SINTEF

Anatomy of wild and farmed fish species

VERSION
V1

DATE
2016-06-21

AUTHOR(S)
Marianne Bakken
Helene Schulerud

CLIENT(S)
FHF

CLIENTS REF.
9011985

PROJECT NO.
102002635

NO. OF PAGES AND APPENDICES:
23 + appendices

ABSTRACT
The main goal of this project has been to assemble a relevant dataset as a basis for development of processing equipment in the fish industry and revision of current processing methods.

Further objectives of this project have been to image bones in whole fish and fillets in 9 different species and to provide detailed information about the size, orientation and location of pinbones and the walking stick bone in fillets. For each species 2-4 whole fish and 2-4 fillets were CT scanned and analysed. The bones and fillet were segmented and length, thickness, position and orientation of the pinbones were estimated.

Comparison with manual control measurements for some of the fillets showed that all the bones were detected, but there were some deviations in the length and thickness measures. The CT pinbone measures gives in average 0.2mm thicker bone than the manual measures and the CT length measures gives in average 3mm shorter bone than the manual measures. In this report a simple analysis of the recorded data is performed.

We present in this report initial analysis of the data. However, the goal of this project has primarily been to assemble a relevant dataset as a basis for further analysis. To enable independent analysis, all data is made available electronically for download. See Appendix A1 for download details.

PREPARED BY
Marianne Bakken

SIGNATURE
Marianne Bakken

APPROVED BY
Jens Thielemann

SIGNATURE
Jens Thielemann

PROJECT MEMO NO.
1

CLASSIFICATION
Unrestricted

SINTEF

Sammendrag

Hovedmålet for prosjektet var a skaffe tilveie et relevant datasett som en basis for utvikling av nye prosesseringsmetoder og utstyr innen fiskeforedlingsindustrien og til videreutvikling av eksisterende utstyr.

Delmålene i prosjektet var å avbilde skjelettet i hel fisk og ben i fileter i 9 ulike fiskeslag og fremskaffe detaljert informasjon om størrelse, orientering og lokasjon av pinnebein og spåmannsbein i fileter. For hvert fiskeslag ble 2-4 hele fisk og 2-4 hele fileter CT skannet og analysert. Bein ble segmentert ut og lengde, tykkelse, posisjon og orientering ble estimert.

Det ble foretatt sammenligning mellom de CT basert målingene med manuelle kontroll målinger i noen fileter. Noe avvik ble avdekket på både tykkelse og lengde. CT målingene gir i snitt 0.2 mm tykkere bein og 3 mm kortere bein enn kontrollmålingene.

I denne rapporten er det foretatt en enkel analyse av dataene. Målet med prosjektet var å fremskaffe og tilgjengeliggjøring data for videre analyse. Derfor er alle data og resultater lagt på eroom Apricotanatomy for elektronisk nedlasting, se Appendix A1 for detaljer.

SINTEF

Table of contents

1 Introduction

Automation of fish processing has been recognized as a key factor in maintaining strong and competitive fish processing industry within the Nordic countries. 3-D imaging information of fish anatomy is an important tool in development of innovative processing methods and in adjusting new technology to anatomy of different fish species.

In the past, automation of manual operations has frequently been focusing on single processing steps. The overall process perspective is sometimes lacking, and there is a need to analyse whether the whole process should be reorganized, for improving factors such as yield and value of products. In a previous project, Apricot Anatomy (FHF project no: 900814) fillets of Salmon, Haddock, Cod and Saithe were scanned, but not whole fishes. In this project, whole fish and untrimmed fillets of 9 different species have been CT scanned.

The budget of the project was 556.000 NOK for covering:

- Raw material – Whole fish and fillets
- Logistics (fish)
- Access to processing and CT-scanning facilities
- Labor cost at SINTEF, Marel, Norway Seafood (analysis, organizing and transport of raw material)
- Project management

FHF founding of 516.000 was to cover costs at SINTEF:

- Raw material – Whole fish and fillets
- Access to processing and CT-scanning facilities
- Labor cost at SINTEF
- Project management

The project consortium consisted of Marel, Norway Seafood and SINTEF. The project coordinator was SINTEF by Helene Schulerud. Marel in collaboration with Norway Seafood has planned and collected fishes for CT-scanning. SINTEF has be responsible for conducting CT-scanning, manual measurements, data analysis and report writing.

SINTEF has been responsible for the general project management. The steering committee was composed of Helene Schulerud (project manager), Kim Gabrielsen (Norway Seafood) and Kristin Anna Thorarinsdottir (Marel).

2 Objectives

The main goal of this project has been to assemble a relevant dataset as a basis for development of processing equipment in the fish industry and revision of current processing methods.

The objectives are to provide detailed information about fish anatomy, the skeleton of whole fish (with head and the size, orientation and location of internal bones (e.g. pin bones) in fillets. This will provide new, detailed knowledge about the bone anatomy of whole fish and after filleting. The information should be of a quality that enable to:

- Identify new processing methods of whole fish (decapitation and filleting)
- Guidance for sensor selection and placement for precise 3D bone positioning in different species
- Guidance for bone removal methods for different fish species
- Guidance for bone detection algorithms for different fish species

Whole fish, gutted with head. 3D-CT of whole fish anatomy will provide mechanical engineers essential tool to review current processing methods and identify new ways primary processing of the fish, such as decapitation and filleting. Digital information on structural alignment of bones with the fish, and provides view of proportion of different tissues.

Fillets. Automation of pin bone detection and removal by combined system of x-rays and water jet cutting (FleXicut) is one of the latest inventions in the whitefish industry. The main focus has been on cod but producers have emphasized the need to transfer the technology to processing of other species. The location of the pin bones, number and alignment in the fillets varies between different fish species. Therefore, it is essential to implement studies on fish anatomy, by techniques such as 3D CT-scanning (in similar way as done in the Apricot anatomy project (FHF project no: 900814).

3 Project description

Norway Seafoods has provided whole fish and fillets of Cod, Haddock, Redfish, Catfish and Tusk, while Ling, Saithe, Catfish, Salmon, Redfish and Hake were purchased from Fiskcentralen in Oslo.

Whole fish and fillets from these nine different species were CT-scanned (3D) at Rikshospitalet in Oslo. Fish and fillet data together with sampling plan are given in Appendix A2 and A3.

Gutted whole fish with head - 4 fish per species

- 2 fishes of medium size (M)
- 2 fishes of small size (S)

Fillet - 4 fillets from 4 different individuals per species

- 2 fillets of medium size (M)
- 2 fishes of small size (S)

The aim was to cover a higher number of species (average size) within this project rather than focus on individual variation. The purpose was to have basic data on parameters such as alignment of pin bones, number of pin bones etc. For example there is a significant variation in number of pinbones (length of pinbone frame) between different gadoid species. To cover variation due to size, condition factor and gender etc. a higher number such as 20 fishes per group would be needed, which is outside the scope of this project.

The fish was scanned as fresh as possible (less than 5 days from catch). Gutted fish was be weighted and the fork length measured. CT results of pinbones were compared with manual control measurements (length, thickness) to check whether all the bones were detected and to evaluate relationship between bone size and detection by CT-scanning.

For the fillets, we extracted high-level information about the bones from the segmented data. The orientation, position, length and size were computed for pinbones and the walking stick bone. Other bones were detected, but not measured.

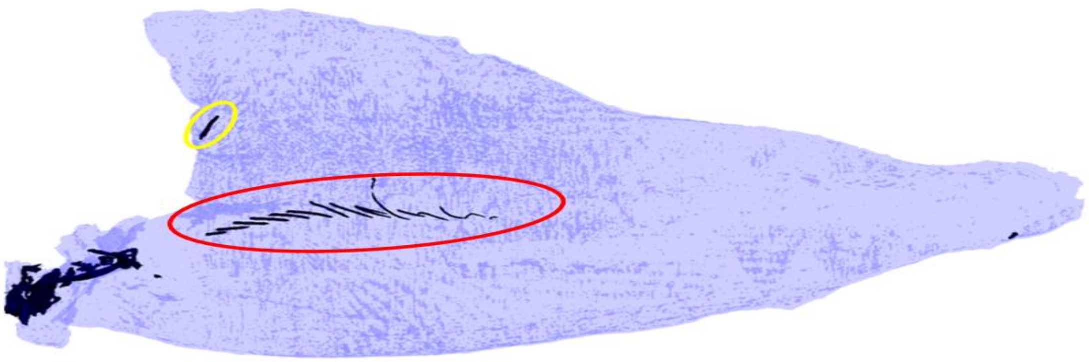


Figure 1. Cod fillet with marked pinbones (within red circle) and walking stick bone (yellow).

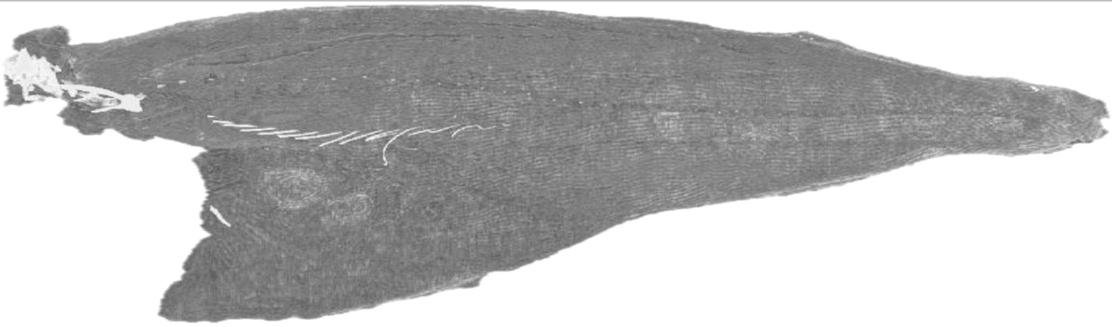
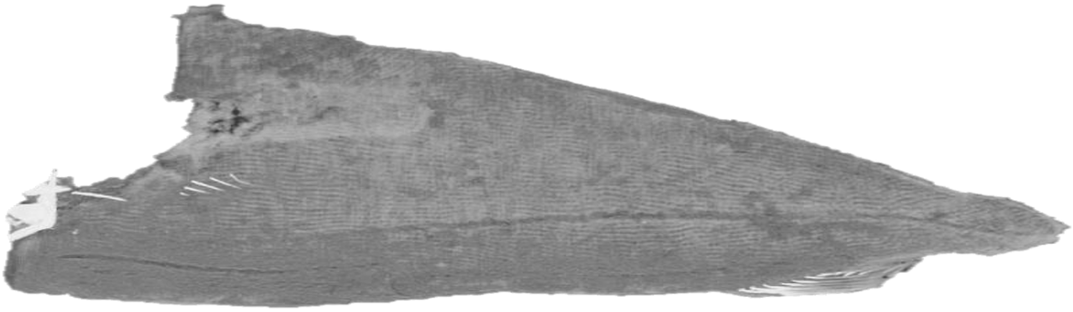
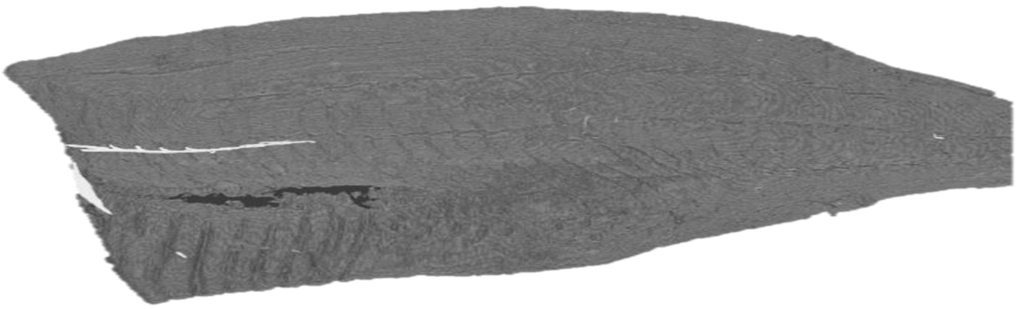
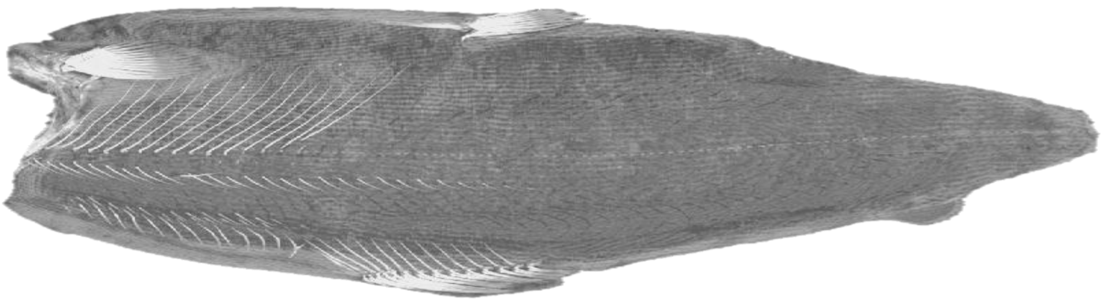
4 Results

In this chapter we present an overview of the recorded data, statistics of the bone measures and comparison of CT and manually control measures. All data and results can be found at the Apricotanatomy eroom, see Appendix A1 for details.

4.1 CT scan images

Example CT images of fillets and whole fish for each species are shown below. The images show the intensity values seen from above, after segmentation and removal of the plate.

Due to large variation in the data, a few fish and fillets failed in the different processing steps, even after adaption per species. Fishing hooks and bended plate are some examples of artefacts that made the algorithms fail. This applies to one Salmon and one Ling for whole fish and two Tusk and one Saithe for the fillets. These cases are missing bone measurements and/or 3D visualization.

Cod (TFM1)	
Haddock (HFS1)	
Saithe (SF2)	
Salmon (LXF2)	

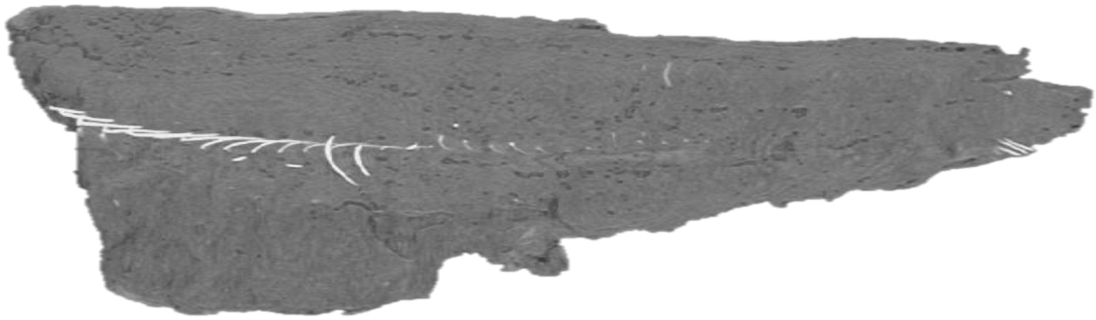
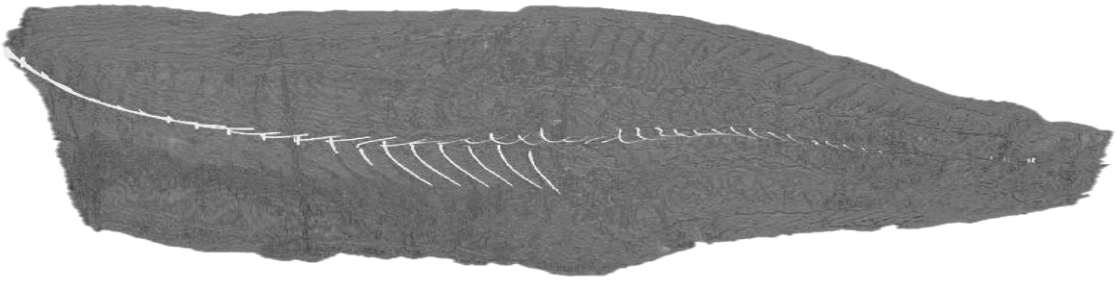
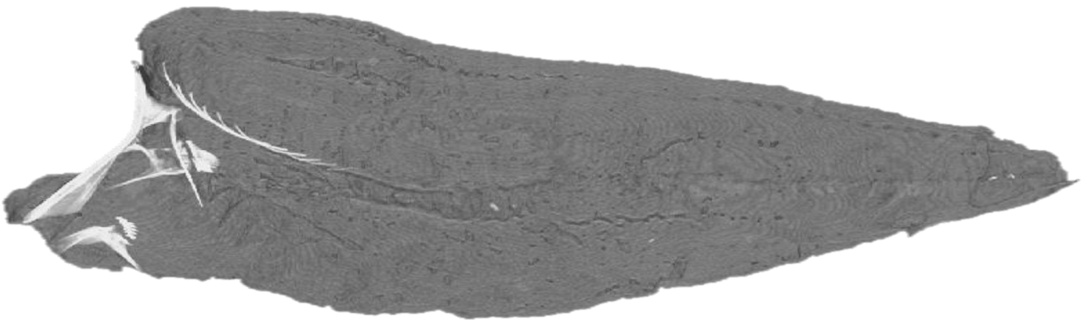
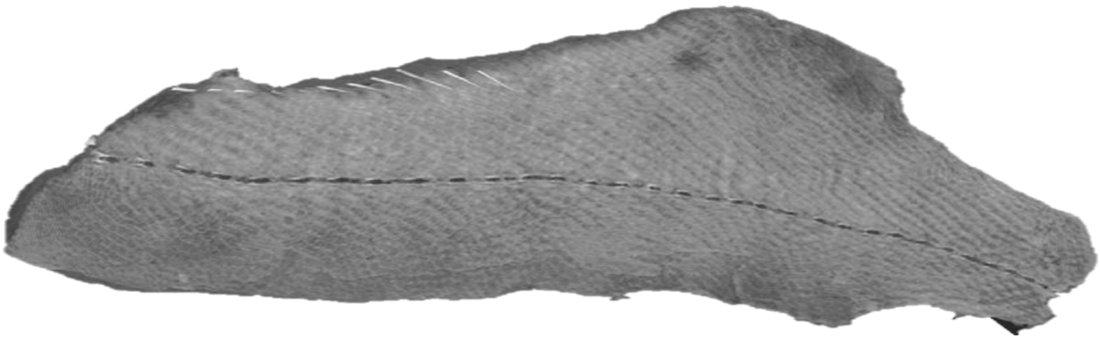
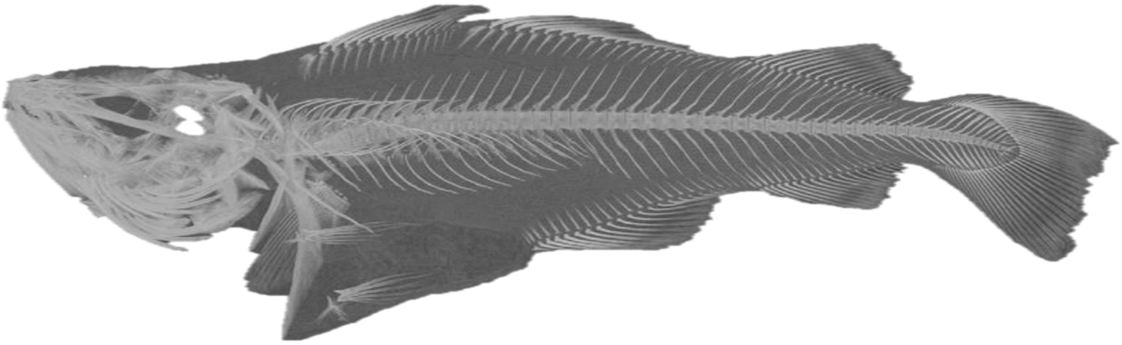
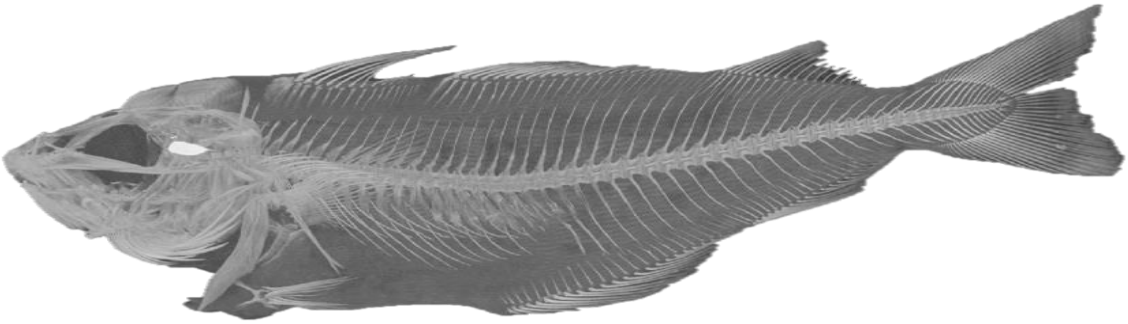
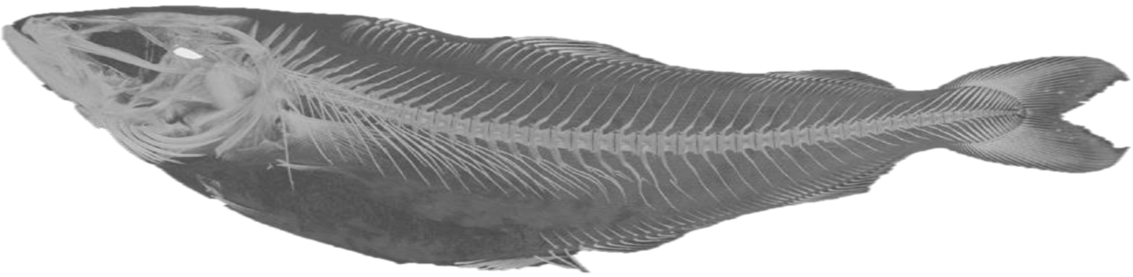
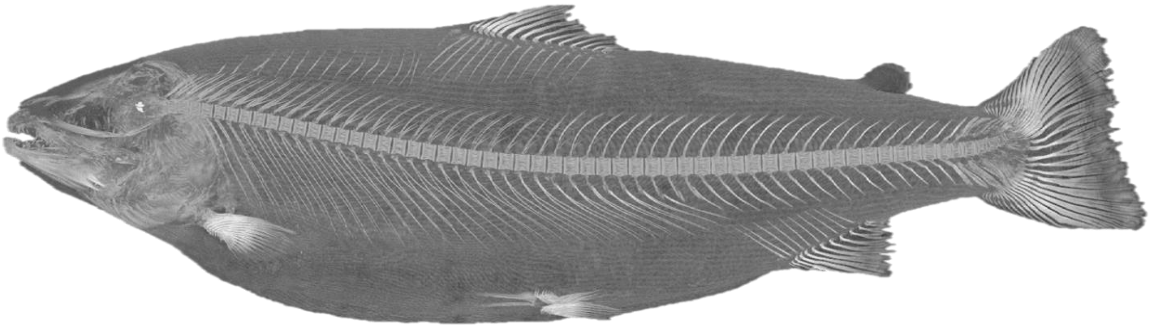
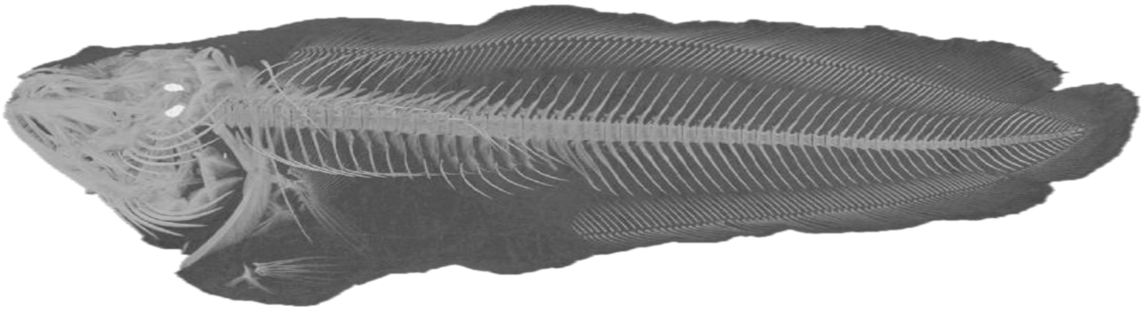
Tusk (BF1)	
Ling (LF1)	
Catfish (STF2)	
Hake (LYF2)	
Redfish (UF1)	

Figure 2. Example CT images of fillets for each species.

Cod (THS2)	
Haddock (HHM2)	
Saithe (SH2)	
Salmon (LXH2)	
Tusk (BH2)	

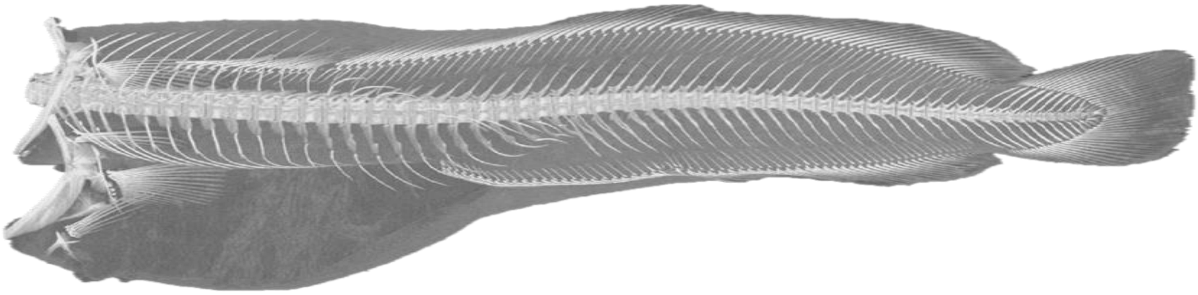
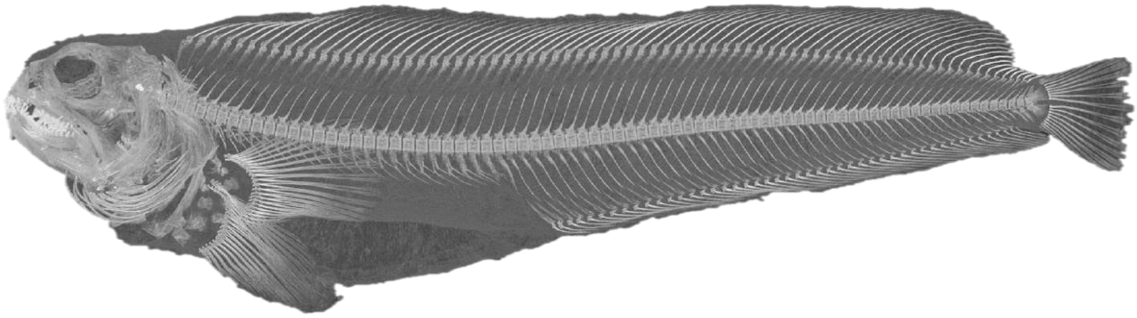
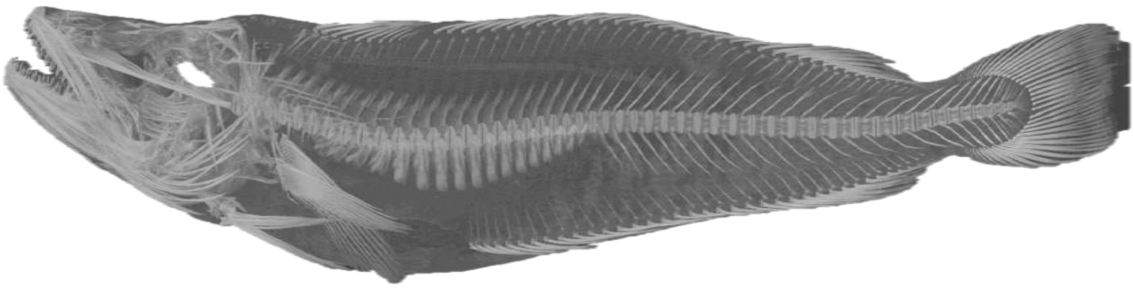
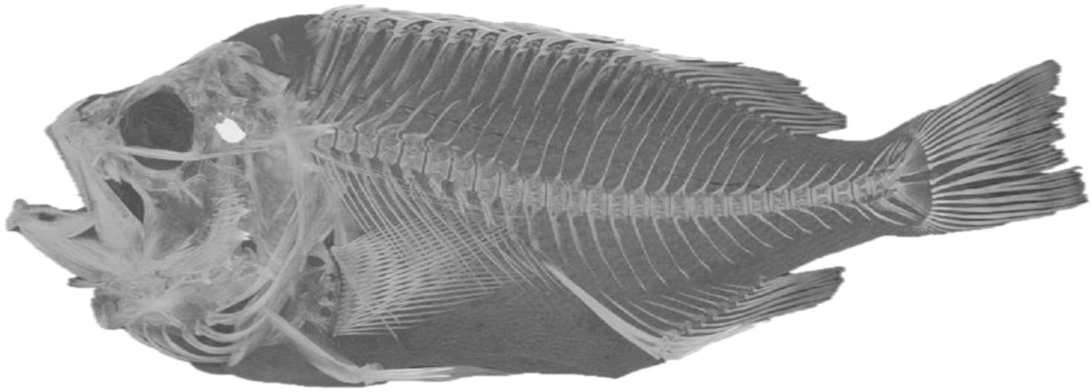
Ling (LH3)	
Catfish (STH2)	
Hake (LYH1)	
Redfish (UH2)	

Figure 3. Example CT images of whole fish for each species.

4.2 Bone detection

All detected bones in fillets and fish are visualized in 3D from different viewpoints in Appendix B in Apricot2_report.pdf and in videos at the Apricotanatomy eroom. See Appendix A1 for detailed information. An example of detected bones in a fillet is shown in

Figure 4.

Additionally, separate visualizations of numbered pinbones are provided in file *3D_pinbones.pdf* at the Apricotanatomy eroom.

As thin bones and fins have almost the exact same intensity values as fish skin in the CT images, it is difficult to detect these when they are close to the skin. There is also an unclear transition between cartilage and bones. These two effects are especially seen in the visualization of the whole fish.

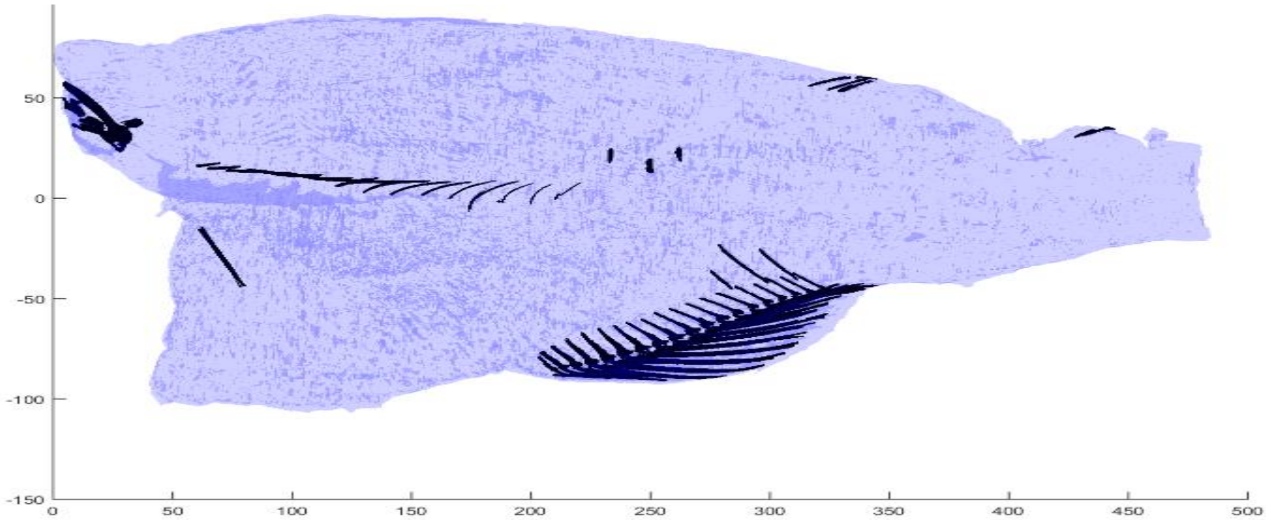


Figure 4. Example of detected bones in an untrimmed fillet.

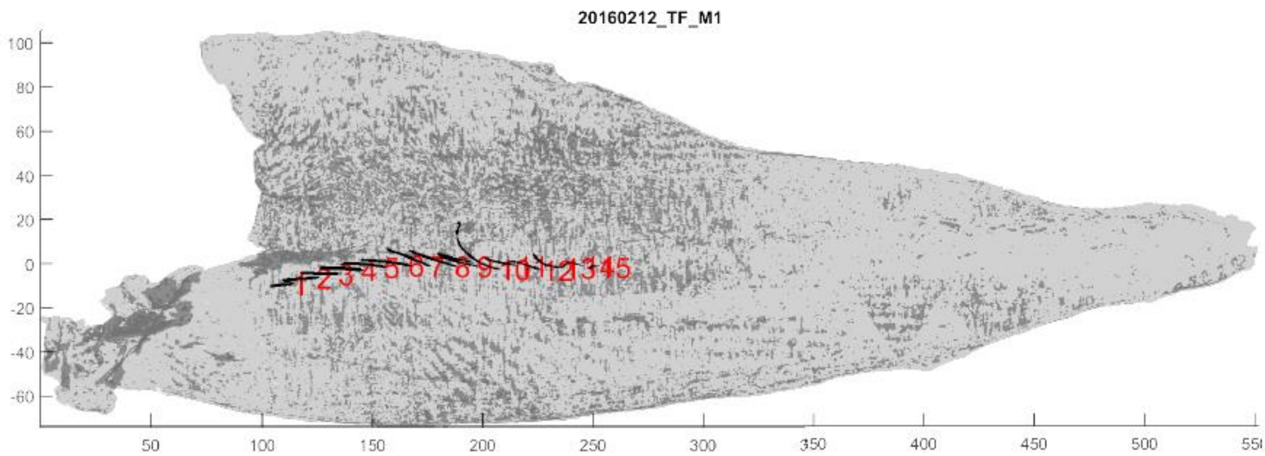


Figure 5. Example of pinbone visualization.

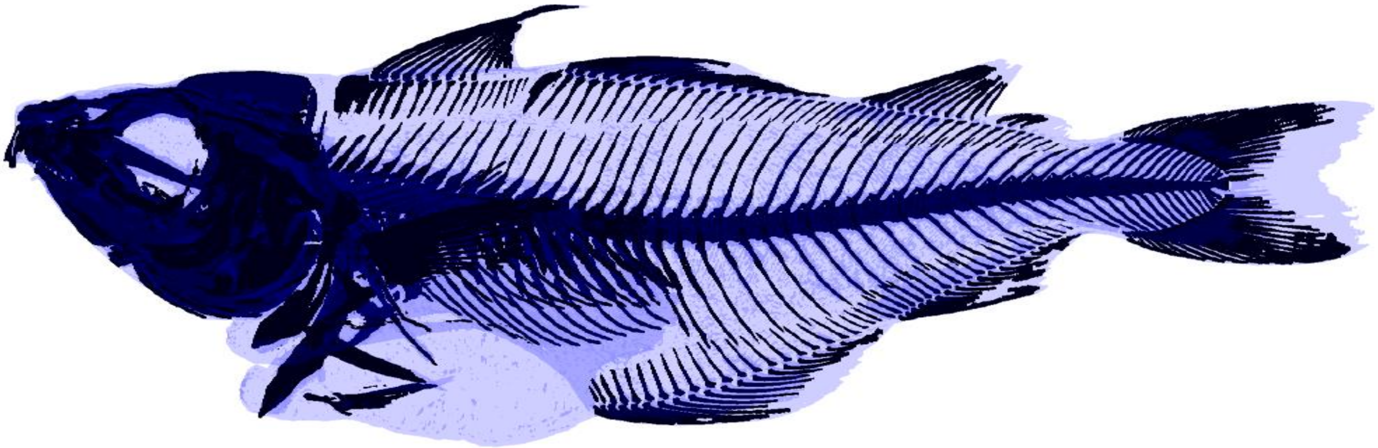


Figure 6. Example of visualization of Haddock skeleton.

4.3 Comparison of CT and manually measured pinbone sizes

In order to verify the CT measurements of the pinbone sizes, bones were manually measured for 3 Cod, 2 Salmon, 2 Saithe, 2 Haddock, 1 Ling, 2 Catfish, 2 Hake and 3 Redfish fillets.

The bones were removed after CT scanning and measured manually by slide caliper. The bone thickness was measured at the center of the bone and the length of the bones was measured in a straight line between the ends. The shape of the fish bone is not always round, but have a more elliptic shape. This results in that the bones often have one thick and one thinner side. We measured the thickness in the thinnest direction.

Comparison with manual control measurements for some of the fillets showed that all the bones were detected, but there were some deviations in the length and thickness measures. The CT pinbone measures gives in average 0.2mm thicker bone than the manual measures and the CT pinbone length measures gives in average 3mm shorter bones than the manual measures. This deviation is mainly due to limitations in the CT resolution.

Table 1 shows the mean values and standard deviations of the differences between manual control measurements and CT measurements of pinbones for all the fish spices. The mean difference between the measured thickness of the pinbones in the CT image and the manually measures, differs from 0.02mm to 0.26mm (previous study gave 0.1mm to 0.3 mm) for the different spices.

Figure 7 shows that the CT pinbone measures in general gives 0.2 mm thicker bones than the manual measures, independent of the pinbone thickness.

The mean difference between the measured lengths in the CT image and manual control measures ranges between 0.4 mm for Cod and Ling to 12.4 mm for Salmon. This corresponds to previous results. The largest deviations occur in Salmon, which is mainly due to the long thin ends of the Salmon pinbones. These thin ends are not imaged by the CT scanner, because of resolution limitations. Since the Salmon fillets were wide, the CT resolution was about 0.5mm, while for thinner fillets the resolution was around 0.2mm.

Figures for each fillet with CT and manually measured length and thickness are shown in Appendix A4 in Apricot2_report.pdf at the Apricotanatomy eroom.

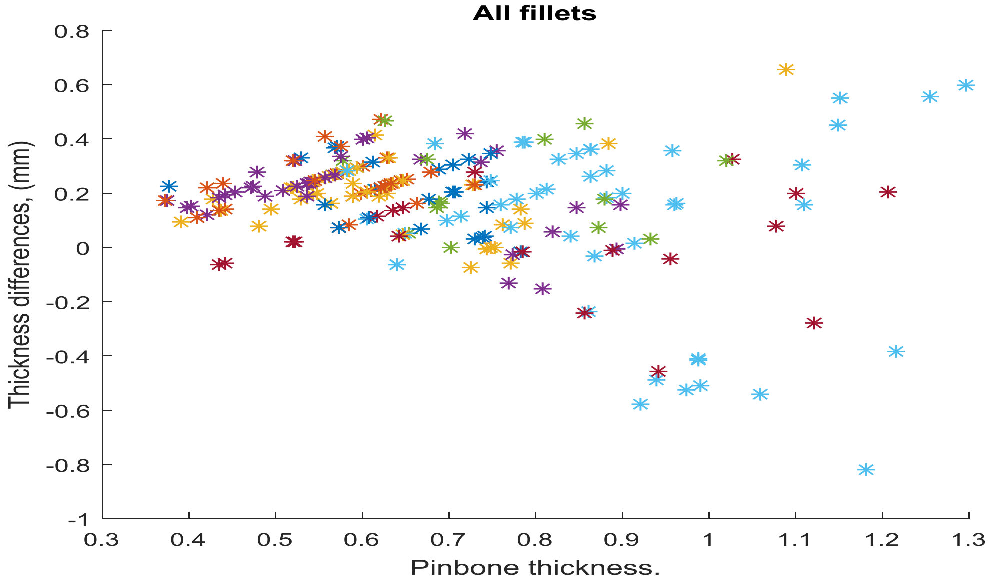


Figure 7. Differences between measured lengths in the CT image and manual control measures as a function of pinbone thickness.

Fish	Fillet id	Mean difference length (mm)	Std of difference length (mm)	Mean diff. thickness (mm)	Std difference thickness (mm)
Haddock	HF_M1	-2.02	1.13	0.14	0.10
Haddock	HF_S1	-4.20	1.18	0.26	0.14
Cod	TF_M1	-2.16	4.37	0.16	0.21
Cod	TF_M2	-1.19	6.61	0.17	0.21
Cod	TF_S1	-0.42	6.07	0.23	0.16
Ling	LF1	-0.41	8.78	0.03	0.36
Saith	SF2	-0.62	6.52	-0.02	0.24
Catfish	STF1	-1.79	3.87	0.27	0.08
Catfish	STF2	-2.45	3.59	0.24	0.06
Salmon	LXF2	-8.66	5.66	0.20	0.07
Salmon	LXF3	-12.40	5.51	0.22	0.06
Hake	LYF1	-2.47	12.12	0.24	0.17
Hake	LYF2	-3.13	2.45	0.25	0.16
Redfish	UF1	-1.38	2.29	0.07	0.10
Redfish	UF2	-1.39	5.27	0.22	0.12
Redfish	UF3	-3.23	2.08	0.23	0.10
Total mean		-2.99	4.84	0.18	0.15

Table 1. Differences between manual control measures and CT measures of pinbone length and thickness.

4.4 Pinbone measurements

The tables below shows the pinbone measurements from the CT data. For all fillets, the number of pinbones as well as minimum, maximum and mean values of pinbone thickness and length are reported in Table 2. Orientation and position are reported in Table 3. A summary of the pinbone statistics for each species are given in Table 4.

Fillet id	No. bones	Length (mm)			Thickness (mm)		
		Min	Max	Mean	Min	Max	Mean
HF_M1	11	3.7	31.6	16.8	0.4	0.8	0.7
HF_M2	7	16.5	26.6	21.0	0.5	1.0	0.7
HF_S1	5	3.2	10.8	8.5	0.6	0.6	0.6
HF_S2	4	9.9	21.9	13.8	0.5	2.2	1.0
TF_M1	15	9.0	31.3	20.0	0.5	1.1	0.7
TF_M2	16	9.5	29.4	22.2	0.5	0.9	0.7
TF_S1	14	9.2	30.5	17.6	0.3	0.8	0.6
TF_S2	13	12.0	25.5	19.3	0.5	0.9	0.7
BF2	25	5.7	30.4	18.9	0.4	1.4	0.7
BF4	25	5.3	24.1	13.6	0.4	0.8	0.6
LF1	42	6.8	57.3	36.7	0.6	1.3	0.9
LF2	38	8.7	68.6	37.8	0.7	1.7	0.9
LF4	38	0.5	71.8	36.1	0.5	1.7	0.9
SF1	10	12.0	62.0	46.3	0.7	4.2	1.3
SF2	10	40.3	53.3	48.4	0.8	1.2	1.0
SF4	12	4.2	45.5	32.4	0.5	2.4	0.9
STF1	24	6.9	15.3	12.5	0.4	0.7	0.6
STF2	26	5.0	17.3	12.2	0.4	0.7	0.5
LXF1	28	13.5	32.1	24.8	0.5	1.0	0.6
LXF2	28	4.8	25.8	18.9	0.4	0.6	0.6
LXF3	26	7.8	19.2	13.8	0.3	0.6	0.5
LXF4	31	8.1	21.0	17.2	0.4	0.7	0.6
LYF1	9	31.3	46.0	39.9	0.7	1.4	0.9
LYF2	10	17.9	38.8	32.2	0.6	1.1	0.8
UF1	11	4.6	22.9	12.6	0.4	0.7	0.6
UF2	6	11.3	31.3	21.4	0.6	0.7	0.7
UF3	8	9.0	16.7	12.7	0.4	0.6	0.5
UF4	9	9.8	17.1	13.9	0.4	0.6	0.5

Table 2. Extracted pinbone information for the fillets; Number of bones, length and thickness

Fillet id	Orientation			Position (mm)	
	YZ mean	XZ mean	XY mean	X start (first bone)	Length of bone area in x direction
HF_M1	13.0	67.2	173.9	21.7	84.6
HF_M2	9.7	62.8	175.4	76.1	68.9
HF_S1	48.8	70.3	159.1	50.3	21.9
HF_S2	60.0	71.8	149.1	66.8	33.6
TF_M1	18.3	54.8	167.3	103.9	148.8
TF_M2	21.1	61.7	164.9	59.9	161.4
TF_S1	26.2	58.0	162.0	101.8	137.4
TF_S2	26.3	58.8	148.8	92.7	130.1
BF2	18.8	29.3	121.3	31.8	197.4
BF4	22.4	41.1	24.7	137.2	186.9
LF1	27.6	45.2	150.6	2.5	627.8
LF2	21.3	58.0	167.1	8.8	670.1
LF4	16.0	59.5	170.6	9.5	692.5
SF1	9.2	61.2	175.1	22.8	132.5
SF2	5.8	62.4	177.0	33.3	139.5
SF4	19.0	64.6	172.3	13.4	109.0
STF1	25.1	57.2	163.3	2.2	160.9
STF2	28.9	58.8	163.8	17.3	167.2
LXF1	35.7	54.9	148.7	25.6	243.7
LXF2	37.5	53.4	150.1	6.0	216.6
LXF3	28.1	46.5	152.5	10.4	174.9
LXF4	43.0	53.7	145.6	11.6	237.4
LYF1	41.7	61.4	151.8	106.3	104.5
LYF2	28.9	60.9	160.9	82.5	94.5
UF1	30.3	69.3	166.3	175.6	109.4
UF2	53.0	64.0	149.9	167.6	49.0
UF3	42.7	58.6	150.9	101.7	45.4
UF4	48.3	66.6	155.7	95.8	58.3

Table 3. Extracted pinbone information for the fillets; Orientation and position

Species	Mean no of bones	Min no of bones	Max no of bones	Mean bone Thickness (mm)	Min bone Thickness (mm)	Max bone Thickness (mm)	Mean bone Length (mm)	Min bone Length (mm)	Max bone Length (mm)
Cod	15	13	16	0,7	0,3	1,1	19,9	9,0	31,3
Haddock	7	4	11	0,7	0,4	2,2	15,9	3,2	31,6
Saithe	11	10	12	1,1	0,4	4,2	41,7	4,2	62,0
Salmon	28	26	31	0,6	0,3	1,0	18,7	4,8	32,1
Tusk	25	25	25	0,7	0,4	1,7	16,3	5,3	68,6
Ling	39	38	42	0,9	0,5	4,2	36,9	0,5	71,8
Catfish	25	24	26	0,6	0,4	1,0	12,3	4,8	32,1
Hake	10	9	10	0,9	0,4	1,4	35,8	4,6	46,0
Redfish	9	6	11	0,6	0,4	0,7	14,6	4,6	31,3

Table 4. Statistics on number of bones, thickness and length for different species.

4.5 Walking stick bone measurements

The walking stick bone was only present in some fillets. An overview of detected walking stick bones is given in Table 5.

For the fillets containing a walking stick bone, the thickness, length, orientation and position measured from the CT data is reported in Table 6.

Fillet ID	Number of fillets with walking stick	Length walking stick (mean, mm)
Haddock	3	19,4
Cod	3	19,4
Saithe	3	35,3
Salmon	0	-
Tusk	0	-
Ling	0	-
Catfish	0	-
Hake	0	-
Redfish	2	6,7

Table 5. Summary of detected walking stick bones for different species.

Fillet ID	Length (mm)	Thickness (mm)	Start position (mm)			Orientation (degrees)		
			x	y	z	yz	xz	xy
HF_M1	25,1	1,7	33,3	22,9	1,6	85,3	87,5	28,4
HF_M2	16,9	1,2	73,7	-34,5	1,5	88,3	87,6	54,4
HF_S1	16,2	0,7	34,7	5,3	1,1	24,7	72,2	171,6
TF_M1	13,5	1,1	101,3	39,5	1,8	89,0	88,7	52,1
TF_M2	32,5	1,6	62,0	-15,9	2,9	85,1	82,2	58,0
TF_S1	12,7	1,0	108,6	36,6	0,3	72,7	79,6	149,4
SF1	38,1	1,1	90,5	-67,3	4,9	86,1	87,2	144,7
SF3	39,7	1,2	62,5	59,0	3,6	83,6	81,9	127,9
SF4	28,2	1,0	53,2	-36,9	3,6	89,0	88,2	120,1
UF1	2,5	1,5	310,7	15,4	17,6	1,6	53,8	178,9
UF2	11,0	2,1	87,7	40,4	0,8	57,7	86,9	175,1

Table 6. Walking stick properties measured from CT data (for fillets with walking stick present).

4.6 Loin height profile

The loin height profiles for all fillets are provided in Appendix C in Apricot2_report.pdf at the Apricotanatomy eroom. The loin thickness (maximum height of the loin profile) are summarized for each species in Table 7.

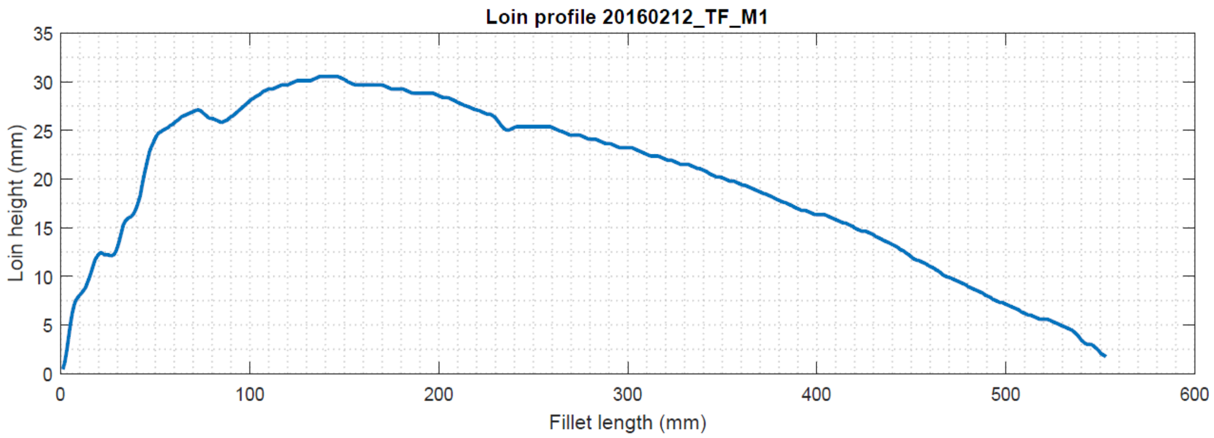


Figure 8. Loin profile for Cod TF_M1.

Species	Loin thickness		
	Mean (mm)	Min (mm)	Max (mm)
Haddock	19,7	15,2	23,2
Cod	27,4	23,4	30,5
Tusk	28,2	24,3	31,2
Ling	37,5	36,5	38,1
Saithe	30,7	26,1	35,3
Catfish	16,7	16,6	16,8
Salmon	30,3	27,7	34,4
Hake	26,9	24,7	29,2
Redfish	22,3	16,4	28,2

Table 7. Statistics for loin thickness (measured at its thickest) for different species.

5 Deliverables

All the results are presented in the report Apricot2_report.pdf. The report together with all CT images and videos of fish skeletons, detected bones and fillet, loin height profiles together with statistics of estimated features of the pinbones and walking stick bone are available for downloading from the eroom Apricotanatomy, see Appendix A.1 for details.

6 Conclusion

In this project, we have imaged bones in whole fish and fillets in 9 different species and provided detailed information about the size, orientation and location of pinbones and the walking stick bone in fillets. For each species 2-4 fillets were CT scanned and analysed. The bones and fillet were segmented and length, thickness, position and orientation of the pinbones were estimated.

Comparison with manual control measurements of the pinbones showed that all the bones were detected in the CT images, but there were some differences in the length and thickness measurements. The CT measures gives some higher thickness (0.2 mm) while the CT measured length was 3 mm shorter. This is mainly due to limitations in resolution of the CT scanner. The thin ends of the bones are below the resolution of the CT images. There was only small differences between the species regarding the pinbone thickness differences, while for pinbone length in Salmon the difference between CT and manual measures was higher than for the other spices. The resolution depends on the width of the fillet, and all fillets with high width are scanned with lower resolution, which results in shorter estimates of the pinbone length.

In this study we found that all the species have a mean pinbone thickness between 0.6-1.1 mm, the mean number of bones detected in this study compared to the previous study was 11 (7) for Saithe and 7 (7) for Haddock, 15 (13) for Cod and 28 (29) for Salmon. The differences are due to the variation in fillet sizes measured.

We present in this report initial analysis of the data. However, the goal of this project has primarily been to assemble a relevant dataset as a basis for further analysis. To enable independent analysis, all data is made available electronically for download. All images and analysed data are available at an eroom, see Appendix A1 for more details.

A.1 Fish and fillet data at eroom

All the CT images in Matlab format, detected bones and fillet in stl format together with statistics of estimated features of the pinbones are available for downloading from the eroom Apricotanatomy (https://project.sintef.no/eRoom/ikt2/Apricotanatomy).

Anyone who is interested will be invited into this eroom by contacting Marianne Bakken (email: marianne.bakken@sintef.no) or Helene Schulerud (email: hsc@sintef.no).

Overview of data at the eroom

1. **Apricot anatomy: Data from the previous FHF project**
2. **Apricot 2: Data from this project**
   - Apricot2_report.pdf : Technical report containing detailed project results
   - Rawdata.zip: Raw CTscanner data (int16) in Matlab format.
   - Apricot2Data.zip: contains one folder for each fillet/fish with the following files
     - bone.stl: Mesh of bones in stl format for import into CAD software
     - fish.stl: Mesh of fillet in stl format for import into CAD software
     - patches.mat: 3D surfaces of bone and fish in MAT format (suitable for later plotting and processing in Matlab through i.e. patch command)
     - For fillets only:
       - stats.mat: Matlab file containing measured lengths, orientations etc per pinbone in the fillet, and overall statistics per fillet. Same statistics for walking stick bone where applicable.
       - segmented.mat: Matlab file with the following variables:
         - info: Raw DICOM info for the captured data
         - resolution: Resolution in XYZ (in mm) for captured data
         - segmented: Segmented data. The following values are used:
           - 0: Background (non-fish)
           - 10: Fish meat
           - 101-150: Each bone is given an individual number in this range
         - xform: Transformation matrix from calibration
   - 3D_fillets.pdf: 3D rendering of fish fillets
   - 3D_fish.pdf: 3D rendering of whole fish
   - 3D_pinbones.pdf: 3D rendering and numbering of pinbones (fillets only)
   - Loin_profiles.pdf: Profile of loin thickness for each fillet (fillets only)
   - Fillet_videos: 3D rendered fillets shown in videos
   - Fish_videos: 3D rendered fish shown in videos
   - Allstats.xls: Minimum, maximum and mean of pinbone length, thickness, orientation and the start point of the first bone and the stop position of the last bone.
     Sheets:
     - Name – name of species and fillets ID
     - All stats- statistics for pinbone measure pr fillet
     - Bone_length – bone lengths for all fillets
     - Bone_thicness – bone thicness for all fillets
     - Stat - statistics for pinbone measures pr spices
     - Manually_bone_thichness – manually measured pinbone thickness
     - Manually_bone_length – manually measured pinbone length

   - Readme.txt: text file describing the content in the different files.

A.2 Fish and fillet data

Whole fish ID	Fillet ID	Species	Weight (g)	Length (cm)	Left/ right fillet	Comment	Delivered by	Scan date
TH-M1		Cod (Torsk)	3260	73	-		Norway Seafoods	12.2.2016
TH-M2		Cod (Torsk)	3531	81	-		Norway Seafoods	12.2.2016
TH-S1		Cod (Torsk)	1799	66	-		Norway Seafoods	12.2.2016
TH-S2		Cod (Torsk)	2214	68	-		Norway Seafoods	12.2.2016
	TF-M1	Cod (Torsk)	904	60	l		Norway Seafoods	12.2.2016
	TF-M2	Cod (Torsk)	1105	50	r		Norway Seafoods	12.2.2016
	TF-S1	Cod (Torsk)	593	55	l		Norway Seafoods	12.2.2016
	TF-S2	Cod (Torsk)	807	60	r		Norway Seafoods	12.2.2016
HH-M1		Haddock (Hyse)	1734	61	-		Norway Seafoods	12.2.2016
HH-M2		Haddock (Hyse)	1898	63	-		Norway Seafoods	12.2.2016
HH-S1		Haddock (Hyse)	925	48	-		Norway Seafoods	12.2.2016
HH-S2		Haddock (Hyse)	779	48	-		Norway Seafoods	12.2.2016
	HF-M1	Haddock (Hyse)	515	43	l		Norway Seafoods	12.2.2016
	HF-M2	Haddock (Hyse)	608	44	r		Norway Seafoods	12.2.2016
	HF-S1	Haddock (Hyse)	230	31	r		Norway Seafoods	12.2.2016
	HF-S2	Haddock (Hyse)	210	34	l		Norway Seafoods	12.2.2016
BH-1		Tusk (Brosme)	4065	72	-		Norway Seafoods	19.2.2016
BH-2		Tusk (Brosme)	3718	72	-		Norway Seafoods	19.2.2016
BH-3		Tusk (Brosme)	1516	61	-		Norway Seafoods	19.2.2016
BH-4		Tusk (Brosme)	731	43	-		Norway Seafoods	19.2.2016

Whole fish ID	Fillet ID	Species	Weight (g)	Length (cm)	Left/ right fillet	Comment	Delivered by	Scan date
	BF-1	Tusk (Brosme)	369	37	l		Norway Seafoods	19.2.2016
	BF-2	Tusk (Brosme)	537	38	l		Norway Seafoods	19.2.2016
	BF-3	Tusk (Brosme)	507	36	r		Norway Seafoods	19.2.2016
	BF-4	Tusk (Brosme)	296	37	r		Norway Seafoods	19.2.2016
LH-1		Ling (Lange)	4859	86		Without head	Fiskcentralen	19.2.2016
LH-2		Ling (Lange)	3271	81		Without head	Fiskcentralen	19.2.2016
LH-3		Ling (Lange)	2770	71		Without head	Fiskcentralen	19.2.2016
LH-4		Ling (Lange)	2019	63		Without head	Fiskcentralen	19.2.2016
	LF-1	Ling (Lange)	3668	84	l		Fiskcentralen	19.2.2016
	LF-2	Ling (Lange)	3013	96	r		Fiskcentralen	19.2.2016
	LF-3	Ling (Lange)	2542	81	r		Fiskcentralen	19.2.2016
	LF-4	Ling (Lange)	3281	97	l		Fiskcentralen	19.2.2016
SH-1		Saithe (Sei)	2019	70			Fiskcentralen	19.2.2016
SH-2		Saithe (Sei)	1920	68			Fiskcentralen	19.2.2016
SH-3		Saithe (Sei)	1815	64			Fiskcentralen	19.2.2016
SH-4		Saithe (Sei)	1987	67			Fiskcentralen	19.2.2016
	SF-1	Saithe (Sei)	1687	63	r		Fiskcentralen	19.2.2016
	SF-2	Saithe (Sei)	1769	63	l		Fiskcentralen	19.2.2016
	SF-3	Saithe (Sei)	693	50	l		Fiskcentralen	19.2.2016
	SF-4	Saithe (Sei)	690	50	r		Fiskcentralen	19.2.2016
STH-1		Atlantic catfish (Steinbit)	1840	66		Without head	Fiskcentralen	19.2.2016
STH-2		Atlantic catfish (Steinbit)	2043	63		Without head	Fiskcentralen	19.2.2016
	STF-1	Atlantic catfish (Steinbit)	344	**50**	l		Fiskcentralen	19.2.2016
	STF-2	Atlantic catfish (Steinbit)	336	**50**	r		Fiskcentralen	19.2.2016
LXH-1		Salmon (Laks)	4217	68			Fiskcentralen	28.2.2016
LXH-2		Salmon (Laks)	4052	76			Fiskcentralen	28.2.2016

SINTEF

Whole fish ID	Fillet ID	Species	Weight (g)	Length (cm)	Left/ right fillet	Comment	Delivered by	Scan date
LXH-3		Salmon (Laks)	2389	63			Fiskcentralen	28.2.2016
LXH-4		Salmon (Laks)	2260	63			Fiskcentralen	28.2.2016
	LXF-1	Salmon (Laks)	1819	59	R		Fiskcentralen	28.2.2016
	LXF-2	Salmon (Laks)	1077	49	R		Fiskcentralen	28.2.2016
	LXF-3	Salmon (Laks)	754	43	L		Fiskcentralen	28.2.2016
	LXF-4	Salmon (Laks)	1034	49	L		Fiskcentralen	28.2.2016
LYH-1		Hake (Lysing)	2714	75			Fiskcentralen	28.2.2016
LYH-2		Hake (Lysing)	2462	76			Fiskcentralen	28.2.2016
	LYF-1	Hake (Lysing)	964	65	R		Fiskcentralen	28.2.2016
	LYF-2	Hake (Lysing)	682	57	L		Fiskcentralen	28.2.2016
UH-1		Redfish (Uer)	2837	56		Not gutted	Fiskcentralen	28.2.2016
UH-2		Redfish (Uer)	1742	53		Gutted at SINTEF	Fiskcentralen	28.2.2016
UH-3		Redfish (Uer)	3172	61		Not gutted	Fiskcentralen	28.2.2016
UH-4		Redfish (Uer)	737	39		Gutted at SINTEF	Fiskcentralen	28.2.2016
	UF-1	Redfish (Uer)	408	35	L		Norway Seafoods	28.2.2016
	UF-2	Redfish (Uer)	421	33	R		Norway Seafoods	28.2.2016
	UF-3	Redfish (Uer)	107	19	L		Norway Seafoods	28.2.2016
	UF-4	Redfish (Uer)	93	19	R		Norway Seafoods	28.2.2016
STHH-1		Catfish (Steinbit)	5000+	89		Flekksteinbit	Norway Seafoods	28.2.2016
STHH-2		Catfish (Steinbit)	3575	78		Flekksteinbit	Norway Seafoods	28.2.2016

A.3 Sampling plan

Batch	Specie (English)	Specie (Icelandic)	Specie (Norwegian)	Scientific name	Whole fish	Size	Fillets (untrimmed/ with pinbones and spamannsbein)	Hrs
A	Cod	Þorskur	Torsk	Gadus morhua	2	M	2	1
A	Cod	Þorskur	Torsk	Gadus morhua	2	S	2	1
B	Haddock	Ýsa	Hyse	Melanogrammus aeglefinus	2	M	2	1
B	Haddock	Ýsa	Hyse	Melanogrammus aeglefinus	2	S	2	1
C	Saithe	Ufsi	Sei	Pollachius virens	2	M	2	1
C	Saithe	Ufsi	Sei	Pollachius virens	2	S	2	1
D	Tusk	Keila	Bromse	Brosme brosme	2	M	2	1
D	Tusk	Keila	Bromse	Brosme brosme	2	S	2	1
E	Ling	Langa	Lange	Molva molva	2	M	2	1
E	Ling	Langa	Lange	Molva molva	2	S	2	1
F	Blue ling	Blálanga	Blålange	Molva dypterygia	2	M	2	1
F	Atlantic catfish	Steinbítur	Steinbit	Anarhichas lupus	2	M	2	1
G	Atlantic salmon	Lax	Laks	Salmon salar	2	M	2	1
G	Atlantic salmon	Lax	Laks	Salmon salar	2	S	2	1
H	Deep sea redfish*)	Djúpkarfi		Sebastes mentella	2	M	2	1
H	European hake	Kolmúli/ lýsingur	Lysing	Merluccius merluccius	2	M	2	1
*) or E	Redfish	Karfi	Uer	Sebastes marinus	4	M	4	2