Comparing Metabolic Rates and Acceleration to Understand the Effects of Commercial Longlining on Sharks

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Introduction

Longlining

Since the 1950s, mortality rates of sharks have been steadily increasing globally due to several human-induced factors, such as longlining (Figure 1). Although longlining is illegal in The Bahamas, it is not very well regulated globally. Longlining can result in unintentional capture of sharks, or bycatch. The combination of physiological stress and physical trauma experienced during longline capture can potentially lead to mortality either during capture or sometime after release.

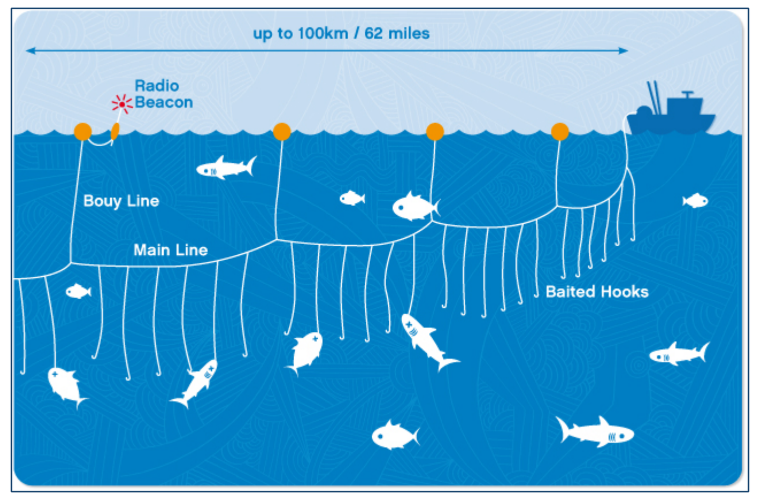

Figure 1. Commercial longlining is a process where baited hooks are cast out on a line, which can be over 60 miles long. These lines can be left out for multiple days.

Measuring Metabolic Rates

Calibrating metabolic rate against a measure of activity level in the lab can be used to measure metabolic rates in wild animals. Metabolic rate can be measured indirectly via oxygen consumption (VO_2). Activity level can be measured through acceleration via overall dynamic body acceleration (ODBA), which states that body acceleration is caused by muscle contraction. ODBA has been shown to be an excellent proxy for VO_2 in many species, including sharks (Gleiss et al. 2010).

Figure 2. An oxygen readout from the data logger graphing a decrease in oxygen concentration in the swim tunnel over time.

Lemon Sharks

Lemon sharks are an excellent model species for this study due to these factors:

- Locally abundant in South Eleuthera (Murchie et al. 2010)
- Remain in the same location for most of their juvenile life (Jennings et al 2008)
- Low hook-and-line capture mortality (Danylchuk et al. 2014)
- Easy to transport and do not need to swim to breathe (Figure 3)

Figure 3. A juvenile lemon shark in transport with an accelerometer attached to its dorsal fin.

Purpose

The purpose of our study is to establish the correlation between VO_2 and ODBA in juvenile lemon sharks so that accelerometers can be put on juvenile lemon sharks and measure their activity-specific metabolic rates.

Methods

Field Work

- Sharks were caught at various creeks along South Eleuthera (Figure 4) in seine nets (Figure 5)
- Placed in holding tanks at the Cape Eleuthera Institute (Figure 6)
- Fed two percent of their body mass daily
- Forty-eight hours prior to experiment, food was withheld

Figure 4. Nursery habitats where juvenile lemon sharks were captured.

Figure 5. Seine netting at Kemps Creek.

Figure 6. Holding tanks at the Cape Eleuthera Institute.

Swim Tunnel Experiment

Accelerometers were attached to the shark's first dorsal fin (Figure 7). Sharks were placed in a swim tunnel respirometer for a six-hour acclimatization period at a low swimming speed (Figure 8). Swimming speed was increased in 10cm s^{-1} increments every 15 minutes until the shark reached its critical swimming speed, or the maximum speed a shark can maintain before it becomes exhausted. The rate of oxygen consumption was measured at every velocity increment for the first ten minutes. To analyze the relationship between VO_2 and ODBA, a standard least squares model was used with individual shark as a random effect, and an alpha value of 0.05.

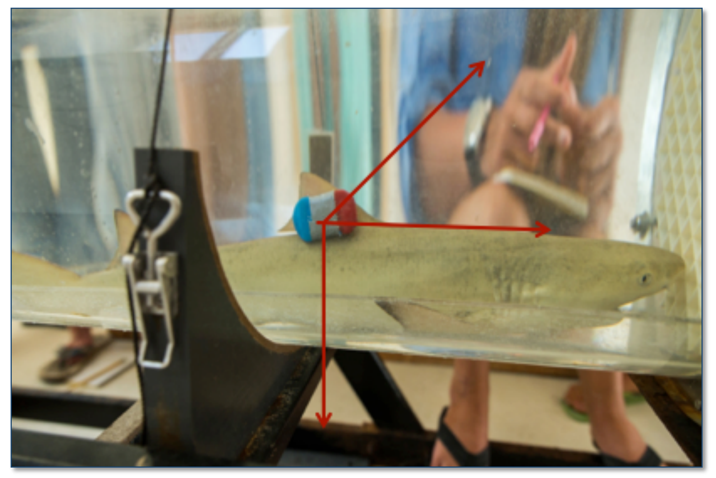

Figure 7. Accelerometer on the dorsal fin of a lemon shark recording tri-axial (indicated by red lines) acceleration.

Figure 8. Juvenile lemon shark in a swim tunnel while oxygen consumption and acceleration were measured.

Results

A total of nine juvenile lemon sharks (seven male and two female) were tested. The mean total length of the nine juvenile lemon sharks was 65.01 $\pm$ 1.40 cm. The mean mass of the sharks was 1.41 $\pm$ 0.10 kilograms. The average water temperature in the flume was 27.45 $\pm$ 0.12 °C.

For each shark, VO_2 was calculated along with ODBA at each swimming speed (20, 30, and 40 cm s^{-1}). Of the nine sharks tested, only four swam to exhaustion, while the remaining five did not swim to exhaustion, or did not swim at all. The standard least squares model showed that there was no statistically significant relationship between ODBA and VO_2 (p=0.0541; Figure 9), however the random effects model showed that there was a significant difference for the intercepts between curves for individual sharks (p<0.001; Figure 10).

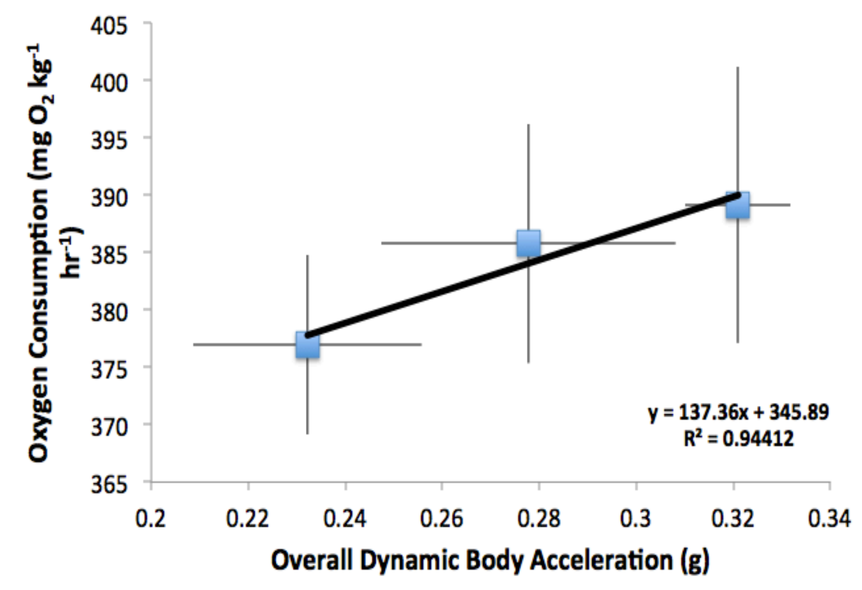

Figure 9. Correlation between the mean overall dynamic body acceleration and the mean oxygen consumption. Points shown have a positive linear trend based on the R-value (0.97) but are not statistically significant (0.0541).

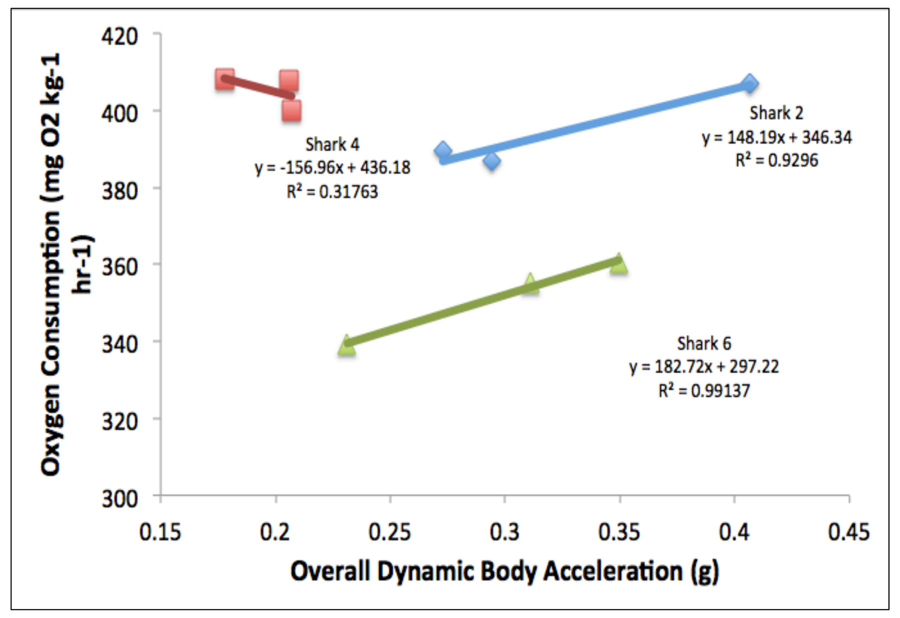

Figure 10. Correlation between overall dynamic body acceleration and oxygen consumption per individual lemon shark. Only three sharks were used as a result of insufficient data.

During the duration of our experiment it became apparent that juvenile lemon sharks were accelerating more at slower swimming speeds. To account for this, the first swim speed, 10 cm s^{-1}, was discarded from the results. 50 cm s^{-1}, the fastest swim speed, was not included in the results because only one shark reached this speed.

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Shark Research & Conservation Program, Cape Eleuthera Institute, The Bahamas

Carleton University

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New England Aquarium — Protecting the blue planet

Discussion

The relationship between ODBA and VO_2 was not statistically significant, which is surprising because ODBA and VO_2 have been shown to correlate very well in many other species, including another shark (Gleiss et al. 2010). Although a low sample size was tested, a study correlating dynamic body acceleration with VO_2 produced statistically significant data with a sample size of only three juvenile hammerhead sharks (Gleiss et al. 2010).

Potential Stressors

Several potential sources of stress may have affected results by raising metabolic rates or causing sharks to swim unnaturally. For example, light or noise from the room (Figure 11) or handling (Figure 12) may have stressed sharks and raised their metabolic rates. In addition, the dimensions of the swim tunnel may not have been large enough to allow sharks to swim as they would in the wild.

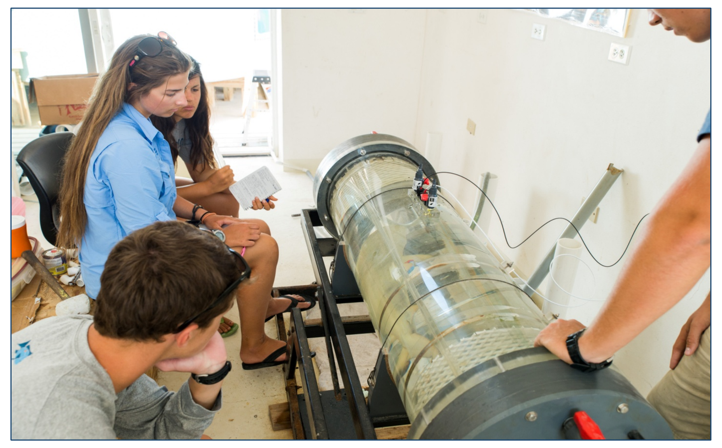

Figure 11. Similar to Lowe (2001), it is possible that flume-related factors may correlate to a higher ODBA values at slower swimming speeds.

Noise and Light Disturbance

Throughout the duration of the experiment, the juvenile lemon sharks were exposed to unnatural light from the room, as well as noise from the propeller in the swim tunnel (Figure 11). To reduce the light disturbance, a towel was placed over the swim tunnel during the acclimation period and the experiment. Unfortunately, there was no way to reduce noise disturbance.

Figure 12. Potential stress caused from handling prior to the experiment. This increase in stress causes an increase in metabolic rate potentially altering the data.

Non-continuous swimming

On occasion, sharks would become uncooperative and rest in the rear of the swim tunnel (Figure 13). Lemon sharks can passively pump water over their gills and do not need to continuously swim to breathe. A full set of data could not be recorded from sharks that would not swim continuously for the duration of the experiment.

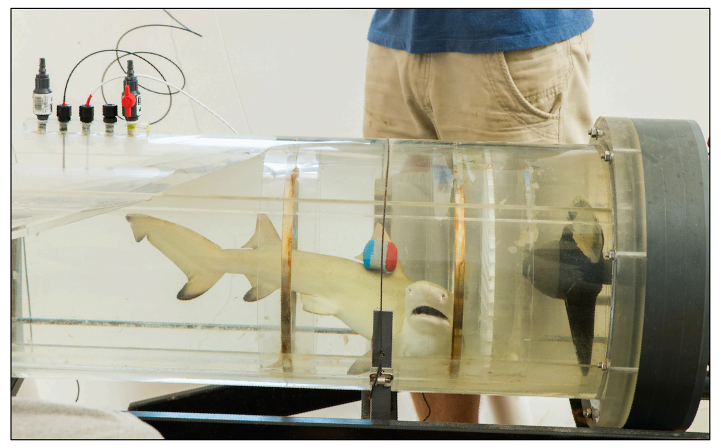

Figure 13. A juvenile lemon shark resting in the rear of the swim tunnel.

Future Objectives

In the future, both an energetic cost of capture and a daily energy budget of juvenile lemon sharks will be measured. A daily energy budget will show the amount of energy a juvenile lemon shark uses throughout its daily activities. Measuring energetic costs of capture will help obtain a broader understanding of a sharks' energy expenditure during capture. An understanding of how a shark uses energy during capture relative to its overall daily energy expenditure can be derived by comparing both of these. These results could potentially persuade governments to regulate commercial fishery practices to help conserve shark populations worldwide.

Citations

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