

# Lemon shark acceleration and oxygen consumption (Shark Metabolic Rate project)

**Website:** <https://www.bco-dmo.org/dataset/670832>

**Data Type:** experimental

**Version:** 1

**Version Date:** 2016-12-21

## Project

» [Determining the Field Metabolic Rate of Marine Predators: Integrating Accelerometry and Respirometry to Bridge the Gap Between the Laboratory and the Field](#) (Shark Metabolic Rate)

Contributors	Affiliation	Role
<a href="#">Whitney, Nicholas</a>	Mote Marine Laboratory (Mote)	Principal Investigator
<a href="#">Hueter, Robert</a>	Mote Marine Laboratory (Mote)	Co-Principal Investigator
<a href="#">Copley, Nancy</a>	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

## Abstract

Captive lemon shark acceleration and oxygen consumption.

---

## Table of Contents

- [Coverage](#)
  - [Dataset Description](#)
    - [Methods & Sampling](#)
    - [Data Processing Description](#)
  - [Data Files](#)
  - [Related Publications](#)
  - [Related Datasets](#)
  - [Parameters](#)
  - [Instruments](#)
  - [Deployments](#)
  - [Project Information](#)
  - [Funding](#)
- 

## Coverage

**Spatial Extent:** N:28.457 E:-80.29 S:24.54 W:-82.83

**Temporal Extent:** 2012 - 2016

## Methods & Sampling

These methods describe all those associated with the project.

### Capture and maintenance:

Respirometry experiments were conducted on juvenile nurse, lemon, and blacktip sharks. Nurse sharks (n=8, 53-132 cm TL) were captured via rod and reel from the Florida Keys, USA. Lemon sharks (n= 30, 69-100 cm TL) were captured with cast nets from Cape Canaveral, FL, and the Florida Keys, USA. Blacktip sharks (n = 8, 53-64 cm TL) were captured with rod and reel from Terra Ceia Bay, FL, USA. All animals were transported to Mote Marine Laboratory in Sarasota, FL, and held in a 150,000 liter indoor, recirculating tank for the duration of experiments. Sharks were fed a diet consisting of herring, squid, and shrimp every other day to satiation, but were fasted prior to the beginning of trials to achieve a post-absorptive state. Nurse sharks were fasted for at least 72 h prior to trials, and lemon and blacktip sharks were fasted for at least 48 h prior to trials. All sharks were kept on a constant 12 h light:dark cycle.

Respirometry trials were run at two temperature groups representing the low (~20°C) and high (~30°C) end

of the temperature range these species are likely to experience in the wild. Sharks were acclimated to trial temperatures in the holding tank for at least a week prior to experimentation. Trials with lemon and blacktip sharks were all run within 1 –2 months of initial capture. Nurse shark trials were run with individuals that had been maintained in captivity for at least one year.

### **Accelerometry:**

During trials, sharks were equipped with Cefas G6A+ acceleration data loggers (Cefas, Inc., Lowestoft, UK), which recorded triaxial acceleration at 25 Hz. Tags were attached to the first dorsal fin of sharks at two points using monofilament (Fig. 4) at least 24 h in advance of the start of a trial. Since sharks tagged in the field would also need to be tracked acoustically in order to retrieve the data loggers, the loggers used in captive trials were paired with a mock acoustic tag (Vemco Inc., Nova Scotia, model V9) in order to maintain the same weight and drag as tags used in field studies (see Fig. 4). The paired tag package measured 37 x 36 x 15 mm and weighed 23 g in air, representing 0.02-0.002% of the body mass of the study animals.

### **Respirometry:**

Trials were conducted in a circular, closed respirometer constructed from a modified fiberglass holding tank, as described in Whitney et al. (2016). Briefly, the respirometer was sealed using a lid constructed from a PVC frame with translucent plastic sheeting stretched across it, and dissolved oxygen (DO) and temperature were measured using a handheld YSI (model Pro 2030, Yellow Springs, OH). In order to ensure even water mixing in the respirometer and create water flow past the YSI probe for accurate DO measurements, a pump was set up in the centre of the tank facing into a T-shaped pipe made of PVC which housed the YSI probe, providing sufficient water movement to mix water throughout the system without creating a current in the tank. The pump and YSI were enclosed in a circular cage made of PVC and rigid plastic mesh during lemon and nurse shark trials to encourage the sharks to swim in full circles around the outer edge of the tank. This mesh cage was not used during blacktip trials because it appeared to induce stress in blacktip sharks. See Fig. 4 for a picture of the respirometer set-up.

Lemon and nurse sharks were placed into the respirometry system at least 12 h prior to the start of trials to allow them to acclimate to the system overnight. Blacktip sharks appeared to fatigue after extended periods in the smaller tank system, and were acclimated to the respirometer for 1 h prior to the start of trials rather than overnight. After the acclimation period, the respirometer tank was isolated from its flow-through system and sealed off with the lid. The tank was surrounded by a curtain to limit extraneous disturbances, and the trials monitored remotely using a live digital video feed. DO and water temperature were recorded every five minutes, and behavior monitored constantly throughout the trials. Trials began with the DO near 100% saturation and were run until the DO reached 80% saturation. To assess background respiration, a blank respirometer (without an animal) was measured for 4 h during each group of trials.

### **Data analysis:**

Periods of the trials where sharks displayed consistent behavior (either constant swimming or resting) for at least 20 min, were used to analyze metabolic rate. Oxygen consumption rate ( $MO_2$ ,  $mgO_2\ kg^{-1}\ h^{-1}$ ) was calculated for each one of these periods using equation 1:

$$(3) \quad MO_2 = (S-b)(60\ min)(V)/(W)$$

Where  $S$  is the slope of the oxygen degradation curve (in  $min$ ),  $b$  is the slope of the background respiration curve,  $V$  is the volume of the respirometer in liters, and  $W$  is the weight of the shark in kg. The volume of the shark ( $<10\ l$ ) was considered to be negligible relative to the respirometer volume (2494 l), representing an error of  $<0.5\%$ , and was thus not incorporated into our model.

Accelerometer data were analyzed using Igor Pro (Wavemetrics, Lake Oswego, OR). Static acceleration (indicating animal body position) was separated from dynamic acceleration (indicating animal movement) using a 3 s box smoother (Shepard, 2008), and ODBA calculated as the sum of the three dynamic acceleration axes. A mean ODBA value was calculated for each time interval where  $MO_2$  was analyzed during respirometry trials, to provide paired ODBA- $MO_2$  points for analyses.

SMR's (Standard Metabolic Rate) were calculated for lemon and nurse sharks at each experimental temperature by averaging metabolic rates during all resting intervals recorded. Since blacktip sharks are a ram-ventilating species, SMR was not directly calculated, but was estimated using the intercept of the ODBA- $MO_2$  relationship. RMRs were calculated for each species and temperature grouping as the mean metabolic rate of all periods where the study animal showed consistent swimming activity. Rest periods for lemon and nurse sharks were not included in RMR calculations.

Due to difficulties in keeping blacktip sharks in captivity for extended periods, a full ODBA -MO<sub>2</sub> calibration was not conducted at temperatures near 20°C. However, a pair of trials was run at 21.6°C on one individual, allowing for the calculation of a preliminary Q<sub>10</sub> value. Since there were insufficient data at the low temperatures to extrapolate an SMR for blacktip sharks, this Q<sub>10</sub> value was calculated based on differences in RMR. Only RMR data that overlapped in ODBA levels between the two temperatures were used in the Q<sub>10</sub> calculation to ensure the comparison was made between metabolic rates from similar activity levels. Q<sub>10</sub> values for nurse and lemon sharks were calculated using SMR data. Q<sub>10</sub> values were calculated according to the Van't Hoff equation

$$(4) \quad Q_{10} = (R_2/R_1)^{10/T_2-T_1}$$

Where R<sub>1</sub> is the metabolic rate at temperature T<sub>1</sub>, and R<sub>2</sub> the metabolic rate at temperature T<sub>2</sub>.

### **Error estimation and modeling:**

Error estimation and modeling were performed in R (R Core Team, 2010), using the lme4 (Bates et al. 2015) and MuMIn (Barton, 2016) packages. Linear mixed models were constructed to describe the relationship between ODBA and oxygen consumption for each species, with ODBA, activity state (resting or swimming), and temperature group as predictor variables, and individual included as a random effect. All combinations of variables and interaction effects were assessed using a comprehensive model selection table produced by the MuMIn package. Models were compared against each other using a corrected Akaike's Information Criterion (AICc), residuals, log likelihood, and R<sup>2</sup> of the models. Using the regression line produced by the best-fit model, the predicted MO<sub>2</sub> for each analysis interval was calculated, and compared against the measured MO<sub>2</sub> to calculate the standard error of the estimate for each species [(predicted MO<sub>2</sub> - observed MO<sub>2</sub>) / predicted MO<sub>2</sub> x 100], which was examined as a percentage of the measured MO<sub>2</sub>. Normality of the residuals of the optimal models was tested using an Anderson-Darling test (Wright et al., 2014).]

### **Data Processing Description**

#### **BCO-DMO Processing notes:**

- added conventional header with dataset name, PI name, version date
- modified parameter names to conform with BCO-DMO naming conventions
- converted formulae to values
- reduced precision of VO<sub>2</sub> column from 12 to 2 digits due to measurement methods
- nd (no data) was entered into all blank cells

[ [table of contents](#) | [back to top](#) ]

---

### **Data Files**

File
<b>lemon_respiration.csv</b> (Comma Separated Values (.csv), 24.39 KB) MD5:d747f268e097f5f9c96775b24476958
Primary data file for dataset ID 670832

[ [table of contents](#) | [back to top](#) ]

---

### **Related Publications**

Bates, D., Maechler, M., & Bolker, B. (2013). lme4: Linear mixed-effects models using Eigen and S4 classes. R package version 0.999999-2.

*Software*

Lear, K. O., Whitney, N. M., Brewster, L. R., Morris, J. J., Hueter, R. E., & Gleiss, A. C. (2016). Correlations of metabolic rate and body acceleration in three species of coastal sharks under contrasting temperature regimes. *The Journal of Experimental Biology*, 220(3), 397-407. doi:[10.1242/jeb.146993](https://doi.org/10.1242/jeb.146993)

*Results*

MuMIn, Barton, K. (2018). multi-model inference. R package version 1.15. 6. 2016. <https://CRAN.R-project.org/package=MuMIn>

*Methods*

Shepard, E., Wilson, R., Halsey, L., Quintana, F., Gómez Laich, A., Gleiss, A., ... Norman, B. (2008). Derivation of body motion via appropriate smoothing of acceleration data. *Aquatic Biology*, 4, 235–241.

doi:[10.3354/ab00104](https://doi.org/10.3354/ab00104)

*Methods*

Wright, S., Metcalfe, J., Hetherington, S., & Wilson, R. (2014). Estimating activity-specific energy expenditure in a teleost fish, using accelerometer loggers. *Marine Ecology Progress Series*, 496, 19–32.

doi:[10.3354/meps10528](https://doi.org/10.3354/meps10528)

*Methods*

[ [table of contents](#) | [back to top](#) ]

---

## Related Datasets

### IsRelatedTo

Whitney, N., Hueter, R. (2016) **Shark acceleration and oxygen consumption trials summary (Shark Metabolic Rate project)**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2016-12-21 <http://lod.bco-dmo.org/id/dataset/670880> [[view at BCO-DMO](#)]

### IsSupplementedBy

Whitney, N., Hueter, R. (2016) **Shark respirometry temperature corrections from other studies (Shark Metabolic Rate project)**. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2016-12-21 <http://lod.bco-dmo.org/id/dataset/670974> [[view at BCO-DMO](#)]

[ [table of contents](#) | [back to top](#) ]

---

## Parameters

Parameter	Description	Units
flume_static	whether trial was in flume or static water	unitless
trial	trial identifier	unitless
time_start	trial start time formatted as HH:MM	unitless
time_stop	trial stop time	unitless
temp	tank temperature	degrees Celsius
VO2	Oxygen consumption of animal during experiment	milligrams oxygen/kilogram/hour (mgO2/kg/h)
ODBA_mean	Overall dynamic body acceleration as measured by an acceleration data logger tag	gravity (g)
weight_kg	shark weight	kilograms
length_totl_cm	shark total length	centimeters

[ [table of contents](#) | [back to top](#) ]

---

## Instruments

<b>Dataset-specific Instrument Name</b>	Cefas G6A+ acceleration data loggers (Cefas, Inc., Lowestoft, UK),
<b>Generic Instrument Name</b>	Accelerometer
<b>Dataset-specific Description</b>	Recorded triaxial acceleration at 25 Hz of shark; attached to first dorsal fin.
<b>Generic Instrument Description</b>	An instrument for measuring acceleration, typically that of an automobile, ship, aircraft, or spacecraft, or that involved in the vibration of a machine, building, or other structure.

[ [table of contents](#) | [back to top](#) ]

---

## Deployments

**Whitney\_2012-16**

<b>Website</b>	<a href="https://www.bco-dmo.org/deployment/670842">https://www.bco-dmo.org/deployment/670842</a>
<b>Platform</b>	Mote Marine Lab
<b>Start Date</b>	2012-04-01
<b>End Date</b>	2016-03-31
<b>Description</b>	shark studies

[ [table of contents](#) | [back to top](#) ]

---

## Project Information

### **Determining the Field Metabolic Rate of Marine Predators: Integrating Accelerometry and Respirometry to Bridge the Gap Between the Laboratory and the Field (Shark Metabolic Rate)**

**Coverage:** Gulf Coast of South Florida and Bimini, Bahamas

*Description from NSF award abstract:*

Energetics is a central theme in ecology, and metabolism may be the primary factor determining the structure of biological systems as a whole. Despite the importance of top level predators in marine ecosystems and the need to understand the impact of their global population declines, surprisingly little is known about energy flow in upper trophic levels. This gap in knowledge is due to the difficulty of assessing the metabolic rate of marine predators and the inability to link experimentally derived metabolic rates to those of free-ranging animals in their natural habitat. Novel accelerometry technology is now making this link possible for the first time. Because Overall Dynamic Body Acceleration (ODBA) has been shown to correlate closely with oxygen consumption in numerous vertebrate taxa, this potentially transformational technique can be used to derive time-energy budgets for free-ranging marine predators.

This study will integrate the use of respirometry and accelerometry technology to bridge the gap between laboratory- and field-based metabolic rates for three species of sharks with different behaviors. The PIs will conduct respirometry experiments on accelerometer-equipped animals in the laboratory to determine the relationship between metabolic rate and ODBA for each species over a range of swim speeds and water temperatures. Using these relationships, the PIs will then conduct field experiments using accelerometry to calculate the absolute energetic expenditure of sharks in their natural habitat over several days. Because accelerometers also provide data with which specific shark behaviors can be quantified, the PIs will be able to partition between standard and active metabolic rate and determine how the relationship changes at varying temperatures. This aspect will have implications for predicting how seasonal or long-term changes in sea surface temperatures are likely to affect the impact of ectothermic predators on their prey.

[ [table of contents](#) | [back to top](#) ]

---

## Funding

<b>Funding Source</b>	<b>Award</b>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1156141</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-1156145</a>

[ [table of contents](#) | [back to top](#) ]