Influence of Shark Metabolic Rate and Body Size on Marine Trophic Position

Group 1: Emma Booth (1149027), Annika Laurin (1183145), Samantha Mok (1126756), Kayla Perez (1175585), Farah Sadoon (1302190)

Introduction: As biodiversity declines due to anthropogenic climate change, it is increasingly important to understand how species loss causes cascading effects on ecosystem functions, services, and resources that humans rely upon[2]. A critical challenge is unpacking the complexity of marine systems, as factors like vertical stratification, temperature and salinity gradients, and nutrient cycling drive the functional specificity of organisms[3, 5]. To investigate how species loss impacts marine communities, this study focuses on apex and meso-predator sharks, as the removal of organisms at higher trophic levels can lead to severe top-down trophic cascades[4, 7].

While existing literature supports the critical role of top predators in managing ecosystems, largely due to their morphological and behavioral traits[6, 9, 12], more research is needed to investigate the effects of physiological traits on trophic position. The metabolic theory of ecology posits that metabolism is a unifying process in biology, controlling the transfer of energy within and between organisms[1]. As it is established that an inverse relationship exists between metabolic rate per unit body mass and body size[8], exploring the relationship between metabolic rate, body size, and trophic position could help clarify the factors driving trophic cascades, enhancing our ability to model ecosystem interactions.

Our research aims to investigate how metabolic rate and body size shape predator-prey interactions, focusing on apex and meso-predator sharks, to clarify their differential impacts on marine ecosystems. We hypothesize that there is a positive relationship between metabolic rate and the trophic position of shark species. Conversely, we investigate the hypothesis that there is a positive relationship between body mass and trophic position of shark species. Therefore, this study predicts: (1) Sharks and rays with higher metabolic rates will occupy a higher trophic position driven by their elevated resource requirements; (2) Sharks and rays with higher body mass will have a higher trophic position due to their competitive dominance over smaller predators.

Methods: We will utilize data from the online databases Fishbase, Sharkipedia, and the paper by Gravel et al., 2024[6]. We will analyze two independent variables: Body Mass (in grams) and Metabolic Rate (measured in watts), and one dependent variable, Trophic Position, which is measured on a scale from 1 to 5, indicating the species' position in the food web.

The dataset will be inspected and corrected for missing values using listwise and pairwise deletion when necessary to maintain consistency. Outliers will be identified through scatter plots, and interquartile range (IQR) analysis. Decisions regarding outliers will be determined on a case-by-case basis to inhibit the distortion of results. Data distribution will be visually and statistically assessed using histograms, and a Shapiro-Wilk test. The homogeneity of variances will be evaluated with Levene's test. If the data is not normally distributed, transformations will be attempted to achieve normality.

If the data is normally distributed, a linear regression will be used to model the data. This was chosen due to its ability to model relationships between continuous variables. If the data is not normally distributed, a Kruskal-Wallis test will be employed for group comparisons. This method was chosen due to its ability to compare groups without assuming normality. All analyses will be conducted using R.

Anticipated Results: After conducting either a Kruskal-Wallis test or a Linear Regression, we expect p-values < 0.05 in either analyses, indicating that both body mass and metabolic rate significantly influence trophic position. Additionally, we anticipate that the model will reveal a positive relationship between either independent variable — metabolic rate or body mass — and the dependent variable, trophic position, with a slope of around 0.04 (Fig. 2 & 3)[14, 13]. This suggests that trophic position increases with body mass or metabolic rate. These findings would support our hypothesis that large sharks or those with faster metabolisms occupy higher trophic positions due to either their dominance over competing predators or their greater resource requirements, respectively.

Significance: The accumulation of Hg in shark tissue has put humans at risk of Hg poisoning. Understanding the effect of body size and metabolisms on trophic position can deepen our understanding of Hg accumulation and help regulate shark product consumption[10, 11].

Additionally, understanding the relationship between metabolic rate and trophic position can help identify the relative growth rates amongst predators. This spectrum can reveal which species are more sensitive to pressures such as overfishing and how their removal would influence trophic cascades[6].

Figure 1. Incomplete raw data showing the relationship between body mass and metabolic rate in sharks

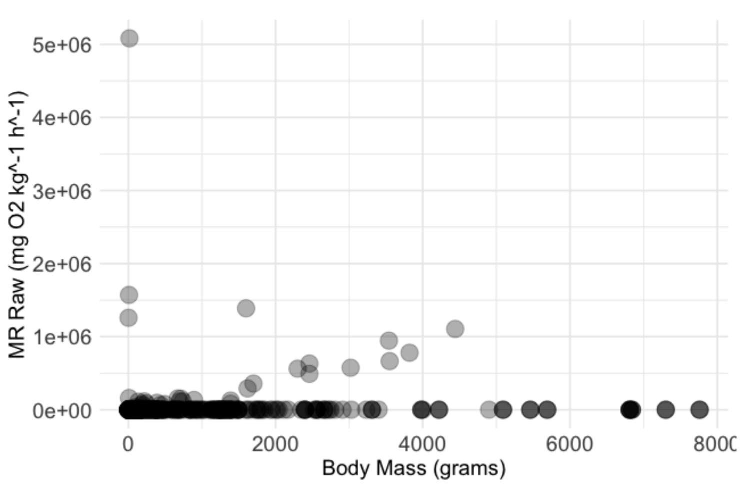


Figure 2. Positive linear regression of shark metabolic rate impact on trophic position

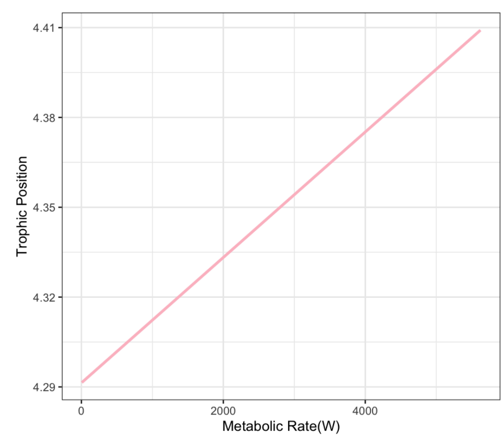
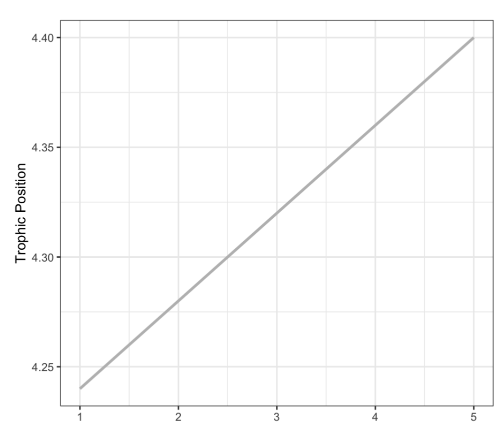


Figure 3. Positive linear regression of shark body mass impact on trophic position



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