Colorado, we used the following regression equation, based on dimensions of extant ziphiids and taken from Bianucci et al. [1]:

$$BL = (9.464 * PW) + 1137$$

where:

PW = postorbital width (in millimeters)

In a previous work [2], PWs were published for several specimens of *Messapicetus gregarius* from the same locality and level; they range from 315 to 352 mm. The calculated BL ranges thus from 4.1 to 4.5 meters.

For estimating the body weight (BW) of the specimen of *M. gregarius* studied here, we used the regression equation proposed by Pyenson & Lindberg [3]:

$$BW = 0.4628 * (OCW)^{3.2087}$$

where:

OCB = width across occipital condyles (11.4 cm for the specimen analyzed here)

A BW of 1842 kg is obtained, possibly somewhat overestimated considering that extant species of *Mesoplodon* with a BL in the range of the estimated BLs for *M. gregarius* do not reach a BW greater than 1540 kg and are generally between 560 and 1100 kg (for stranded, therefore possibly less healthy animals; [4]).

3. SIZE AND WEIGHT ESTIMATES FOR *SARDINOPS* SP. CF *S. SAGAX*

For the reconstruction of the ichthyomass associated to the skull and chest of *Messapicetus gregarius*, we applied a morphometric approach, starting from the mean length of the vertebrae in every vertebral column segment counting 8 vertebrae or more. We based our estimates on four preliminary assumptions:

I - No huge variations in the length of the vertebrae can be observed along the vertebral column of the extant Pacific sardine *Sardinops sagax*, with the important exception of the last caudal vertebra (which is strongly elongated and modified in order to form the urophore complex, supporting the caudal fin). Nevertheless, it should be pointed out that the central vertebrae are generally slightly longer than both the anteriormost and the posteriormost vertebrae.

II - The average number of vertebrae in *Sardinops* (including the last vertebra supporting the caudal fin, and with regard to the Humboldt Current System population) is ~51 (e.g. [5]).

III - De Buen et al. [6] report that, in the Peruvian stock of Pacific sardine, the length of the head (HL) represents 27 to 28.5% of the standard length (SL).

[SL is measured from the anterior end of the jaw to the termination of the flesh part of the caudal peduncle [7]; thus SL comprises the last, deeply modified vertebra.]

IV- In lateral view, the operculum hides the anteriormost vertebrae until the first half of the 4th vertebra [8].

On the basis of these assumptions we calculated SL for each vertebral column segment with the following equation:

$$SL = [(VL * (51-3.5)) / (1 - (HL/SL))]$$

where:

VL = average length of a vertebra

HL = average length of the head

Assuming HL/SL = 27.75%, we calculated SL for every segment of vertebral column. We obtained an average SL of 33.0 cm, that is, not far from the maximum SL value ever published for a Pacific sardine (39.5 cm, fide [9]). The standard deviation of our estimate is 2.0 cm.

[Please note that, since the anomalous elongation of the last vertebra is not taken into account in the equation written above, the SL could be slightly underestimated. Moreover, calculating SL starting from a vertebral column segment constituted by very anterior (or very posterior) vertebrae could result in a slight underestimation of SL, whereas calculating SL starting from a vertebral column segment constituted by central vertebrae could result in a slight overestimation of SL; these opposite effects could generate a wide (and artificial) range of SL values. This is the reason why we have preferred to consider in our estimate neither isolated vertebrae (or vertebral column segment constituted by a low number of vertebrae) nor vertebrae near to the caudal fin or to the skull. Anyway, the low relative standard deviation for the 15 calculated SL values means that these effects are in fact negligible for the purposes of the present work.]

It should be noted that all the many isolated fish vertebrae we observed in association with the other fish remains fall in the length range of the articulated ones we measured for this estimate.

Phillips [7] proposes the following relationship between SL and TL (total length, measured from the anterior end of the jaw to the termination of the tail):

$$SL = TL * 0.85$$

We used this equation to calculate TL for our 15 specimens. We obtained an average TL of 38.8 cm. The standard deviation of our estimate is 2.3 cm. It should be noted that this high value of average TL is fully compatible with the observation of very wide scales in the sample (some of them approaching a width of 2.0 cm). Many body length (SL or TL) - body weight (BW) correlations have been proposed (e.g. [10-15]). However, most of these curves have been constructed considering only small individuals (generally TL < 20 cm, and often TL < 10 cm), thus providing unreliably high estimates of BW for our remarkably long sardines. Nevertheless, the correlation curve proposed by Graas [14] is built on 181 Pacific sardines comprising a huge amount of adult specimens (many of them displaying TL > 25 cm). The correlation proposed by Graas [14] presents $R^2 = 0.99$.

We tested the reliability of the six above listed body length-BW correlations with respect for large sardine individuals by recalculating the weight of the heaviest *Sardinops sagax* specimen ever published, which shows FL = 39.4 cm and BW = 486 g [FL = Fork length, measured from the tip of the snout to the end of the middle caudal fin rays]. In order to obtain an estimate of BW for this individual, we recalculated its TL on the basis of the FL-TL correlation equation proposed by Graas [14] for the Pacific sardine:

$$TL = (FL-0,82)/1,061$$

It turned out that the TL-BW equation proposed by Graas [14] is the only one able to predict the weight of this specimen within a tolerance of ± 5% (in fact, we obtained BW = 507 g for this somewhat extreme individual). The other body length - body weight equations heavily overestimated the BW value, with the exception of the curve by Gartz [13], which heavily underestimated the BW value; anyway, the curve by Gartz [13] is built on juvenile specimens (TL < 10 cm), and as such, its BW estimates are not reliable for our aged and long sardines. Therefore, we used the equation proposed by Graas [14] to calculate the BW of our sardines:

$$BW = 0.094 * TL^{2.29}$$

We obtained an average BW of 410 g. The standard deviation of our estimate is 55 g.

Table S1. Measurements for vertebral column segments of *Sardinops* sp. cf. *S. sagax* found along the *Messapicetus gregarius* specimen at Cerro Colorado. AVL = average vertebral length; SL = estimated standard length; TL = estimated total length; BM1 = body mass estimated according to Clark [10]; BM2 = body mass estimated according to Kimura & Sakagawa [11]; BM3 = body mass estimated according to Walker [12]; BM4 = body mass estimated according to Gartz [13]; BM5 = body mass estimated according to Graas [14]; BM6 = body mass estimated according to Stewart et al. [15].

Average values (Av. Val.) and standard deviation (St. Dev.) are reported at the bottom of the table. Estimates selected in this work are in red.

	AVL (mm)	SL (mm)	TL (mm)	BM1 (g)	BM2 (g)	BM3 (g)	BM4 (g)	BM5 (g)	BM6 (g)
1	5.30	348	410	509	2099	550	332	464	662
2	5.01	329	388	426	1755	460	284	408	554
3	4.99	328	386	421	1733	455	281	404	547
4	5.19	341	401	476	1964	515	313	442	620
5	5.25	345	406	494	2037	534	324	454	643
6	4.70	309	364	349	1432	377	237	352	453
7	5.41	356	418	543	2241	586	352	486	707
8	4.40	289	340	283	1161	306	197	303	368
9	5.23	344	405	488	2012	527	320	450	635
10	5.20	342	402	479	1976	518	315	444	624
11	4.81	316	372	375	1542	405	253	371	487
12	5.28	347	408	503	2074	543	329	460	654
13	4.63	304	358	333	1365	359	228	340	432
14	5.10	335	394	451	1857	487	298	425	587
15	4.70	309	364	349	1432	377	237	352	453
Av. Val.	**5.01**	**330**	**388**	**432**	**1779**	**467**	**287**	**410**	**562**
St. Dev.	**0.30**	**20**	**23**	**78**	**322**	**84**	**46**	**55**	**101**

4. COMPARISON OF CERVICAL VERTEBRAE ANKYLOSIS AND SIZE AMONG ZIPHIIDAE

The specimen of *Mesapicetus gregarius* MUSM 2548 mentioned in the following tables is a new partial skeleton recently found in Cerro Colorado (field number = O37; see figure 1).

Table S2. Comparison of the degree of fusion of cervical vertebrae across Ziphiidae. * specimen consulted; † fossil species.

Species	Collection number	Source	Fused cervical vertebrae	Fused cervical centra	Fused cervical neural arches	Ontogenetic stage
Messapicetus gregarius* †	**MUSM 2548**	**this paper**	**0**	**0**	**0**	**adult**
*Berardius arnuxii**	MNHN A3244	[16]	3 (C1 to C3)	2 (C1 to C2)	2 (C1 to C2)	subadult
Berardius arnuxii	WRM?	[17]	3	?	?	?
Berardius arnuxii	?	[17]	3	?	?	?
Berardius arnuxii	NMNZ Dom. Mus. 614	[18]	2 (C1 and C2)	?	?	new born
Berardius bairdii	USNM A 49726	[19]	3? (not stated explicitely)	?	?	adult
Berardius bairdii	USNM A 49725	[19]	3? (not stated explicitely)	?	?	adult
Berardius bairdii	USNM A 49727	[19]	3? (not stated explicitely)	?	?	subadult
*Hyperoodon ampullatus**	MNHN A3236	[20]	7	7	7	subadult
*Hyperoodon ampullatus**	SNM CN1	this paper	7	7	7	adult
*Hyperoodon ampullatus**	SNM CN17	this paper	7	7	6 (C1 to C6)	neonate
*Hyperoodon ampullatus**	SNM CN19x	this paper	7	7	6 (C1 to C6)	immature
*Hyperoodon ampullatus**	SNM CN15x	this paper	7	7	7	adult
*Hyperoodon ampullatus**	SNM CN26x	this paper	7	7	5 (C1 to C5)	subadult
*Hyperoodon ampullatus**	SNMMCE1 634	this paper	7	7	6 (C1 to C6)	subadult
*Hyperoodon ampullatus**	SNM CN257	this paper	7	7	7	adult
*Hyperoodon ampullatus**	SNM CN2x	this paper	7	7	7	subadult
*Hyperoodon ampullatus**	SNM CN20x	this paper	7	7	7	adult

*Hyperoodon ampullatus**	MSNUP 268	this paper	7	5 (C1 to C5)	5 (C1 to C5)	subadult
Indopacetus pacificus	PEM292	[21]	5 (C1 to C5)	?	?	immature
Indopacetus pacificus	MRC?	[21]	5 (C1 to C5)	?	?	adult
*Mesoplodon bidens**	MNHN A14519	this paper	4 (C1 to C4)	?	?	adult
Mesoplodon bidens	NHM?	[22]	2	?	?	immature
Mesoplodon bidens	IRSNB?	[20]	3	?	?	?
*Mesoplodon bidens**	SNM CN4x	this paper	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	immature
*Mesoplodon bowdoini**	MSNUP M269	this paper	3 (C1 to C3)	2 (C1 to C3)	2 (C1 to C2)	adult
Mesoplodon bowdoini	AMNH 35027	[23]	3 (C1 to C3)	2 C1 to C3)	2 C1 to C2)	adult
Mesoplodon bowdoini	?	[24]	3 (C1 to C3)	?	?	adult
*Mesoplodon densirostris**	USNM 572986	this paper	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	adult
*Mesoplodon densirostris**	USNM 593522	this paper	5 (C1 to C5)	3 (C1 to C3)	3 (C1 to C3)	adult
Mesoplodon densirostris	?	[20]	6 (C1 to C3 + C5 to C7)	?	?	?
Mesoplodon densirostris	AMNH 139931	[25]	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	adult
Mesplodon europaeus	USNM 504738	[26]	6 (C1 to C4 + C5 to C6)	?	?	adult
Mesplodon europaeus	USNM 23346	[19]	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	immature
Mesoplodon ginkgodens	NSMT 8744	[27]	5 (C1 to C3 + C4 to C5)	3 (C1 to C3)	3 (C1 to C3)	adult
Mesoplodon ginkgodens	TWM?	[28]	3 (C1 to C3)	?	?	?subadult
Mesoplodon ginkgodens	AORI?	[28]	3 (C1 to C3)	?	?	adult
*Mesoplodon grayi **	MNHN 1877-329	[29]	2 (C1 to C2)	2 (C1 to C2)	2 (C1 to C2)	subadult
Mesoplodon grayi	RCSEng?	[29]	2	2 (C1 to C2)	2 (C1 to C2)	immature
Mesoplodon grayi	?	[17]	2	?	?	?
Mesoplodon grayi	CM?	[17]	2	?	?	?
Mesoplodon hectori	MACN-Ma 22444	[30]	2? (not explicitely stated)	?	?	subadult
Mesoplodon layardii	NMNZ?	[17]	2	?	?	immature
Meosplodon mirus	RCSEng?	[22]	3	3 (C1 to C3)	3 (C1 to C3)	adult
Mesoplodon mirus	ANSP 20484	[31]	5 (C1 to C3 + C4 to C5)	5 (C1 to C3 + C4 to C5)	5 (C1 to C3 + C4 to C5)	adult
Mesoplodon	?	[32]	3 (C1 to	3 (C1 to	3 (C1 to	adult

mirus			C3)	C3)	C3)	
Mesoplodon perrini	USNM 504853	[33]	2	?	?	adult
Mesoplodon perrini	USNM504259	[33]	2	?	?	immature
Mesoplodon perrini	USNM504260	[33]	2	?	?	immature
Mesoplodon perrini	TMMC-C75	[33]	2	?	?	immature
Mesoplodon stejnegeri	MFRS?	[34]	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	immature
*Nazcacetus urbinai† **	MUSM 949	[35]	2	2 (C1 to C2)	2 (C1 to C2)	adult
*Ninoziphius platyrostris† **	MNHN SAS 941	[36]	2	2 (C1 to C2)	2 (C1 to C2)	adult
*Tasmacetus shepherdi**	NMNZ MM02183	this paper	6 (C1 to C6)	5 (C1 to C5)	5 (C1 to C5)	adult
*Tasmacetus shepherdi**	NMNZ MM002184	this paper	5 (C1 to C5)	5 (C1 to C3 + C4 to C5)	5 (C1 to C3 + C4 to C5)	immature
*Tasmacetus shepherdi**	NMNZ MM002914	this paper	6 (C1 to C6)	5 (C1 to C3 + C4 to C5)	5 (C1 to C3 + C4 to C5)	adult
*Ziphius cavirostris**	MSNUP 270	this paper	4 (C1 to C4)	2 (C1 to C2)	2 (C1 to C2)	adult
Ziphius cavirostris	USNM 504094	[26]	4 (C1 To C4)	?	?	adult
Ziphius cavirostris	USNM A 20971	[19]	4 (C1 to C4)	4 (C1 to C4)	4 (C1 to C4)	adult
Ziphius cavirostris	USNM A 45599	[19]	4 (C1 to C4)	3 (C1 to C3)	3 (C1 to C3)	adult
Ziphius cavirostris	A 21975	[19]	3 (C1 to C3)	3 (C1 to C3)	3 (C1 to C3)	young adult
Ziphius cavirostris	WRI ZC2	[37]	4 (C1 to C4)	?	?	immature
Ziphius cavirostris	WRI ZC11	[37]	4 (C1 to C4)	?	?	juvenile
Ziphius cavirostris	WRI ZC12	[37]	6 (C1 to C6)	?	?	adult
Ziphius cavirostris	WRI ZC3	[37]	4 (C1 to C4)	?	?	adult
Ziphius cavirostris	WRI ZC7	[37]	3 (C1 to C3)	?	?	juvenile
Ziphius cavirostris	WRI ZC1	[37]	4 (C1 to C4)	?	?	adult
Ziphius cavirostris	WRI ZC10	[37]	4 (C1 to C4)	?	?	adult
*Ziphius cavirostris**	MSNUP 270	this paper	4 (C1 to C4)	?	?	adult
*Ziphius cavirostris**	MZUF 7466	this paper	5 (C1 to C5)	?	?	adult
*Ziphius cavirostris**	MZUF 18854	this paper	4 (C1 to C4)	?	?	subadult
*Ziphius cavirostris**	SNM CN1x	this paper	4 (C1 to C4)	3 (C1 to C3)	4 (C1 to C4)	adult

Table S3. Comparison of size for cervical vertebrae among Ziphiidae. Measurements in mm. e estimated; * specimen consulted; † fossil species; n/a not applicable

Species	Collection number	Cervical vertebra	Width centrum	Height centrum	Anteroposterior length unfused centrum	Ratio length/width centrum	Ratio length/height centrum
***Messapicetus gregarius* † ***	**MUSM 2548**	**Atlas**	**-**	**-**	**-**	**n/a**	**n/a**
		Axis	**-**	**-**	**12**	**n/a**	**n/a**
		A	**73**	**75**	**21**	**0.29**	**0.28**
		B	**74**	**76**	**28**	**0.38**	**0.38**
Berardius arnuxii	MNHN A3244	Atlas	221e	147e	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	-	-	36e	-	-
		C5	-	-	36e	-	-
		C6	-	-	38e	-	-
		C7	132e	107e	46e	0.38	0.43
*Mesoplodon bidens**	SNM CN4x	Atlas	100	61	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	47	40	10	0.21	0,25
		C5	46	41	9	0.20	0.22
		C6	44	38	9	0.20	0.24
		C7	45	36	9	0.20	0.25
*Mesoplodon bowdoini**	MSNUP M269	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	57	40	13	0.23	0.33
		C5	53	43	13.5	0.25	0.31
		C6	53	46	14.5	0.27	0.32
		C7	57	49	18	0.32	0.37
Mesoplodon bowdoini	? [24]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	71	58	15	0.21	0.26
		C5	71	58	15	0.21	0.26
		C6	75	58	16	0.21	0.28
		C7	76	62	19	0.25	0.31
Mesoplodon ginkgodens	NSMT 8744 [27]	Atlas	122	48	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	79	48	-	n/a	n/a
		C5	74	57	-	n/a	n/a
		C6	72	58	14	0.19	0.24

		C7	76	58	18	0.24	0.31
*Mesoplodon grayi**	MNHN 1877-329	Atlas	84	59	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	9	-	-
		C4	-	-	10	-	-
		C5	-	-	11	-	-
		C6	-	-	11	-	-
		C7	54	42	12	0.22	0.29
Mesoplodon hectori	MACN-Ma 22444 [30]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	53	43	8	0.15	0.19
		C4	51	45	7	0.14	0.16
		C5	52	46	8	0.14	0.16
		C6	52	45	9	0.17	0.2
		C7	55	44	15	0.27	0.34
Mesoplodon stejnegeri	MFRS? [34]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	59	41	-	n/a	n/a
		C4	56	38	11	0.20	0.29
		C5	54	41	10	0.19	0.24
		C6	54	43	12	0.22	0.28
		C7	60	43	15	0.25	0.35
Ninoziphius platyrostris †	MNHN SAS 941 [36]	Atlas	106	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	63	57	24	0.38	0.42
		C4	60	58	22	0.37	0.38
		C5	-	-	-	-	-
		C6	61	60	22,1	0.36	0.37
		C7	-	-	-	-	-
Ziphius cavirostris	WRI ZC2 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	64	51	6	0.09	0.18
		C5	60	50	15	0.25	0.3
		C6	63	50	14	0.22	0.28
		C7	75	52	17	0.23	0.33
Ziphius cavirostris	WRI ZC11 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	73	60	-	n/a	n/a
		C5	68	58	17	0.25	0.29
		C6	68	58	17	0.25	0.29
		C7	91	54	19	0.21	0.35
Ziphius cavirostris	WRI ZC12 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a

		C4	-	-	-	n/a	n/a
		C5	-	-	-	n/a	n/a
		C6	81	83	-	n/a	n/a
		C7	115	69	25	0.22	0.36
Ziphius cavirostris	WRI ZC3 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	80	71	-	n/a	n/a
		C5	78	71	18	0.23	0.25
		C6	78	73	22	0.28	0.30
		C7	106	76	27	0.25	0.36
Ziphius cavirostris	WRI ZC7 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	83	70	-	n/a	n/a
		C4	77	71	20	0.26	0.28
		C5	74	71	20	0.27	0.28
		C6	73	73	22	0.30	0.30
		C7	72	71	28	0.39	0.39
Ziphius cavirostris	WRI ZC1 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	87	72	-	n/a	n/a
		C5	81	73	25	0.31	0.34
		C6	79	73	24	0.30	0.33
		C7	92	76	26	0.28	0.34
Ziphius cavirostris	WRI ZC10 [37]	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	90	79	-	n/a	n/a
		C5	87	74	18	0.21	0.24
		C6	85	76	19	0.22	0.25
		C7	112	80	25	0.22	0.31
*Ziphius cavirostris**	MSNUP 270	Atlas	-	-	-	n/a	n/a
		Axis	-	-	-	n/a	n/a
		C3	-	-	-	n/a	n/a
		C4	-	-	-	n/a	n/a
		C5	73	63	20	0.27	0.32
		C6	69	65	20	0.29	0.31
		C7	73	66	25	0.34	0.38

5. COMPARISON OF RELATIVE HUMERAL LENGTH AMONG ZIPHIIDAE

Table S4. Comparison of relative humeral length among Ziphiidae. Measurements in mm. e = estimated; * specimen consulted; † fossil species.

Species	Collection number	Source	Humeral length	Bizygomatic width	Ratio humeral length/bizygomatic width	Ontogenetic stage
Messapicetus gregarius* †	**MUSM 2548**	**this paper**	**150**	**310-313**	**0.48**	**adult**
Berardius arnuxii	MNHN A3244	[16]	274	671	0.41	subadult
Berardius bairdii	?	[38]	321	e722	0.44	adult
Berardius bairdii	USNM A 49725	[19]	340	675	0.50	adult
Berardius bairdii	USNM A 49727	[19]	248	520	0.48	subadult
*Hyperoodon ampullatus**	MSNUP M268	this paper	240	677	0.35	subadult
*Hyperoodon ampullatus**	SNM CN17x	this paper	88	143	0.62	neonate
*Hyperoodon ampullatus**	SNM MCE1634	this paper	220	664	0.30	subadult
Mesoplodon bowdoini	AMNH 35027	[23]	123	335	0.37	adult
*Mesoplodon bowdoini**	MSNUP M269	this paper	116	334	0.35	adult
Mesoplodon carlhubbsi *	USNM 504128	this paper	112	364	0.31	adult
Mesoplodon densirostris	AMNH 139931	[25]	131	325	0.40	adult
Mesoplodon europaeus	USNM 23346	[19]	107	302	0.35	immature
Mesoplodon grayi	MNHN 1877-329	[29]	135	298	0.45	subadult
Mesoplodon grayi	RSCEng?	[29]	132	282	0.47	immature
Mesoplodon ginkgodens	NSMT 8744	[27]	129	e356	0.36	adult
Mesoplodon mirus	ANSP 20484	[31]	137	364	0.38	adult
Mesoplodon mirus	PMNH 02430	[32]	133	345	0.39	adult

*Tasmacetus shepherdi**	USNM 484878	this paper	e185	e470	e0.39	adult
Ziphius cavirostris	USNM A 20971	[19]	168	503	0.33	adult
Ziphius cavirostris	USNM A 49599	[19]	177	548	0.32	adult
Ziphius cavirostris	USNM A 21975	[19]	130	415	0.31	subadult
*Ziphius cavirostris**	MSNUP M300	this paper	165	485	0.34	adult
*Ziphius cavirostris**	SNM CN1x	this paper	165	472	0.35	adult

6. ABBREVIATIONS FOR INSTITUTIONS

AMNH – American Museum of Natural History of New York, USA

ANSP – Academy of Natural Sciences of Philadelphia, USA

AORI – Atmosphere and Ocean Research Institute, University of Tokyo, Japan

CM – Canterbury Museum, New Zealand

IRSNB – Institut royal des Sciences naturelles de Belgique, Belgium

MACN – Museo Argentino de Ciencas Naturales "Barardino Revadavia", Buenos Aires, Argentina

MFRS – Maizuru Fisheries Research Station, Kyoto University, Japan

MRC – Marine Research Centre, Ministry of Fisheries, Agriculture and Marine Resources, Republic of Maldives

MNHN – Muséum national d'Histoire naturelle, Paris, France

MSNUP – Museo di Storia Naturale e del Territorio di Pisa, Italy

MUSM – Museo de Historia Natural, Universidad Nacional Mayor de San Marco, Lima, Peru

MZUF – Museo di Zoologia, Università di Firenze, Italy

NHM – Natural History Museum, London, UK

NMNZ – National Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand

NSMT – National Science Museum, Tokyo, Japan

PEM – Port Elisabeth Museum, South Africa

PMNH – Peabody Museum of Natural History, Yale University, New Haven, Connecticut, USA

RCSEng – Museum of Royal College of Surgeons, London, UK

SNM – Statens Naturhistoriske Museum, Copenhagen, Denmark

TMMC – The Marine Mammal Center, Sausalito, USA

TWM – Taiji Whale Museum, Japan

USNM – National Museum of Natural History, Washington DC, USA

WRI – Whales Research Institute, Tokyo, Japan

WRM – Whanganui Regional Museum, New Zealand

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