Applications of hyperspectral imaging for documenting smoltification status and welfare in Atlantic salmon

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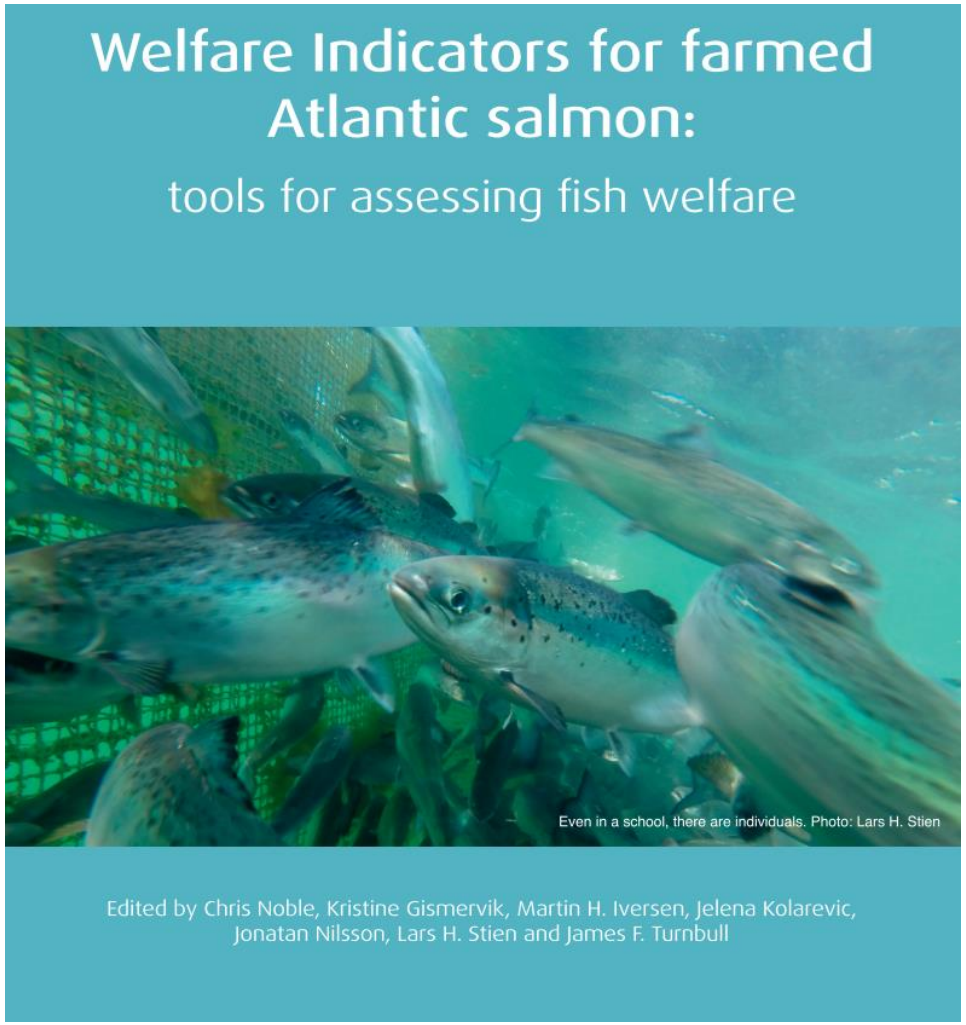

Nofima An FHF-financed project, led by Nofima in partnership with:

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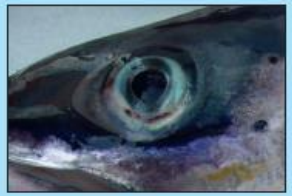
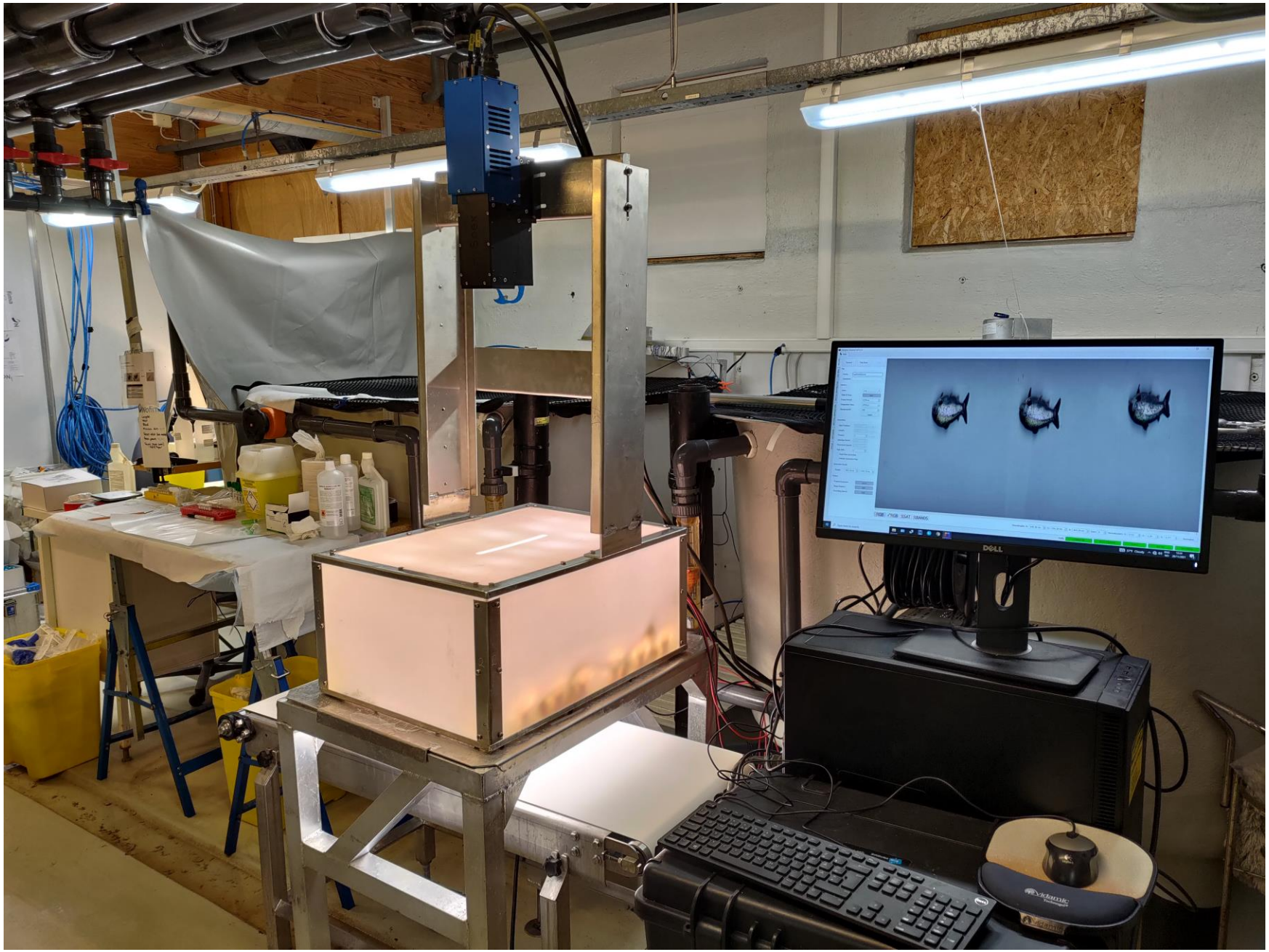
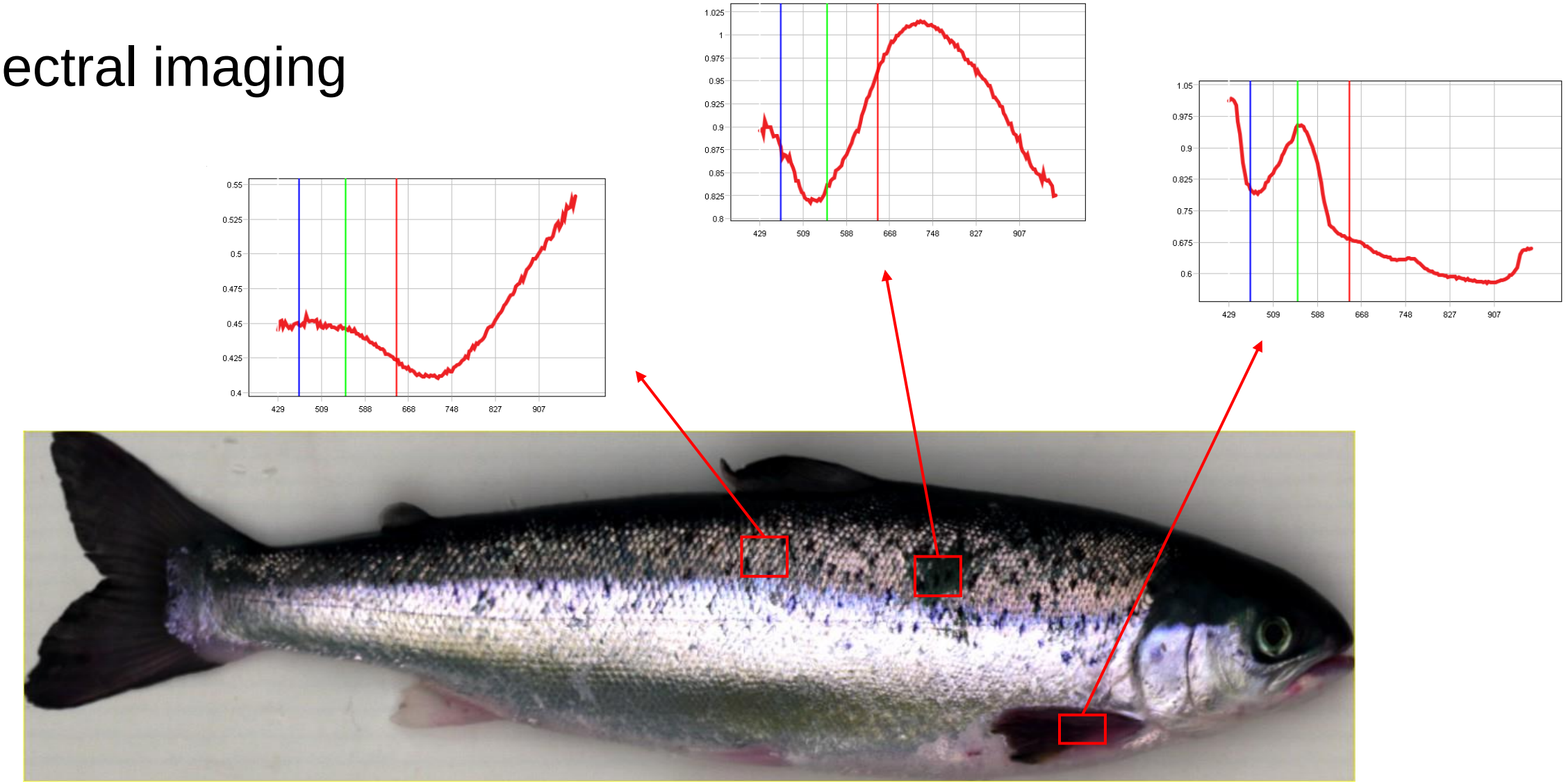
FISHWELL Morphological Operational Welfare Indicators (OWI's) for farmed Atlantic salmon v1.1

Level 0: Little or no evidence of this OWI, i.e. normal (not illustrated).
Level 1, minor to Level 3, clear evidence of the OWI.

	Eye haemorrhaging	Exophthalmia	Opercular damage	Snout damage	Upper jaw deformity	Lower jaw deformity	Emaciation
1	 Minor haemorrhages	 Eye protruding a little	 Operculum only partly covering gills	 Minor wound on snout (either jaw)	 Suspected malformation	 Suspected malformation	 Potentially emaciated
2	 Larger haemorrhages, or traumatic injury	 Moderate eye protrusion	 Operculum absent on one of the gills (gill exposed)	 Moderate wound and broken skin on snout	 Distinct malformation	 Distinct malformation	 Emaciated
3	 Large haemorrhages / traumatic injury. Eye may be ruptured	 Major eye protrusion	 Both opercula absent (both gills exposed)	 Large deep and extensive wound. Can cover the whole head	 Major malformation, jaw pointing backwards	 Major malformation, jaw pointing backwards	 Extremely emaciated


DELL

Spectral imaging



Summary of trials

	Feature	Number of fish scanned with HSI	Number of fish with manual reference	Indicator type	Agreement with manual WI
Trial 1	Dorsal fin injuries	725	290	OWI	0.54
Trial 2	Plasma chloride	849	120	LABWI	0.73
Trial 3	Eye injuries	300	300	OWI	0.55
Trial 4	Lice count	1124	1124	OWI	0.65

Trial 1: Active fin damage (splitting and/or haemorrhaging)

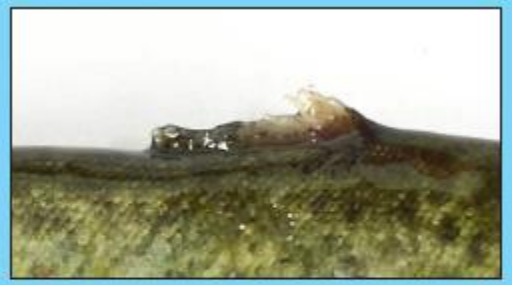
1

Most of the fin remaining

2

Half of the fin remaining

3

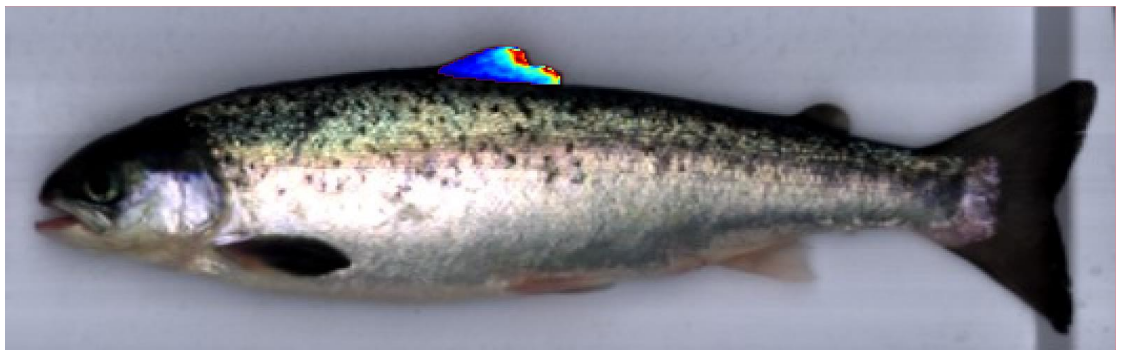


Very little of the fin remaining

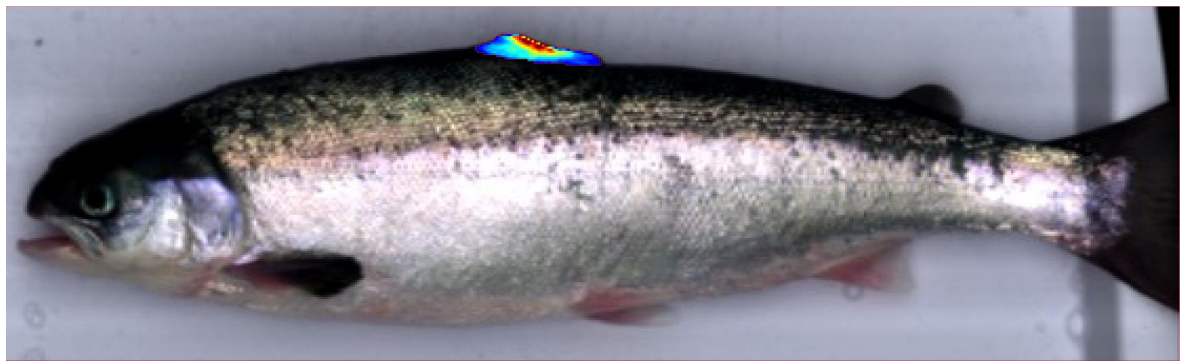
0

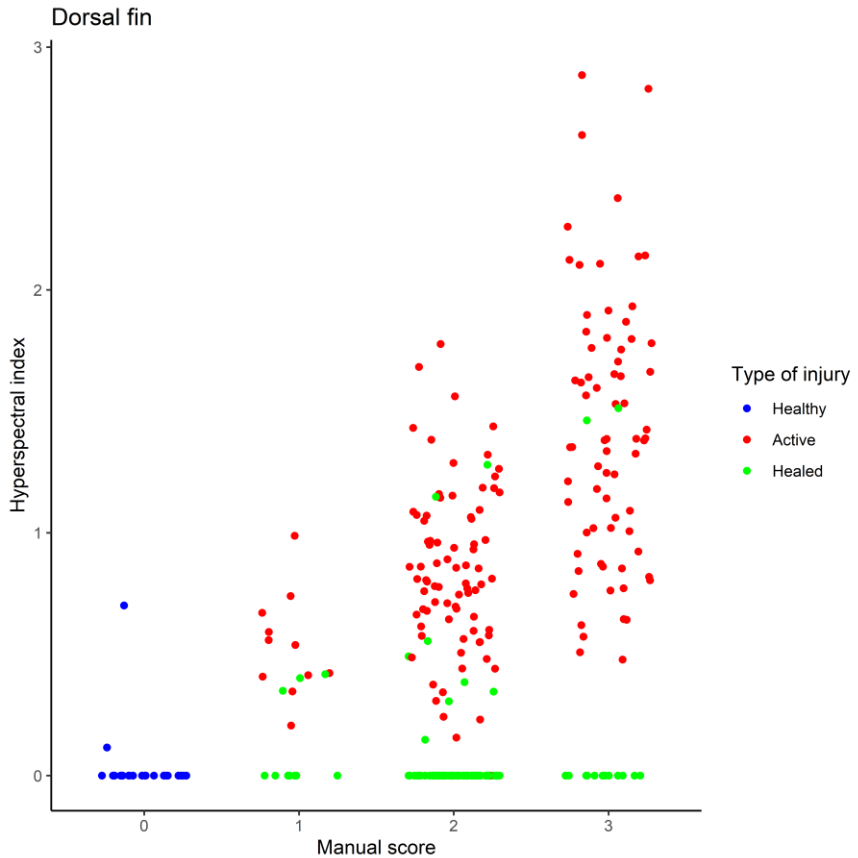
1

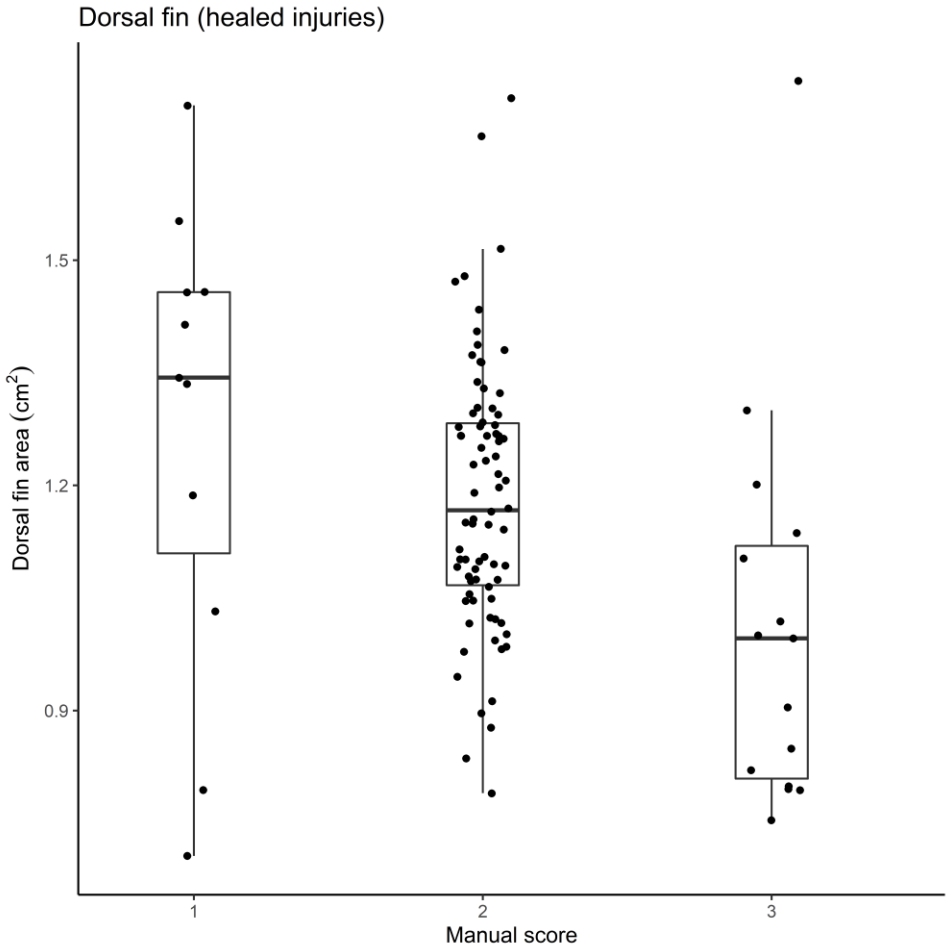
2



3

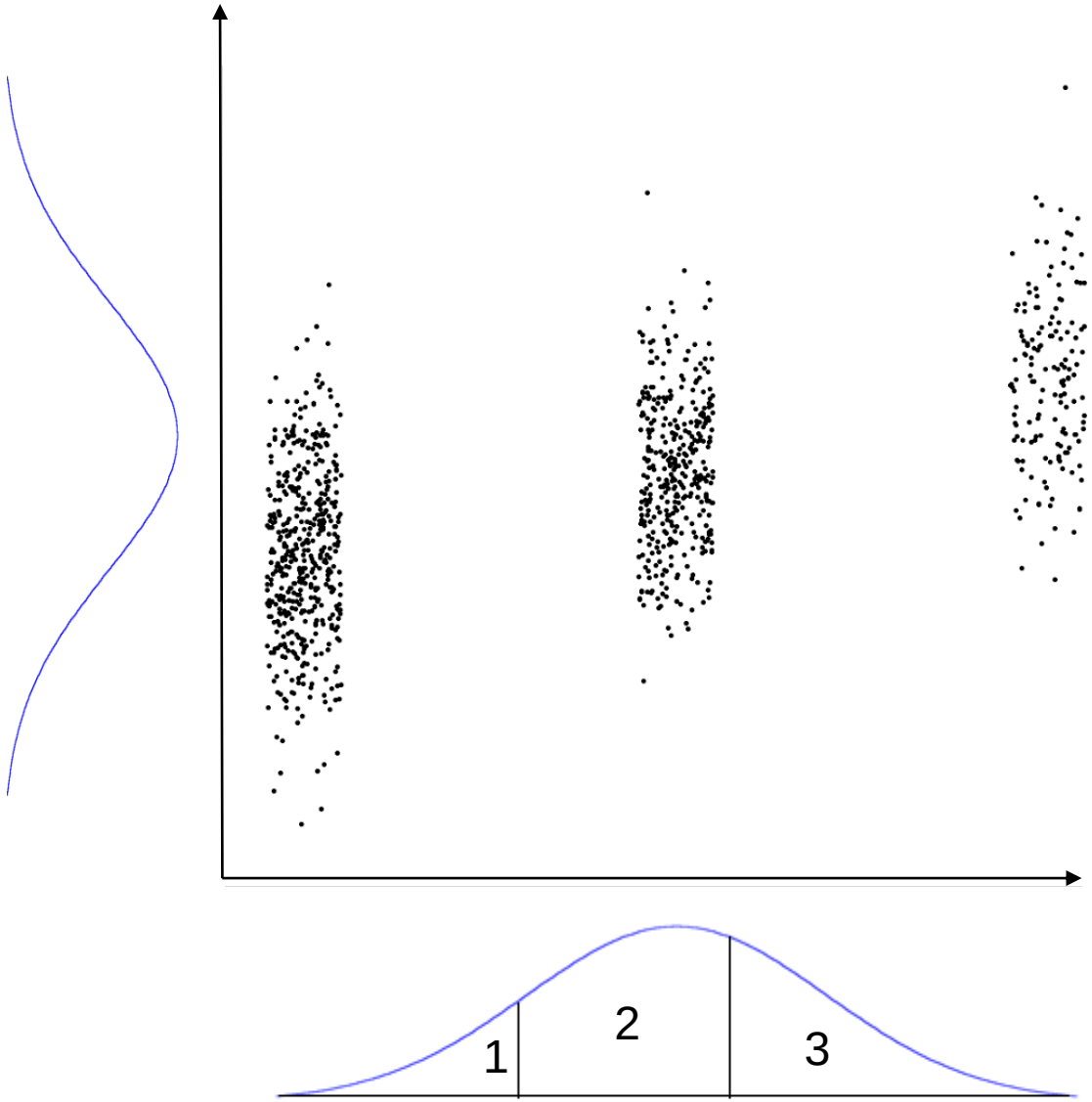



Dorsal fin
Hyperspectral index
Manual score
Type of injury
Healthy
Active
Healed


Dorsal fin (healed injuries)
Dorsal fin area (cm²)
Manual score

Polychoric correlation

Cox (1974). Estimation of the Correlation between a Continuous and a Discrete Variable.

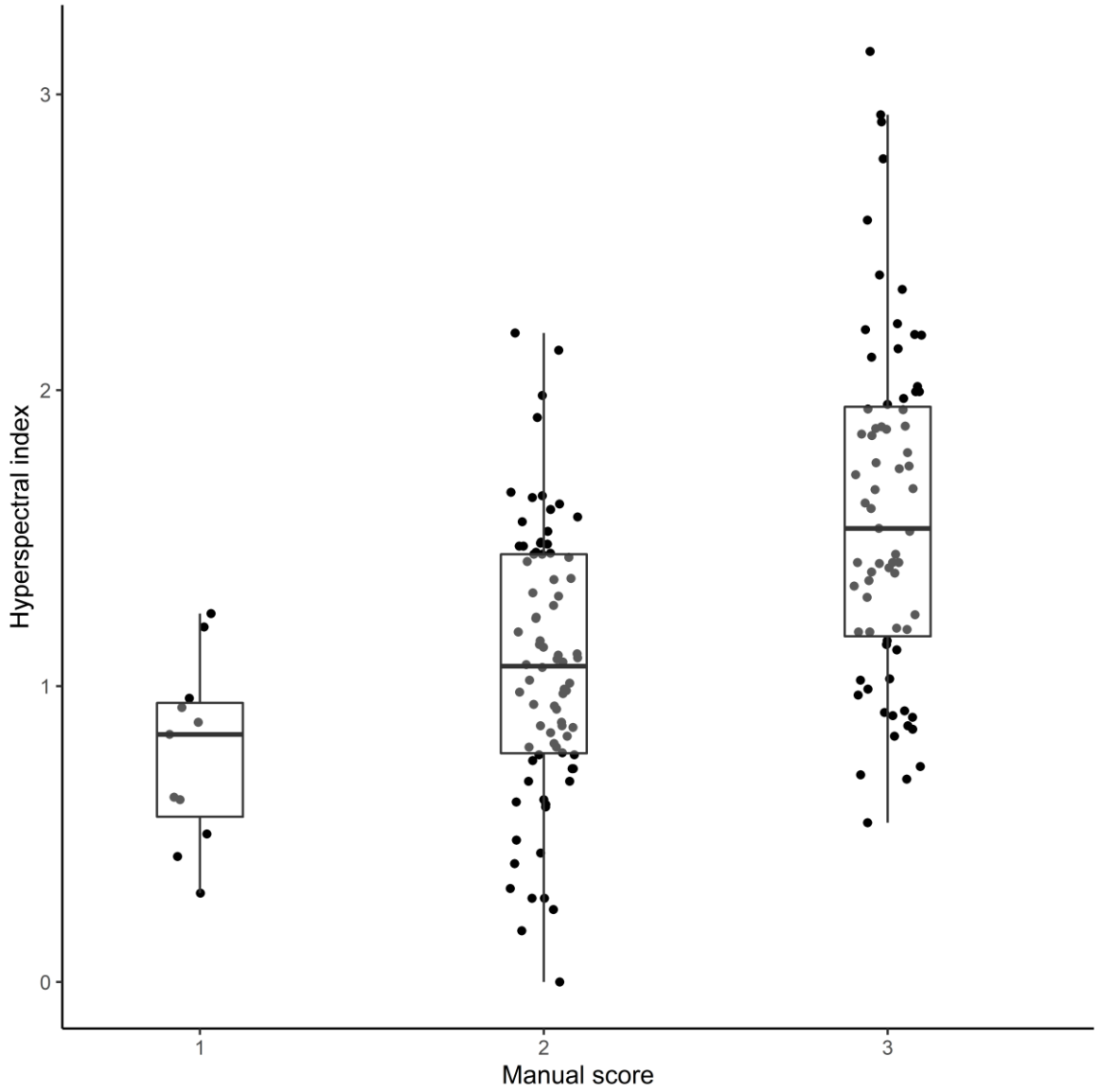


Manual scoring of two scorers

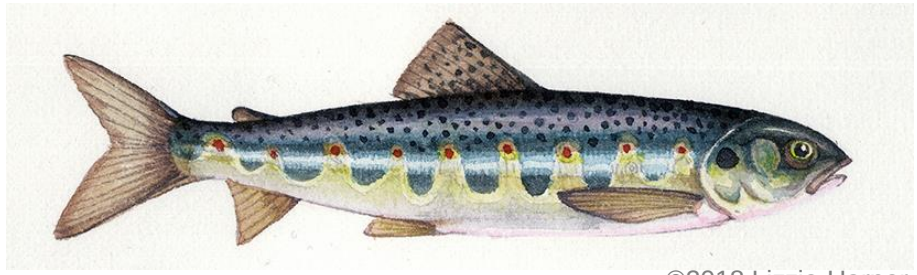
Spearman’s correlation: 0.56
Interrater agreement: 0.66
Cohen’s kappa: 0.40

Manual scores and camera output

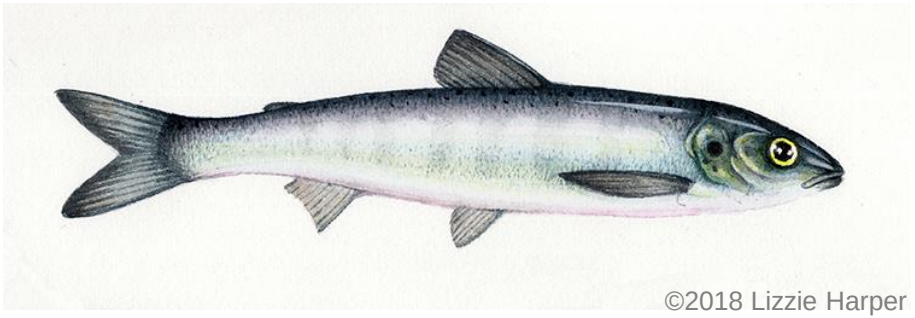
Polychoric correlation: 0.54



Trial 2: Smoltification



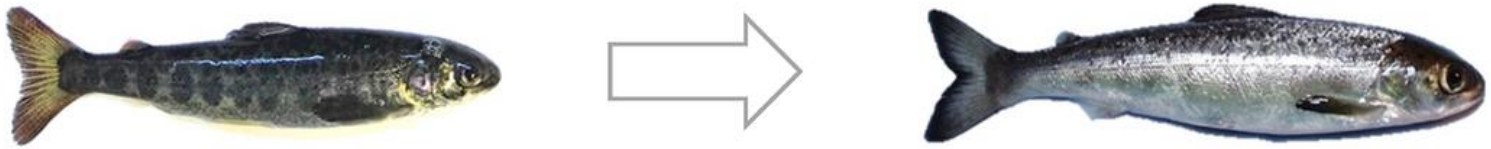
Parr



Smolt

Picture source: http://www.lizzieharper.co.uk/news/article/155/Natural_History_Illustration_Salmon_life_cycle

Debes et al., 2020



Parr *vs* Smolt

Odei et al., 2020

Characteristic	Index (point)[a]			
Parr mark	Clear (1)	Visible (2)	Weak (3)	None (4)
Silver coloration	Clear (1)	Weak (2)	Visible (3)	Silver (4)
Fin margins	Clear (1)	Weak (2)	Visible (3)	Black margin (4)

Note:
[a]*The transition of Atlantic salmon parr to smolt is indicated in the gradual increasing score from 1 to 4.*

Khaw et al., 2021

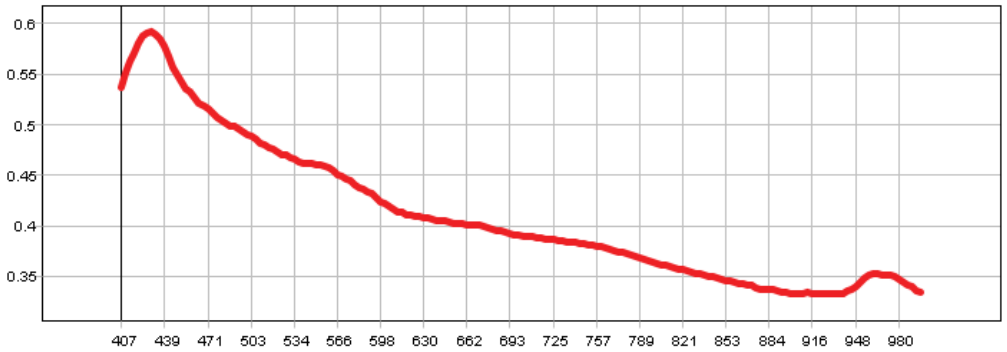
Experimental setup

- Spectral imaging followed by a 24 hour seawater challenge
  - 15.02.2021 (40 fish x 2 replicates) – week 3 (sampling 2)
  - 08.03.2021 (40 fish x 2 replicates) – week 6 (sampling 3)
  - 22.03.2021 (40 fish x 2 replicates) – week 8 (sampling 4)

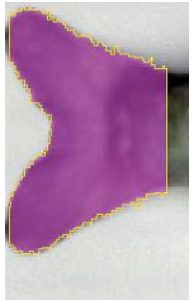
- Spectral image features → Plasma chloride ion levels after seawater challenge

- 80 % training set, 20 % test set

Feature extraction

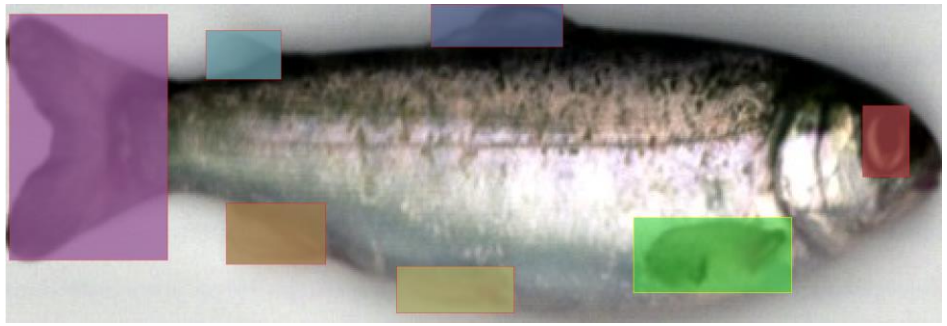


Average



Background removal

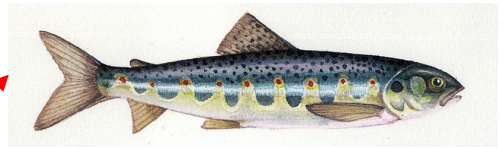
YOLO V4

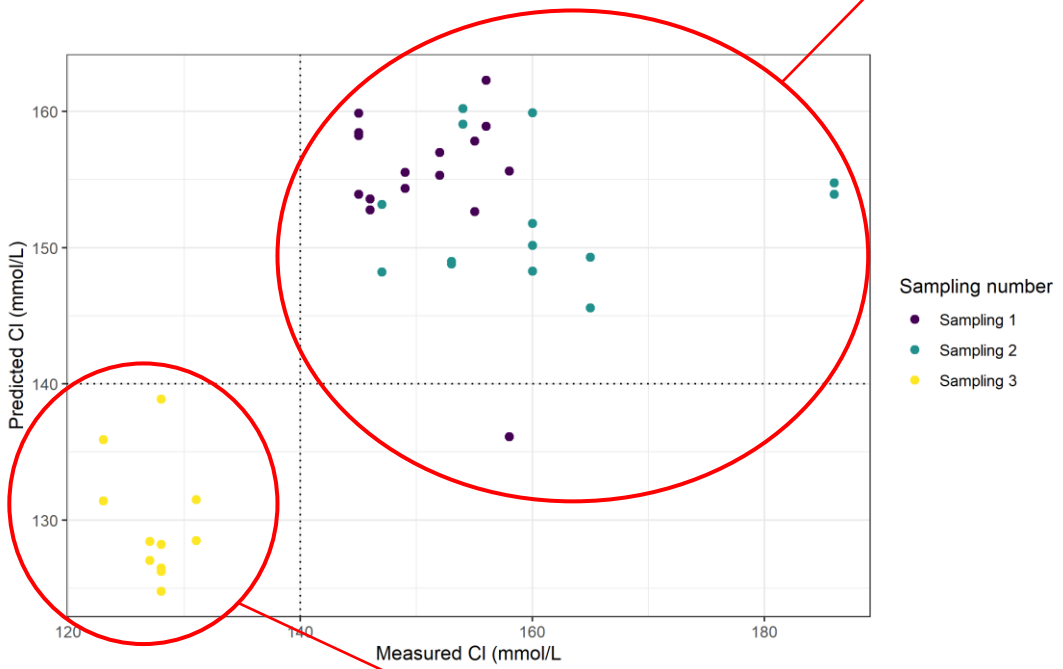


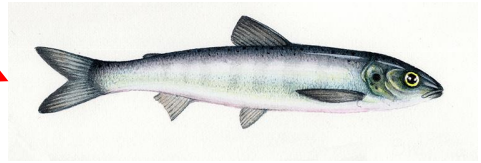
Type
- Adipose_fin
- Anal_fin
- Caudal_fin
- Dorsal_fin
- Eye
- Pectoral_fin
- Pelvic_fin

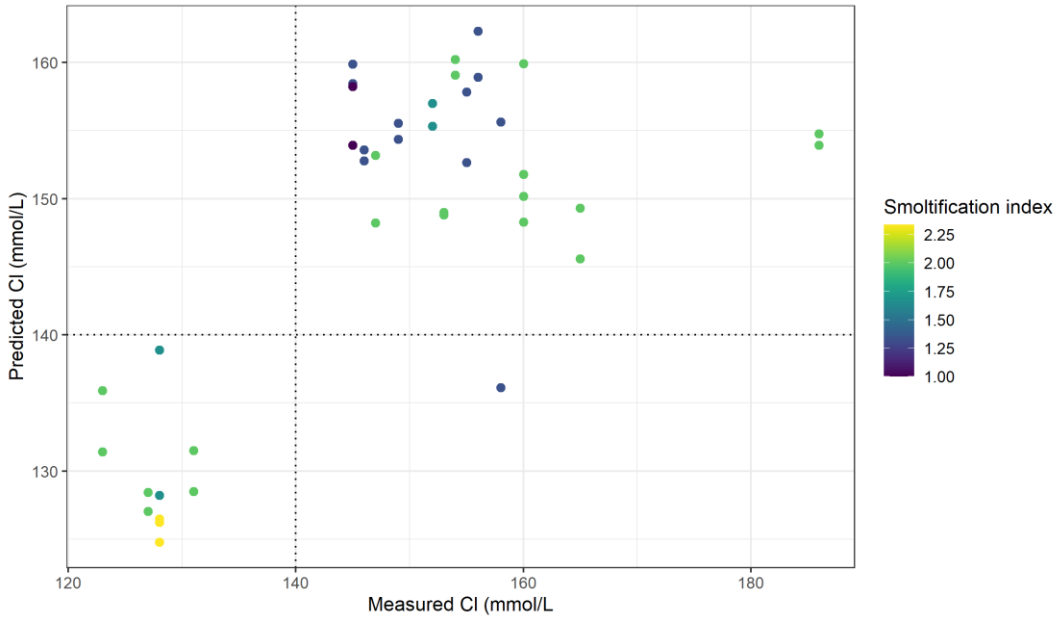
Results

Test set R2 = 0.73









Summary and future work

- Proof of concept

- Individual health screening, e.g.:
  - Smoltification assessment
  - Sea lice infection level assessment
  - Delousing injury assessment
  - Early warning for infectious diseases

- Better quality of life -> happier fish
- Reduced mortality -> happier farmers