Vertical movement behaviour of the starry smooth-hound shark *Mustelus asterias* in the North Sea

Master Thesis

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Abstract

Still to be written.

Keywords: acoustic telemetry, geolocation modelling, mustelus asterias

Table of contents

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- Each thesis should contain the following phrase on the inside of the front page: 'No data can be taken out of this work without prior approval of the thesis promoter / supervisor (this has to be discussed beforehand by the promoter/co-promoter and the thesis supervisor)'
- defense: oral presentation (15 minutes) followed by a defense before a Jury and a debate including the public present (15 minutes).

- submission details: By June 6, 2023, at 4pm CET (first session exam period - the exact date may change yearly) students submit the thesis manuscript (PDF-file) and the raw data (preferably as ZIP-file) in electronic format on the thesis platform (https://matix.imbrsea.eu). Raw data (or at least the metadata) must also be included in the thesis manuscript as an annex. Thesis manuscripts up to 50 MB can be uploaded, while the maximum size for the raw data is 10 GB. In case of confidential raw data, students must provide at least the metadata and indicate how to retrieve the data in case this would be necessary. Upon submission, students receive an email of confirmation.

Structure

- executive summary (400 words): contains a summary of all relevant information documented in the thesis (Introduction, M&M, Results, Conclusion), discuss/mention hypotheses
- abstract (200 words) is conform with the summary but without detailed information about Methods and Results
- Intro: state of the art, if applicable: project context
  - Aims: + working hypotheses
- Materials & Methods
- Results
- Discussion
- Conclusion
- Acknowledgements
- References

Journal of Animal Biotelemetry

- Use double line spacing
- Include line and page numbering
- Use SI units: Please ensure that all special characters used are embedded in the text, otherwise they will be lost during conversion to PDF
- Do not use page breaks in your manuscript
- Figure titles (max 15 words) and legends (max 300 words)
- width of 85 mm for half page width figure, width of 170 mm for full page width figure, maximum height of 225 mm for figure and legend_ Formatting the 'Availability of data and materials' section of your manuscript
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- unpublished data and personal communication shall not be cited but included as footnotes.
- reference style: https://paperpile.com/s/animal-biotelemetry-citation-style/

1. Meyer E. Physics. Controlling friction atom by atom. Science. 2015;348:1089.

Markdown syntax

Here is some normal text, and then we'll use the **custom command** to make this text bold. Also, this is a reference test Dodge et al. (2013). And to combine references, we can use this (Nathan, 2008; Dodge et al., 2013)

1. Introduction

1.1. History of fish tagging/biologging

- Different telemetry methods

1.2. Acoustic telemetry

1.3. Acoustic data storage tags

1.3.1. Geolocation modelling

- Method: HMM with observation and behavioural model
- Different techniques for behavioural states
- Spectral method by Heerah 2017
- Tidal method by Pedersen 2008
- Drawbacks of the methods for species with limited knowledge, a benthic lifestyle with a broad range of horizontal movement

1.4. The starry smooth-hound shark

1.4.1. Morphology

- Ventral snout: perfect for feeding on animals on seafloor
- All time spent swimming above seafloor

1.4.2. Ecology

1.4.2.1. Life history.

- Feeding: crustaceans, swimming shorewards at night

1.4.2.2. Migration.

- Sex bias: Males into Northern North Sea, females into Bay of Biscay
- Daily horizontal distance: up to 70km

1.4.2.3. Reproduction.

- Aplacentary viviparous, unlike M. mustelus but e.g. like M. antarcticus
- Different life stages of young
- Multiple paternity, sperm storage up to a year

1.4.3. Research gaps

1.4.3.1. Migration.

sex bias known, but no exact locations, timing also unknown

- Horizontal and vertical behaviour during migration
- Until now, many capture/recapture studies, but no in-depth tracking studies (to our knowledge)

1.4.3.2. Reproduction.

reproductive habitats already studied to some extent, but e.g. parturition site Western Scheldt unconfirmed

- General details about parturition: all pups released at once, batches?

1.4.4. Abundance

- only species in NE Atlantic

1.5. Communication of fish movement ecology studies

1.5.1. Problem

the data is complex and difficult to understand for non-experts, yet it is imperative to communicate the scientific results to transform them into action/change

1.5.2. The quadruple helix

- Communication from (fish) scientists to politicians to inform political and fishery management decisions
- Creating awareness within the general public
- Information of industry stakeholders, e.g. wind farm companies

1.6. Aims of the work

1.6.1. Characterizing the vertical behaviour (i.e. the depthlogs) of the migrating sharks

- Motivation: provide additional input for geolocation models(Behavioural switches)
- Implement unsupervised learning aka k means clustering to infer behavioural states/switches = test a new way of inferring behavioural states

1.6.1.1. Working hypothesis.

Using k-means on summary statistics and their wavelet analysis results successfully identifies putative migration periods, as identified by visual analysis of the raw depthlog

1.6.2. Exploratory and descriptive analysis of the female sharks' vertical behaviour

in the Western Scheldt using the acoustic detections data

- Sub-dataset of July 2019 since this has the highest density of acoustic detections (~6000 out of ~10000 total detections)

1.6.2.1. Working hypothesis.

Sharks predominantly use the seafloor section of the space around a receiver (predominantly = xx%, or result of chi2?)

1.6.2.2. Working hypotheses about the acoustic dataset in general.

the seasonal presence of M. asterias is reflected in the acoustic detection dataset

- H0 = the mean # detections per month in summer months, here: March – September significantly differs from that in winter months (t-test or Levene test)

the sex bias, i.e. that females are predominantly present in the WS, is reflected in the acoustic detections - H0 = number of females detected per month significantly differs from the number of males (t test)

1.6.3. Converting the first results

into a format that transmit relevant messages to one/several groups of non-scientists

- No working hypothesis, bc only concept and first draft version, but outlook: further development and then study with people about how well they understood the information provided

2. Materials and Methods

2.1. Study Area

2.1.1. The BPNS

2.1.1.1. Human activities.

- Windfarms
- Shipwrecks
- Submarine power and telecommunication cables

2.1.2. The Scheldt Estuary

2.1.2.1. The Westerschelde.

- Acoustic receiver arrays in WS

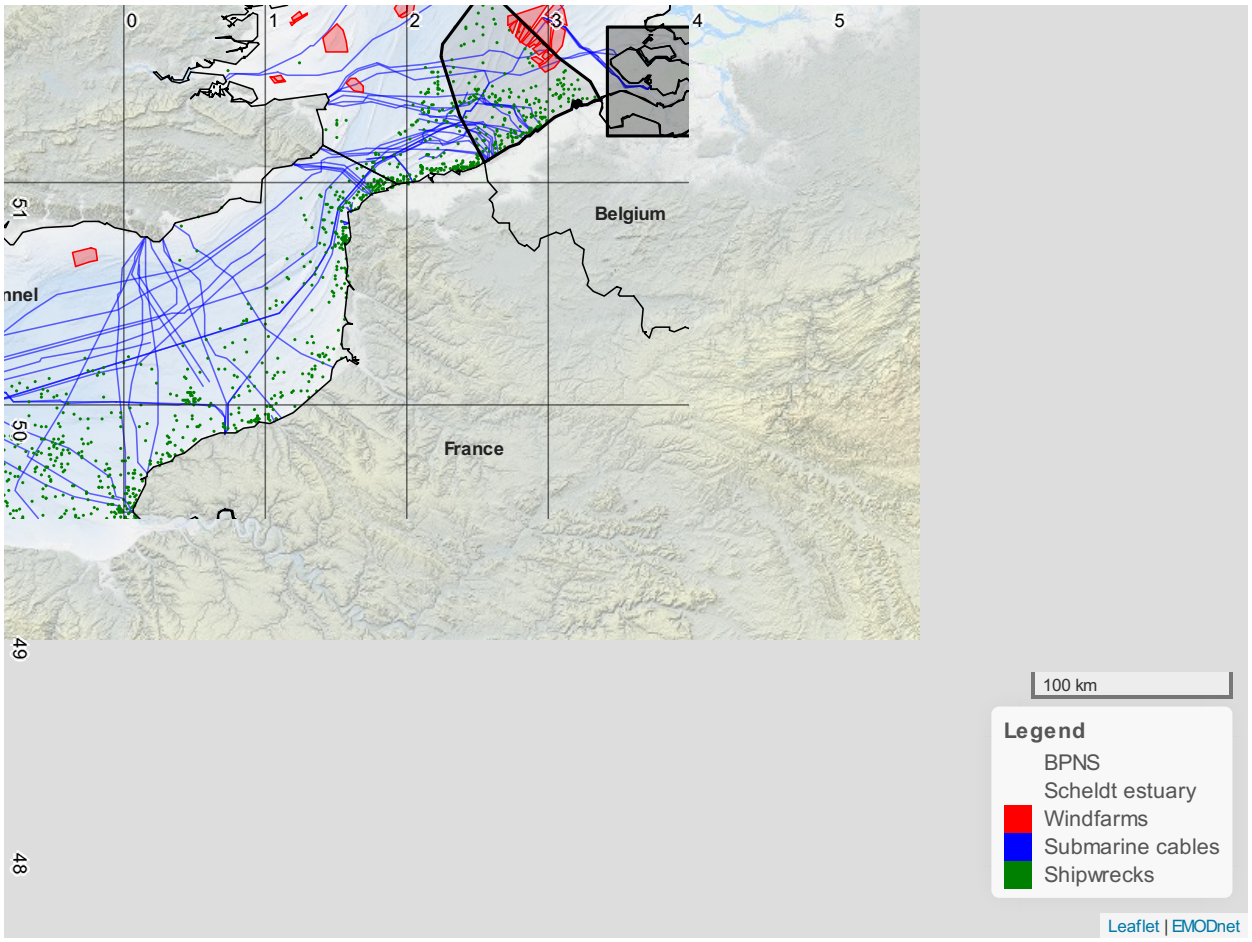


Figure 1: Map of the study area.

- Mixing
- Salinity
- Food abundance for the sharks
- Biodiversity and most prominent species

2.1.3. The English channel

- Bathymetry
- Maybe map with bathy contour lines?
- Food abundance?
- Temperature seasonality

2.2. Acoustic (receiver) Array

- *Find out: how many ac. Receivers in study area?*
- *Question: TABLE with lat lon & names of receiver stations?*
- Detection range

2.3. Tags & Tagging Procedure

- Dates of boat trips
- tags technical details
- tagging procedure

2.4. Data Analysis

2.4.1. Acoustic Detections

2.4.1.1. Descriptive analysis.

- Omitted tags
- Summary statistics
-

3. Individuals and # detections per station/array

3.0.0.1. Depth use analysis.

- Bathymetry dataset
- Method: radius of 200m (=detection range)

3.0.1. Data Storage Tags

3.0.1.1. Summary statistics.

- Mean/median depth, depth range, max and min depth, vert. speed
- Daily, weekly, monthly #### Migration Patterns/Long term DST/Migration Analysis
- Wavelet on daily summary statistics
- Identified putative migration weeks: Wavelet on raw depth values (? Does that make sense? To assess diel vertical behavior during migration)
- Method: extract week of likely migration and do wavelet analysis on raw (maybe scaled?) depth data for that time: no daily summaries!
- FFT on depth values for putative migration periods

4. Results

4.1. Tagged animals

4.2. Acoustic detections

4.2.1. Vertical space use analysis

4.3. Data Storage Tags

- How many tags got recovered

4.3.1. Raw depthlogs

The depth log of tag 304 is shown below (see Figure 2).

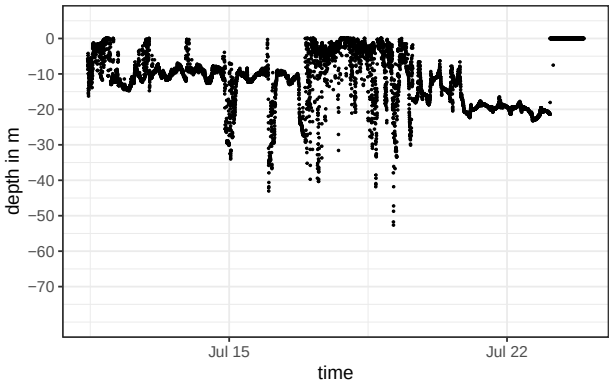


Figure 2: Depth log from the recovered tag 304.

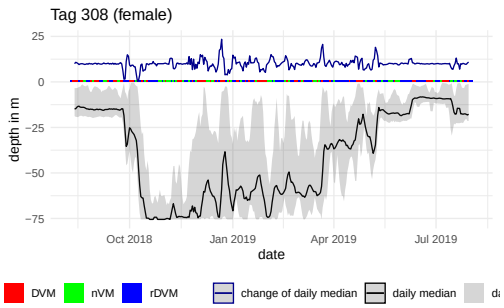
4.3.2. Geolocation model outputs (include?)

Question: I didn't do this: include y/n?

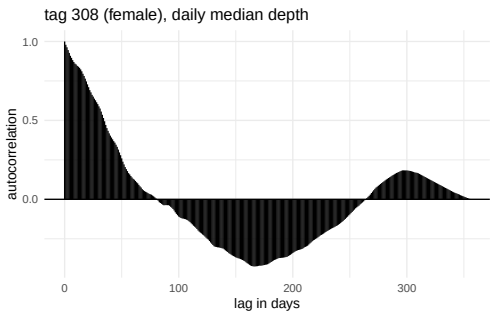
4.3.3. Summary statistics

Below the summary statistics for dst tag 308 are displayed (Figure 3). Lat's check if the cross referencing of sections works, see Section 1.

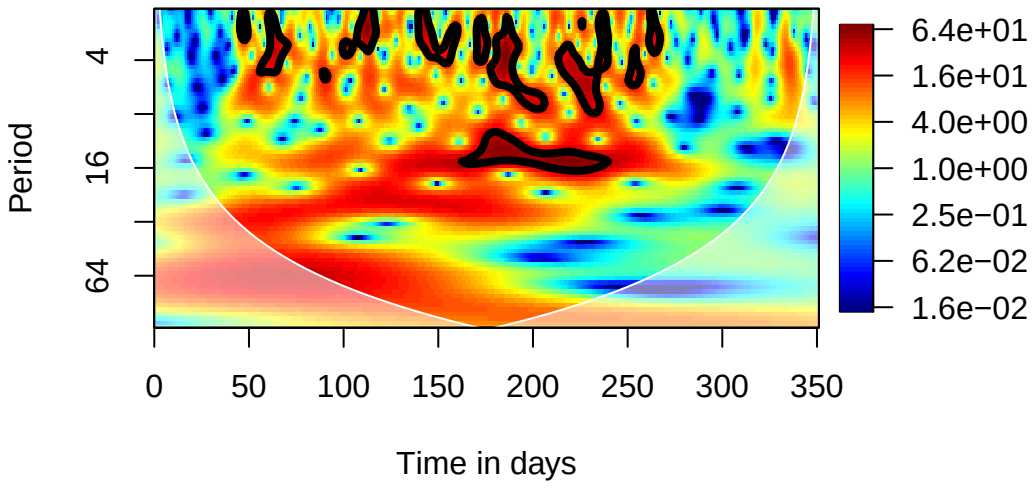
4.3.4. Wavelet analysis



(a) Daily median depth and depth range of tag 308.



(b) Autocorrelation of the daily median depth.



(c) Wavelet transform result.

Figure 3: Summary statistics for tag 308.

4.3.5. Unsupervised learning

5. Discussion

5.1. Seasonality of starry smooth-hound presence

in/around westerschelde, according to ac. detections

- Highly seasonal (only in summer)
- Sex-biased (mostly females)
- Possible pupping area, but this dataset not sufficient to confirm

5.2. Tag recoveries

5.2.1. Possible death reasons of short term dst's

- Tagging consequences
- High sensitivity (verhelst, pers. Comm.)
- Not likely: death bc of seals (no temp increase)
- Laying dead on seafloor (tidal signal)

5.3. Ecological inferences from migration dataset analysis

5.3.1. Vertical patterns during migration

- Yes, but eventually swimming inshore
- How strong are diel patterns in putative migration weeks? Check wavelet median depth

5.4. Limits of biologging/ fish tagging

- Geolocation modelling already leads to impressive results for comparatively well-studied species (e.g. cod (?), sea bass), but still limited in accuracy for not wellknown species

5.4.1. Limits of geolocation modelling

- Resolution of bathymetry dataset
- Possible that shark was in certain area but bc bathymetry grid = summary (e.g. mean), geolocation model rules this location out (cf Woillez 2016)
- Behaviour incorrectly/not inferred
- E.g. active vs inactive behaviour:

5.4.2. current state of fish tagging

- It's kind of the best we can do today, but non-satellite tagging methodologies have huge drawbacks still
- Acoustic telemetry: high resolution on regional scale (i.e. where the receivers are placed) but outside of receiver networks: no knowledge at all

5.5. Limits of the chosen analysis methods

- Wavelet analysis: no super fine scale analysis possible bc of limited res in both time and freq domain

5.6. Limits of the acoustic detection dataset

- There are ~10 000 detections within ~2 yrs but compared to other studies (ref to other studies!) this is not that much.
- the horiz resolution of receivers, esp in/around the WS is not good bc rather receiver gate than array to monitor species swimming into/out of the Scheldt river (= different use case scenario: receiver array needed to resolve locations of sharks better, and to e.g. enable triangulation)

5.7. Limits of the data storage tag dataset

- Female shark: deeper than tag depth limit (68m): geolocation model inaccurate, shark putatively went into the Hurd deep (MRGID: 3321) in English channel
- Only one individual per sex: not reliable, no statistics possible

6. Conclusion

brief summary of the main findings (original data, lesson learned,…)

- Possible improvements of tagging procedure (correct place here?)

7. Outlook

Alle kapitel aus der Einleitung wieder aufnehmen

7.1. Acoustic detections additional analyses

- Vertical space use: resolve individuals to see if there are differences between ind. Sharks ## Improvements of geolocation model for M. asterias
- Boundary condition: max depth of fish per day == max depth of bathy for that day
- Behavioural switch: migration/non-migration or migration/winter resident/summer resident ## Information tool
- make into interactive application (RShiny) and do tests with some of the target groups to understand how well the information is taken in

8. Acknowledgements

*funding agencies, field workers

Question: Who provided the money for the tags? What project was that under?*

References

9. Annex

All the raw data have to be added in annex

9.1. Acoustic detections

9.2. DST datasets

9.2.1. FFT plots for all tags

9.2.2. Wavelet plots for all (in the k means clustering included) summary statistics

References

Dodge, S., Bohrer, G., Weinzierl, R., Davidson, S.C., Kays, R., Douglas, D., Cruz, S., Han, J., Brandes, D., Wikelski, M., 2013. The environmental-data automated track annotation (env-DATA) system: linking animal tracks with environmental data. Movement Ecology 1, 3. URL: http://dx.doi.org/10.1186/2051-3933-1-3, doi:10.1186/2051-3933-1-3.

Nathan, R., 2008. An emerging movement ecology paradigm. Proceedings of the National Academy of Sciences of the United States of America 105, 19050–19051. URL: http://dx.doi.org/10.1073/pnas.0808918105, doi:10.1073/pnas.0808918105.