Ontogenetic Transitions, Biomechanical Trade-Offs And Macroevolution Of Scyphozoan Medusae Swimming Patterns

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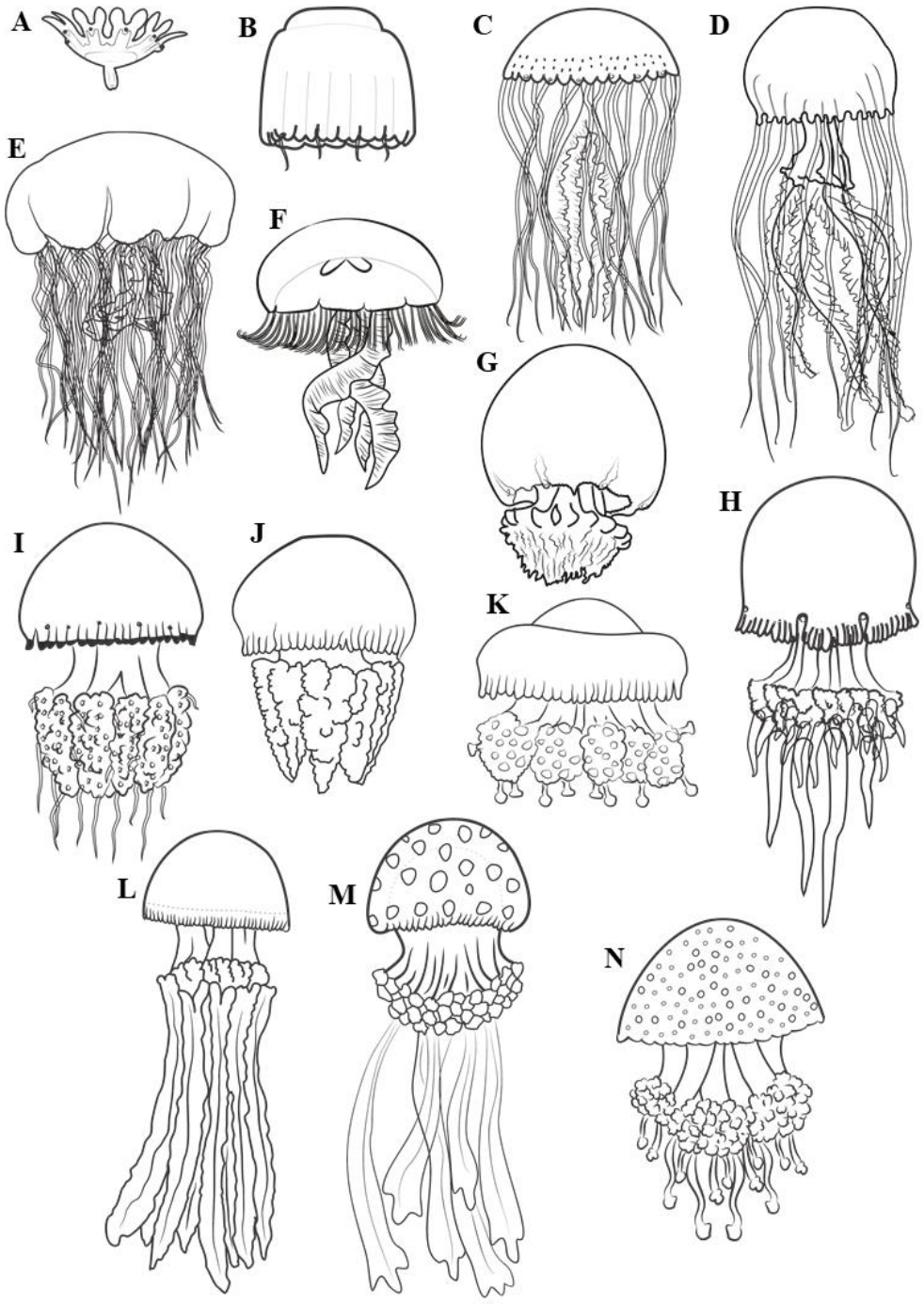
Supplementary Material

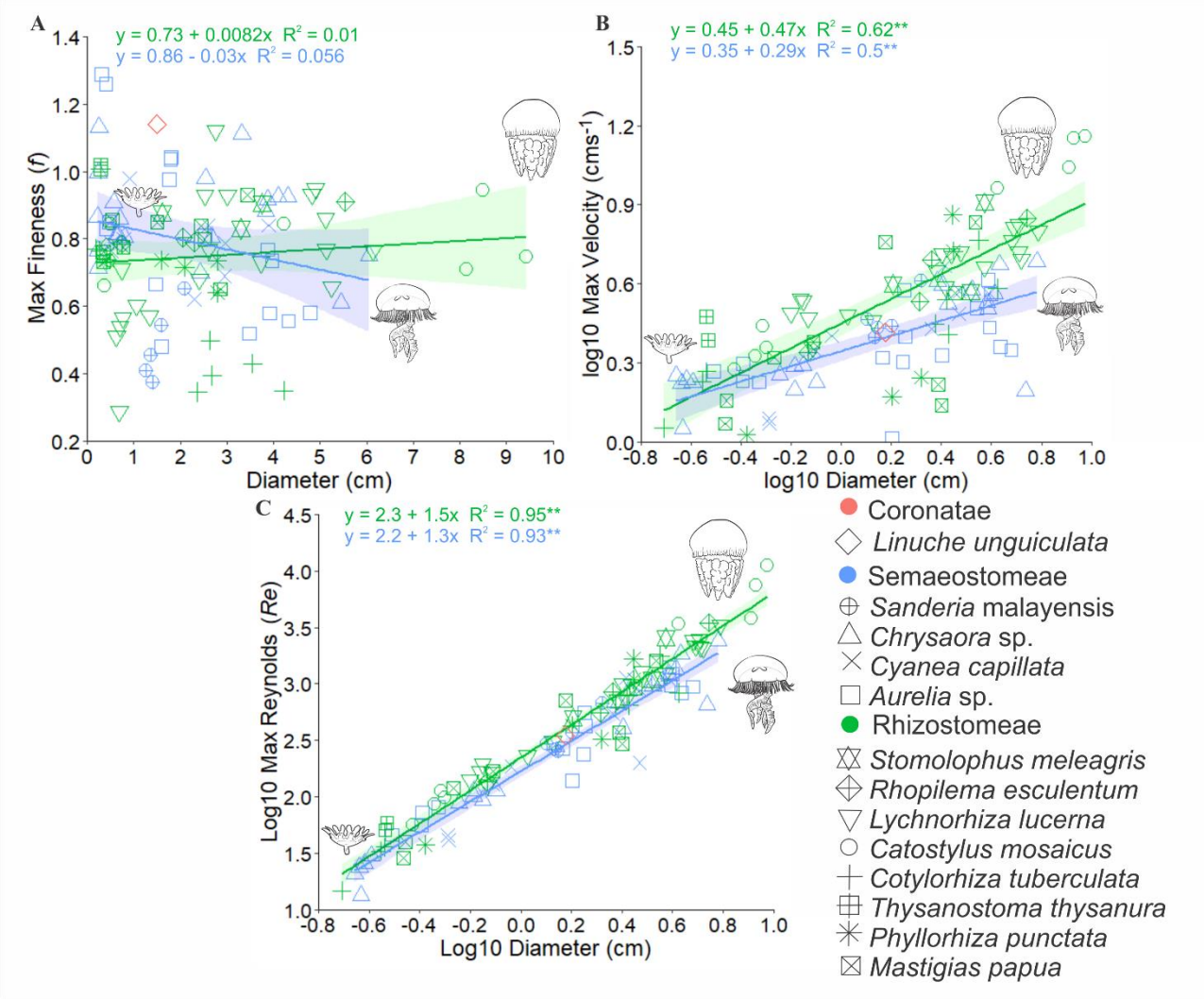
The file includes:

Figs. S1 to S17

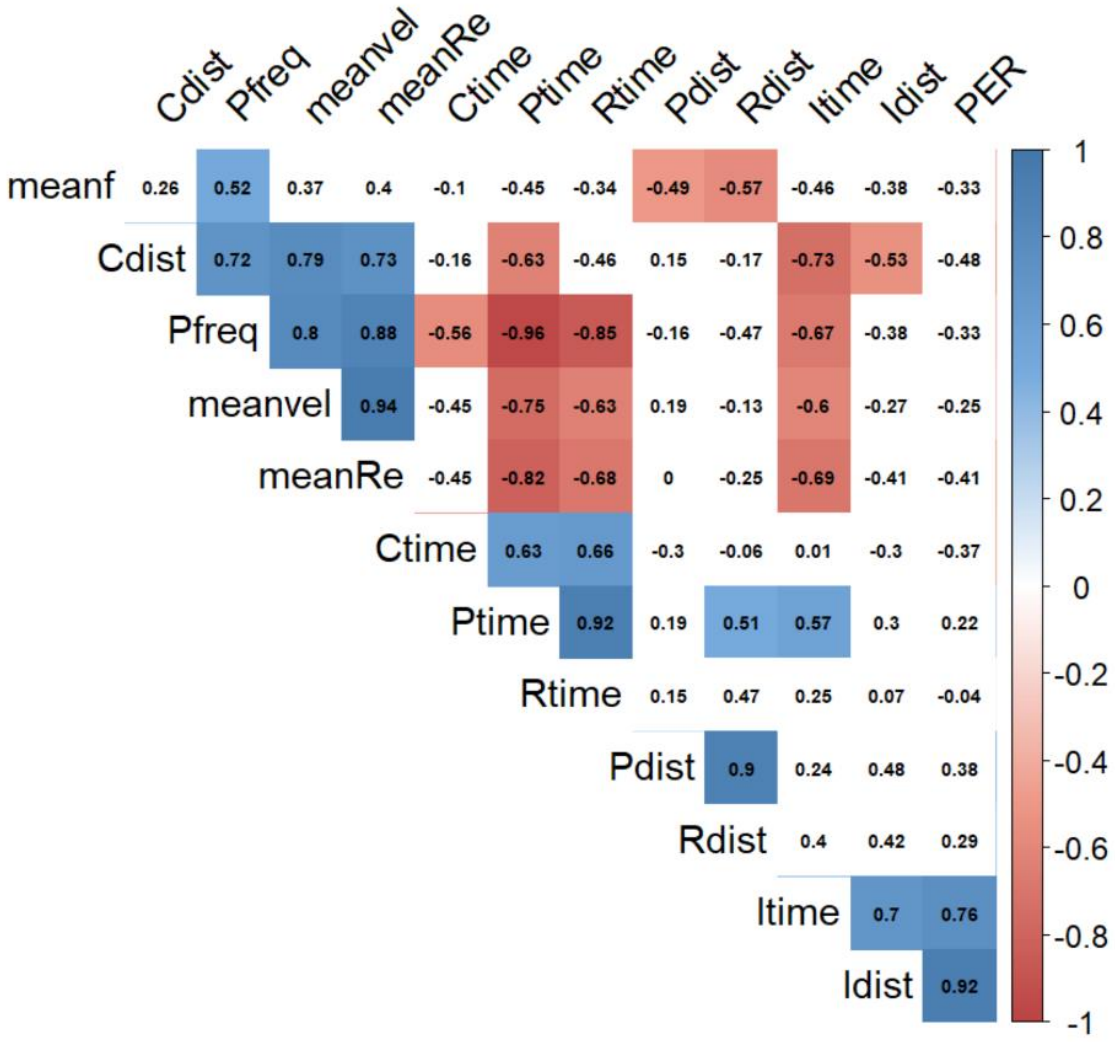
Table S1



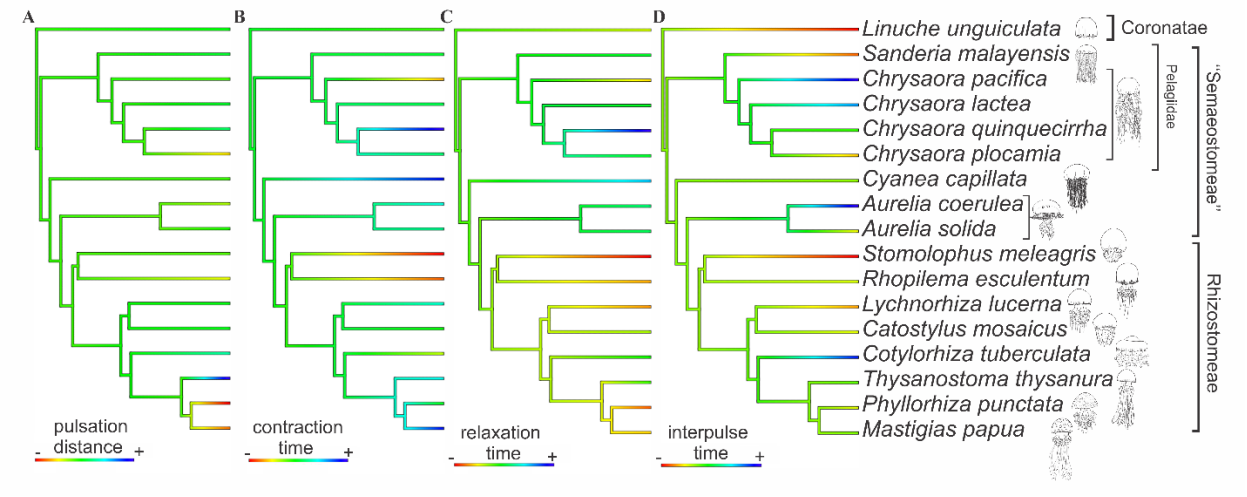
Supplementary figure S1. Analysed scyphozoa species and representative morphologies in members of different genera. **A)** Ephyrae generalised morphology; **B)** *Linuche unguiculata*; **C)** *Sanderia malayensis*; **D)** *Chrysaora* sp.; **E)** *Cyanea capillata*; **F)** *Aurelia* sp.; **G)** *Stomolophus meleagris*; **H)** *Rhopilema esculentum*; **I)** *Lychnorhiza lucerna*; **J)** *Catostylus mosaicus*; **K)** *Cotylorhiza tuberculata*; **L)** *Thysanostoma thysanura*; **M)** *Mastigias papua*; **N)** *Phyllorhiza punctata*. Based on Jarms *et al*. (2019) and images of live specimens.



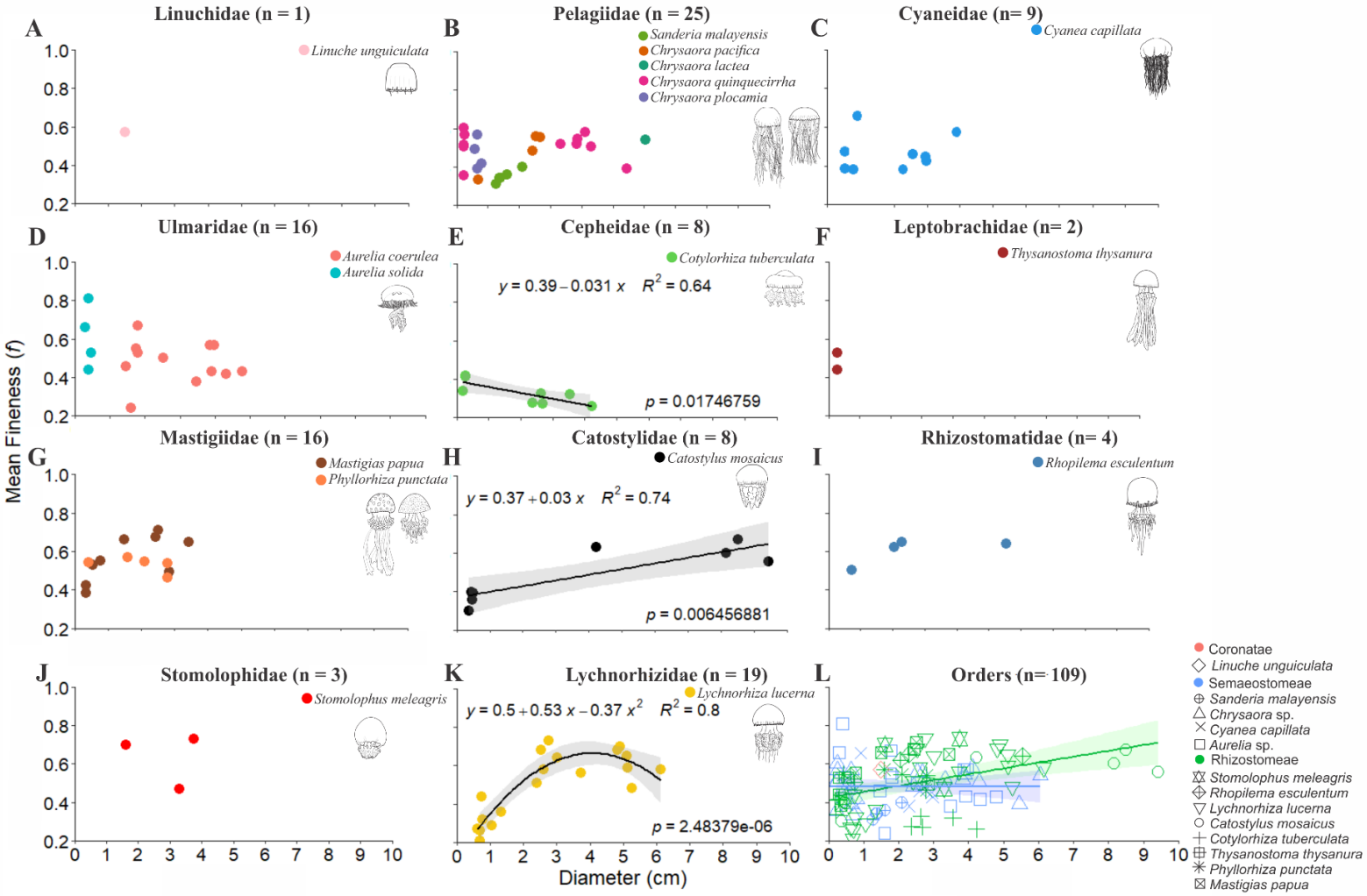
Supplementary figure S2. Scyphozoa orders relationship between diameter (cm) and: **A)** Maximum fineness; **B)** Maximum velocity; **C)** Maximum Reynolds. Label displays the shape of each plotted species. in red is the Coronatae = *Linuche*; in blue are the Semaeostomeae = *Sanderia*, *Chrysaora*, *Cyanea* and *Aurelia*; in green are the Rhizostomeae = *Stomolophus*, *Rhopilema*, *Lychnorhiza*, *Catostylus*, *Cotylorhiza*, *Thysanostoma*, *Phyllorhiza* and *Mastigias*. Images of representative morphologies were used, common generalized ephyrae, *Aurelia* for Semaeostomeae and *Catostylus* for Rhizostomeae.



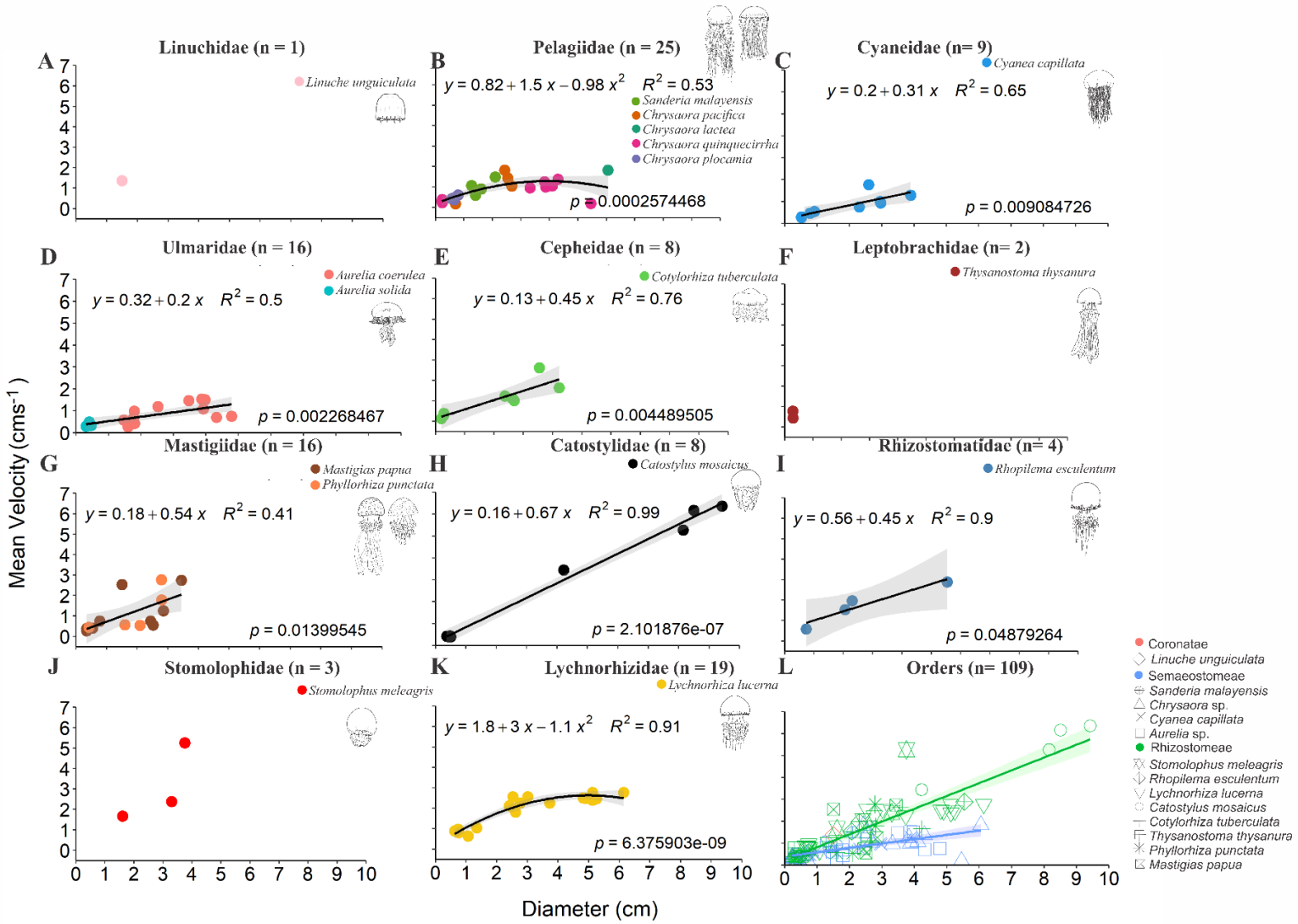
Supplementary figure S3. Biomechanics and kinematics variables of swimming. Scale bar represents Pearson correlation coefficient (*r*), ranging from 1, very high positive correlation, to -1, very high negative correlation. Values inside the squares display coefficient number. Squares in blank represent statistically non-significant coefficient values ($p > 0.05$).



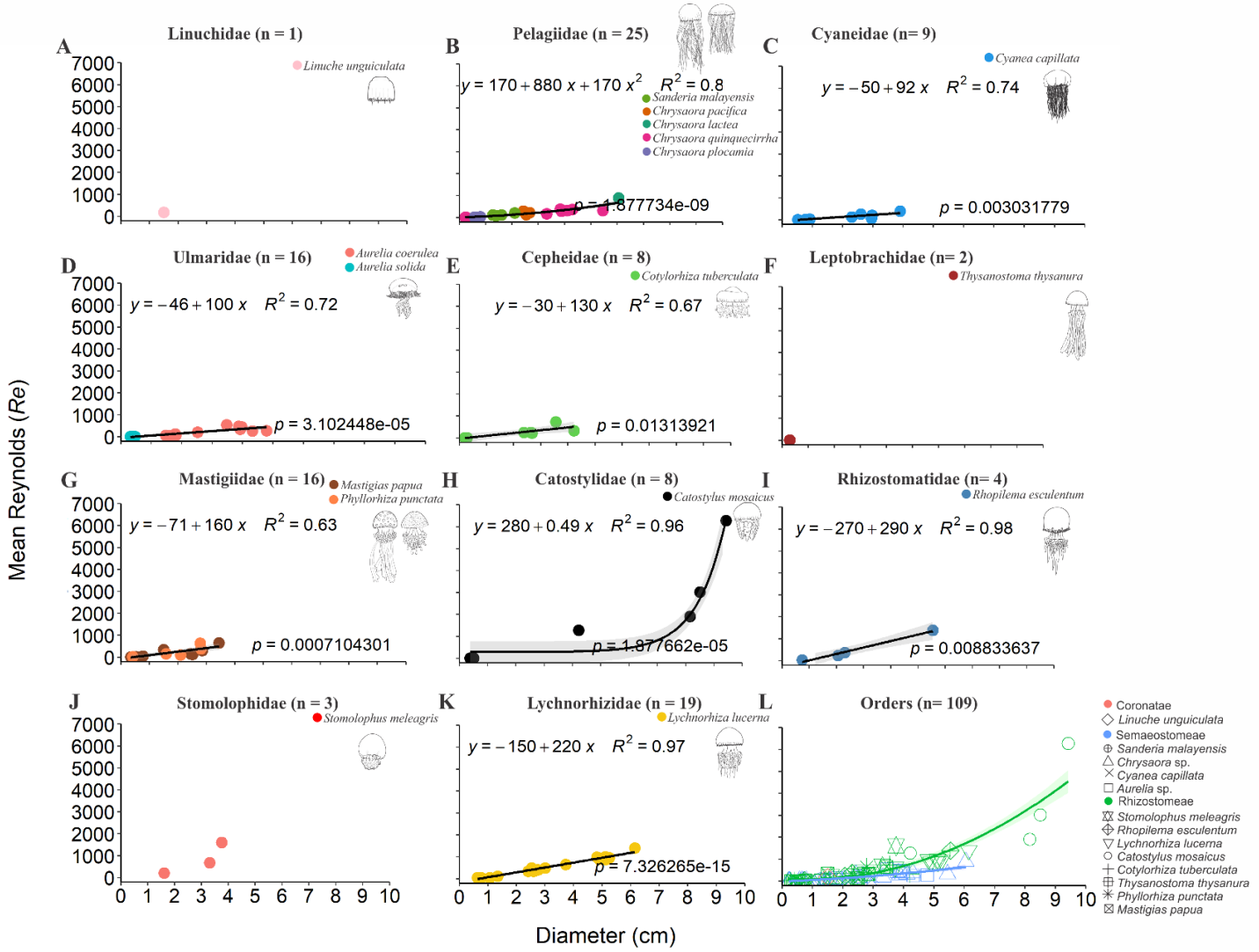
Supplementary figure S4. Ancestral character reconstructions estimated from regression residuals of Scyphozoa: **A)** pulsation distance; **B)** contraction time; **C)** relaxation time; and **D)** interpulse time. Warm and cool colours on the scale for each variable represent higher and lower values, respectively.



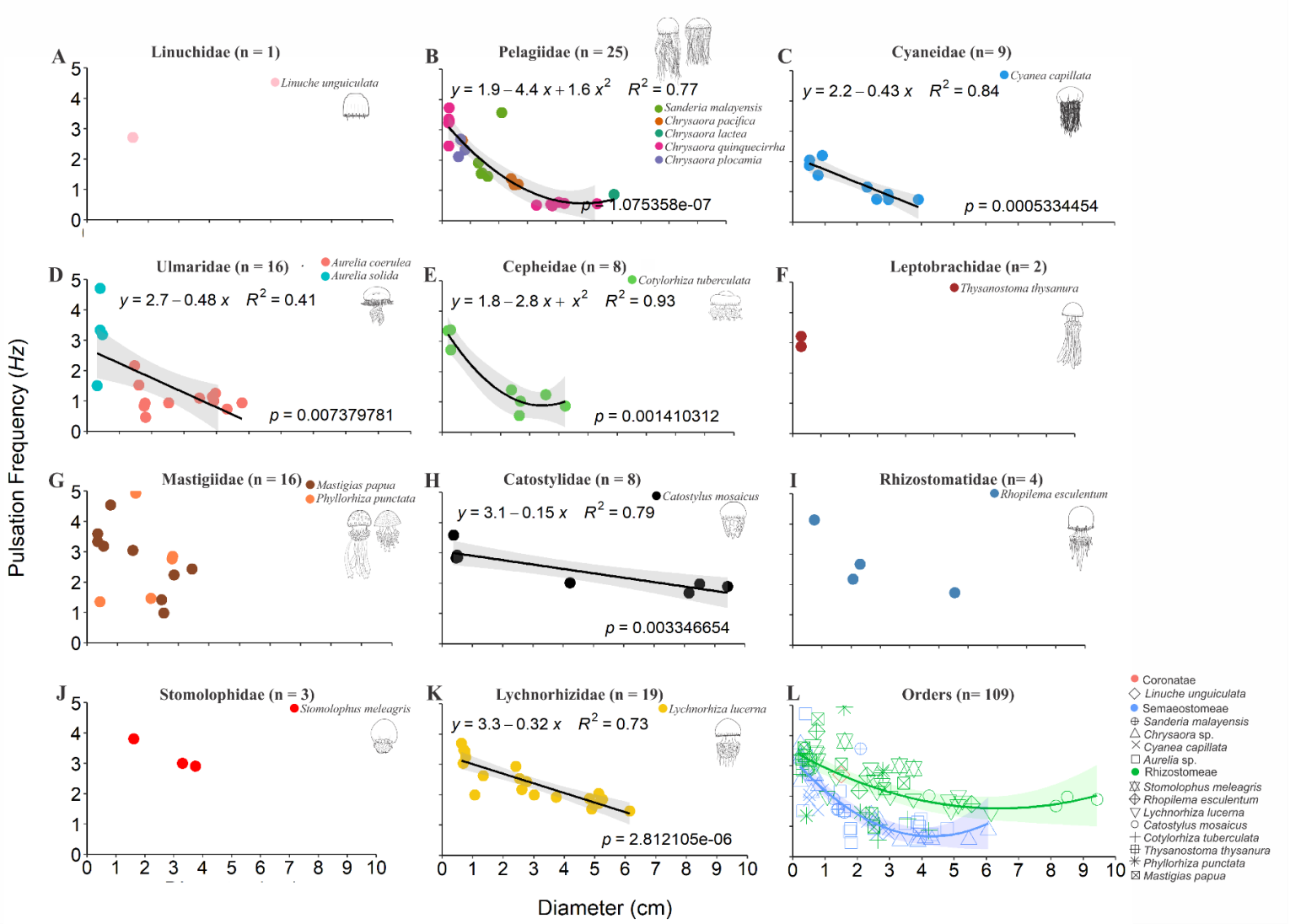
Supplementary figure S5. Scyphozoa families' mean fineness regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



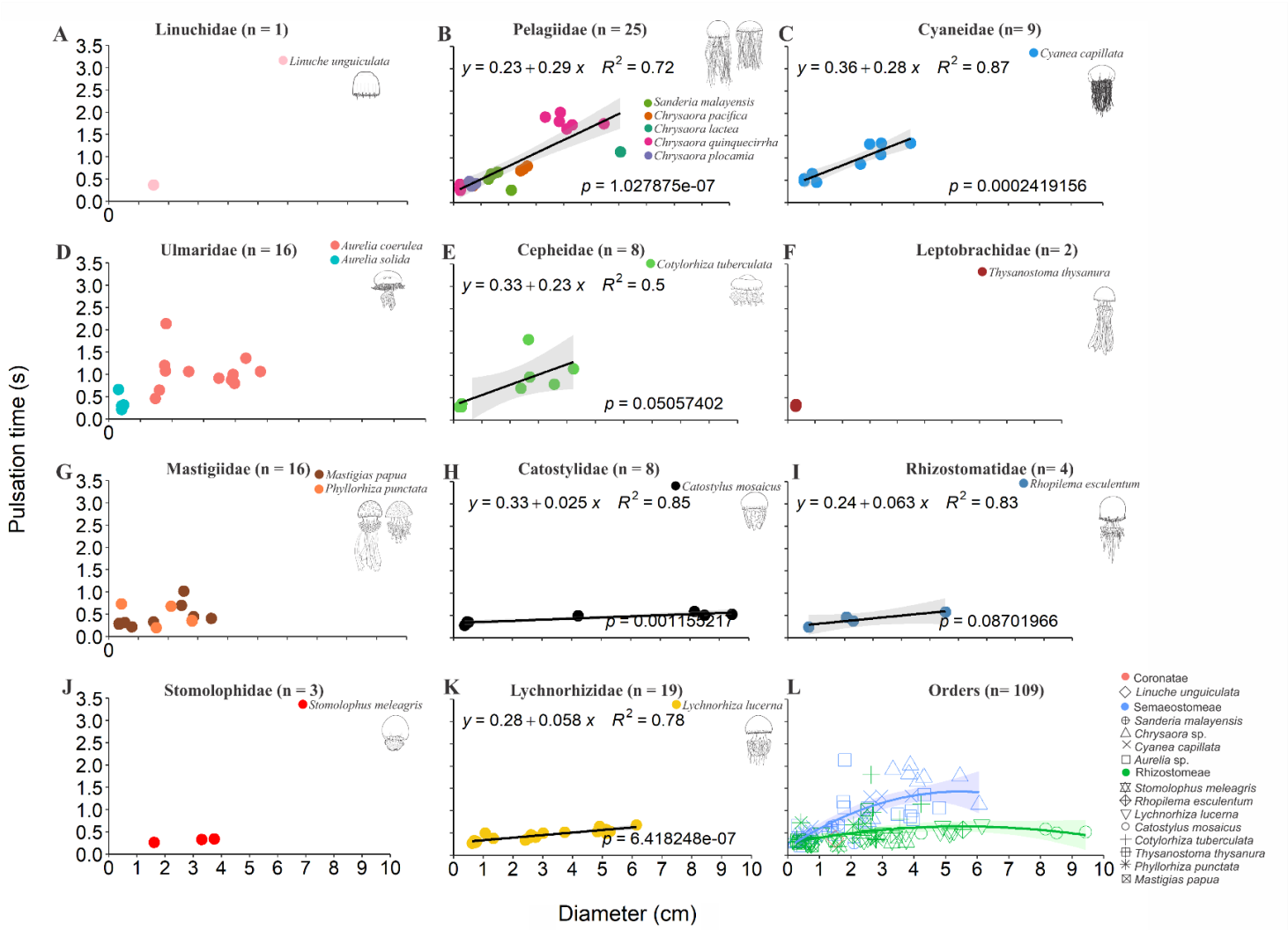
Supplementary figure S6. Scyphozoa families' mean velocity regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



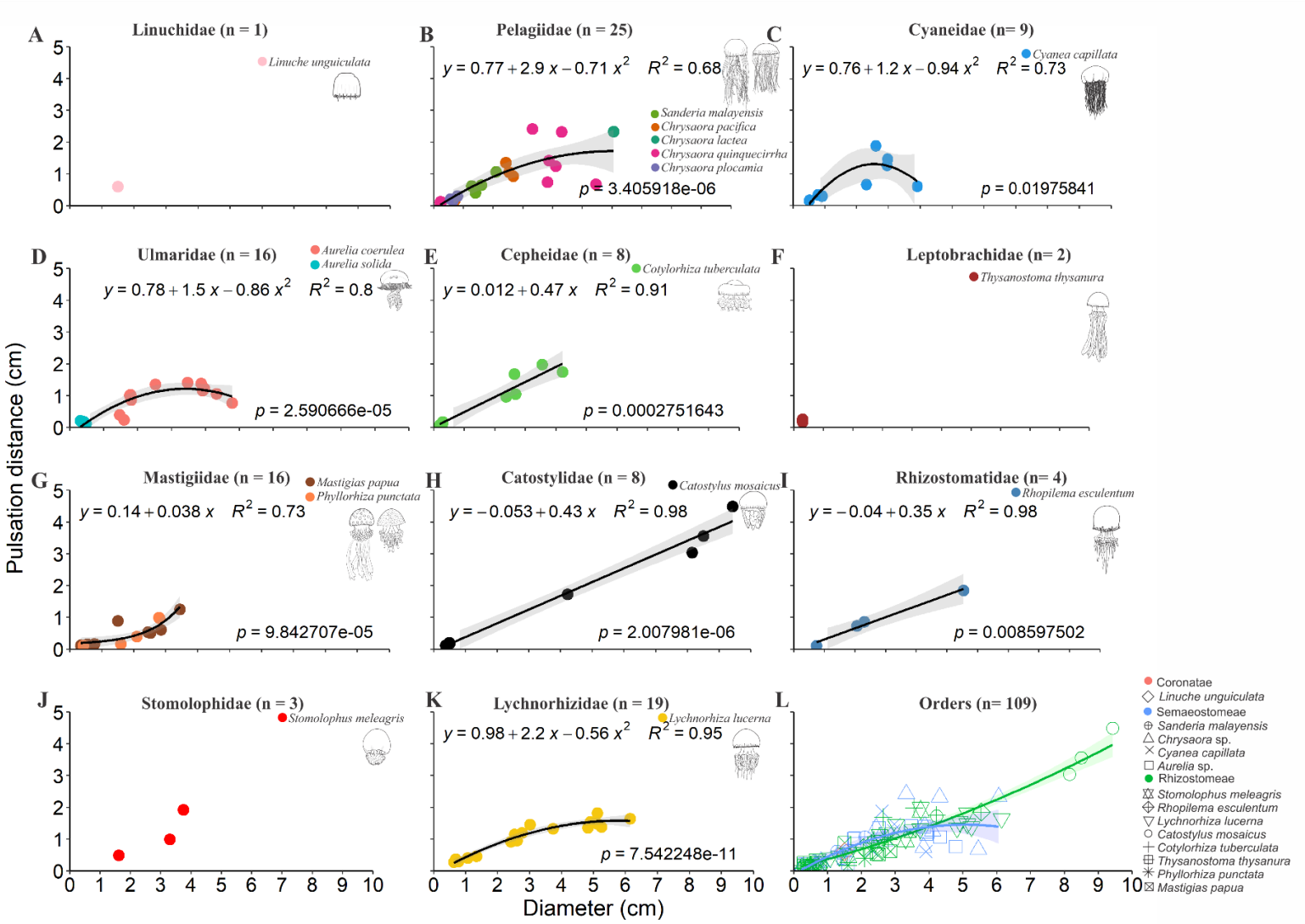
Supplementary figure S7. Scyphozoa families' mean Reynolds regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



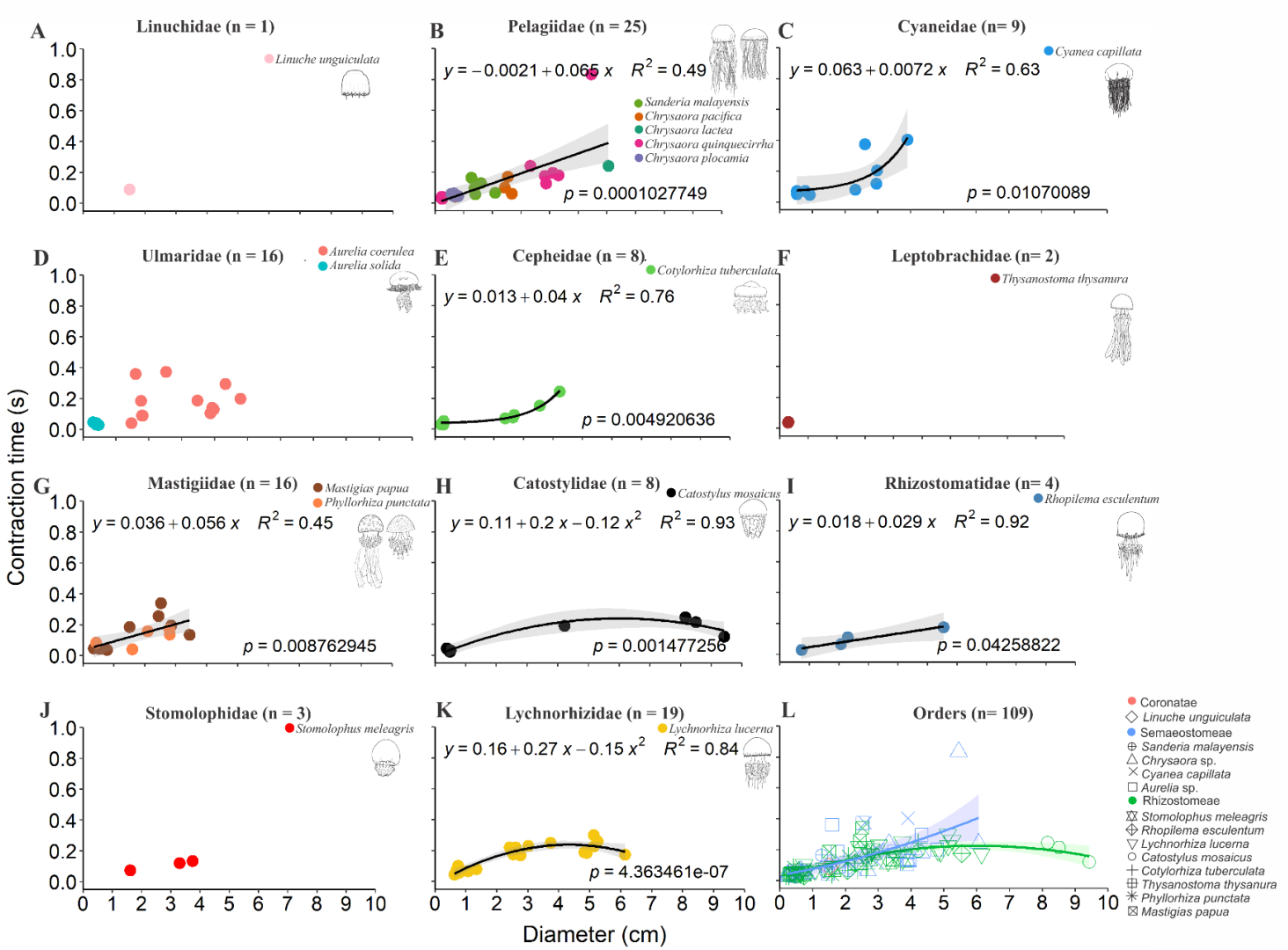
Supplementary figure S8. Scyphozoa families' pulsation frequency regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



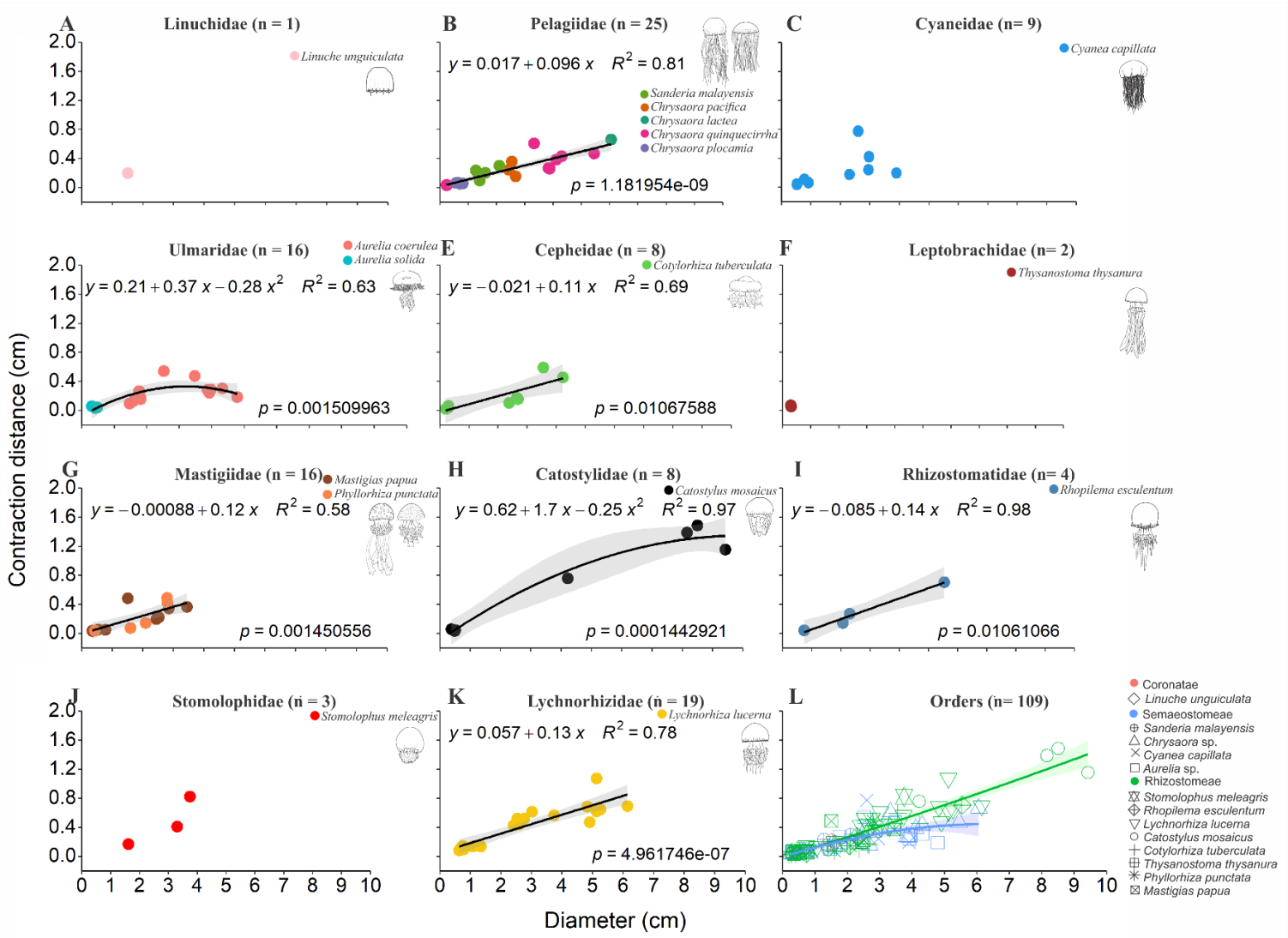
Supplementary figure S9. Scyphozoa families' pulsation time regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



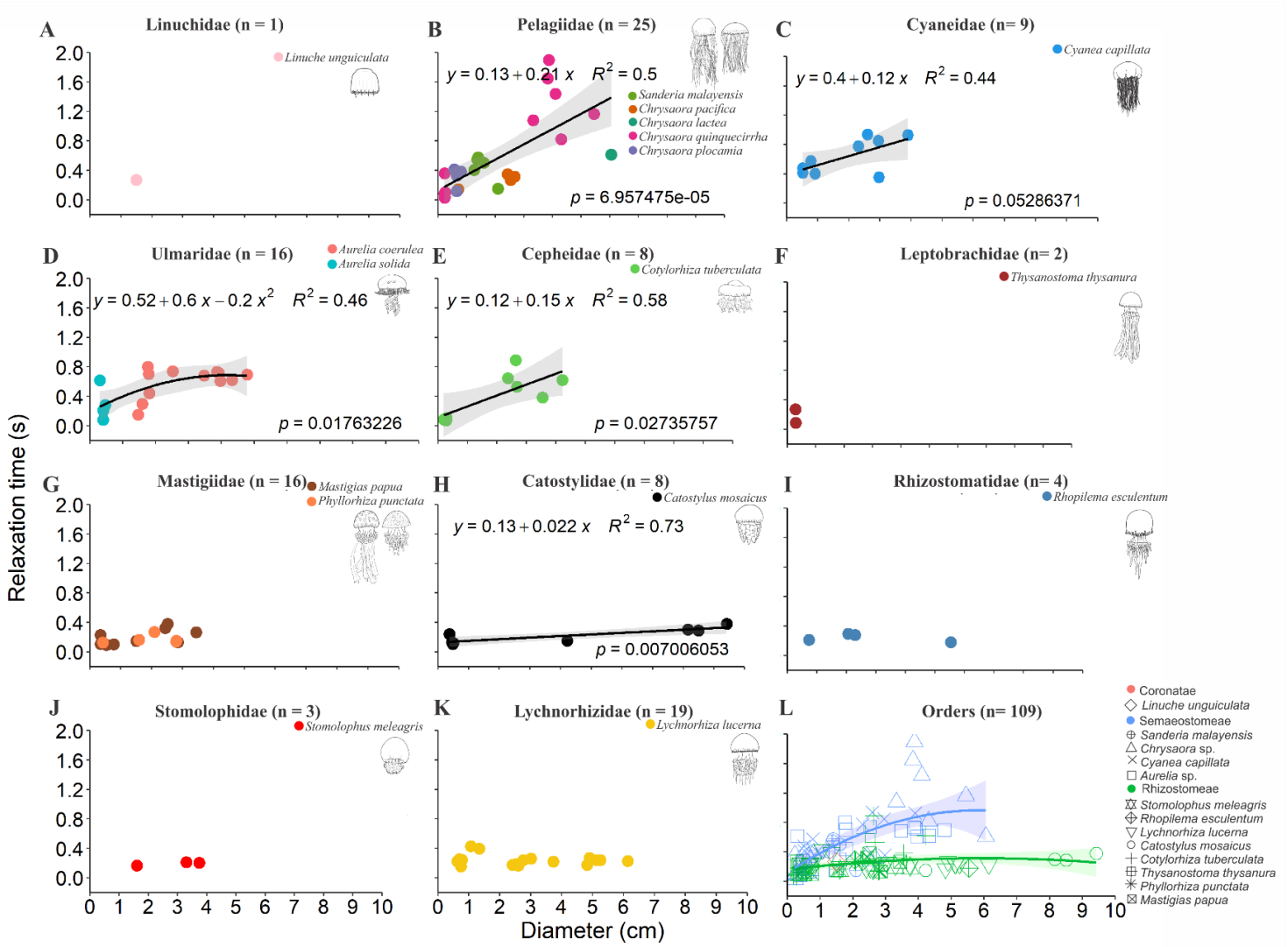
Supplementary figure S10. Scyphozoa families' pulsation distance regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



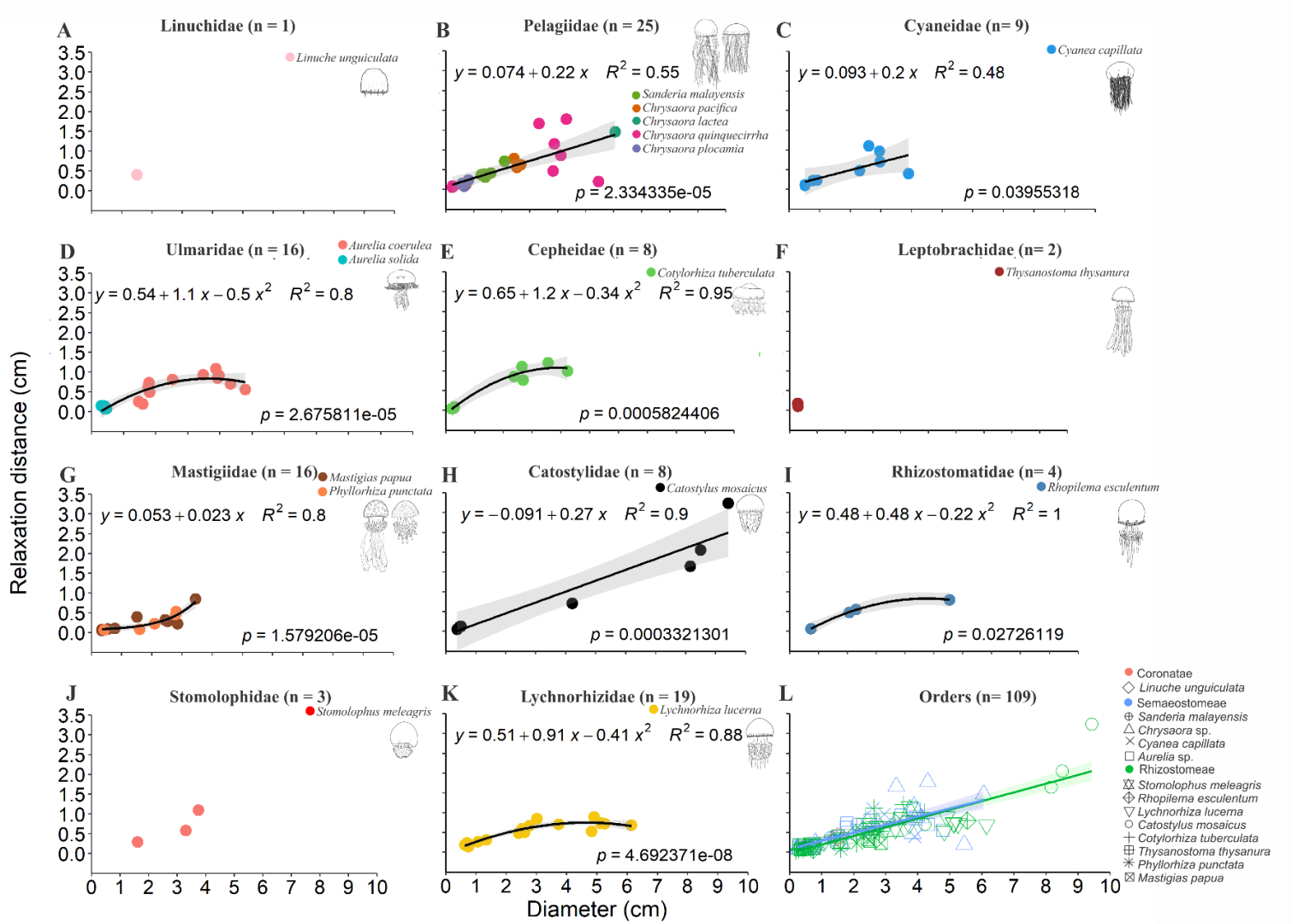
Supplementary figure S11. Scyphozoa families' contraction time regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



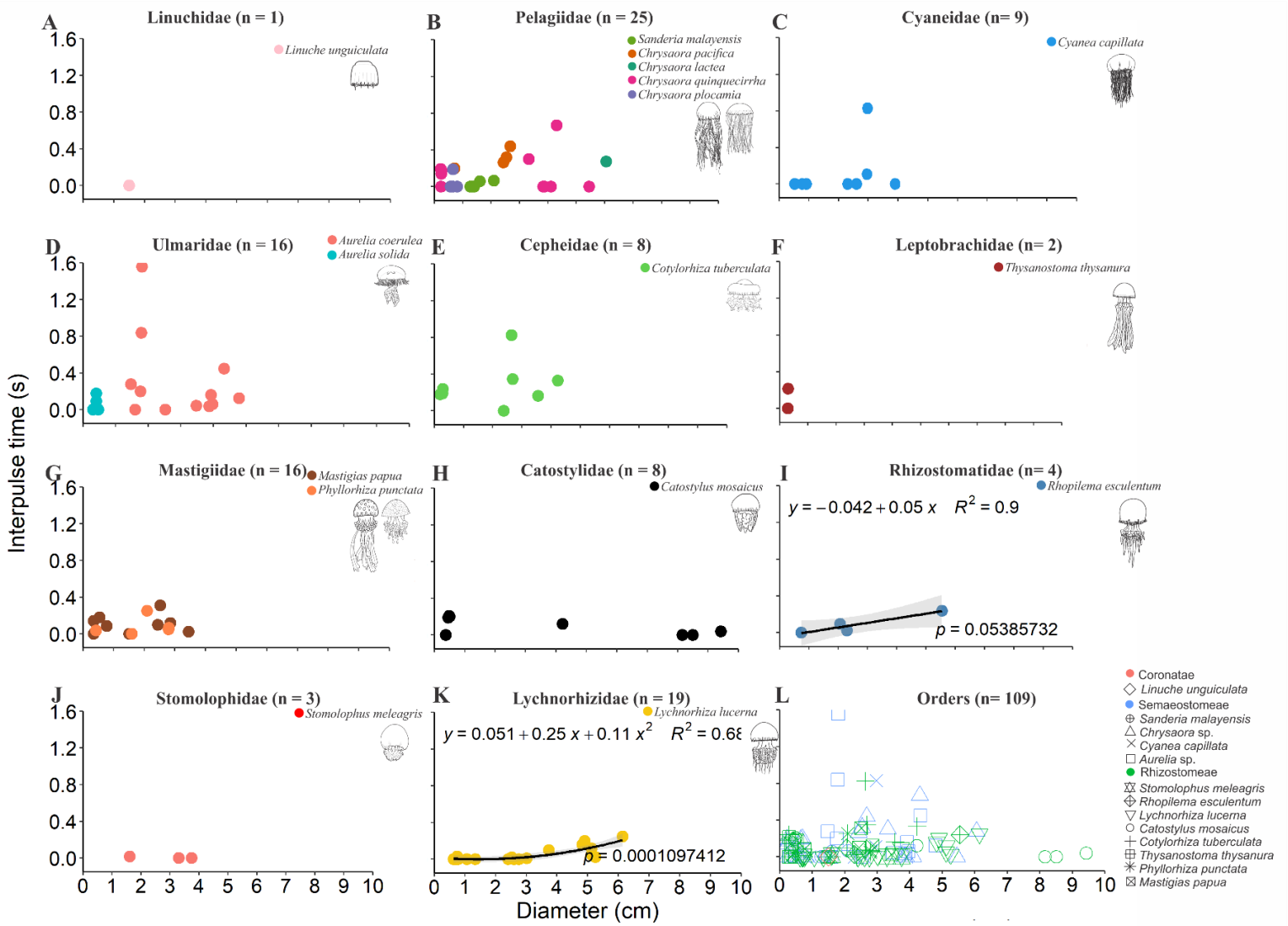
Supplementary figure S12. Scyphozoa families' contraction distance regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



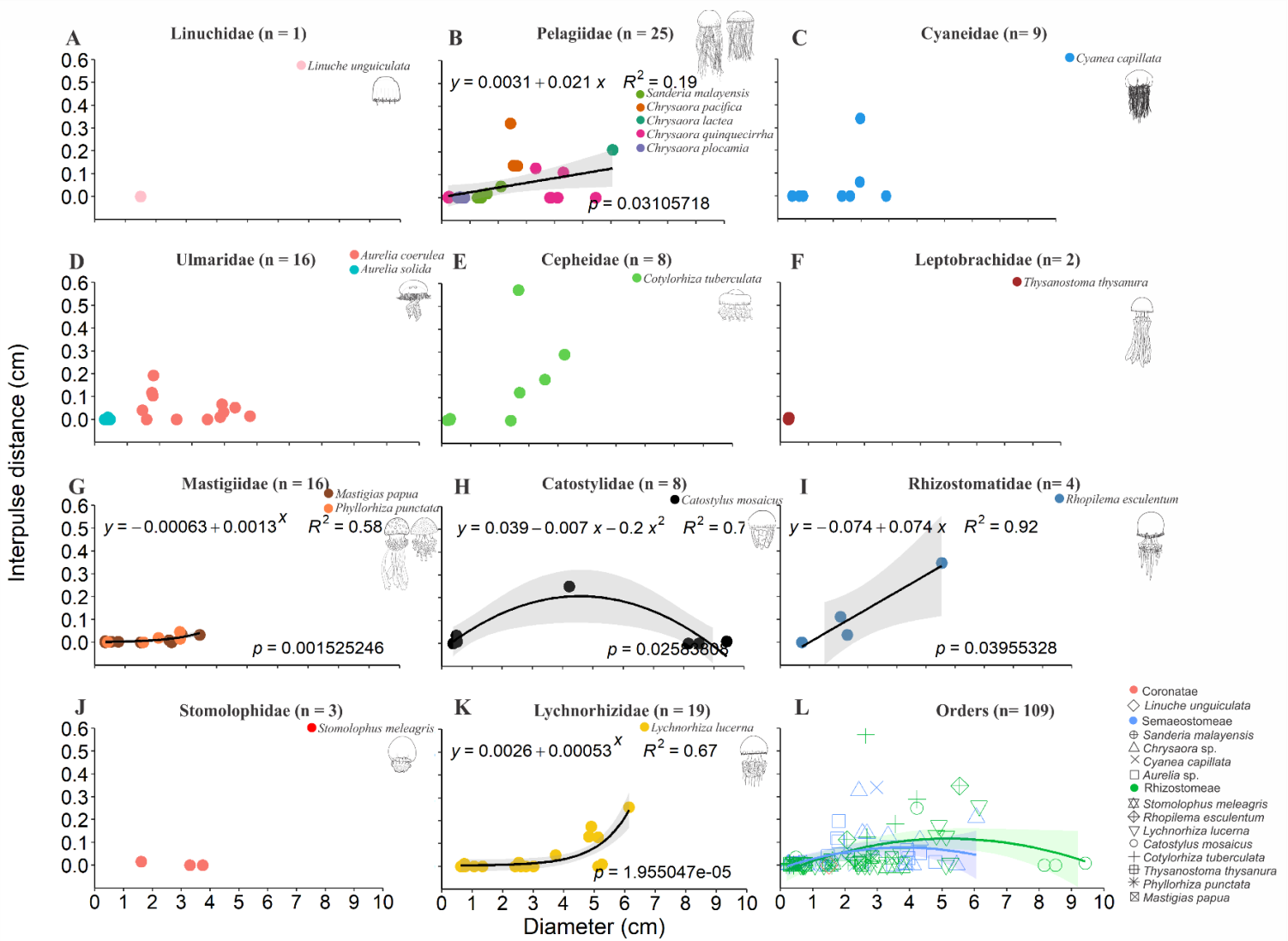
Supplementary figure S13. Scyphozoa families' relaxation time regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



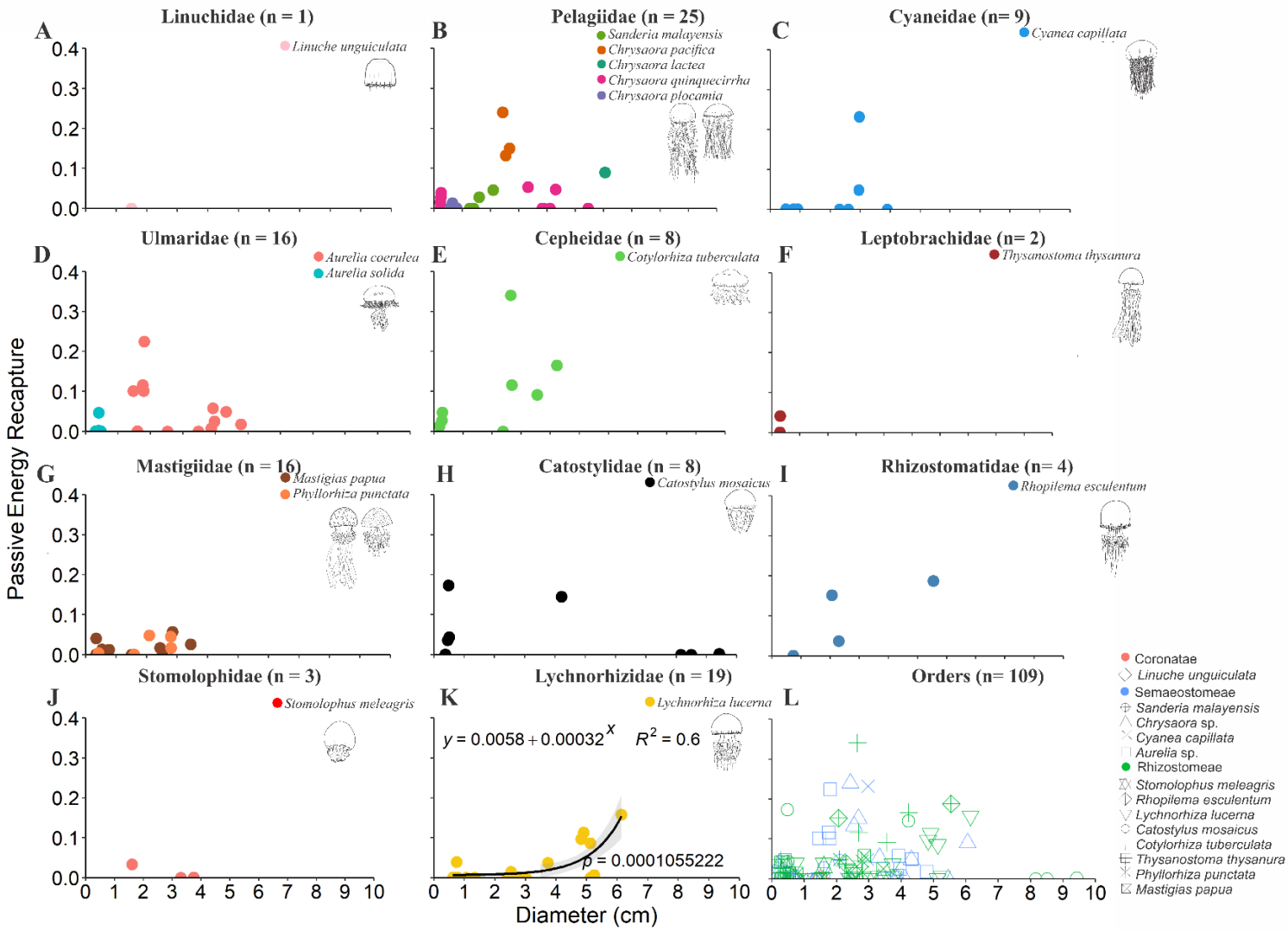
Supplementary figure S14. Scyphozoa families' relaxation distance regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



Supplementary figure S15. Scyphozoa families' interpulse time regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



Supplementary figure S16. Scyphozoa families' interpulse distance regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).



Supplementary figure S17. Scyphozoa families' passive energy recapture regressions. Regression lines are displayed with confidence intervals of 95%. **A)** Linuchidae; **B)** Ulmaridae; **C)** Pelagiidae; **D)** Cyaneidae; **E)** Cepheidae; **F)** Leptobrachidae; **G)** Mastigiidae; **H)** Catostylidae; **I)** Rhizostomatidae; **J)** Stomolophidae; **K)** Lychnorhizidae; **L)** Orders (red – Coronatae, blue – "Semaeostomeae", green – Rhizostomeae).

Supplementary table S1. Principal components analysis variables contributions (Ctr) and correlation (Cor) values for the regressions extracted residuals. The 5 variables that most contributed for each component were highlighted in bold.

		PC1		PC2		PC3		PC4	
Variable (unit)	Abreviations	Ctr	Cor	Ctr	Cor	Ctr	Cor	Ctr	Cor
Mean fineness (*f)*	meanf	5,39	-0,59	2,72	-0,28	**6,17**	**-0,34**	**75,32**	**0,66**
Mean Velocity (cms^{-1})	meanvel	**10,47**	**-0,83**	4,20	0,35	3,96	0,27	**3,11**	**0,13**
Mean Reynolds (*Re*)	meanRe	**12,52**	**-0,90**	1,68	0,22	2,02	0,19	0,11	0,03
Pulsation Frequency (*Hz*)	Pfreq	**14,00**	**-0,96**	1,64	0,22	0,46	-0,09	0,19	-0,03
Pulsation Time (s)	Ptime	**12,74**	**0,91**	2,73	-0,28	2,53	0,22	**3,05**	**0,13**
Pulsation Distance (cm)	Pdist	1,12	0,27	**16,93**	**0,71**	**21,32**	**0,63**	1,80	0,10
Contraction Time (s)	Ctime	2,21	0,38	**20,76**	**-0,78**	2,85	0,23	0,20	-0,03
Contraction Distance (cm)	Cdist	9,37	-0,78	0,14	0,06	**11,67**	**0,47**	0,98	-0,08
Relaxation Time (s)	Rtime	8,50	0,74	6,41	-0,43	8,45	0,40	**7,90**	**0,21**
Relaxation Distance (cm)	Rdist	4,54	0,54	**7,17**	**0,46**	**22,25**	**0,65**	**3,23**	**0,14**
Interpulse Time (s)	Itime	**9,76**	**0,80**	3,70	0,33	5,64	-0,33	0,50	-0,05
Interpulse Distance (cm)	Idist	5,18	0,58	**15,76**	**0,68**	3,97	-0,27	2,88	0,13
Passive Energy Recapture (cm)	PER	4,20	0,52	**16,17**	**0,69**	**8,72**	**-0,40**	0,72	0,06