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SUPPLEMENTARY ONLINE MATERIAL FOR

Intraspecific variation and new morphological characters revealed by multimodal imaging analysis on the Late Cretaceous coleoid *Dorateuthis syriaca*

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Supplementary Online Material

Figure S1. Close up images of the arms showing the position of the interpreted suckers.

Figure S2. Relative size of gladii in the sample.

Figure S3. The characteristic apical (opening) angle of the gladius vs gladius length.

Figure S4. The individual specimens of *D. syriaca* from the database of co-author (DF).

Table S1. Summary of information regarding collection numbers, repository location, genus/species-level assignment, locality information, if, and where, the specimens have been previously figured, and the type of imaging utilized for specimens included in the study.

Table S2. Summary of the measurements collected for the specimens used in the study.

Table S3. Indices calculated for the specimens used in the study.

Table S4. Characters observed in the specimens in the study.

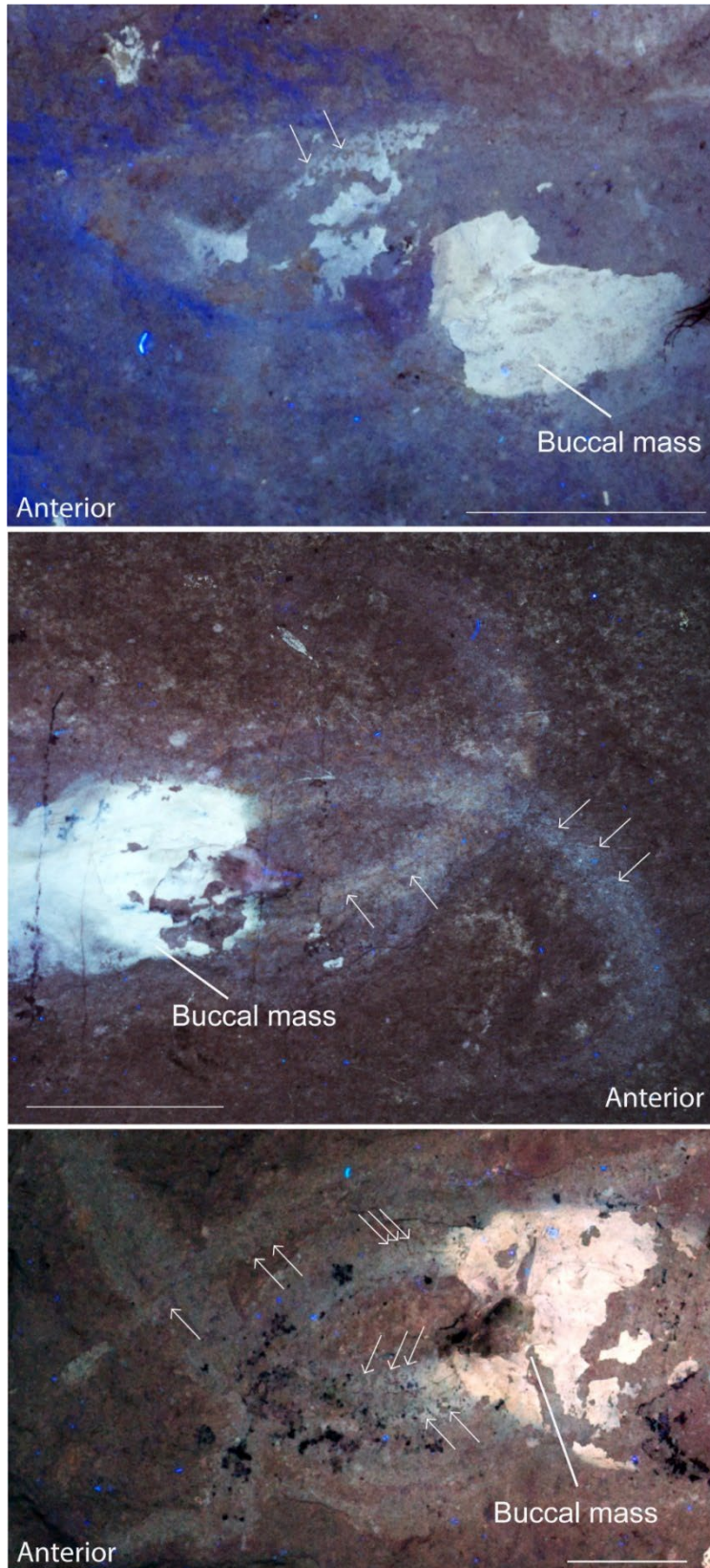
Table S5. Soft tissues preserved in the specimens, and how they appear in the different imaging techniques.

Table S6. Genera-level comparisons between *Dorateuthis* and other prototeuthids.

Table S7. Character coding of *Dorateuthis syriaca* in the existing matrices of Whalen & Landman 2022, and comparisons with Sutton et al. 2016

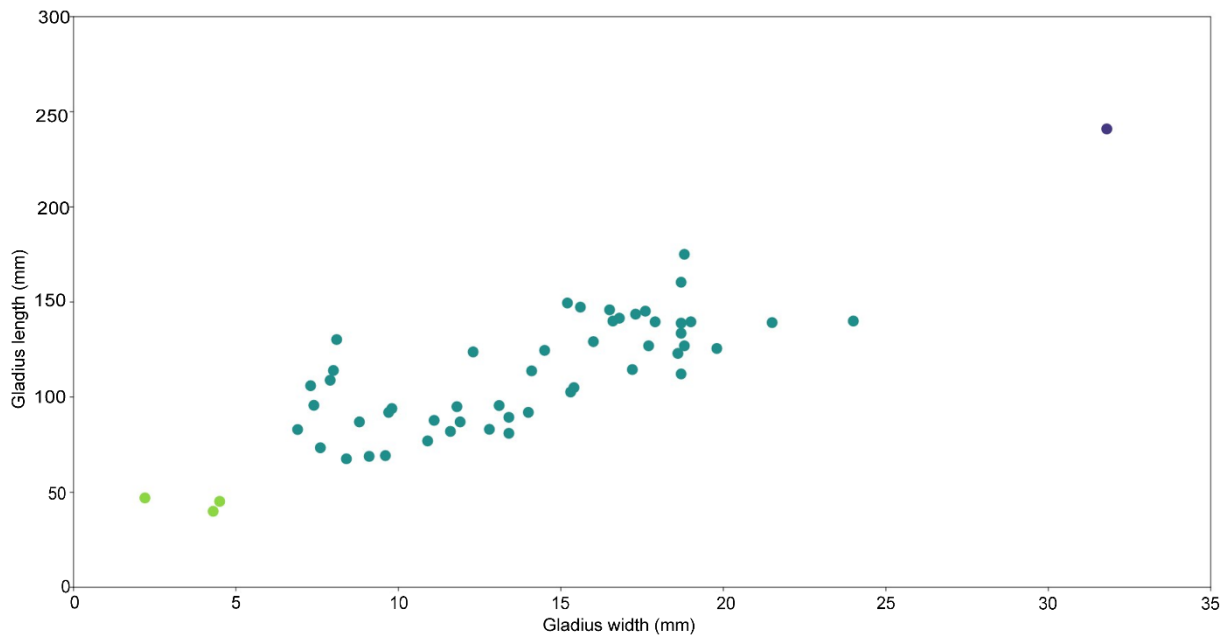
Whalen, C.D. and Landman, N.H. 2022. Fossil coleoid cephalopod from the Mississippian Bear Gulch Lagerstätte sheds light on early vampyropod. evolution. *Nature Communications* 13 (1): 1107.

Sutton, M., Perales-Raya, C., and Gilbert, I. 2016. A phylogeny of fossil and living neocoleoid cephalopods. *Cladistics* 32: 297–307.

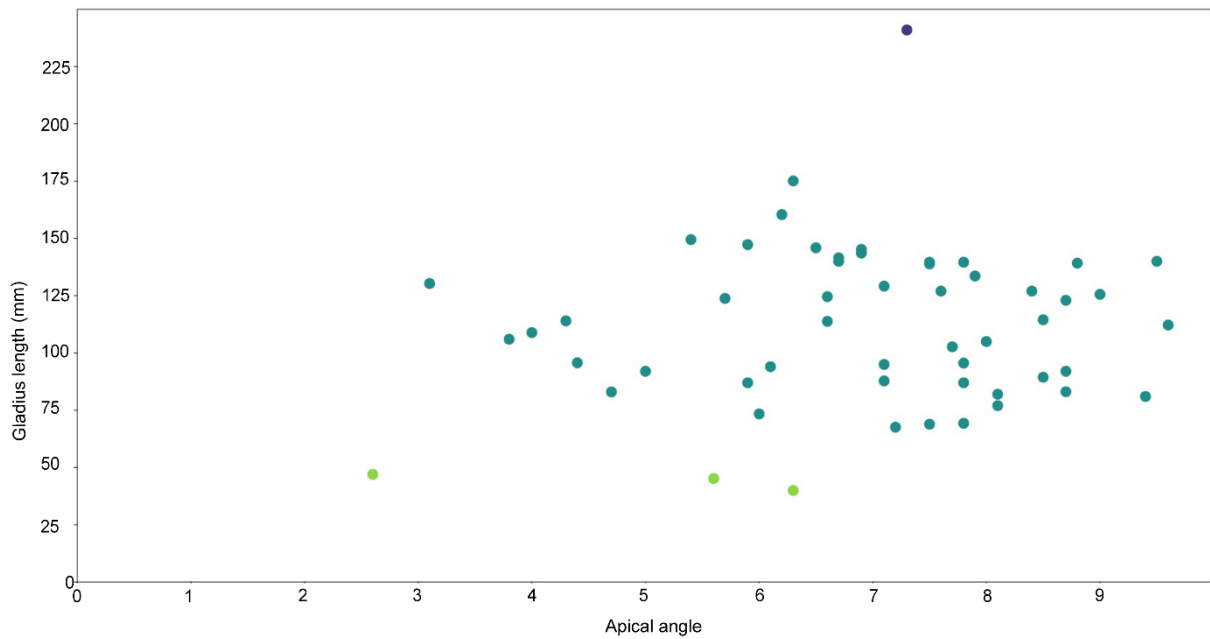


Supplementary Figure 1: Close up images of the arms showing the position of the interpreted suckers.

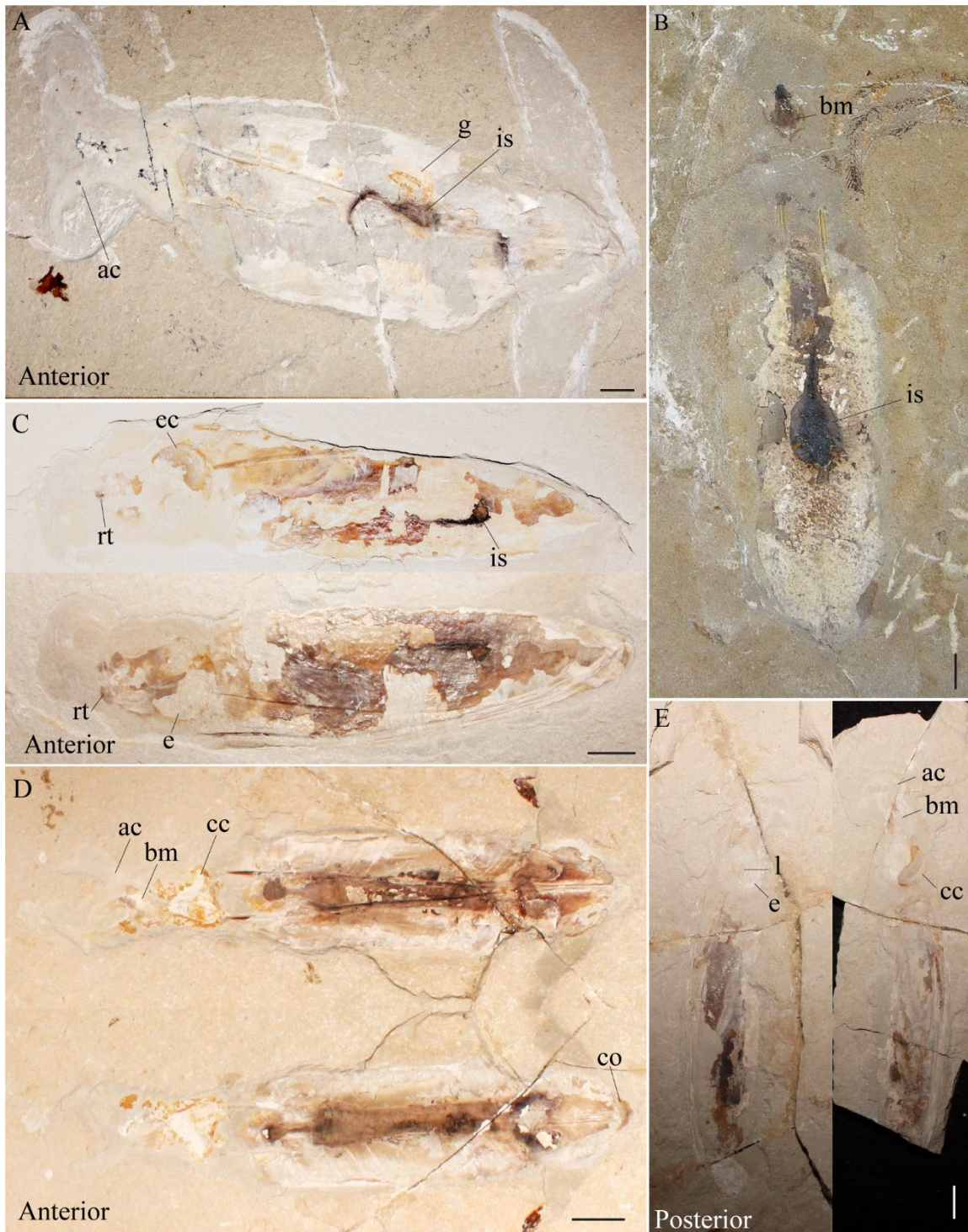
Top (BHI 2203); center (BHI 2201), and bottom (BHI 2229). Scale bars 10mm.



Supplementary Figure 2: Relative size of gladii in the sample. The three different colours represent the mantle size delineations from “small” to “very large” outlined in Fuchs (2020) and followed here. All the specimens of *D. syriaca* fall within the variation from "very small" to "medium" according to this categorization. Three specimens are “very small” (<50 mm) and are represented by the pale green points. The holotype is included in this group. The majority of specimens (dark green points) are “small” (50 – 200 mm). Only one specimen (MNHN.F.A50402) is “medium” (201–400 mm) (purple point) in size.



Supplementary Figure 3: The characteristic apical (opening) angle of the gladius is described as $<12^\circ$ for *D. syriaca* (Fuchs 2020), and between $6\text{--}10^\circ$ for *D. syriaca* (Fuchs & Larson 2011). All individuals in the sample reflect an apical angle smaller than the upper limit (10°) for the species, though some are smaller than the lower limit (6°). The smallest angle here (2.6°) belongs to MNHN.F.A68491 and the largest (9.6°) to BHI 2222. The holotype has an apical angle of 6.3° . The mean angle is 6.9° (Standard error: 0.2).



Supplementary Figure 4: The individual specimens of *D. syriaca* from the database of co-author, DF. A) Coll Nohra_1; B) RS_1; C) V_33; D) V_54; E) V_61. Scale bars 10 mm. Abbreviations: ac – arm crown, bm – buccal mass, cc – cephalic cartilage, co – conus, e – eye, g – gill, is – ink sac, rt – rostrum tip.

Supplementary Table 1: Summary of information regarding collection numbers, repository location, genus/species-level assignment, locality information, if, and where, the specimens have been previously figured, and the type of imaging utilized for all the specimens included in the study. μ XRF major-to-trace elemental mapping (XRF) was acquired at SOLEIL Synchrotron (PUMA Beamline), Saint-Aubin, France, Centre de Recherche sur la Conservation, MNHN, CNRS (M6 Jetstream Bruker XRF, UAR 3224) Paris, France, and the iXRF facility (ATLAS M benchtop microEDXRF (micro XRF) spectrometer), Austin, TX, USA. Reflectance Transformation Imaging (RTI) and UV light photography was completed at the MNHN, Paris, France; UV-visible-near infrared multi-spectral imaging (MSI) was acquired at SOLEIL Synchrotron (IPANEMA Platform), Saint-Aubin, France. X-ray absorption spectroscopy (XAS) was acquired at SOLEIL Synchrotron (PUMA Beamline), Saint-Aubin, France. Abbreviations: DF = Dirk Fuchs, co-author.

Specimen number	Reposited	Originally Assigned Genus	Locality	Age	Preserved Orientation	XRF	XAS	MSI	RTI	UV	Photo	Figured
BMNH_C5017_HOLOTYP	BMNH	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Ventral	X			X	X	X	Woodward 1883; Fuchs 2006; Fuchs&Larson 2001; Fuchs 2006 (Thesis) 171
BNHM_No label	BMNH		Lebanon, undetermined		Ventral						X	
MNHN.F.A88588	MNHN		Hjoula	Cenomanian	Dorsal	X	X	X	X	X	X	
MNHN.F.A88589	MNHN		Hjoula	Cenomanian		X		X	X	X	X	
MNHN.F.A88590	MNHN		Hjoula	Cenomanian	Dorsal	X		X	X	X	X	
MNHN.F.A50394	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Ventral			X	X	X	X	Jattiot et al. 2015, Fig 5.1; 12
MNHN.F.A50396	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Ventral	X			X	X	X	Jattiot et al. 2015, Fig 12
MNHN.F.A50398	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Ventral				X	X	X	Jattiot et al. 2015, Fig 4.3; 5; 9; 10
MNHN.F.A50400 (counter A69219)	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Dorsal/Ventral				X	X	X	Jattiot et al. 2015, Fig 7; 13
MNHN.F.A50402 (counter A68475)	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Dorsal/Ventral					X	X	Jattiot et al. 2015, Fig 4.3; 13.2 and 3 - ink sac: 13.2 "50402" - actually 69297. Fig. 13.3 "50401" - actually 50402.
MNHN.F.A69297 (A50405?)	MNHN	<i>Belemnites sp.</i>	Haqel	Cenomanian	Ventral						X	Jattiot et al. 2015, Fig 5.2, 11.1; 12
MNHN.F.A68491	MNHN	<i>Belemnites sp.</i>	Lebanon		Ventral				X	X	X	Jattiot et al. 2015
MNHN.F.R06746	MNHN	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Dorsal/Ventral	X		X	X	X	X	Roger 1946, Planche IX: Jattiot et al. 2015, Fig 14; Donovan & Fuchs 2016 Fig 15
NPL52121a&b	UT, Austin	<i>Dorateuthis</i>	Haqel	Cenomanian	Dorsal/Ventral						X	Fuchs 2020
BHI 2200	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal					X	X	
BHI 2201	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral					X	X	Fuchs & Larson 2011, Fig. 2
BHI 2202	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral					X	X	
BHI 2203	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal and Ventral					X	X	
BHI 2205	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X				X	X	Fuchs & Larson 2011. Figs2&5
BHI 2206	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventro-lateral						X	
BHI 2207	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral					X	X	Fuchs & Larson 2011, Fig2 & 4; Fuchs et al 2016 (locomotion) fig. 9
BHI 2208	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventro-lateral						X	
BHI 2209	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal/Ventral					X	X	
BHI 2210	BHI	? <i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal					X	X	Fuchs & Larson 2011, Fig 2
BHI 2212	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral					X	X	
BHI 2213	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal					X	X	
BHI 2214	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventro & dorso-lateral					X	X	
BHI 2215	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral					X	X	
BHI 2216	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral						X	
BHI 2217	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral						X	
BHI 2219	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral						X	Fuchs & Larson 2011 Fig.6
BHI 2220	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal					X	X	Fuchs & Larson 2011; Fuchs et al. 2016 (locomotion) fig. 1
BHI 2221	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal					X	X	
BHI 2222	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral						X	

BHI 2223	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventro-lateral		X	
BHI 2225	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X	X	
BHI 2226	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal		X	
BHI 2227	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X	X	
BHI 2228	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X	X	
BHI 2229	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X	X	
BHI 2232	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal	X	X	
BHI 2233	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Ventral	X	X	Fuchs & Larson2011 Fig 5.3
BHI 5779	BHI	<i>Dorateuthis sp.</i>	Hjoula	Cenomanian	Dorsal		X	Larson 2010, Fig.1, 3A. Donovan & Fuchs 2016 Fig 12. Fuchs 2020 Fig.3,1b; Fuchs & Larson, 2011a, fig 4 & 10; Jattiot et al 2015, fig 11.4. Nixon 2015, fig 6
Coll Nohra_New Image (DF)	Private collection	<i>Dorateuthis</i>	Lebanon, undetermined		Dorsal		X	
RuSmith (DF)	Private collection		Hjoula	Cenomanian			X	
MSNMi_25128	MSNM		Lebanon, undetermined				X	
MSNMi 24800	MSNM	<i>Dorateuthis syriaca</i>	Hjoula	Cenomanian	dorso-lateral	X	X	Fuchs 2006, P2
MSNMi 25134	MSNM	<i>Dorateuthis syriaca</i>	Hjoula	Cenomanian	dorso-lateral	X	X	Fuchs 2006 Pl.III
MSNMi 25144	MSNM	<i>Dorateuthis syriaca</i>	Hjoula	Cenomanian	Ventral	X	X	Fuchs2006 Pl. 1a, b. Fuchs 2006 (Thesis) 17J
NHMW1998z01050000	NHMW	<i>Dorateuthis syriaca</i>	Sahel Alma	Santonian	Ventral			Fuchs & Larson2011 Fig 3: Lukeneder & Harzhauser 2004, fig 2, plates 1 & 2; Fuchs2006 Pl.II. Jattiot2015 Fig.12. Nixon 2015, fig. 6
V_33 (DF)	Private collection		Lebanon, undetermined		Dorsal/Ventral		X	
V_54 (DF)	Private collection		Lebanon, undetermined		Dorsal/Ventral		X	
V_61 (DF)	Private collection		Lebanon, undetermined		Dorsal		X	
MNHNL_CRE047	MNHNL	<i>Dorateuthis syriaca</i>	Haqel	Cenomanian	Ventral		X	Jattiot et al. 2015 fig 11.2, Fuchs & Larson 2011 Fig. 4, Don&Fuchs2016 Fig.15.b

British Museum of Natural History (BMNH)
Muséum national d'Histoire naturelle (MNHN)
UT, Austin (Jackson School Museum of Earth History)
The Black Hills Institute of Geological Research, Inc. (BHI)
Museo Civico di Storia Naturale di Milano (MSNM)
Natural History Museum Vienna (NHMW)
Musée national d'histoire naturelle, Luxembourg (MNHNL)
Staatliches Museum für Naturkunde Stuttgart (SMNS)

Supplementary Table 4: Characters observed in the specimens in the study.

Specimen number	Median field triangular: Yes/No	Widest section of the gladius is at the median field: Yes/No	Fin Shape: (Name)	Are lateral reinforcements (keels) present: Yes/No	Are the lateral reinforcements (keels) pronounced: Yes/No	The lateral reinforcements (keels) are continuous from anterior-posterior extremities: Yes/No	Is there a Central Median Field (Linear area in the central part of the median field)	Is there a Median reinforcement (Line or ridge) present: Yes/No	If Yes, is this a Line or Ridge. If No the cell is empty	If Yes, is this Unipartite or Bipartite. If No the cell is empty	Lateral Fields Present: Posterior/Anterior/Both/No	Is there a conus present: Yes/No	Is the cephalic cartilage visible? (Yes/No)	Cephalic cartilage orientation: Lateral/Dorsal/Ventral. If not present the cell is empty	Ink sac	Paired structures Present	Gills preserved?	Stomach contents	Eye/s preserved	Beak/Cavity preserved	Suckers	Axial nerve
BMNH_C5017 HOLOTYPE	Yes	Yes	Oar-shaped?	Yes	Yes	Yes	No	Yes	Ridge	Bipartite			Yes		Yes	Yes	Yes?	Yes	Yes?	Yes		
BMNH No label	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite			Yes	Ventral	Yes							
MNHN.F.A88588	Yes	Yes	Oar-shaped	Yes	Yes	Yes	Yes	Yes	Line	Unipartite	Anterior		Yes	Dorsal	Yes						Yes	
MNHN.F.A88589	Yes	Yes	Oar-shaped	Yes	Yes	Yes	No	No					Yes	Ventral	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
MNHN.F.A88590	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite			Yes	Ventral	Yes						Yes	
MNHN.F.A50394	Yes	Yes		Yes	Yes	Yes	No	Yes	Ridge	Bipartite	Posterior				Yes	Yes					Yes	
MNHN.F.A50396	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite					Yes	Yes			Yes		Yes	
MNHN.F.A50398	Yes	Yes		Yes	Yes	Yes	No	Yes	Ridge	Unipartite					Yes						Yes	
MNHN.F.A50400 (counter A69219)	Yes	Yes		Yes	Yes	Yes	No	No							Yes	Yes					Yes	
MNHN.F.A50402 (counter A68475)	Yes	Yes		Yes	Yes	Yes	No	No							Yes			Yes	Yes	Yes		
MNHN.F.A50405? (A69297)	Yes	Yes		Yes	Yes	Yes	No	No							Yes							
MNHN.F.A68491	Yes	Yes		Yes	Yes	Yes	No	No							Yes			Yes			Yes	
MNHN.F.R06746	Yes	Yes		Yes	Yes	Yes	No	Yes	Ridge	Bipartite					Yes			Yes	Yes	Yes	Yes	
NPL52121a&b	Yes	Yes	Oar-shaped	Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Dorsal	Yes	Yes	Yes				Yes	
BHI2200	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Ventral	Yes		Yes				Yes	
BHI2201	Yes	Yes		Yes	Yes	Yes	Yes	No			Anterior			Ventral	Yes						Yes	
BHI2202	Yes	Yes		Yes	Yes	Yes	No	Yes	Ridge	Unipartite					Yes		Yes					
BHI 2203	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	unipartite	Anterior				Yes		Yes				Yes	
BHI 2205	Yes	Yes	Oar-shaped	Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Ventral	Yes		Yes	Yes	Yes	Yes	Yes	Yes
BHI 2206	Yes	Yes		Yes	Yes	Yes	No	No							Yes							
BHI 2207	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Ridge	Unipartite	Anterior			Ventral	Yes							
BHI 2208	Yes	Yes		Yes	Yes	Not visible	No	No							Yes							
BHI 2209	Yes	Yes		Yes	Yes	Yes	No	No						Ventro & dorso-lateral	Yes				Yes	Yes		
BHI 2210	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Ridge	Unipartite					Yes							
BHI 2212	Yes	Yes	Oar-shaped	Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Dorsal?	Yes			Yes	Yes	Yes	Yes	Yes
BHI 2213	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Ridge	Unipartite					Yes		Yes		Yes	Yes	Yes	Yes
BHI 2214	Yes	Yes		Yes	Yes	Yes	No	Yes	Ridge	Bipartite				ntrol & dorso-late	Yes			Yes	Yes	Yes	Yes	Yes
BHI 2215	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Ventro-lateral	Yes			Yes	Yes	Yes	Yes	Yes
BHI 2216	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Ventral	Yes			Yes	Yes	Yes	Yes	
BHI 2217	Yes	Yes		Yes	Yes	Yes	Yes	No			Anterior				Yes							
BHI 2219	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite				Ventral	Yes		Yes	Yes	Yes	Yes	Yes	
BHI 2220	Yes	Yes		Yes	Yes	Yes	Yes	No							Yes		Yes	Yes	Yes	Yes	Yes	
BHI 2221	Yes	??		Yes	Yes	Yes	No	Yes	Line	Unipartite					Yes			Yes	Yes	Yes	Yes	
BHI 2222	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Ridge	Bipartite	Anterior			Ventral	Yes	Yes			yes	yes	Yes	Yes
BHI 2223	Yes	Yes		Yes	Yes	Yes	No	No							Yes						Yes	
BHI 2225	Yes	Yes		Yes	Yes	Yes	No	No			Posterior			Ventral	Yes		Yes	Yes	Yes	Yes	Yes	
BHI 2226	Yes	??		Yes	Yes	Yes	Yes	Yes	Line	Unipartite	Posterior				Yes							
BHI 2227	Yes	Yes	Oar-shaped	Yes	Yes	Yes	Yes	No						Ventral	Yes						Yes	Yes
BHI 2228	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line	Unipartite				ventral	Yes			Yes	Yes	Yes	Yes	Yes
BHI 2229	Yes	Yes		Yes	Yes	Yes	No	No						Ventral	Yes			Yes	Yes	Yes	Yes	Yes
BHI 2232	Yes	Yes		Yes	Yes	Yes	No	No							Yes			Yes	Yes	Yes	Yes	
BHI 2233	Yes	Yes		Yes	Yes	Yes	No	No			Posterior				Yes		Yes					
BHI 5779	Yes	Yes		Yes	Yes	Yes	Yes	No						Dorsal	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Coll Nohra_New Image (DF)	Yes	Yes		Yes	Yes	Yes	No	No							Yes		Yes					
RuSmith (DF)	Yes	Yes		Yes	Yes	Yes	No	No							Yes						Yes	
MSNMi 25128	Yes	Yes		Yes	Yes	Yes	Yes	No							Yes							
MSNMi 24800	Yes	Yes		Yes	Yes	Yes	No	No				Yes			Yes		Yes					
MSNMi 25134	Yes	Yes		Yes	Yes	Yes	No	No							Yes		Yes				Yes	
MSNMi 25144	Yes	Yes		Yes	Yes	Yes	No	No			Posterior				Yes		Yes					
NHMW1998.01050000	Yes	??		Yes	Yes	Yes	No	Yes	Ridge	Unipartite					Yes	Yes		Yes			Yes	
V 33 (DF)	Yes	Yes		Yes	Yes	Yes	No	No							Yes				Yes	Yes	Yes	
V 54 (DF)	Yes	??		Yes	Yes	Yes	Yes	??				Yes	Yes	Dorsal and ventra	Yes				Yes	Yes	Yes	Yes
V 61 (DF)	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Line					Lateral	Yes		Yes		Yes	Yes	Yes	Yes
MNHL_CRE047	Yes	Yes		Yes	Yes	Yes	No	No						Ventral	Yes		Yes		Yes	Yes	Yes	Yes

Supplementary Table 5: Soft tissues preserved in the specimens, and how they appear in the different imaging techniques.

	Muscular Mantle	Head mantle fusion	Arms	Tentacles	Tentacular pockets	Circular Suckers	Hooks	Cirri-like appendages	Sucker rings	Arm web	Funnel	Fins	Cephalic Cartilage	Fin cartilage	Buccal Mass	Beak	Esophagus	Stomach	Crop	Respiratory system	Circulatory system	Excretory system	Reproductive system	Digestive system	Axial nerves	Eyes	Lens in eye	Brain/Optic lobes	Statocysts	Paired structures Present	Ink sac			
Donovan & Fuchs 2016	1		1									1	1		1	1	1	1	1	1			?											
This study	1		1	X	X	1	X	X	X	X	1	1	1		1	1	1	1	1	1	1 (Gills ~22%, branchial heart ~2%)	1 (blood vessels in eyes)	1 (Coprolite)	1 (Oviducts?)	1 (Digestive gland? ~2%, lower intestine ~2%)									
Hadjouta	1		1			1					1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1		
Hakel	1					1					1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1		
Sahel Alma	1		1			1					1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	
Percentage	~70%		~48%			~11%					~2%	~13%	~46%		56%	~67%	~20%	~31%	~4%	~24%	~22%	~2%	~2%	~4%	~4%	~41%	~7%	~6%	~7%	~15%	~94%			
Natural light	1		1			1					1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	
<u>Visible as:</u>	Stain/white coating		Not visible/stain/imprint/faint white coating			Not visible/faint white coating					indicated by Black/brown colour	Imprint/faint staining			Brown Mass/imprint	Contour/outline	Staining	Mass, or bones/fins etc.	bones/fins etc.	Imprints/stained lamellae (orange/black)	Orange filaments	Stained corresponding shape	Imprints		White coating (digestive gland), Black/brown corresponding shape.	Stain	ovoid imprints/stained orange	ovoid imprints/stained orange	Orange staining	Orange staining	Imprint/faint staining	Black/brown corresponding shape.		
UV light	1		1			1					1	1		1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	
<u>Visible as:</u>	White coating		faint white coating											Faint staining	White coating	Black triangular shape	White coating	Does not fluoresce	Does not fluoresce	Black filaments/lamellae with faint white coating	Black filaments	Does not fluoresce	Does not fluoresce		White coating (digestive gland), Black/brown corresponding shape.	Stain	Not visible	White coating	White coating	Black staining	Staining/white coating	Black/brown corresponding shape.		
MSI																																		
<u>Visible as:</u>											Faint staining				White coating	Black triangular shape	White coating	Does not fluoresce	Does not fluoresce	lamellae with faint white coating	Not observed in MSI specimen						Faint black corresponding shape		White coating					
µXRF	1		1								1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1
<u>Visible as:</u>	Yttrium, Strontium		Faint Yttrium, Strontium			-					Faint Yttrium, Strontium	Faint Yttrium, Strontium	Yttrium, Titanium	Yttrium	Faint Yttrium, Strontium	Yttrium, Titanium	Yttrium	No unique elemental trace	No unique elemental trace	No unique elemental trace	Not observed in µXRF specimen	Titanium		Yttrium, Strontium	Yttrium, Strontium	Not observed in µXRF specimen	Yttrium, Titanium	Yttrium, Strontium	Yttrium, Strontium	No unique elemental trace	Yttrium, Strontium	Black/brown corresponding shape.		
n=	38		26			6					1	7	25		30	36	11	17	2	13	12	1	1	2	2	22	4	3	4	8	51			

Supplementary Table 6: Genera-level comparisons between *Dorateuthis* and other prototeuthids. *D. syriaca* is also included in the table. Genus-level data is taken from Fuchs (2020).

	<i>Dorateuthis</i>	<i>D. syriaca</i> (F&L'11)	This sample	<i>Boreopeltis</i>	<i>Plesioteuthis</i>	<i>Paraplesioteuthis</i>	<i>Senefelderteuthis</i>	<i>Romaniceuthis</i>
Character: Body size	Medium		Small - large	Medium	Medium	Medium	Medium	Medium
Measurement: Total body size (mm)	201 - 400 mm		< 200; >400	201 - 400 mm	201 - 400 mm	202 - 400 mm	201 - 400 mm	202 - 400 mm
Character: Gladius size			Very small - Medium					
Measurement: Gladius length (mm)			40 - 214					
Mantle outline		"Bullet- or torpedo-shaped mantle outline"	Torpedo, arrow, and rugby ball-shaped outline					torpedo-shaped
Character: Gladius width	Slender	Slender	Very slender - slender	Slender - moderate	Very slender - slender	Slender - moderate	Very slender - slender	Very slender - slender
Indices: Gladius width	0.10-0.19		0.05 - 0.17	0.15-0.25	0.05-0.15	0.15 - 0.25	0.05-0.15	0.05-0.15
Character: Median Field	Very slender		Same as gladius width indices	Slender	Slender	Slender - moderate	Very slender - slender	Very slender
Indices: Median Field			0.05 - 0.17	0.20-0.30	0.25-0.34	0.25-0.35	0.15-0.25	0.10 - 0.19
Median Field opening (apical) angle (°)	<12°	6 - 10°	2.6 - 9.6°	12 - 17°	12°-19°	14-20°	9-14°	<12°
Median Field area (Character)	Very Large		Very large	Large	Very Large	Large - Very large	Large - Very large	Large - Very large
Indices: Median Field area	>0.95		0.8 - 0.9	0.70-0.80	>0.90	0.75-0.85	0.75-0.85	0.75-0.85
Median reinforcements	No keel	Bipartite ridge ("delicate")	Line or Ridge (unipartite or bipartite), and/or Central median field	Broad median line, no keel	pronounced uni- or bipartite keel (posterior only)	bipartite median ridge	pronounced median keel absent except in conus region, broad reinforcement anteriorly.	Median keel
Anterior margin of Gladius	Lateral keels and central median field anteriorly projected	Possibly concave with short anterior projection of the median reinforcement	Convex	convex	weakly convex	Anterior projection of the median and lateral reinforcement		Poorly known
Lateral reinforcements (keels)	Pronounced. Continuous from anterior to posterior.	Pronounced. Continuous from anterior to posterior.	Pronounced. Continuous from anterior to posterior.	Anteriorly narrow, posteriorly wide	Anterior	present	Pronounced. Continuous from anterior to posterior.	
Character: Lateral fields	Poorly known. "If present then both very short and very slender"			Slender	Slender	Slender	Moderate	Slender - moderate
Indices: Lateral fields	Poorly known. "If present then both very short and very slender"		Anterior: Posterior:	0.55-0.80	0.65-0.75	0.85-0.95	1.00-1.10	0.95-1.05
Conus	Poorly known. "If present then both very short and very slender"	Poorly known	Poorly known	Pointed conus				
Hyperbolar zone (Character)		Unknown		Long	Very short - short	Moderate - long	Moderate	Short
Indices: Hyperbolar zone		Unknown		0.5-0.7	0.05-0.15	0.45-0.55	0.35-0.45	0.20-0.29
Character: Arm length	Moderate (0.40 - 0.80)		Unknown	Unknown	Short	Poorly known	Moderate - long	Short
Indices: Arm length	~0.5		Unknown	Unknown	~0.2	Poorly known	0.7-1.0	~0.25
Arm morphology	Dorsal arm pair elongated	8 arms. The longest and thickest are in dorsal position. The shortest and most delicate arms are ventral, and the ventrolateral and dorsolateral arm pairs are equal in length and thickness		Unknown	Dorsal arm pair elongated		Poorly known	
Fins	"oar-shaped"			Unknown		Poorly known		
Age	Lower - Upper Cretaceous			Upper Jurassic - Upper Cretaceous	Jurassic	Lower Jurassic	Upper Jurassic	Mid-Jurassic
Localities	Lebanon, Germany, Cape Verde Islands, Netherlands		Lebanon	Germany, France	Germany, France	Germany, France, Canada	Germany	France, (Germany, UK?)

Supplementary Table 7: Character coding of *Dorateuthis syriaca* in the existing matrices of Whalen & Landman 2022, and comparisons with Sutton et al. 2016. The minor modifications included in Kruta et al. 2016 and Rowe et al. 2022 are also included. New characters added by Whalen et Landman 2022 are indicated by X highlighted in orange. Character state change suggestions from the observations documented in the present study are highlighted in yellow.

	Shell/gladus/vestigial shell: absent (0); present (1)	Shell location in relation to the rest of the body: external (0); internal (1)	Shell extent along A-P axis: anterior half (0); posterior half (1); whole or most of the body length (2)	Shell extent along D-V axis: dorsal half (0); whole or most of the body height (1)	Discrete proostracum developed: no (0); yes (1)	Anterodorsally extended proostracum: absent (0); present (1)	Septate phragmocone: absent (0); present (1)	Mineralized phragmocone: absent (0); present (1)	Siphuncle linking chambers, or homologous structure: absent (0); present (1)	Position of siphuncle within the shell: ventral (0); central (1)	Median field (or homologous rachis): absent (0); present (1)	Median field (or homologous rachis): absent (0); present (1)	Lateral fields (or homologous wings): absent (0); present (1)	Primordial rostrum: absent (0); present (1)	Mineralized primordial rostrum: absent (0); present (1)	Primordial rostrum length: short, up to 25% of the shell length (0); strongly developed, 25% or more of the shell length (1)
<i>Dorateuthis syriaca</i>																
Character # Whalen & Landman 2022	1	2	3	4	5	6	7	8*	9	10	11	12	13	14	15	16
New Character in Whalen & Landman 2022						X								X	X	
Character state	1	1	2	0	1	1	0	-	-	-	1	0	1	0	-	-
Character # Sutton et al. 2016	0	1	2	3	5		7	4	8	9	11	12	13			15
Character state	1	1	2	?	1		0	?	?	?	1	0	1			-
#6, 10, 18, 21, 27, 28, 30, 31, 32, 33, 36, 37, 50, 77, not in Whalen & Landman 2020. In Sutton et al. 2015, 0, 0, -, 0, 0, ?, -, -, -, -, 0, -, 0, 0, *																
* = adapted																
Character # Kruta et al. 2016	0	1	2	3	5		7	4	8	9	11	12	13			15
Character state	1	1	2	?	1		0	?	?	?	1	0	1			?
Amended character states: this study														Two types		
Character # Rowe et al. 2020	0	1	2	3	5		7	4	8	9	11	12	13			15
Character state	1	1	2	?	1		0	?	?	?	1	0	1			?

	Rostrum or guard: absent (0); present (1)	Conus (primary cone): absent (0); present (1)	Shell coiled: no (0); yes, endogastric (1); yes, exogastric (2)	Condition of the primary cone: funnel-like cone (0); cup-like cone (1)	Primary cone open ventrally: absent (0); present (1)	Patella: absent (0); present (1)	'Cone flags': absent (0); present (1)	Ventral folding of posterolateral gladius margin: flat, not folded (0); folded (1)	Ventral folding of posterolateral gladius margin: folded but not fused (e.g., 'pseudocone') (0); folded and fused ventrally ('secondary cone') (1)	Gladius length / gladius width: < 2 (0); ≥ 2 (1); ≥ 3 (2); ≥ 4 (3); ≥ 5 (4); ≥ 10 (5) [ordered character]	Vane length / rachis length: < 0.3 (0); ≥ 0.3 (1); ≥ 0.5 (2); ≥ 0.7 (3); ≥ 0.9 (4) [ordered character]	Wing length / rachis length: < 0.3 (0); ≥ 0.3(1); ≥ 0.5 (2); ≥ 0.7 (3); ≥ 0.9 (4) [ordered character]	Cone flags length / gladius length: < 0.3 (0); ≥ 0.3 (1)	Vane width / rachis width at vane: < 0.25 (0); < 0.75 (1); < 1.25 (2); < 2.5 (3); < 4 (4); ≥ 4 (5) [ordered character]	Wing width / rachis width at wing: < 0.25 (0); < 0.75 (1); < 1.25 (2); ≥ 2.5 (3) [ordered character]	Position of greatest width of median field / rachis: at extreme anterior (0); posterior to extreme anterior (1)	Position of greatest width of median field / rachis: anterior to hyperbolar zone / vane insertion but not at extreme anterior (0); at hyperbolar zone / vane insertion (1)	Rachis width at vane insertion / rachis width 2/3 of the way between vane insertion and the anterior: ≤ 1 (0); ≤ 1.5 (1); ≤ 2.5 (2); > 2.5 (3) [ordered character]	Concave inflexion or inflexions in median field / rachis: absent (0); present (1)	Outline of posterior margin of lateral field / wings: convex (0); straight (1); concave (2)
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
0	1	0	0	-	X	1	0	-	4	-	2	0	-	0	0	-	-	0	0	
14	16	17	20	19	22	23	23	24	25	26	29	34	35	38	38	39	40	41		
0	1	0	?	?	?	?	?	5	-	0	-	-	?	2	2	-	0	?		
14	16	17	20	19	22	23	23	24	25	26	29	34	35	38	38	39	40	41		
0	1	0	?	?	?	?	?	5	?	0	?	?	?	2	2	?	0	?		
14	16	17	20	19	22	23	23	24	25	26	29	34	35	38	38	39	40	41		
0	1	0	?	?	?	?	?	5	?	0	?	?	?	2	2	?	0	?		

	Shape of posterior end of median field / rachis: concave (0), flat (1), convex (2)	Nature of convex end: rounded (0); pointed (1)	Shape of anterior tip of median field: concave (0), flat (1), convex (2)	Nature of convex tip: rounded (0); pointed (1)	Inflexion in gladius outline where lateral asymptote intersects margin: absent (0); present (1)	Inflexion in gladius outline where lateral asymptote intersects margin: weak (0); strong/sharp (1)	Tapering of the hyperbolic zone / vane both anteriorly and posteriorly (forming a spindle shape): absent (0); present (1)	Angle between inner/median asymptote and midline: ≤ 5 degrees (0); > 5 and ≤ 10 degrees (1); > 10 and ≤ 15 degrees (2); > 15 and ≤ 20 degrees (3); > 20 degrees (4) [ordered character]	Angle between outer/lateral asymptote and midline: ≤ 5 degrees (0); > 5 and ≤ 10 degrees (1); > 10 and ≤ 15 degrees (2); > 15 and ≤ 20 degrees (3); > 20 degrees (4) [ordered character]	Ventral median field / rachis in transverse section: smooth (0); interrupted by a median or sub-median structure or structures ('interruption(s)') (1)	Form of ventral interruption(s): concave (0); convex (1)	Form of ventral interruption(s): line (0); rib/keel (1)	Form of ventral interruption(s): rib (0); keel (1)	Anterior ventral interruption(s): absent (0); present (1)	Posterior ventral interruption(s): absent (0); present (1)	Ventral interruption bipartite (at any point anterior-posterior)?: no (0); yes (1)	Dorsal median field / rachis in transverse section: smooth (0); interrupted by a median or sub-median structure or structures ('interruption(s)') (1)	Form of dorsal interruption(s): concave (0); convex (1)	Form of dorsal interruption(s): line (0); rib/keel (1)	Form of dorsal interruption(s): rib (0); keel (1)
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	
2	1	0	-	-	-	-	1	-	1	0	-	-	1	1	?	1	1	1	1	
42	43	44	45	46	46	47	48	49	51	52	52	52	53	53	54	55	56	56	56	
2	1	0	-	-	-	-	0	0	1	0	0	0	2	2	?	1	3	3	3	
42	43	44	45	46	46	47	48	49	51	52	52	52	53	53	54	55	56	56	56	
2	1	0	?	?	?	?	0	0	1	0	0	0	2	2	?	1	3	3	3	
	2	0													1?		Keel not in Dora.Line/Ridge			
42	43	44	45	46	46	47	48	49	51	52	52	52	53	53	54	55	56	56	56	
2	1	0	?	?	?	?	0	0	1	0	0	0	2	2	?	1	3	3	3	

Number of fin pairs: 1 pair (0); 2 pairs (1)	Shape of fins: lobate (0); rhomboidal (1); skirt-like (2)	Posterior fin termination: subterminal (0); terminal (1)	Maximum length of unmodified arms compared to mantle length: shorter (0); longer or approximately equivalent (1)	Maximum length of unmodified arms compared to mantle length: approximately the same, $\pm 10\%$ (0); longer (1)	Number of appendage pairs: many (0); 4-5 (1)	Reduction of appendage pair II: not reduced (0), reduced to filaments or absent (1)	Loss of appendage pair II: retained (0); lost (1)	Modification of appendage IV into a tentacle: absent (0); present (1)	Loss of tentacles in adulthood: no (0); yes (1)	Retractile tentacles: absent (0); present (1)	Tentacle suckers: in up to 4 rows (0); in more than 4 rows (1)	Tentacle locking apparatus: absent (0); present (1)	Tentacle locking apparatus: present on carpus only (0); present on manus and carpus (1)	Interbrachial web: absent (0); present (1)	True arm hooks: absent (0); present (1)	Cirri or spines on arms: absent (0); present (1)	Suckers on any appendage: absent (0); present (1)	Sucker-hooks: absent (0); present (1)	Sucker symmetry: radial (0); bilateral (1)
77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
0	0	0	0	-	1	1	X	0	X	X	-	-	-	0	0	1	?	0	?
75	76	78	79	79	80	81		82			83	84	84	85	86	87	88		89
0	0	0	0	0	0	?		0			-	-	-	0	0	1	?		?
75	76	78	79	79	80	81		82			83	84	84	85	86	87	88		89
0	0	0	0	0	0	?		0			?	?	?	0	0	1	?		?
	shape name						1									0	1	0	0
75	76	78	79	79	80	81		82			83	84	84	85	86	87	88		89
0	0	0	0	0	0	?		0			?	?	?	0	0	1	?		?

	Sucker-stalk on arms: absent (sessile, unstalked) (0); present (1)	Sucker-stalk on arms: attached to arm muscles (0); not clearly attached to arm muscles (1)	Shape of stalks attached to the arm muscles: conical pillar with base and neck (0); cylinder (1)	Lining of arm suckers: neither horny nor cuticular ring (0); horny ring (1); cuticular ring (2)	Suckers (on arms) proximally: absent (0); present (1)	Suckers (on arms) proximally: 1 row (0); > 1 rows (1)	Suckers (on arms) proximally: 2 rows (0); > 2 rows (1)	Suckers (on arms) medially: absent (0); present (1)	Suckers (on arms) medially: 1 row (0); > 1 rows (1)	Suckers (on arms) medially: 2 rows (0); > 2 rows (1)	Suckers (on arms) distally: absent(0); present (1)	Suckers (on arms) distally: 1 row (0); > 1 rows (1)	Suckers (on arms) distally: 2 rows (0); > 2 rows (1)	Ink sac: absent (0); present (1)	Nuchal cartilage: absent (0); present (1)	Chromatophores: (0) absent; (1) present	Buccal crown: (0) absent; (1) present	Buccal membrane connective attachment to arm-pair V: dorsal (0); ventral (1)	Number of buccal lappets (supports): 6 (0); 7 (1); 8 (2); Many (3)	Suckers on buccal membrane: absent (0); present (1)
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	
?	?	?	?	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	
90	90	91	92	93	93	93	94	94	94	95	95	95	96	97	98	99	100	101	102	
?	?	?	?	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	
90	90	91	92	93	93	93	94	94	94	95	95	95	96	97	98	99	100	101	102	
?	?	?	?	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	
				1	0		1	0		1	0									
90	90	91	92	93	93	93	94	94	94	95	95	95	96	97	98	99	100	101	102	
?	?	?	?	?	?	?	?	?	?	?	?	?	1	?	?	?	?	?	?	

Posterior salivary gland: absent (0); present (1)	Posterior salivary gland position: posterior to brain (0); proximal to buccal mass (1)	Branchial canal: absent (0); present; (1)	Gill-lamellae attachment: free (0); sessile (1)	Nidamental glands: (0) absent; (1) present	Accessory nidamental glands: (0) absent; (1) present	Right oviduct: absent (0); present (1)	Oviducal gland symmetry: radial (0); bilateral (1); asymmetrical (2)	Oviducal gland position: gland terminal (located at end of oviduct) (0); gland subterminal (1)	Arm-pair I hectocotylyzation or other sexual modifications: absent (0); present (1)	Arm-pair IV hectocotylyzation or other sexual modifications: absent (0); present (1)	Arm-pair V hectocotylyzation or other sexual modifications: absent (0); present (1)	Spermatophore type: with ejaculatory mechanism (0); sperm-packets as in cirrate octopods (1); with encapsulated coil (2)	Dorsal mantle cavity: absent (0); present (1)	Collagenous tunic on mantle: absent (0); present (1)	Stellar ganglia connected by a commissure: absent (0); present (1)	Development of a commissure between the mantle and visceral nerve: absent (0); present (1)
137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153
?	?	?	?	?	X	?	?	?	?	?	?	?	X	X	X	X
?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
120	121	122	123	124	125	126	127	128	129	130	131					
?	?	?	?	?	?	?	?	?	?	?	?					
120	121	122	123	124	125	126	127	128	129	130	131					
?	?	?	?	?	?	?	?	?	?	?	?					
1																
120	121	122	123	124	125	126	127	128	129	130	131					
?	?	?	?	?	?	?	?	?	?	?	?					