Linking Ecological and Life History Traits to Ventilatory Behavior in Sharks

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Introduction

Sharks rely on continuous water flow across their gills to obtain oxygen, and many active species accomplish this through ram ventilation, a behavior that requires the mouth to remain open while swimming. However, little is known about how ventilatory behaviors such as mouth gape vary among shark species or how these behaviors relate to ecological and life history traits. This project aims to quantify natural variation in mouth gape across a wide range of ram-ventilating sharks using measurements collected from images of sharks in the wild. By analyzing gape angle in relation to morphological features such as caudal fin aspect ratio and gill slit height, as well as habitat and taxonomy, we seek to better understand the functional and ecological factors that influence ventilatory strategies. Establishing these relationships will help determine whether gape angle can be predicted from known metabolic and morphological traits, providing new insight into shark physiology and behavior

Purpose & Research Question

The primary goal of this project is to investigate how ventilatory behavior, specifically mouth gape angle, varies among shark species and how this behavior is linked to ecological and morphological traits. The central research questions are: (1) How much variation exists in gape angle across different species of ram-ventilating sharks in natural settings? (2) Are gape angles related to indicators of activity level, such as caudal fin aspect ratio and gill slit height? and (3) Can gape angle be predicted from published metabolic and swimming performance data? By addressing these questions, this study seeks to determine whether morphological and ecological characteristics can be used to explain or predict ventilatory strategies in sharks. Understanding these relationships will provide insight into how anatomy, behavior, and physiology interact to support the energetic demands of different shark species. This research also aims to contribute to broader knowledge of shark functional biology and how species adapt to different environmental conditions. Ultimately, identifying patterns in gape behavior may help improve future studies of shark energetics and conservation physiology.

Subjects, Methods & Analysis

This study focused on actively swimming, ram-ventilating shark species from nine families, including Lamnidae, Carcharhinidae, Sphyrnidae, and Alopiidae. Only images of sharks observed swimming normally in the wild were used, while photographs showing feeding, resting, or non-ventilatory mouth opening were excluded. For each species, up to 25 high-quality images were collected from online sources, and anatomical landmarks were measured using ImageJ software. Measurements included eye height and width, gill slit heights, lower jaw length, mouth gape distance, and gape angle. These data were combined with morphological metrics extracted from field guide illustrations, such as caudal fin aspect ratio and gill slit dimensions, to provide standardized comparisons across species.

Analysis focused on quantifying average gape angle and variation within and among species and determining whether gape behavior could be predicted from ecological or morphological traits. Relationships between gape angle, activity level proxies, and gill morphology were examined using correlation and regression analyses. Results from earlier analyses of related shark groups suggest that more active, pelagic species tend to exhibit smaller and more consistent gape angles, while less active species show greater variability. By comparing measurements from action images to field guide data, this project evaluates whether structural traits can serve as reliable indicators of ventilatory behavior in natural settings

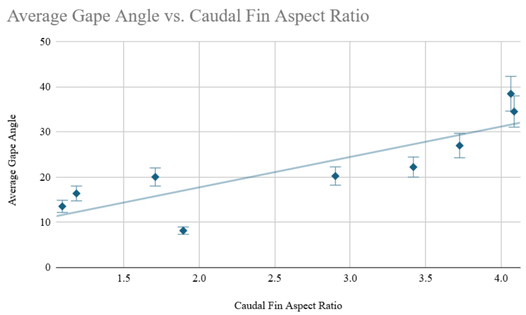

Figure 1. Relationship between caudal fin aspect ratio and average gape angle across shark species. Each point represents the mean gape angle for a species, with error bars showing variability. The positive trend suggests that sharks with higher aspect ratios tend to exhibit larger gape angles during swimming.

Results

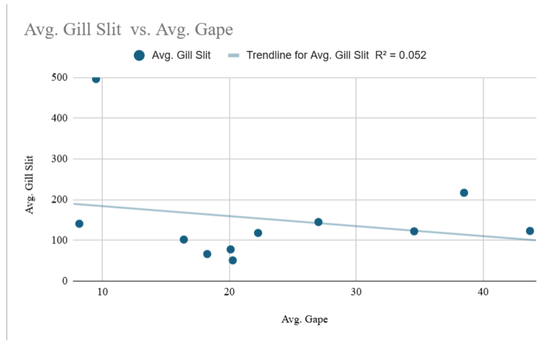

Figure 2. Relationship between average gape angle and average gill slit height across shark species. Each point represents the mean measurements for a single species. A linear trendline is shown to illustrate the overall pattern (R^2 = 0.052). The low R^2 value indicates little to no correlation between gill slit size and gape angle, suggesting that variation in ventilatory gape is not strongly predicted by gill morphology alone.

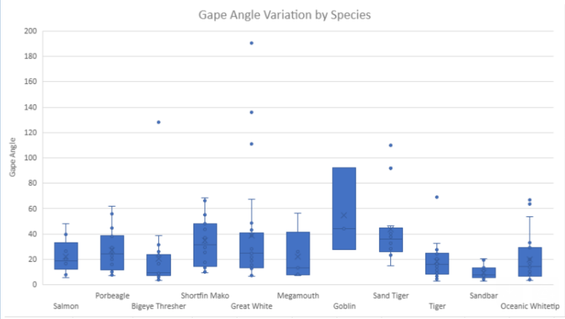

Figure __. Variation in gape angle across shark species. Boxplots display the distribution of individual gape angle measurements for each species, with points representing outliers. Differences in spread and median values illustrate that ventilatory gape behavior varies substantially both within and among species.

These results indicate that ventilatory gape behavior is highly variable among shark species and is influenced by ecological and functional traits. The positive relationship between caudal fin aspect ratio and gape angle suggests that more active sharks may require wider gapes to meet higher oxygen demands during ram ventilation. In contrast, the lack of correlation between gill slit height and gape angle indicates that gill morphology alone does not determine ventilatory behavior. Together, these findings highlight gape angle as a potentially informative metric for understanding shark physiology and ecological specialization.

Conclusions

This study demonstrates that ventilatory gape behavior in sharks varies widely among species and is influenced by ecological and functional traits. Analysis of action images revealed substantial differences in average gape angle and variability across species, indicating that gape is a behaviorally flexible and species-specific characteristic. A positive relationship between caudal fin aspect ratio and gape angle suggests that more active, pelagic sharks tend to swim with wider gapes, likely reflecting higher metabolic and oxygen demands. In contrast, no meaningful correlation was found between gill slit height and gape angle, indicating that gill morphology alone does not strongly predict ventilatory behavior. Together, these findings suggest that gape angle is more closely linked to swimming performance and ecological lifestyle than to simple anatomical features. While additional species and larger sample sizes are needed, this work highlights gape angle as a useful metric for understanding the relationship between shark physiology, behavior, and ecology.

Directions for Future Research

Future research should expand this study to include a greater diversity of shark species and larger sample sizes in order to better evaluate patterns across different ecological groups. Incorporating additional families, as well as more coastal and benthic-associated species, would help determine whether the relationships observed here apply broadly across sharks. Further work could also integrate direct measurements of metabolic rate, swimming speed, and environmental conditions to more accurately link gape angle to physiological demand. High-resolution video analysis, rather than still images alone, would allow researchers to examine how gape changes dynamically with swimming behavior. Finally, combining morphological data with field observations and tagging studies could help clarify how ventilatory strategies vary in real-world contexts. Together, these approaches would provide a more comprehensive understanding of the functional and ecological significance of gape behavior in sharks.