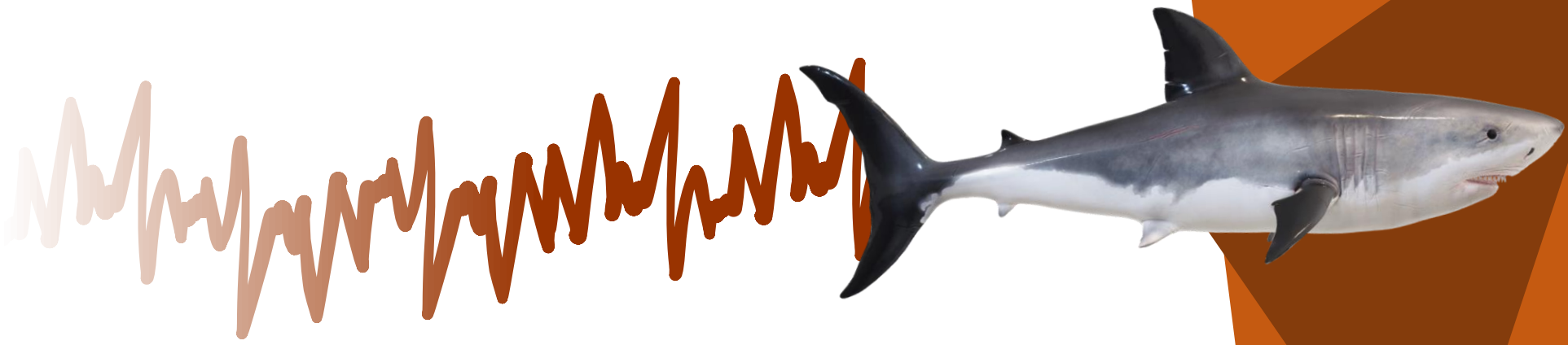
Acceleration and HMMs

CANSSI 2023



Topics

1. Biologging
2. Choosing Appropriate Metrics
3. Temporal Resolution
4. Example HMMs
5. Tutorial Dataset

Biologging

Biologger = Miniaturized animal-borne electronic data loggers

Common data types:

- Environmental (Temperature, salinity, depth, sound)
- Physiological (Body temperature, heart rate)
- Behavioural (Acceleration, Magnetic fields for heading)

Biologging

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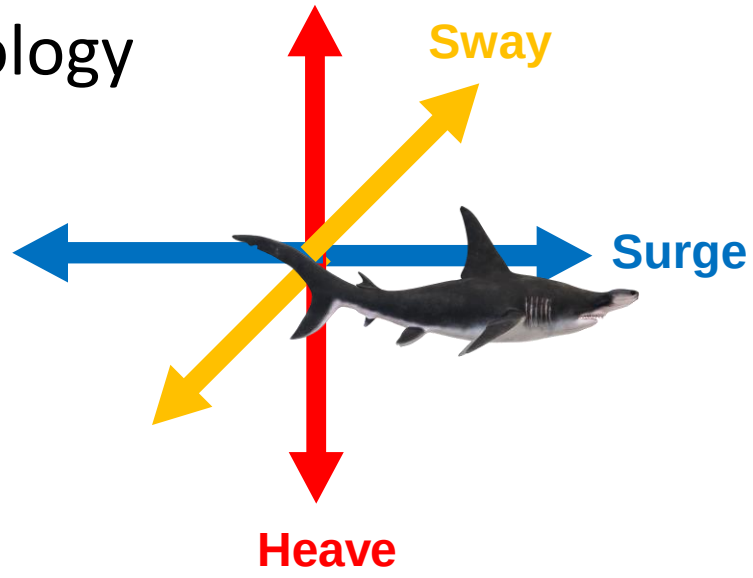
Biologging - Accelerometers

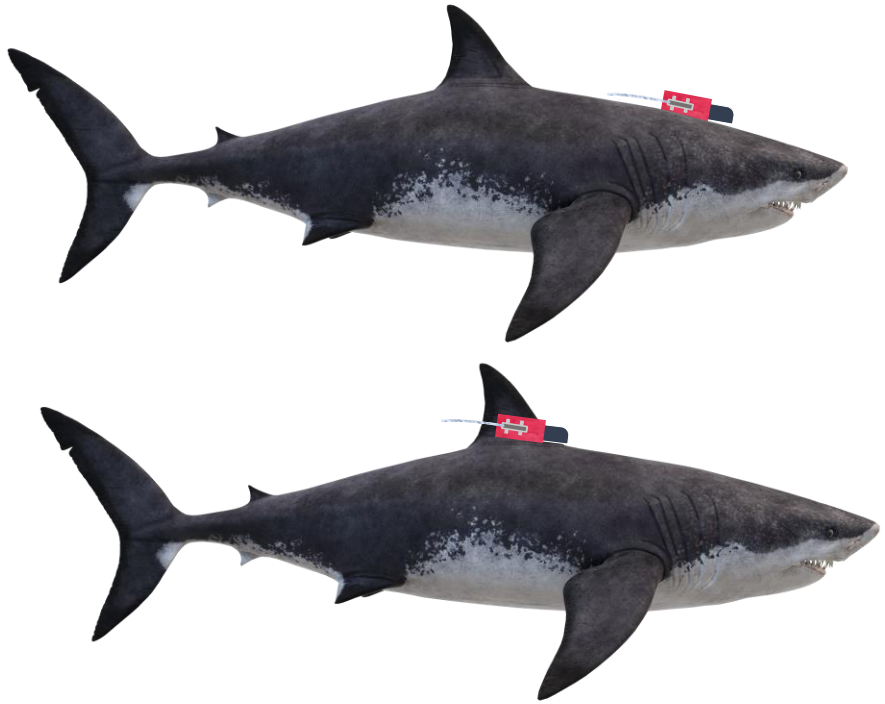
- Inertial sensor
- Measures changes in velocity over time
- Often log acceleration in 3 dimensions
- High-resolution data
- Many applications for behavioural ecology



Choosing Appropriate Metrics

Choosing Appropriate Metrics

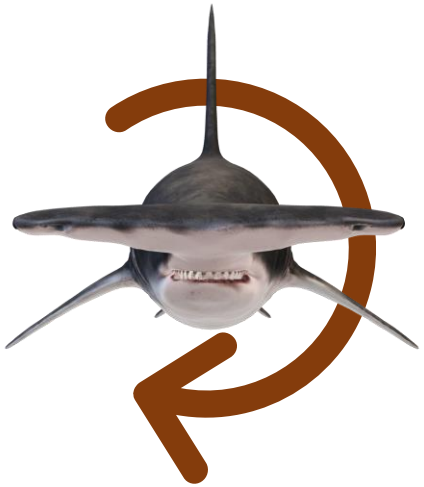
- Relevance to research question
- Species’ ecology
- Tagging methods



Choosing Appropriate Metrics

- Orientation/ Body Position

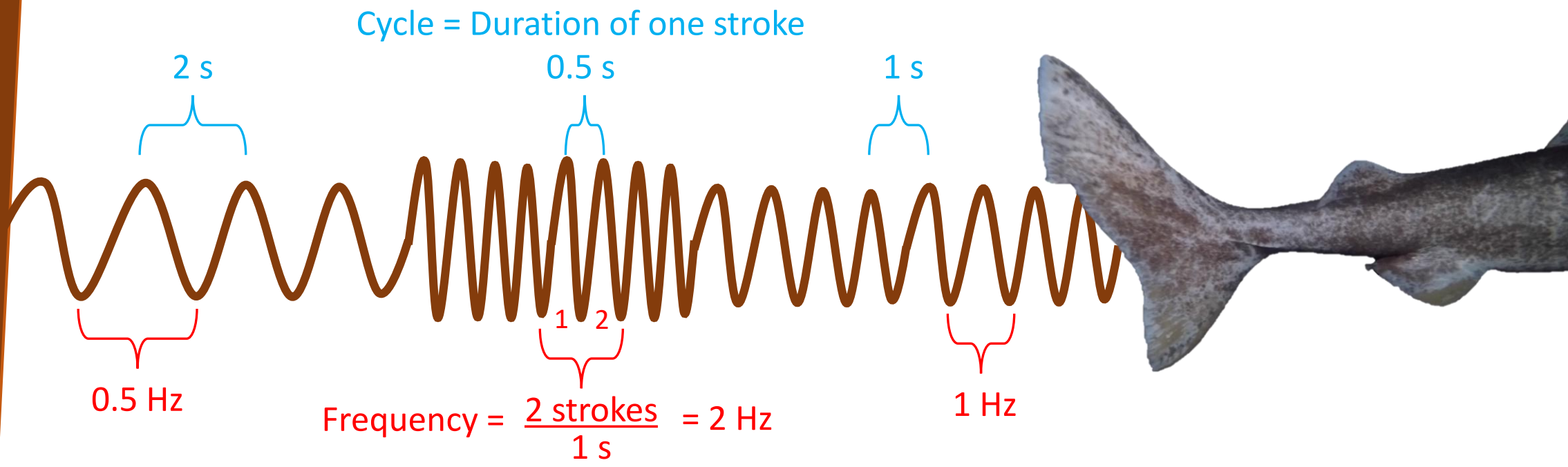
Pitch



Roll

Choosing Appropriate Metrics

- Orientation/ Body Position
- Stroke Frequency/Cycle (Swimming effort)



Choosing Appropriate Metrics

- Orientation/ Body Position
- Stroke Frequency/Cycle
- Overall or Vectorial Dynamic Body Acceleration (Activity)
  1. Remove effect of gravity/body position (Dynamic = Raw – Static)
  2. Take the absolute sum (ODBA) or the vectorial sum (VeDBA) of dynamic acceleration in all 3 axes.

$$ODBA = |dyn.X| + |dyn.Y| + |dyn.Z|$$

$$VeDBA = \sqrt{dyn.X^2 + dyn.Y^2 + dyn.Z^2}$$

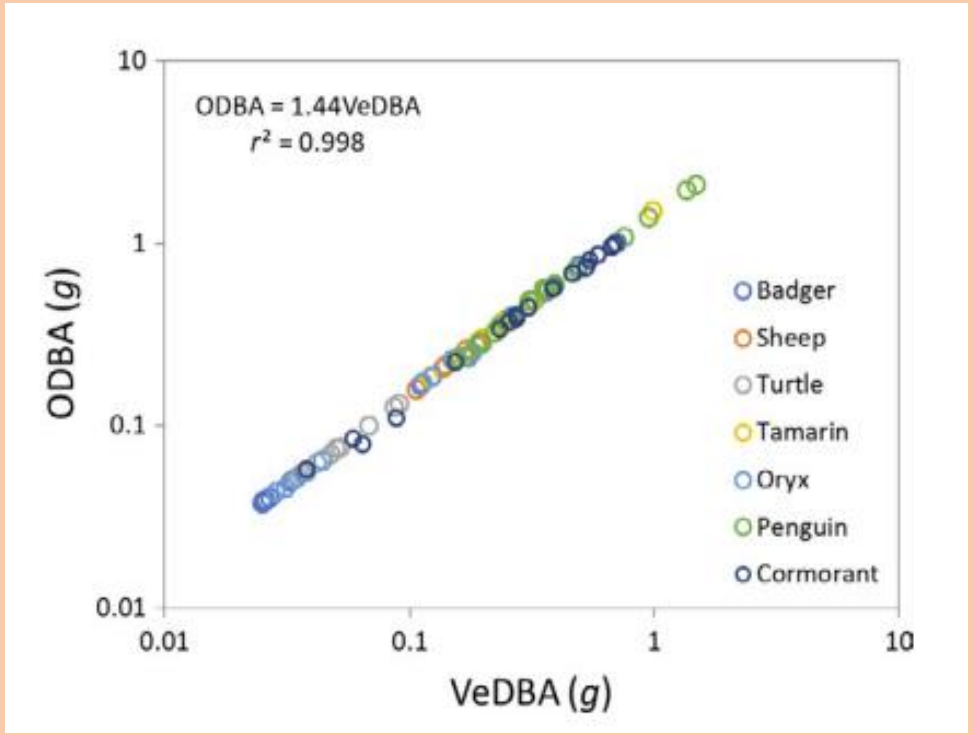
Choosing

- Orientation/
- Stroke Frequ
- Overall or Ve
  1. Remove
  2. Take the
     dynamic

$$ODBA = |dyn$$

$$VeDBA = \sqrt{dy$$

ODBA vs VeDBA



- Strongly correlated
- VeDBA better mathematically
- ODBA slightly better for energetics

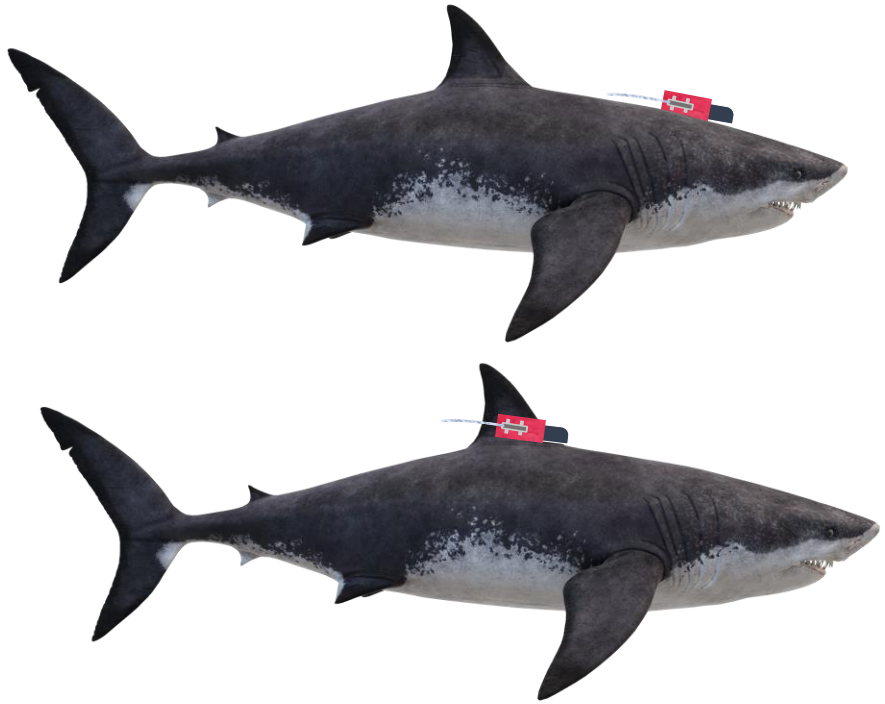
(Wilson et al. 2019)

Choosing Appropriate Metrics

- Orientation/ Body Position
- Stroke Frequency/Cycle
- Overall or Vectorial Dynamic Body Acceleration
- Jerk
  - Rate of change of Acceleration
  - Highlights abrupt changes in an animal's motion
  - Often used in studies focused on feeding/predation

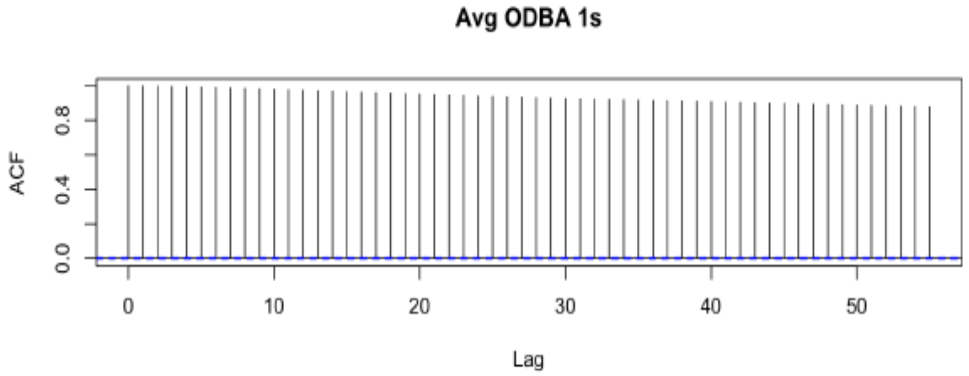
Choosing Appropriate Metrics

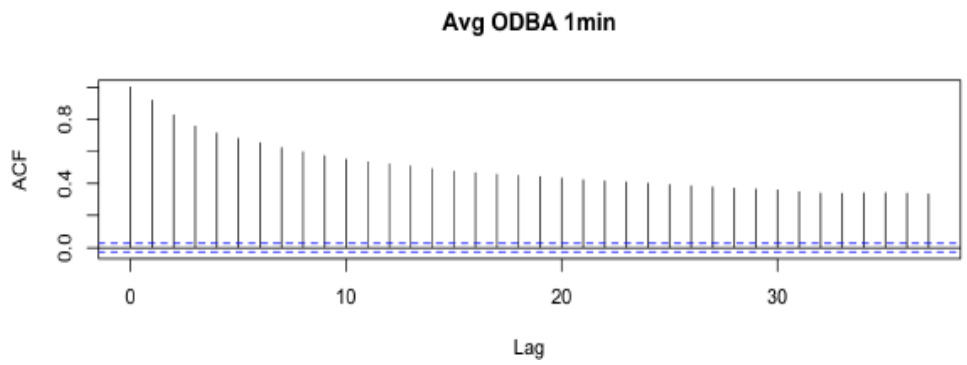
- Relevance to research question
- Species’ ecology
- Tagging methods



Temporal Resolution

- Accelerometers often log data at a very high sampling rate
- HMMs can be computationally intensive
- High resolution data may break the assumption of conditional independence
- It is sometimes necessary to down-sample your data
- **Make sure resolution is ecologically relevant!**





Example HMM – Oceanic Whitetips

How does activity vary with depth and time of day in oceanic whitetip sharks?

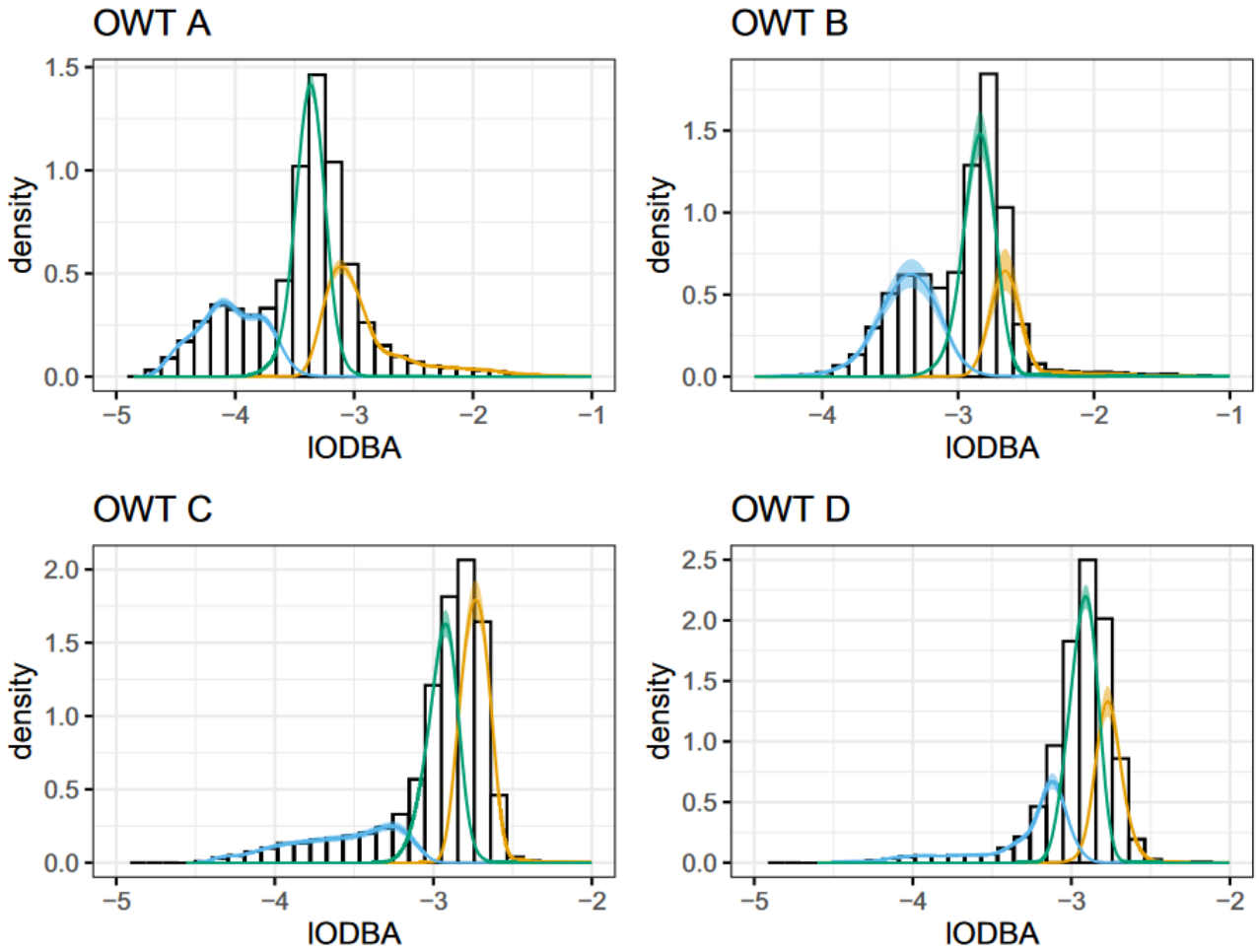
HMM:

- 3 states
- Observed data = log(ODBA)

By Johanlantz at the English-language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2066589

(Papastamatiou et al. 2022)

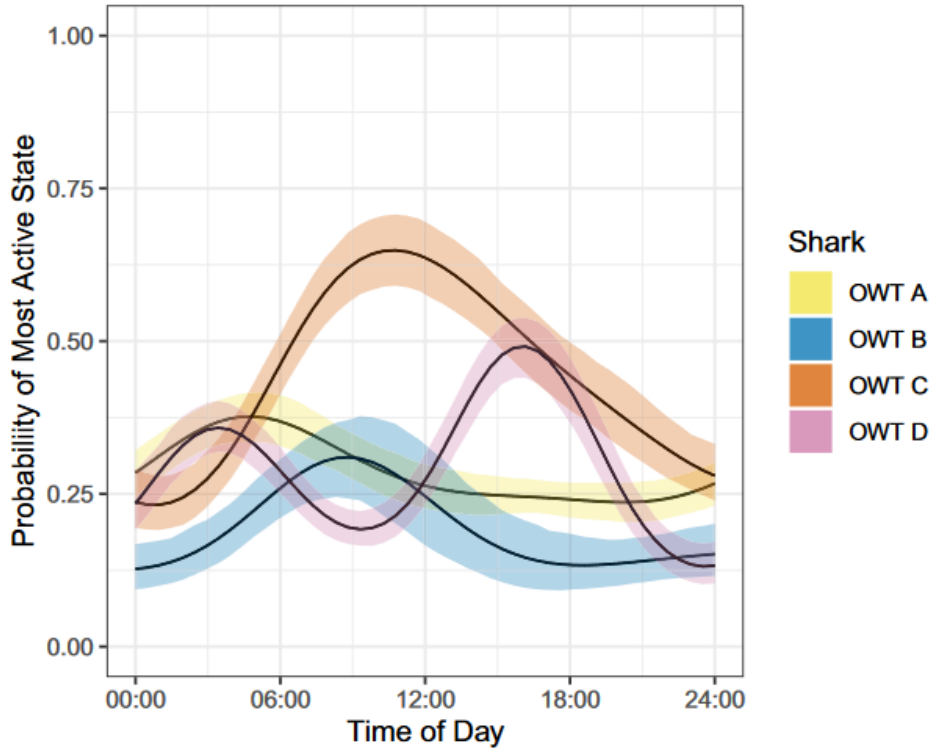
Example HMM – Oceanic Whitetips

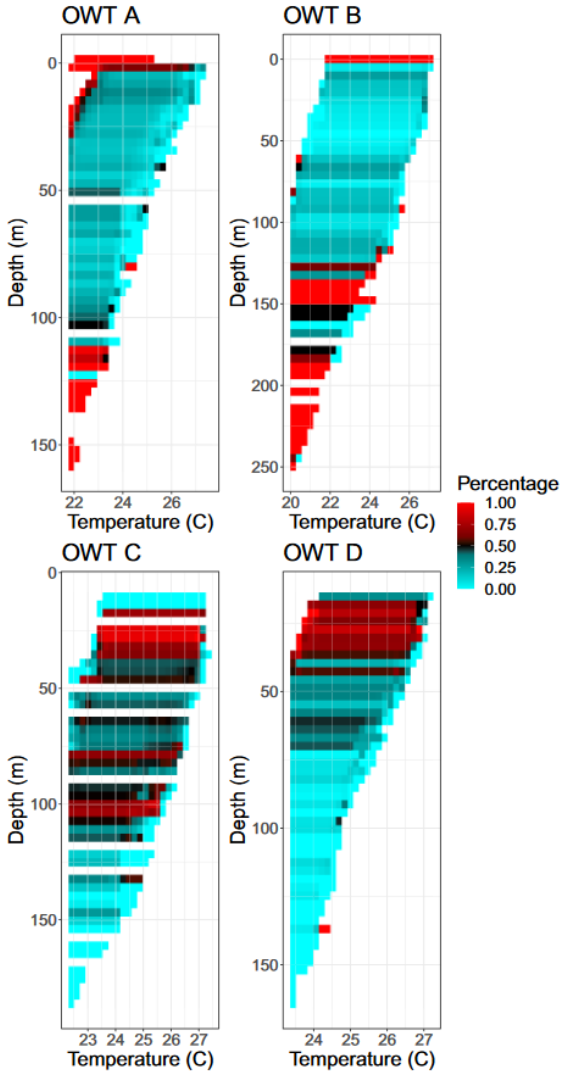


(Papastamatiou et al. 2022)

Example HMM – Oceanic Whitetips

Study found individual differences in how activity levels change with TOD and depth

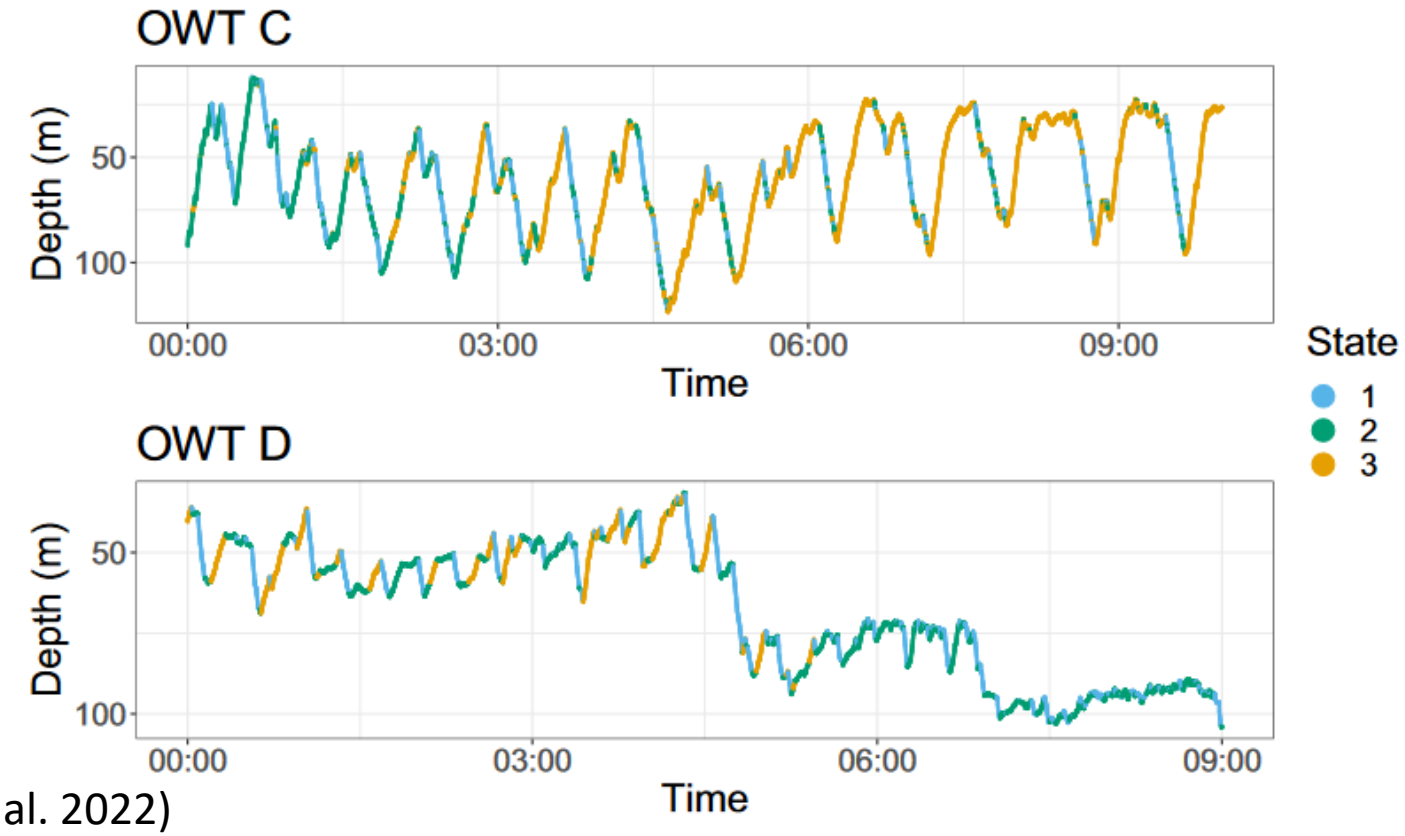




(Papastamatiou et al. 2022)

Example HMM – Oceanic Whitetips

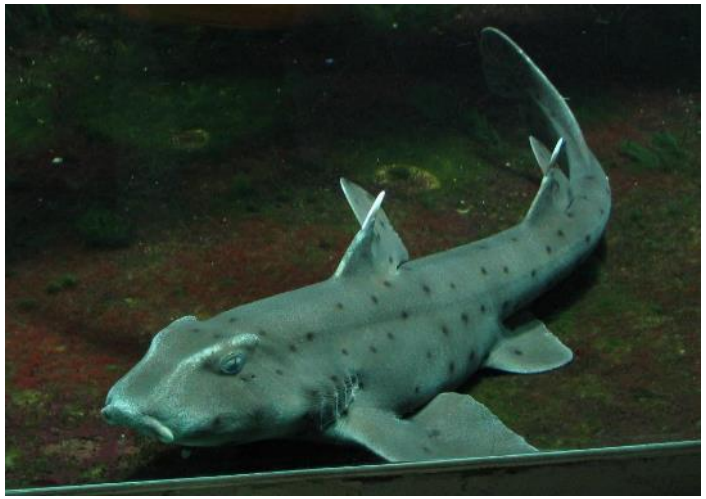
Plotting the decoded states also highlighted the sharks' negative buoyancy (i.e. low activity state on the descents)



(Papastamatiou et al. 2022)

Example HMM – Horn Sharks

Study aimed to elucidate the spatio-temporal patterns in horn shark behaviour



By Cymothoa exigua - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6433192

Problem:

- Horn sharks are bottom dwelling, non-obligate ram ventilators
- Movement data alone is insufficient to differentiate behaviours like foraging and rest…

(Adam et al. 2019)

Example HMM – Horn Sharks

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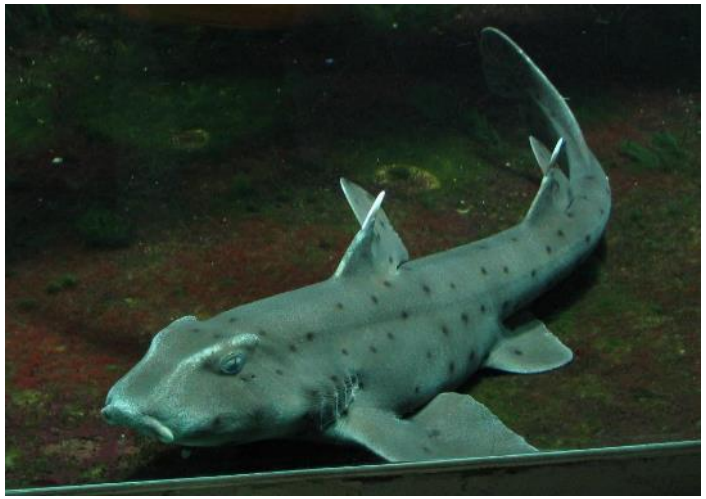

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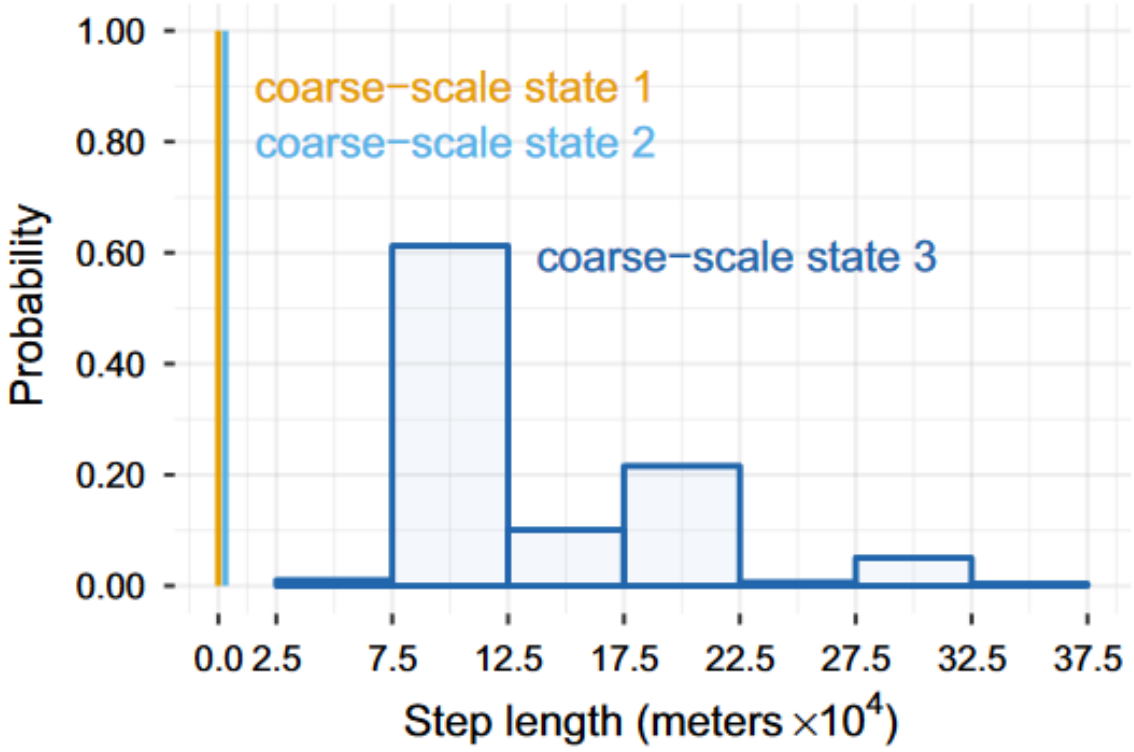
Hierarchal HMM:

- 3 Course states (from Acoustic telemetry)
- 3 Fine states (from Accelerometers [ODBA])
- No covariates

(Adam et al. 2019)

Example HMM – Horn Sharks

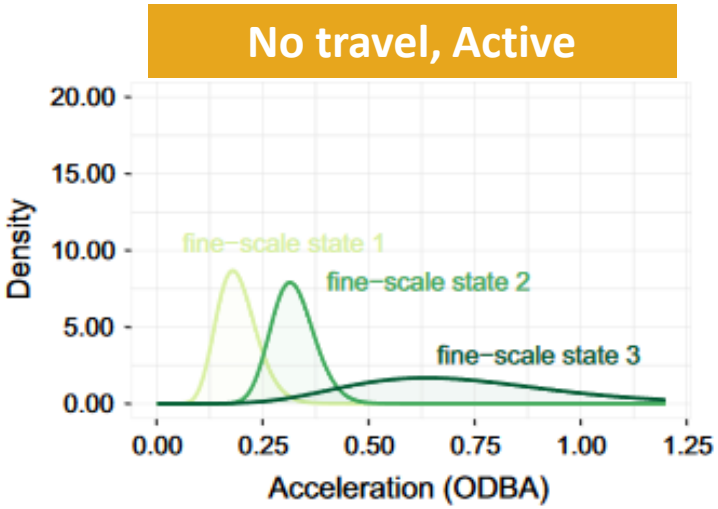


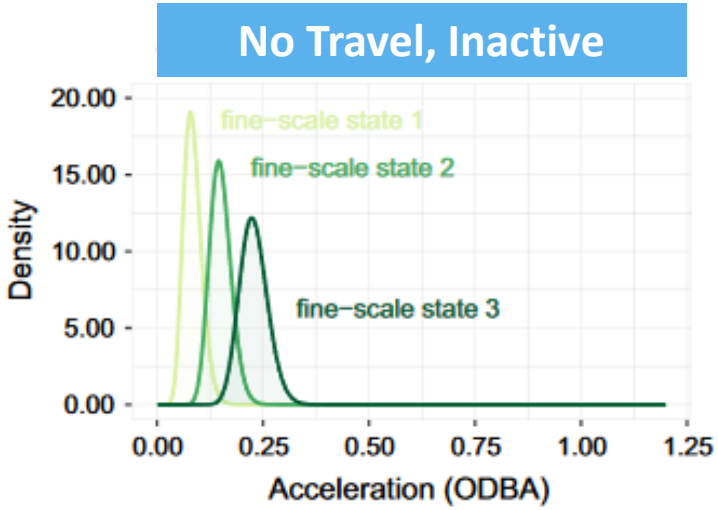
Coarse states:

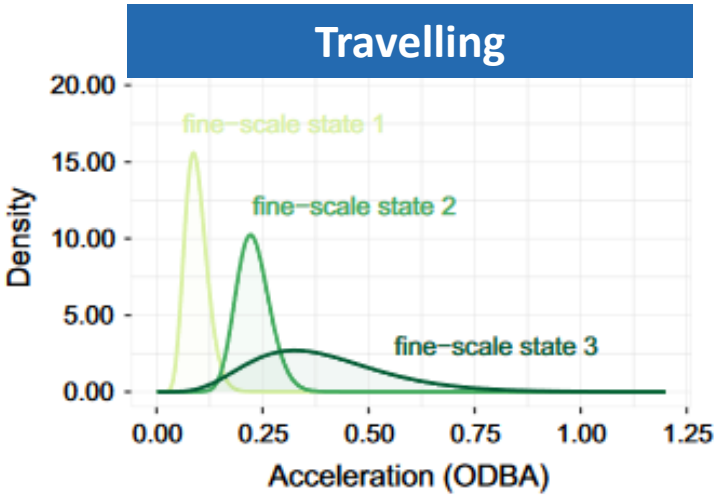
1. Zero distance travelled and active (15% of time)
2. Zero distance travelled and not active (36% of time)
3. Travelling (49% of time)

(Adam et al. 2019)

Example HMM – Horn Sharks





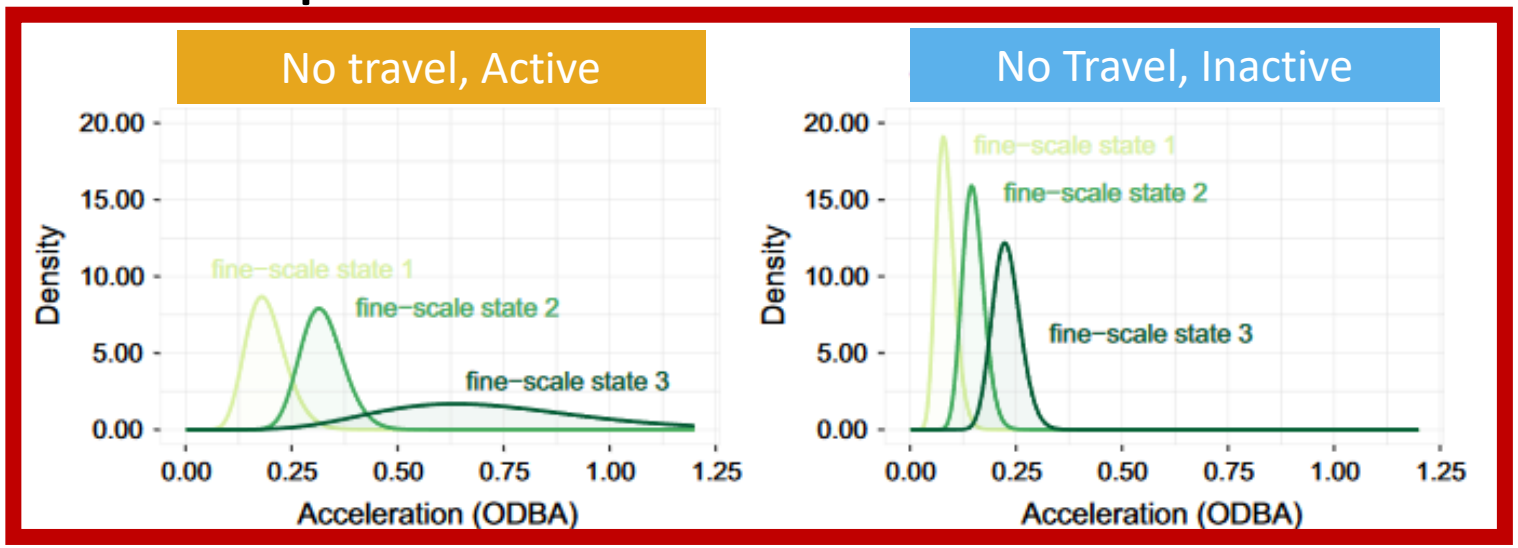


Fine states:

1. Low activity
2. Moderate activity
3. High Activity

(Adam et al. 2019)

Example HMM – Horn Sharks



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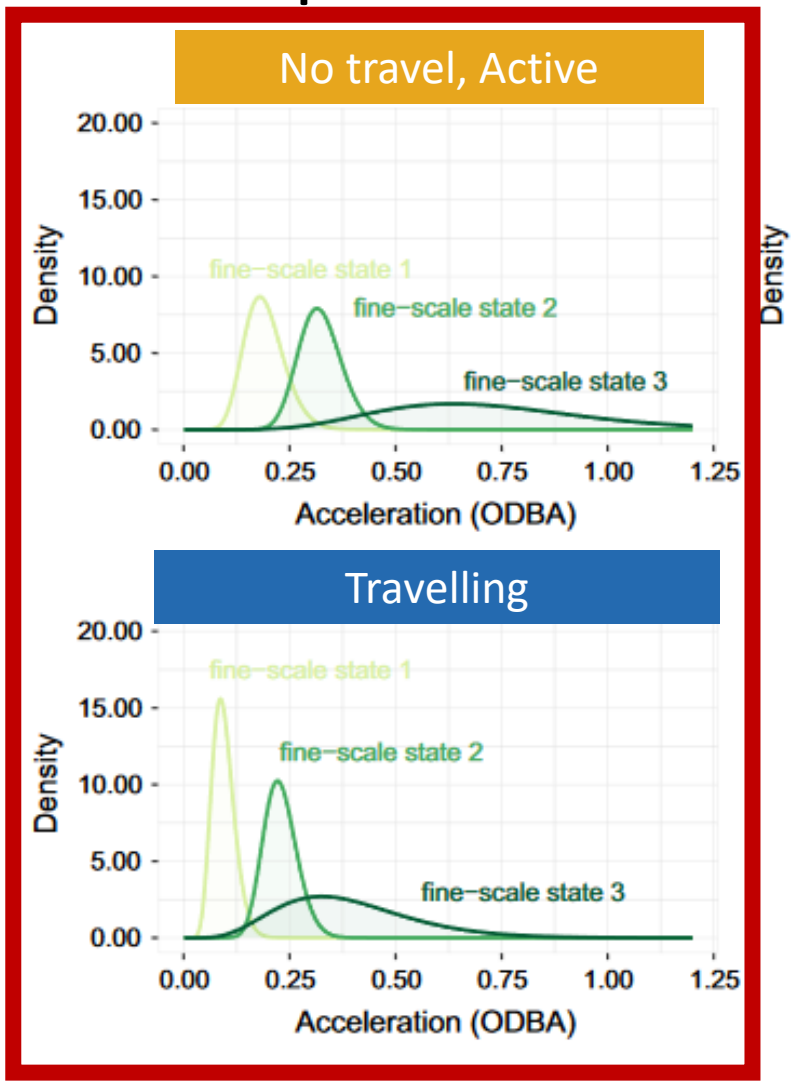
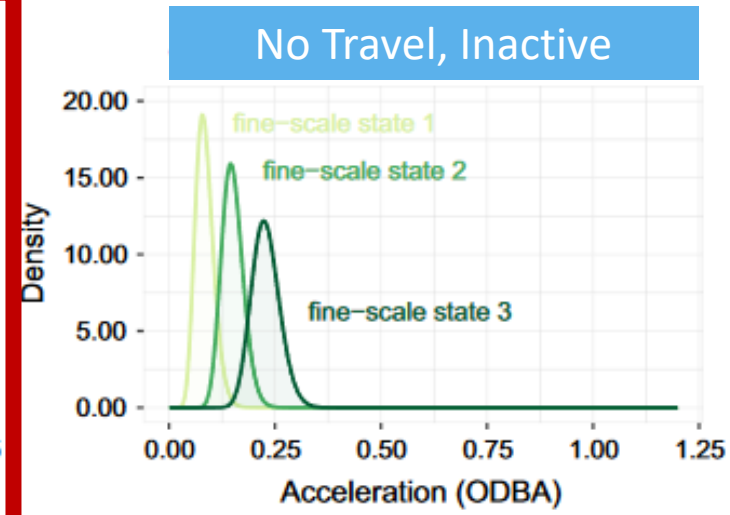
Example HMM – Horn Sharks





(Adam et al. 2019)

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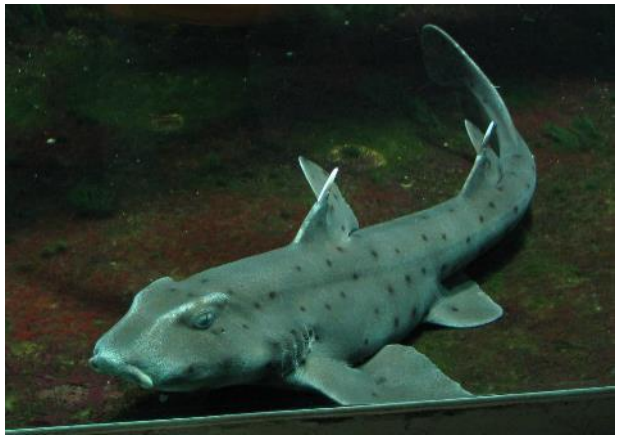
Example HMM – Horn Sharks

Take home:

- Movement only models may misrepresent activity/rest dynamics in species like the horn shark
- Hierarchal HMMs are a useful tool to address these issues by jointly modelling data collected at different scales



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(Adam et al. 2019)

Tutorial Dataset

Primary Data: 4 days of acceleration data (ODBA)

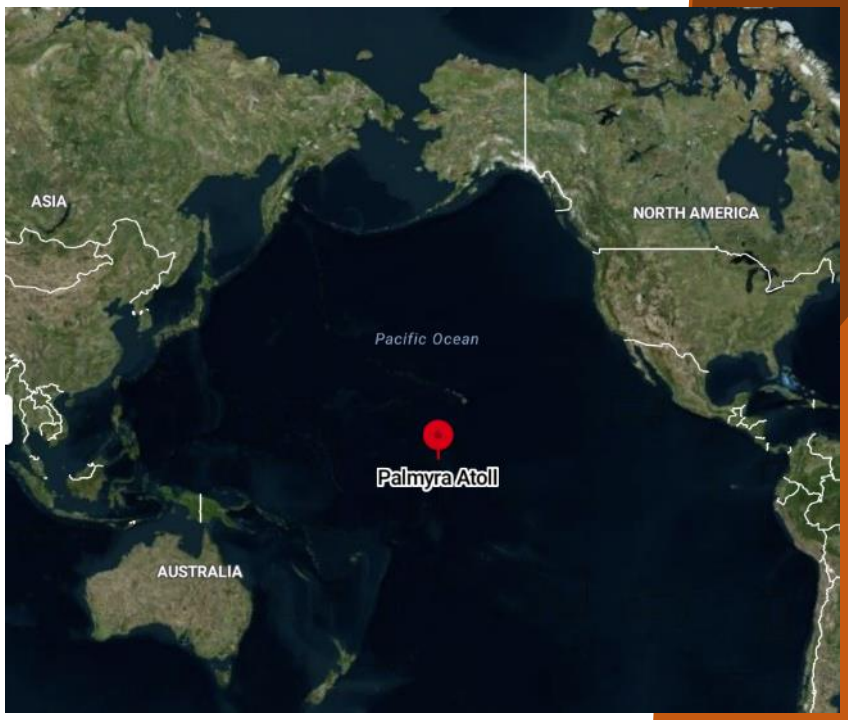
Possible Covariates: Time of Day, Depth, Temperature

Species: Blacktip reef shark (*Carcharhinus melanopterus*)

Location: Palmyra Atoll

Resolution: 1Hz

Source: Leos-Barajas et al. 2017



MomentHMM Refresher

Important Functions:

- **prepData:** Pre-process data streams and covariates
- **fitHMM:** Fit an HMM
- **plotPR:** Make pseudo-residual plots
- **viterbi:** Get most likely state sequence using the Viterbi algorithm
- **plotStates:** Plot the decoded states and state probabilities

Let’s get Coding!