

# Activity Patterns of Bull Sharks in Fresh Water

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The project was initiated by Professor Roland Langrock (Bielefeld University) and the researchers Dr. Adrian Gleiss and Evan Byrnes (Murdoch University) as a part of the class *Statistical Consulting*.

## Project

The **Fitzroy River** is a river system in the Kimberly region (**Western Australia**). During the dry season (**July-November**), the river dries up into separated pools (less than 5 m deep) with fresh water. Bull sharks use this river system as a nursery for the first years of their life.

**Research question:** How do varying environmental conditions, especially moon illumination, influence the time spent in different activity states of juvenile bull sharks?

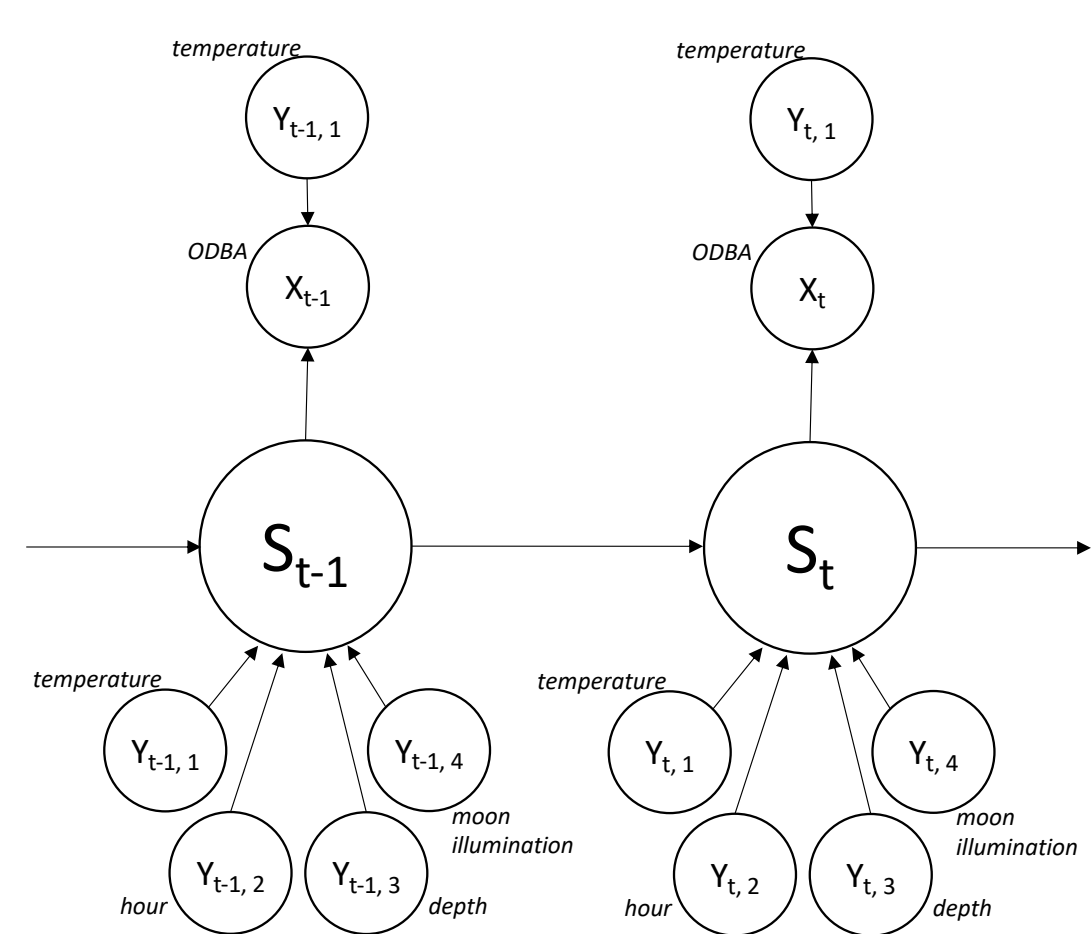


## Data

The data of **five juvenile sharks** is used for analysis. The acoustic tags implanted to each animal in **July 2016** have transmitted information about the **time of records**, **depth**, **temperature** and **overall dynamic body acceleration (ODBA)** as the measure of activity over three months. Additionally, information about the **moon illumination** is provided.



## The Hidden Markov Model



The **unobservable process** of switching between the activity states  $S_t$  ("low activity" or "high activity"), directly influences the **observable ODBA values**  $X_t$  for each time point  $t$ . The variables temperature, time of day, depth and moon illumination affect the unobservable process. Additionally, temperature directly influences the observable activity of the sharks within both activity states.

## Variable Selection

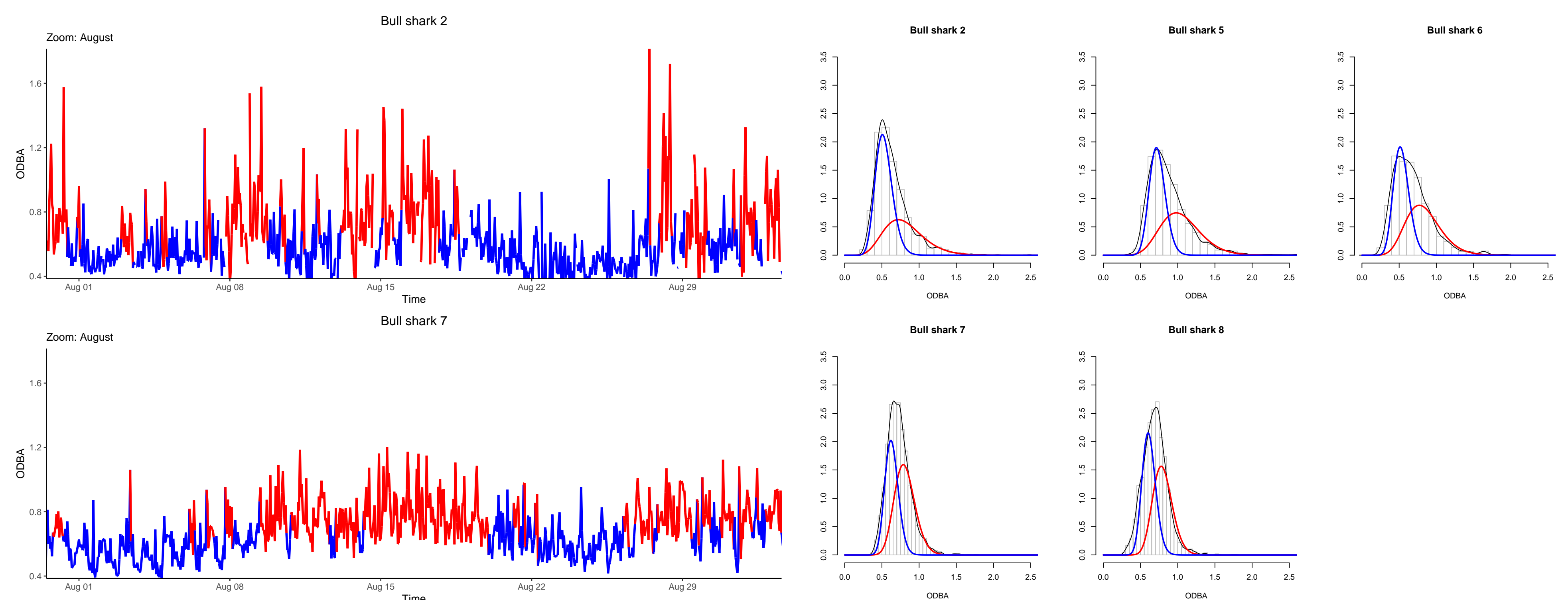
To understand which of the four variables play an important role in the unobservable state-switching process, we perform variable selection via the comparison of the values of Akaike's Information Criterion (**AIC**) for different models. The AIC takes into account the likelihood of the data given the model while also penalizing excessive complexity. The smaller the AIC value, the better the model avoids both over- and underfitting.

The full model includes all variables: temperature, time of day, depth and moon illumination. The remaining models are built by excluding one of the four variables from the full model. To compare the models, we take the difference between  $AIC_{full}$  and the AIC values of the other models. The larger the difference, the more important is the variable for the explanation of the sharks' activity patterns.

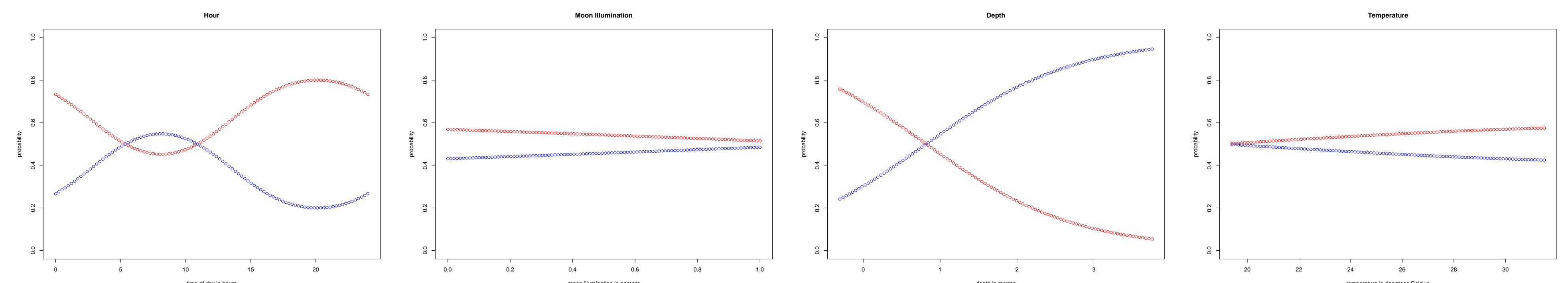
Model	Full Model	Without Hour	Without Moon	Without Temp.	Without Depth
AIC	<b>-7498.260</b>	-4242.738	-7493.369	-7480.562	-7475.298
$\Delta$ AIC	—	-3255.523	-4.891	-17.699	-22.962

The **hour of the day** is the **most important** variable. Surprisingly, the variable **moon illumination** has the **weakest impact** on the sharks' activity. We continue to work with the full model because it has the lowest AIC value out of all models considered.

## Results



The left figure exemplarily describes the sequence of activity states of shark 2 and shark 7 in August 2016. **Blue** denotes the **low activity state** and **red** indicates the **high activity state**. The two colours show what the model assumes to be the most likely state for the shark to be in, for each time point. The densities of the ODBA values for both states (right figure) show that higher ODBA values are more likely in the high activity state. Because we assumed different densities for each of the five sharks, the same ODBA values do not imply the same activity state for different animals.



The four plots above show the estimated probability of being in each state for different values of each variable.

**Hour:** The sharks tend to be in the high activity state during dusk and night and in the low activity state in the daytime. The result fits with the known behaviour of sharks.

**Moon illumination:** High activity is slightly more likely during days of little moon illumination.

**Depth:** In the high activity state, sharks spend more time in shallow water foraging and hunting. During the daytime, they spend their time in the low activity state in deeper areas of the water.

**Temperature:** Higher temperature values result in higher ODBA values.

The effect of the temperature is also included in the observable process of the model. Within both activity states, sharks move more (higher ODBA values) when the water temperature rises. Studying the effect of the water temperature on marine fish is particularly interesting considering that water temperatures are rising due to the climate change.

## Take Home Messages

- **no influence of moonlight** on activity states of bull sharks in fresh water
- **no influence of temperature** on state-switching,
- **time of day** is an **important** variable in explaining the sharks' activity
- **higher temperature** leads to **higher activity** levels within the states