The Evolution of Intelligence in Cephalopods

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Introduction

Intelligence between species dramatically varies, but cephalopods are exceedingly intelligent marine animals. Cephalopods have evolved from other molluscs to be free of an external shell, which has allowed them to adapt different traits that escalate their intelligence [1]. These traits include camouflage ability, decentralized nervous system, and memory/personality [3]. One of the most important traits for cephalopod intelligence is their large brain size, which has been linked to intelligence in vertebrates [4].

Hypotheses

Alternative: Of the cephalopod species, octopus evolved to have higher cognitive abilities than the other species.

Null: Of the cephalopod species, octopus did not evolve to have higher cognitive abilities than the other species.

Prediction

We predict that cognitive abilities of octopus evolved to be higher than other cephalopod species.

Methods

We will test these hypotheses by comparing the brain volume and percentage of brain volume in the chromatophore lobe between octopus and non-octopus species. This data is obtained from a peer-reviewed journal [2]. Along with this, we will create a phylogeny that shows these trait differences.

Phylogeny

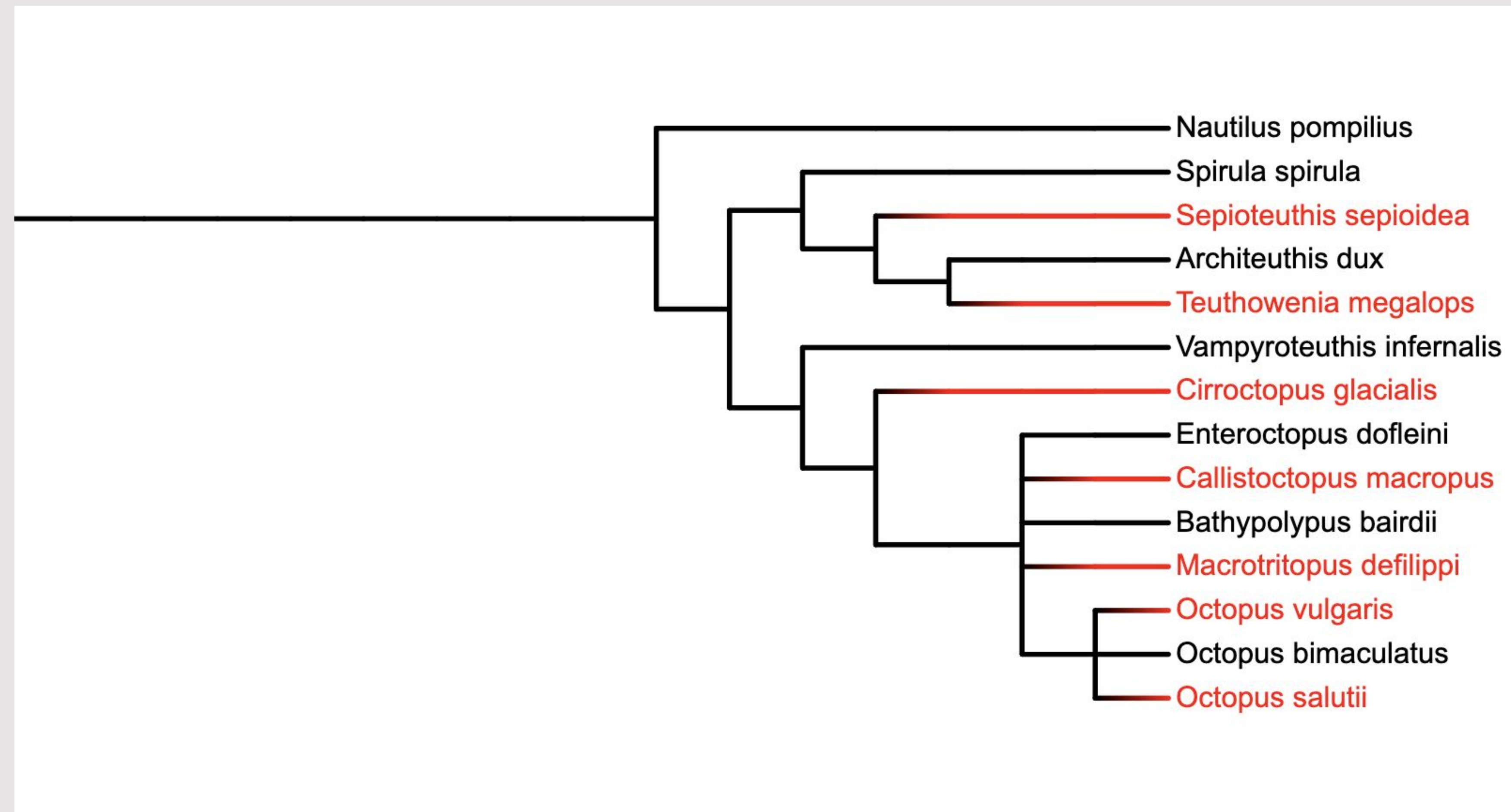

Fig 1. Phylogeny showing the evolutionary history of the selected cephalopods. The phylogeny was created using nucleotide datasets available from NCBI. Shown on the phylogeny in red is any species with chromatophore lobes taking up great than .5% of total brain volume. There does not seem to be an evidence supporting the evolution of intelligence leading to more chromatophores in Cephalopods as chromatophores seemed to have evolved independently.

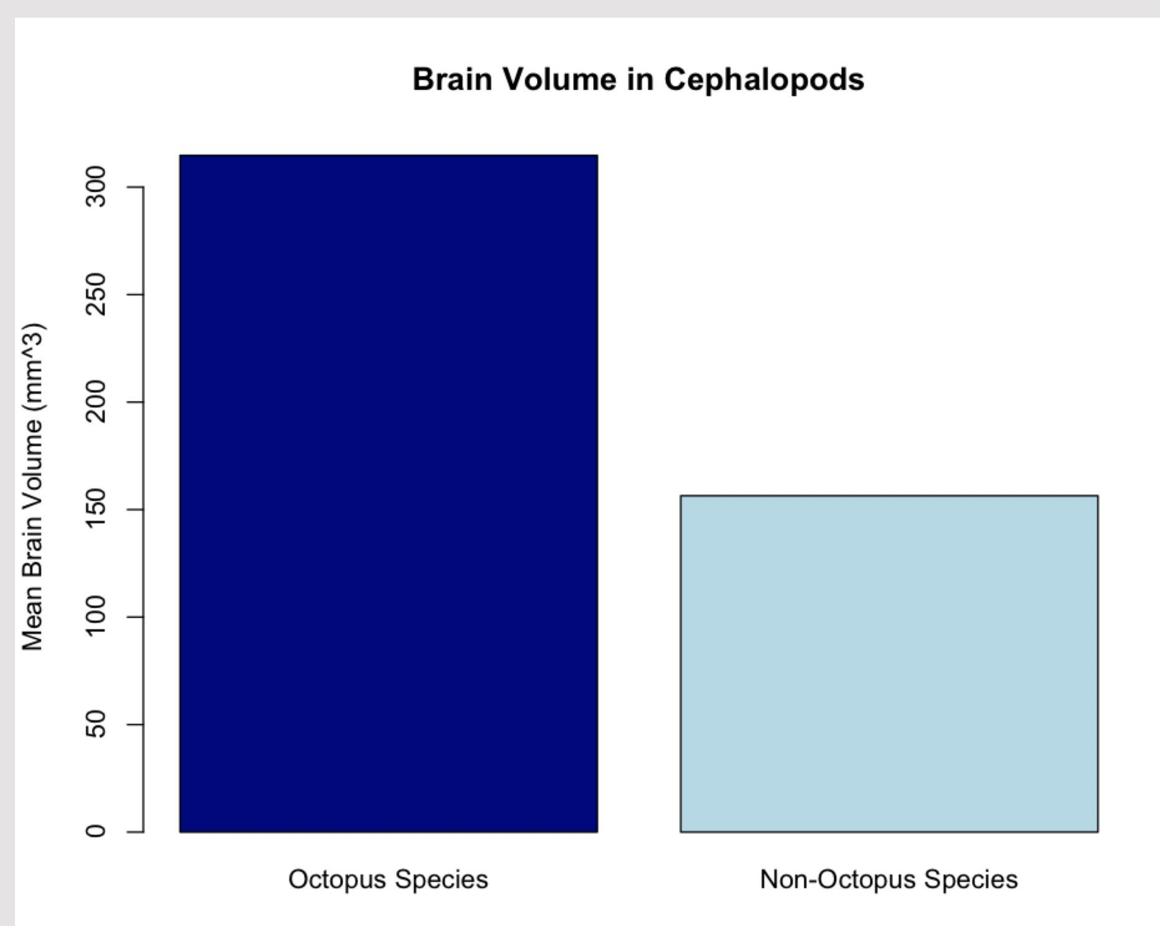

Fig 2. Bar graph showing the difference in mean brain volume in octopus species versus non-octopus species. Mean brain volume for octopus species = 314.77. Mean brain volume for non-octopus species = 156.44. Graph was computed in R Studio using data compiled from a peer-reviewed source.

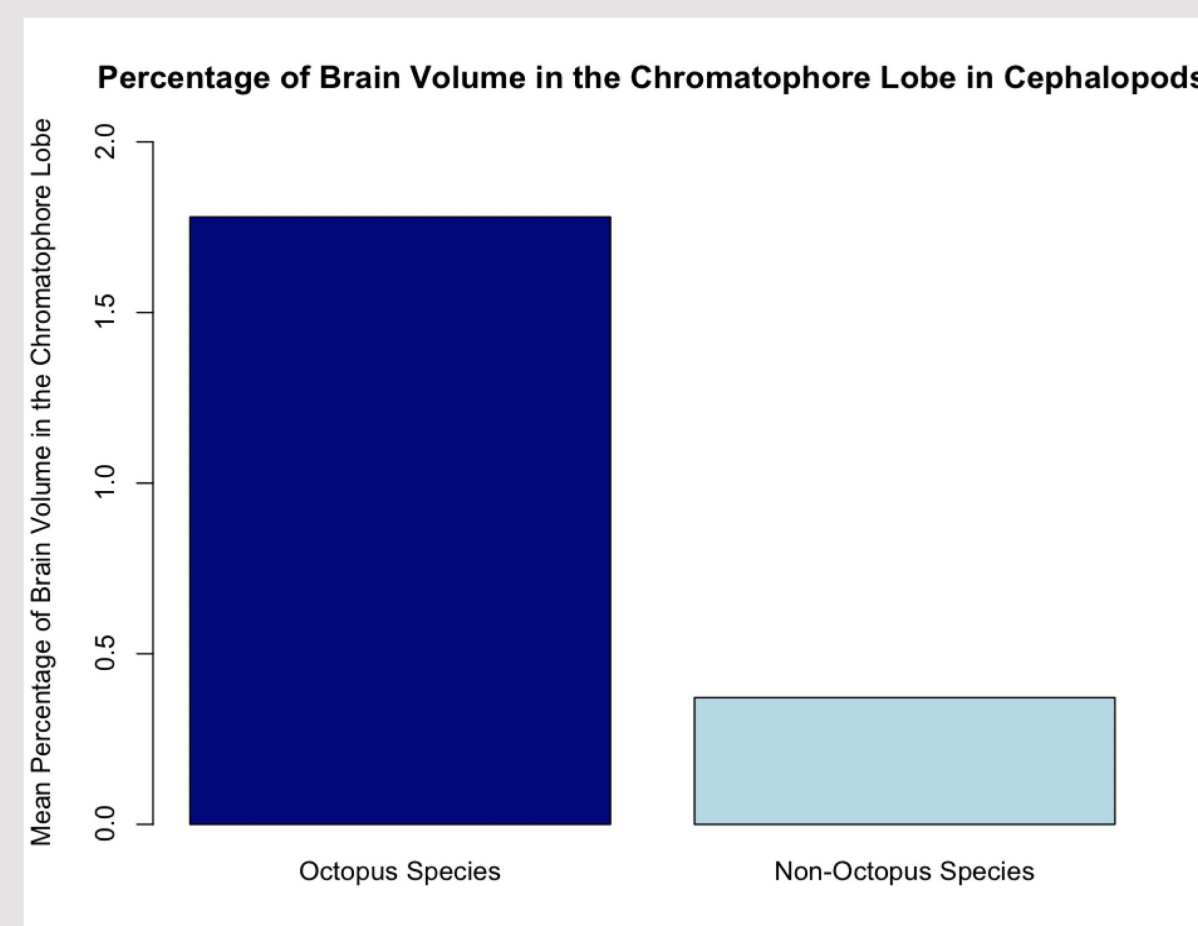

Fig 3. Bar graph showing the difference in mean percentage of brain volume in the chromatophore lobe in octopus species versus non-octopus species. Mean percentage for octopus species = 1.78%. Mean percentage for non-octopus species = 0.37%. Graph was computed in R Studio using data compiled from a peer-reviewed source.

Conclusion

Ultimately, we cannot make the claim that there is statistical significance between the level of intelligence in octopus and their number of chromatophores in comparison to other cephalopods. Although we can see a trend in our graph, we can not make a statistically significant claim due to the difference in means between the two. The P-value (0.437), t (0.8066), and df (10.989) of the graph depicting brain volume compared to the P-value (0.1348), t (1.6753), and df (7.5235) of the graph depicting brain volume in the chromatophore lobe do not show a significant correlation which would be needed in order for us us to make a claim. Our phylogeny that we created also does not support the claim that Octopus evolved to have a higher intelligence leading to more chromatophores.

Discussion

This lack of statistical significance could be due to the fact that our data was observational and not self collected. Because we were relying on data found by other people rather than ourselves, we were limited in the data that we could focus on and make connections from. Creating correlations is difficult when there are gaps in the data that we cannot fill nor predict. This confounding variable could have affected our results.

References

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2. Maddock, L. and Young, J.Z. (1987), Quantitative differences among the brains of cephalopods. Journal of Zoology, 212: 739-767. https://doi.org/10.1111/j.1469-7998.1987.tb05967.x
3. MatherJennifer A. and KubaMichael J.. The cephalopod specialties: complex nervous system, learning, and cognition. *Canadian Journal of Zoology*. 91(6): 431-449. https://doi.org/10.1139/cjz-2013-0009
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Data Chart

Species	Brain Volume (mm^3)	Percentage of Brain Volume in the Chromatophore lobe	
Octopus vulgaris	92.6	5.09%	
Nautilus pompilius	109.1	0.00%	
Vampyroteuthis infernalis	10.6	0.00%	
Octopus bimaculatus	49.8	0.00%	
Macrotritopus defilippi	12.6	1.29%	
Enteroctopus dofleini	926.2	0.00%	
Bathypolypus bairdii	129.4	0.00%	
Architeuthis dux	846.8	0.00%	
Cirroctopus glacialis	14.8	0.90%	
Teuthowenia megalops	51.4	0.60%	
Spirula spirula	7.0	0.00%	
Sepioteuthis sepioidea	55.4	2.00%	
Callistoctopus macropus	926.2	1.94%	
Octopus salutii	62.6	4.14%	

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	Welch Two Sample t-test

data:  octopusdata$Brain.Volume[octopusdata$Species == "Octopus"] and octopusdata$Brain.Volume[octopusdata$Species == "Non-Octopus"]
t = 0.8066, df = 10.989, p-value = 0.437
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -273.7560  590.4131
sample estimates:
mean of x mean of y 
 314.7714  156.4429 
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	Welch Two Sample t-test

data:  octopusdata$Brain.Volume.Percent[octopusdata$Species == "Octopus"] and octopusdata$Brain.Volume.Percent[octopusdata$Species == "Non-Octopus"]
t = 1.6753, df = 7.5235, p-value = 0.1348
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.5518731  3.3690160
sample estimates:
mean of x mean of y 
1.7800000 0.3714286 
```