Morphology analysis on the saccular otolith of the European hake

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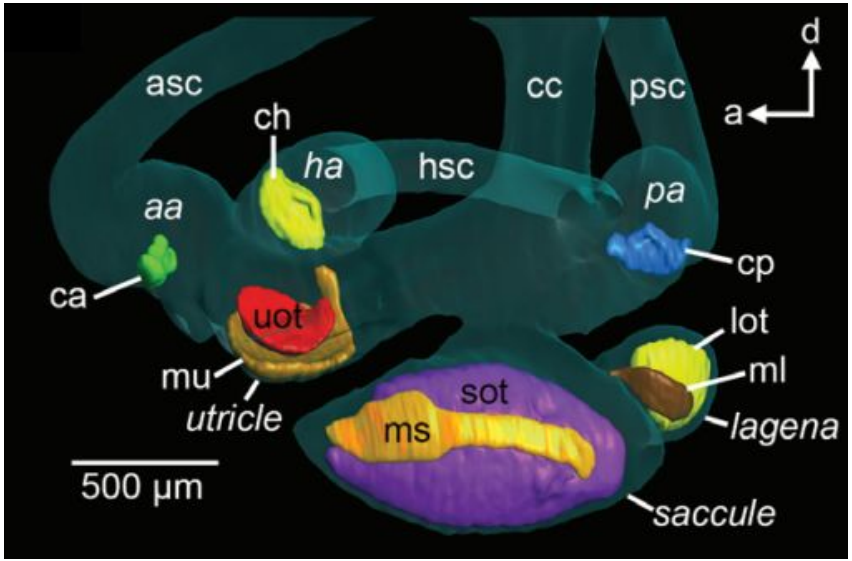
Introduction - European hake

1. Shorter hakes prefer depths of 170 - 200 meter
2. Longer hakes prefer depths of 70 - 100 meter

Introduction - Otoliths

1. **Lapillus (uot):**
   Utricle → Acoustic function
2. **Asteriscus (lot):**
   Lagena → Acoustic function
3. **Sagitta (sot):**
   Saccule → *Vestibular function*



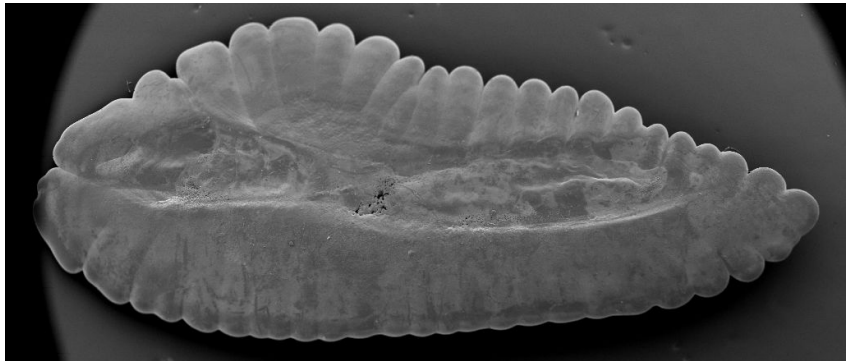
Introduction - Otoliths

Sulcus acusticus:

- Sulcus is in contact with macula
- Sulcus size : otolith size (S : O ratio)

Curvature:

- Younger otoliths are smoother
- Protuberances



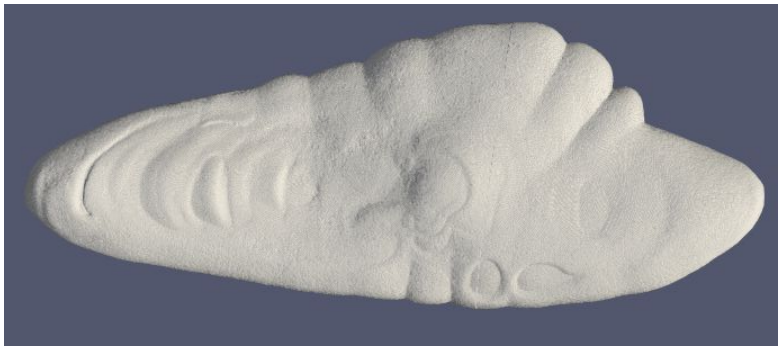
Proximal face of right saccular otolith of European hake

Introduction - Data acquisition

24 micro-CT scans of right saccular otoliths of European hake:

- 6 juveniles (50 - 150 mm TL)
- 9 females (150 - 400 mm TL)
- 9 males (150 - 400 mm TL)

Proximal face of sagitta



External face of sagitta

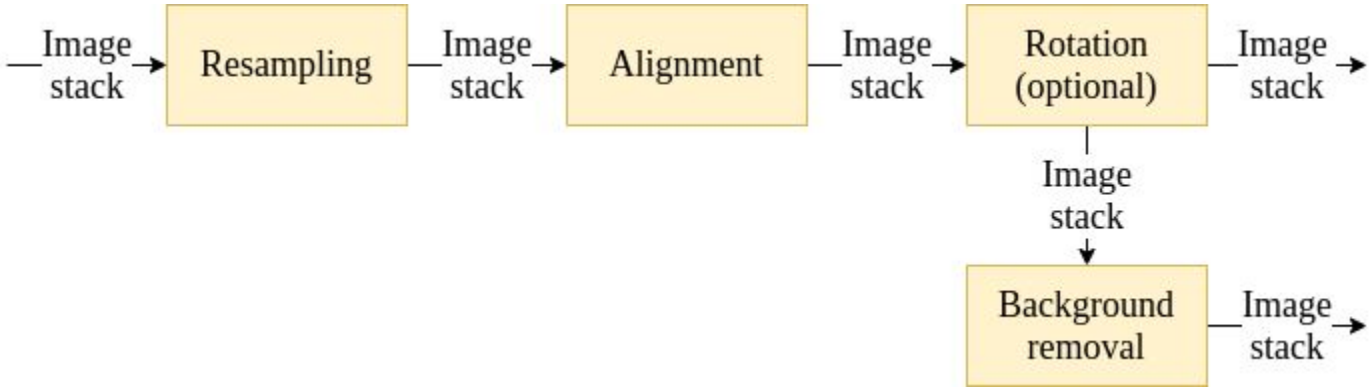
Introduction - Research questions

RQ1: “How does the saccular sulcus size relate to the saccular otolith size for the European hake?” *(sulcus analysis)*

RQ2: “How does the curvature of the saccular otolith of the European hake change over time?” *(curvature analysis)*

Method - Data transformation

Objective: prepare **image stacks** for analysis



Method - Sulcus analysis

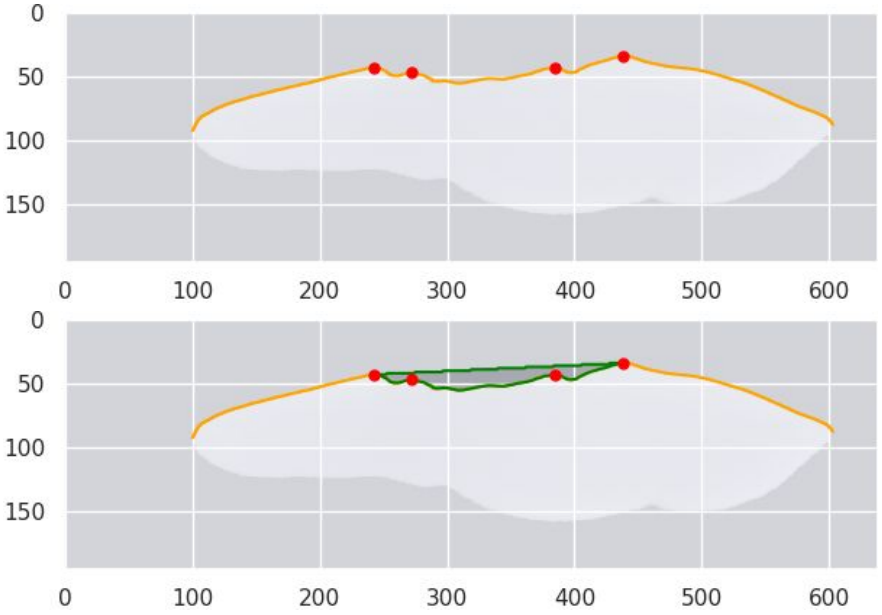
RQ1: “How does the saccular sulcus size relate to the saccular otolith size for the European hake?”

1. Partition sulcus
2. Measure sulcus/otolith size:
    - Surface area
    - Volume
3. Perform experiments

Method - Sulcus analysis

Partition sulcus:

1. Detect peaks in slice
2. Use peaks to obtain sulcus area
3. Repeat for all slices



Sulcus reconstruction in slice 867 of otoF83.

Method - Sulcus analysis

Partition sulcus:

Juvenile (otoI47)

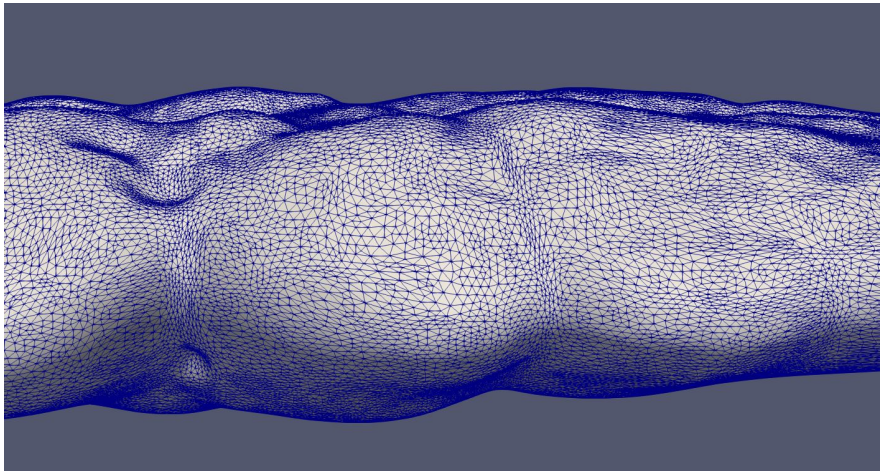
Female (otoF83)

Male (otoM257)

Method - Sulcus analysis

Measure sulcus/otolith size:

- Transform image stack into triangular mesh (Marching Cubes)
- Use mesh to obtain:
  - Surface area
  - Volume



Triangular mesh of otol48

Method - Sulcus analysis

Perform experiments:

1. Total length vs sulcus/otolith size
2. Sulcus size vs otolith size (S : O ratio)
3. Total length vs S : O ratio
   → Higher S : O ratio for shorter/younger hakes

Method - Curvature analysis

RQ2: “How does the curvature of the saccular otolith of the European hake change over time?”

1. Derive mean curvature *H*
2. Localize protuberances (tops)
3. Perform experiments

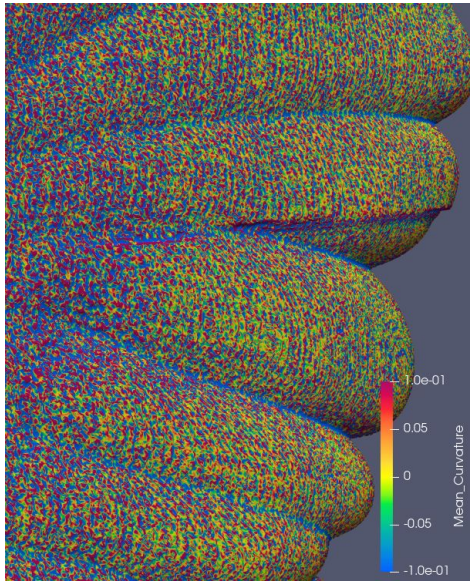
Method - Curvature analysis

Derive mean curvature *H*:

1. Image stack to mesh (Marching Cubes)
2. Improve mesh topology
3. For vertex *p* derive *H*

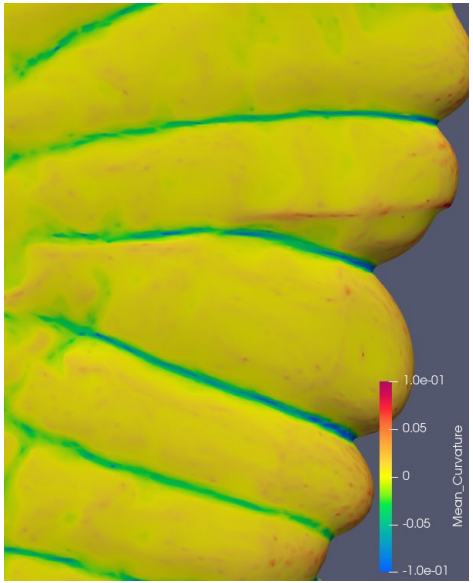
Method - Curvature analysis

Derive mean curvature *H*:



Original mesh

Decimation &
Smoothing

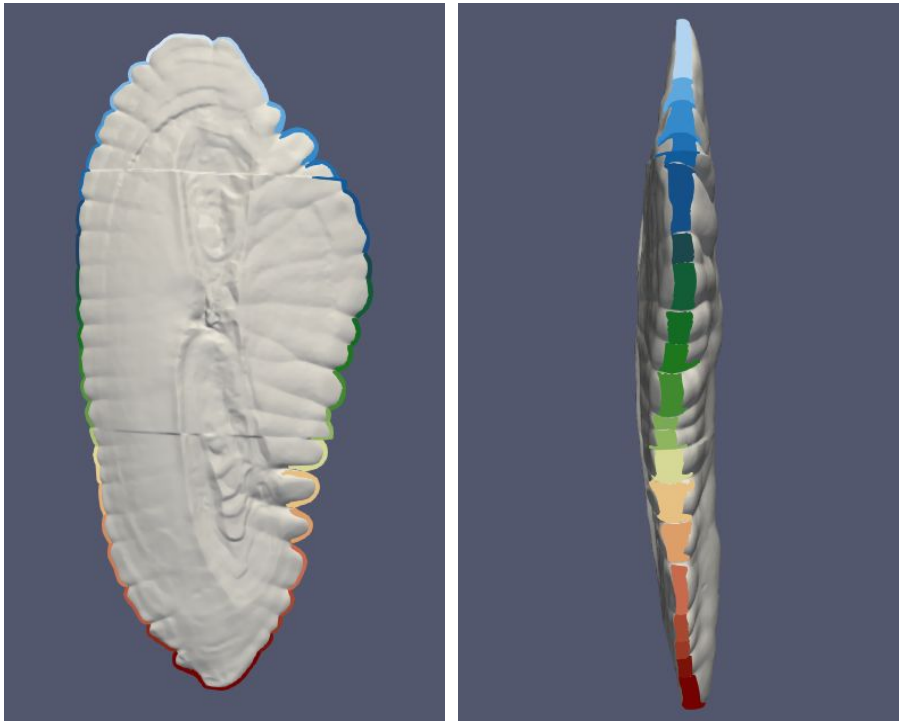


Transformed mesh

Method - Curvature analysis

Localize protuberances (tops):

1. Filter *p* on direction of normal vector *n*
2. Filter *p* on *H(p)* > 0
3. Group filtrate on distance



Protuberance detection on otol9

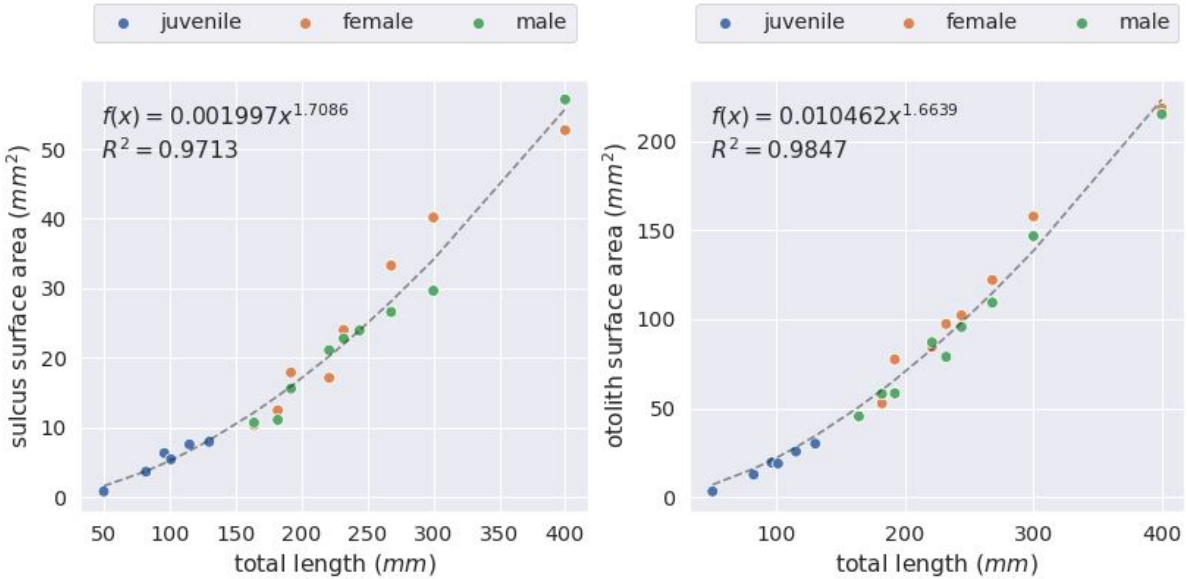
Method - Curvature analysis

Perform experiments:

1. Total length vs number of protuberances
2. Compare *H* for female and male otoliths

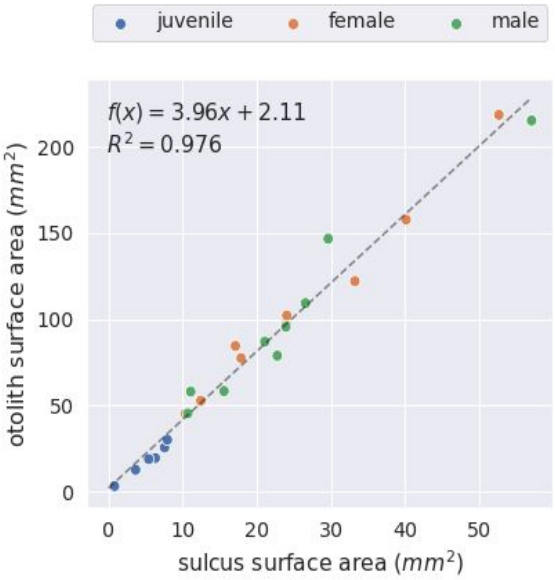
Results - Sulcus analysis

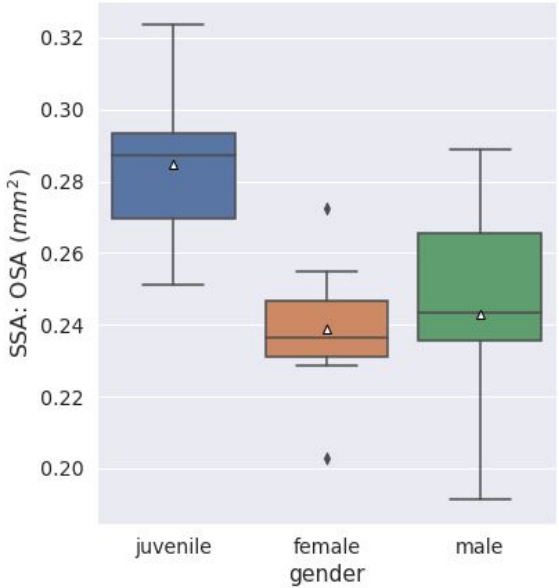
Surface area:

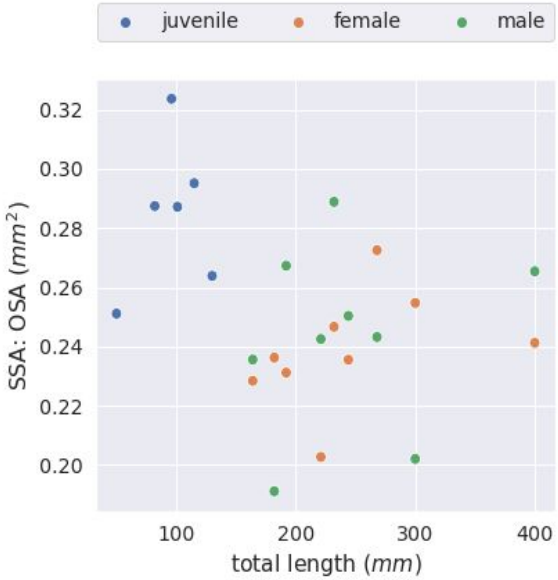


Results - Sulcus analysis

Surface area:

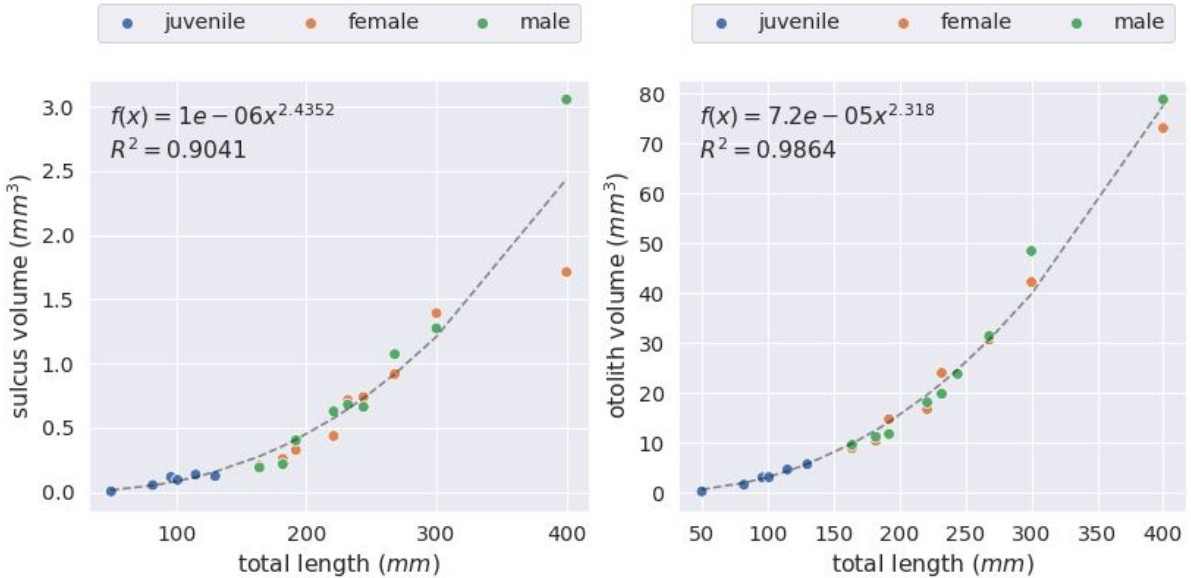






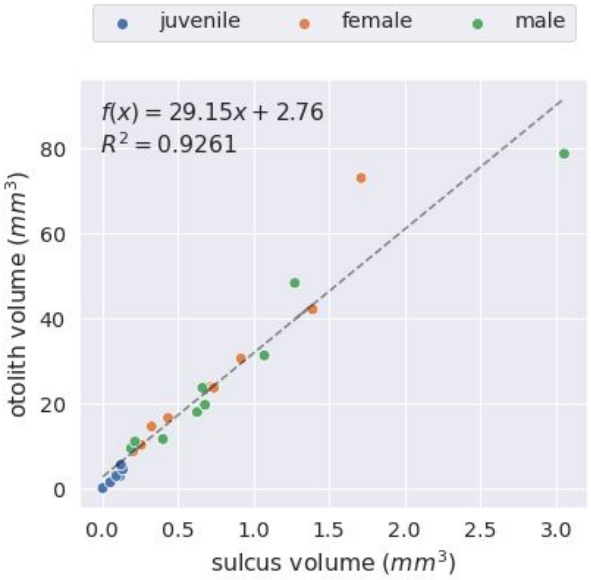
Results - Sulcus analysis

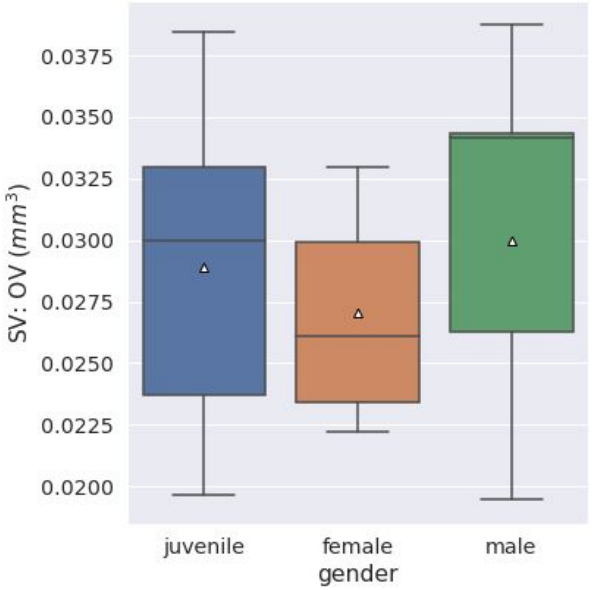
Volume:

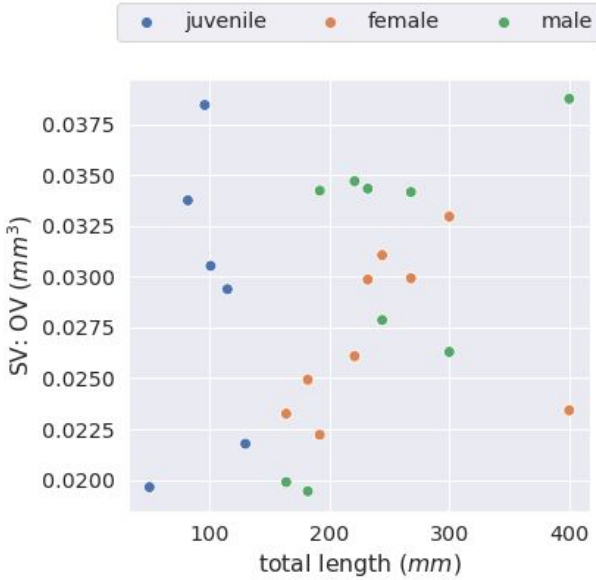


Results - Sulcus analysis

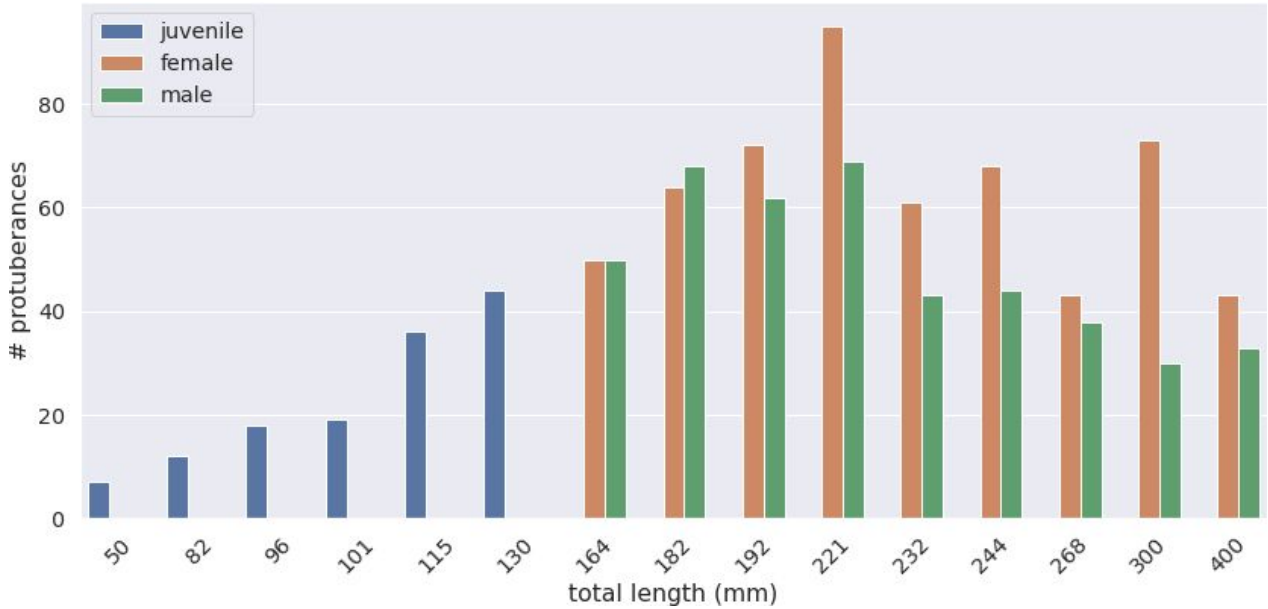
Volume:





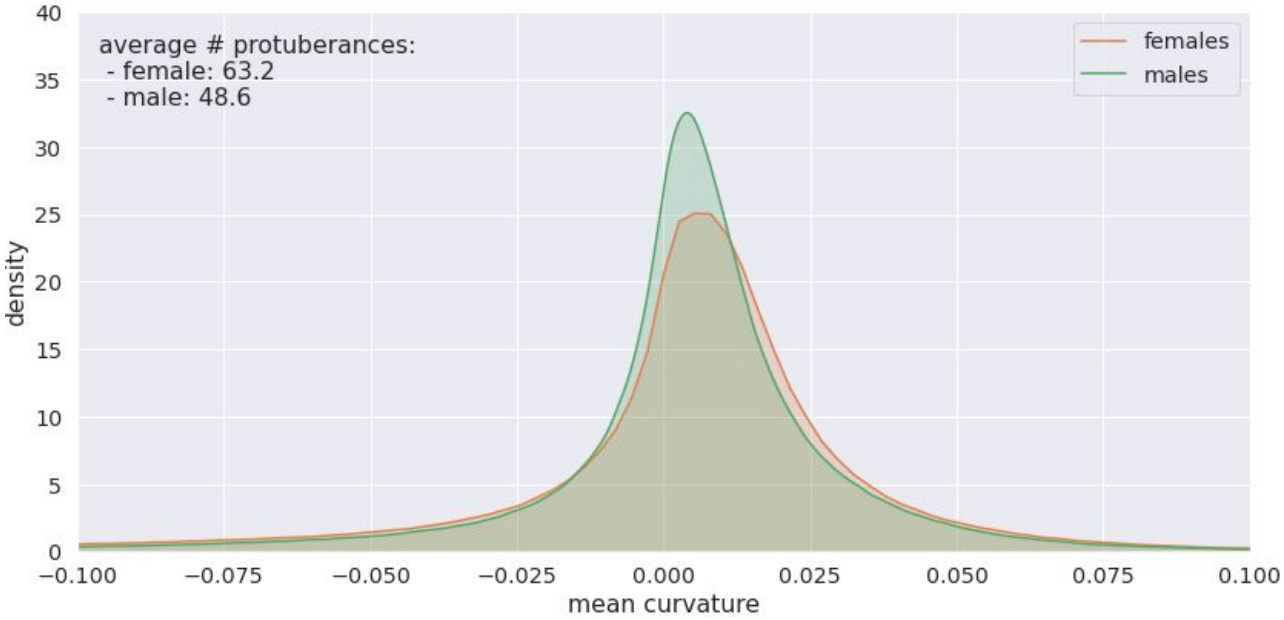


Results - Curvature analysis



Number of detected protuberances per total length

Results - Curvature analysis



Density curve for H on surface of all female/male otoliths

Discussion - Sulcus analysis

Surface area:

- SSA : OSA ratio for juveniles is higher
  → Protuberances influence SSA : OSA ratio

Volume:

- SV : OV ratio more equally distributed among genders
  → less affected by protuberances

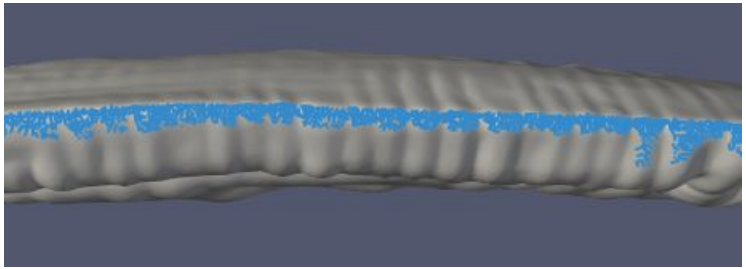
Discussion - Curvature analysis

Protuberances:

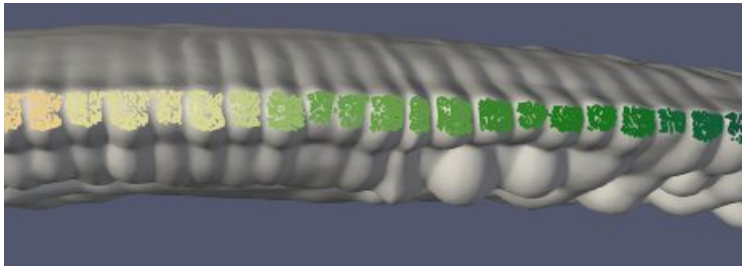
- Protuberances detection only detects tops
- High variability for matures
  → Elongated region

Mean curvature:

- Indeterminable error for *H*
  Solutions in literature are inaccessible



Elongated region for otoF83 (268 mm)



Elongated region for otoF73 (300 mm)

Conclusion - Sulcus analysis

RQ1: “How does the saccular sulcus size relate to the saccular otolith size for the European hake?” *(sulcus analysis)*

Surface area:

1. TL : SSA → power equation (negative allometric)
2. TL : OSA → power equation (negative allometric)
3. SSA : OSA → linear equation
4. Average SSA : OSA ratio for juveniles is higher than for adults
   Protuberances influence ratio

Future work: Proximal surface area

Conclusion - Sulcus analysis

RQ1: “How does the saccular sulcus size relate to the saccular otolith size for the European hake?” *(sulcus analysis)*

Volume:

1. TL : SV → power equation (negative allometric)
2. TL : OV → power equation (negative allometric)
3. SV : OV → linear equation
4. Average SV : OV ratio for juveniles is higher than for adults
   Ratio is more equally distributed among genders

Conclusion - Curvature analysis

RQ2: “How does the curvature of the saccular otolith of the European hake change over time?” *(curvature analysis)*

- For juveniles: # protuberances increase with TL
- For matures: high variability
- For equal TL: # protuberances female > # protuberances male (sex dimorphism)
- Density curve male > density curve female (sex dimorphism)

Future work:

- Improve protuberance detection
- Reduce mean curvature error

Questions?