

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

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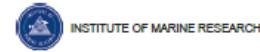
# Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare



Even in a school, there are individuals. Photo: Lars H. Stien

Edited by Chris Noble, Kristine Gismervik, Martin H. Iversen, Jelena Kolarevic,  
Jonatan Nilsson, Lars H. Stien and James F. Turnbull

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

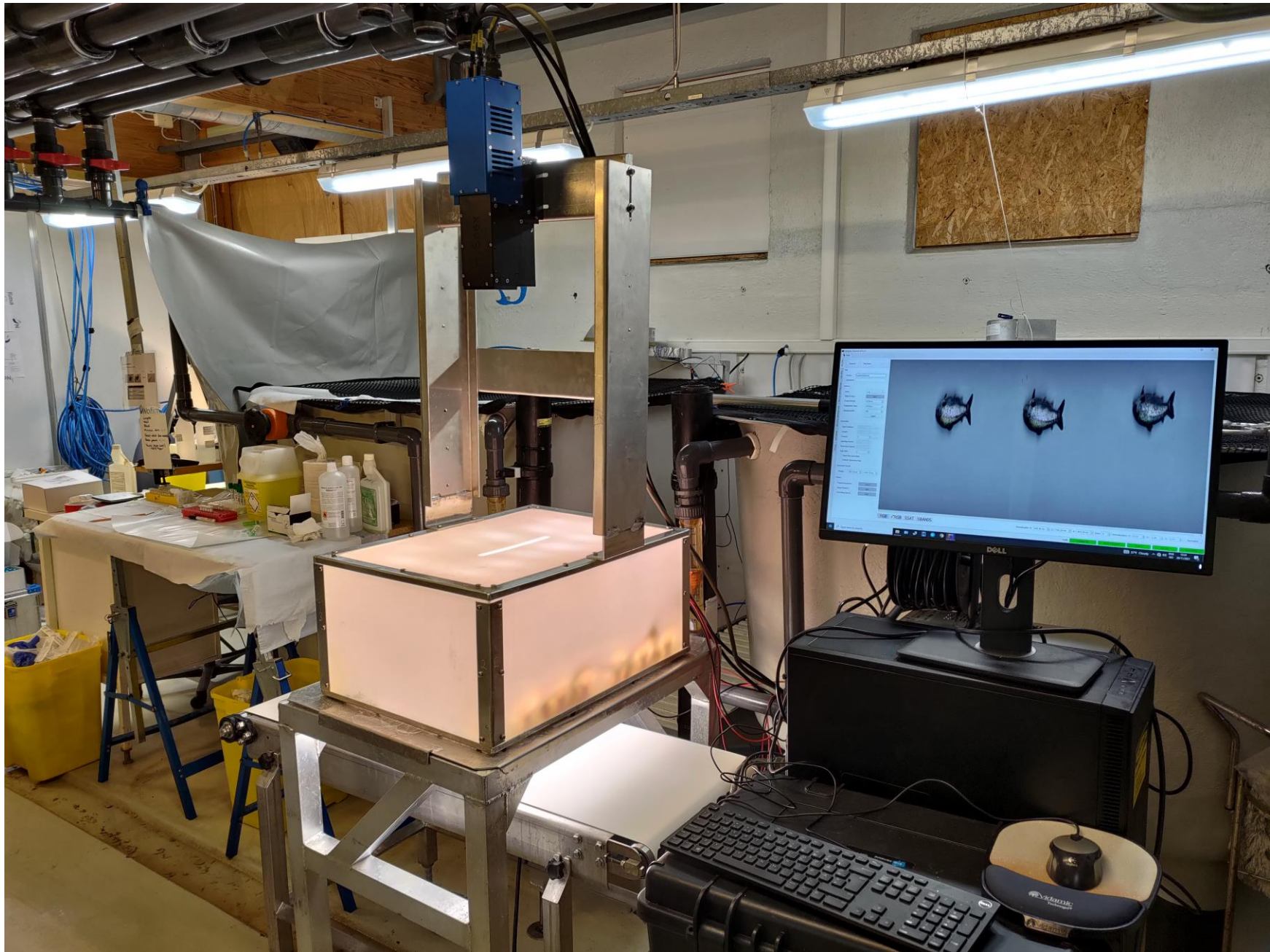


# FISHWELL Morphological Operational Welfare Indicators (OWI's) for farmed Atlantic salmon v1.1

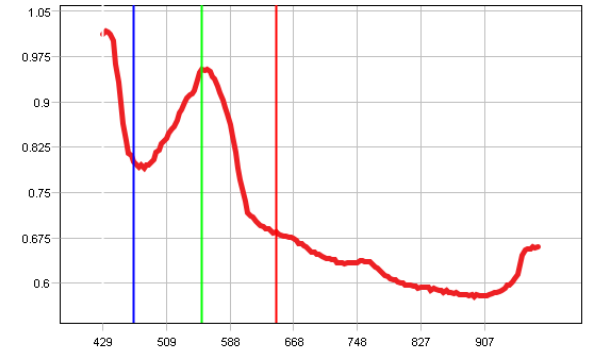
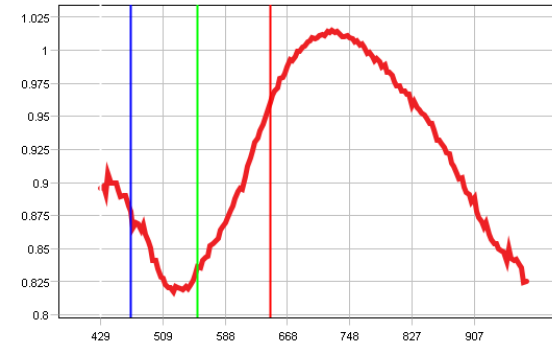
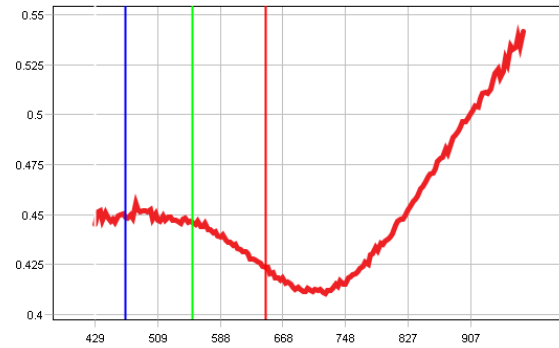
Level 0: Little or no evidence of this OWI, i.e. normal (not illustrated).

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



# 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



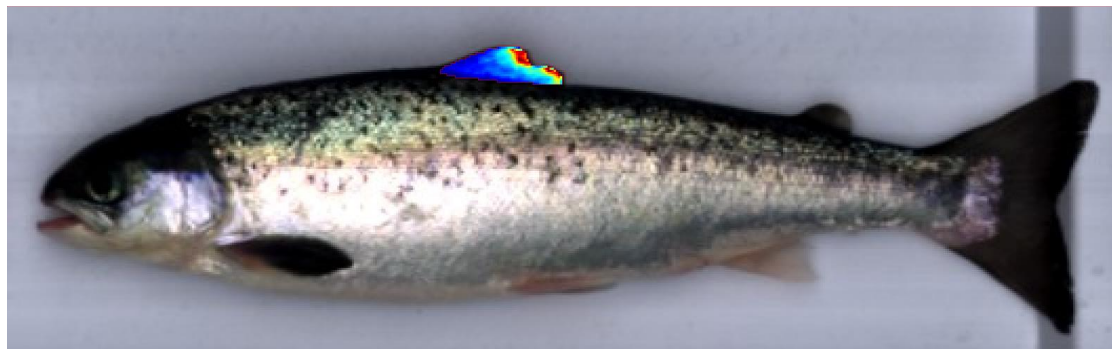
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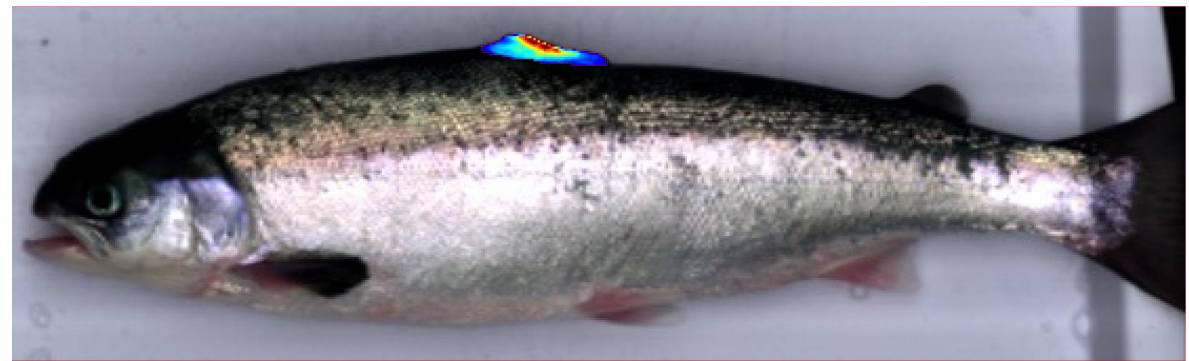
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2

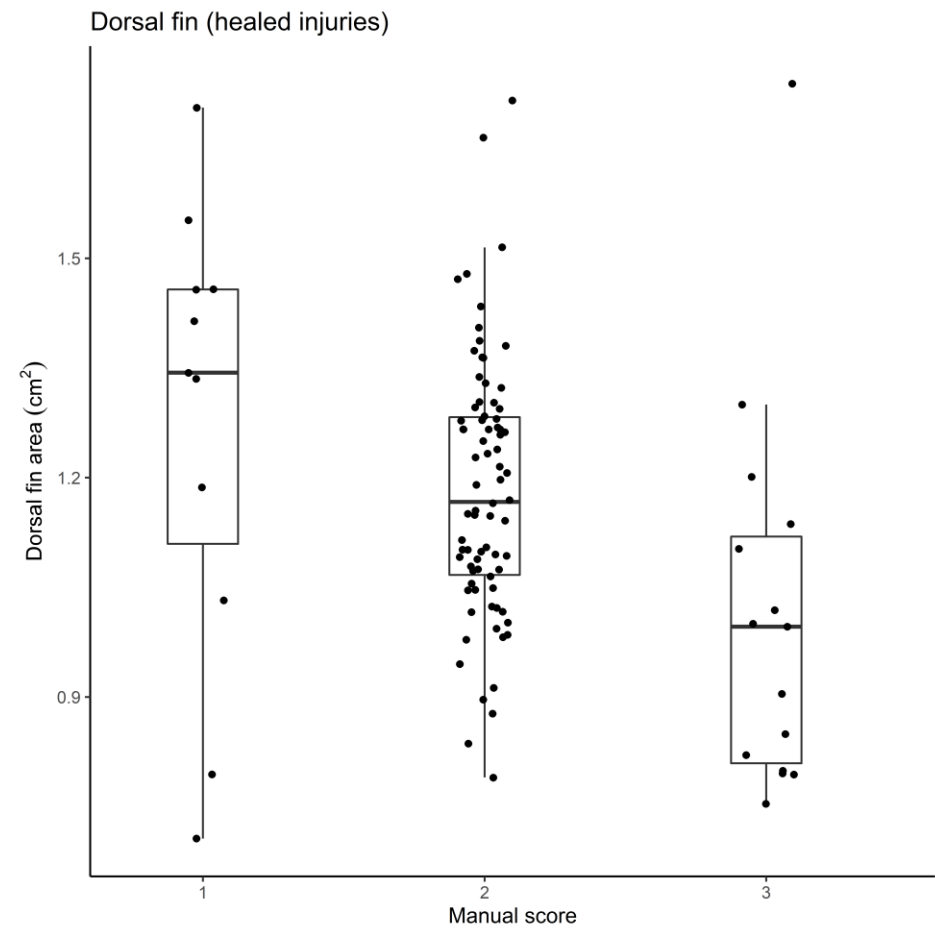
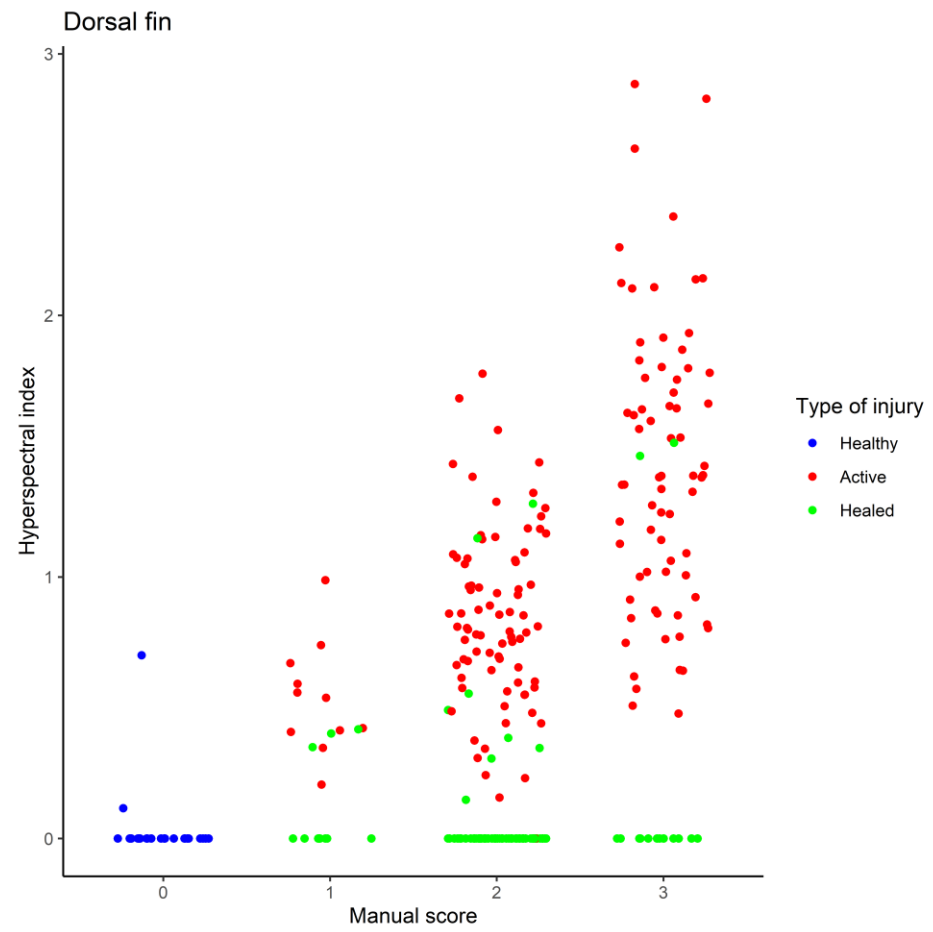


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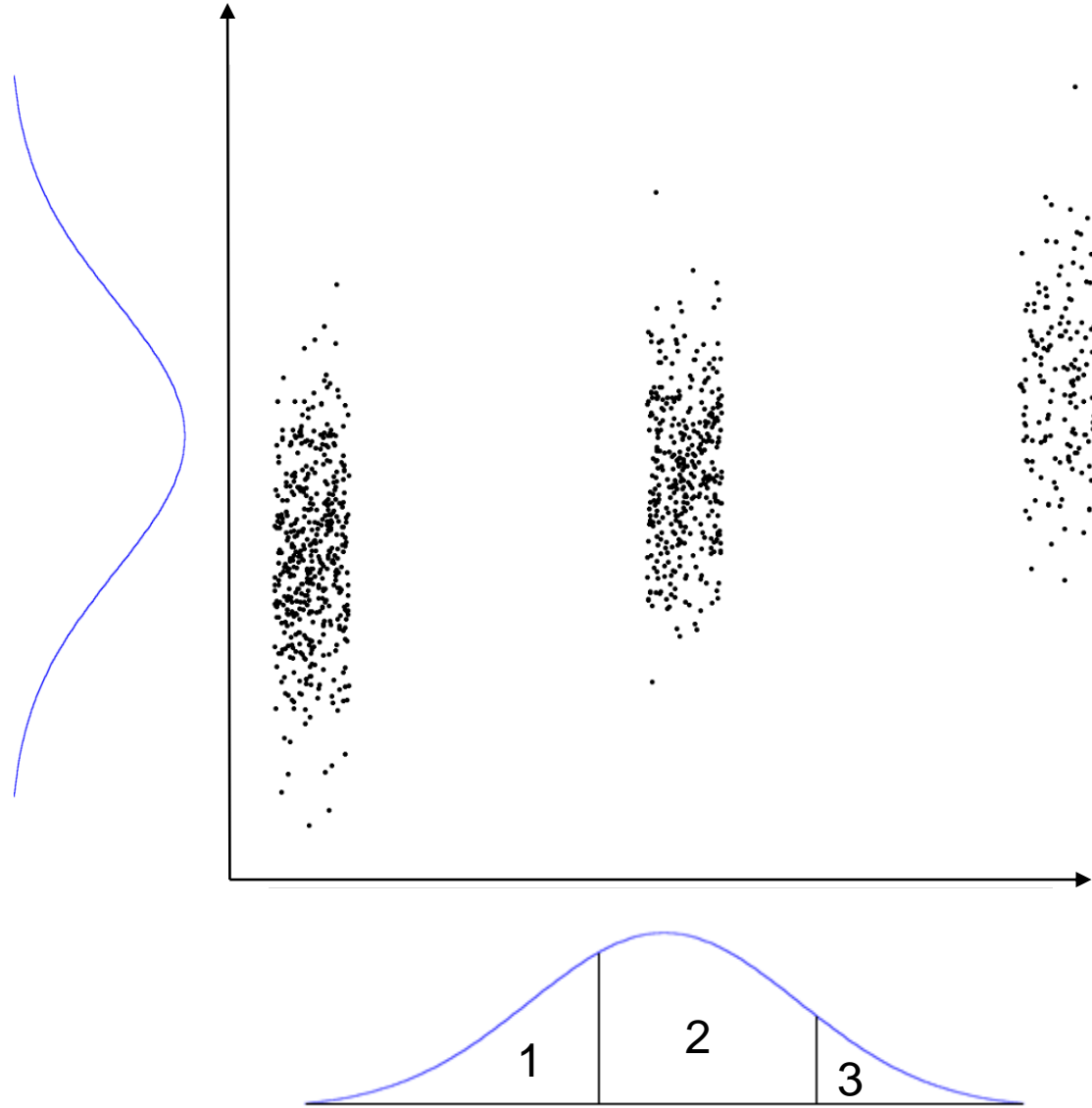
8





# Polychoric correlation

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



### Manual scoring of two scorers

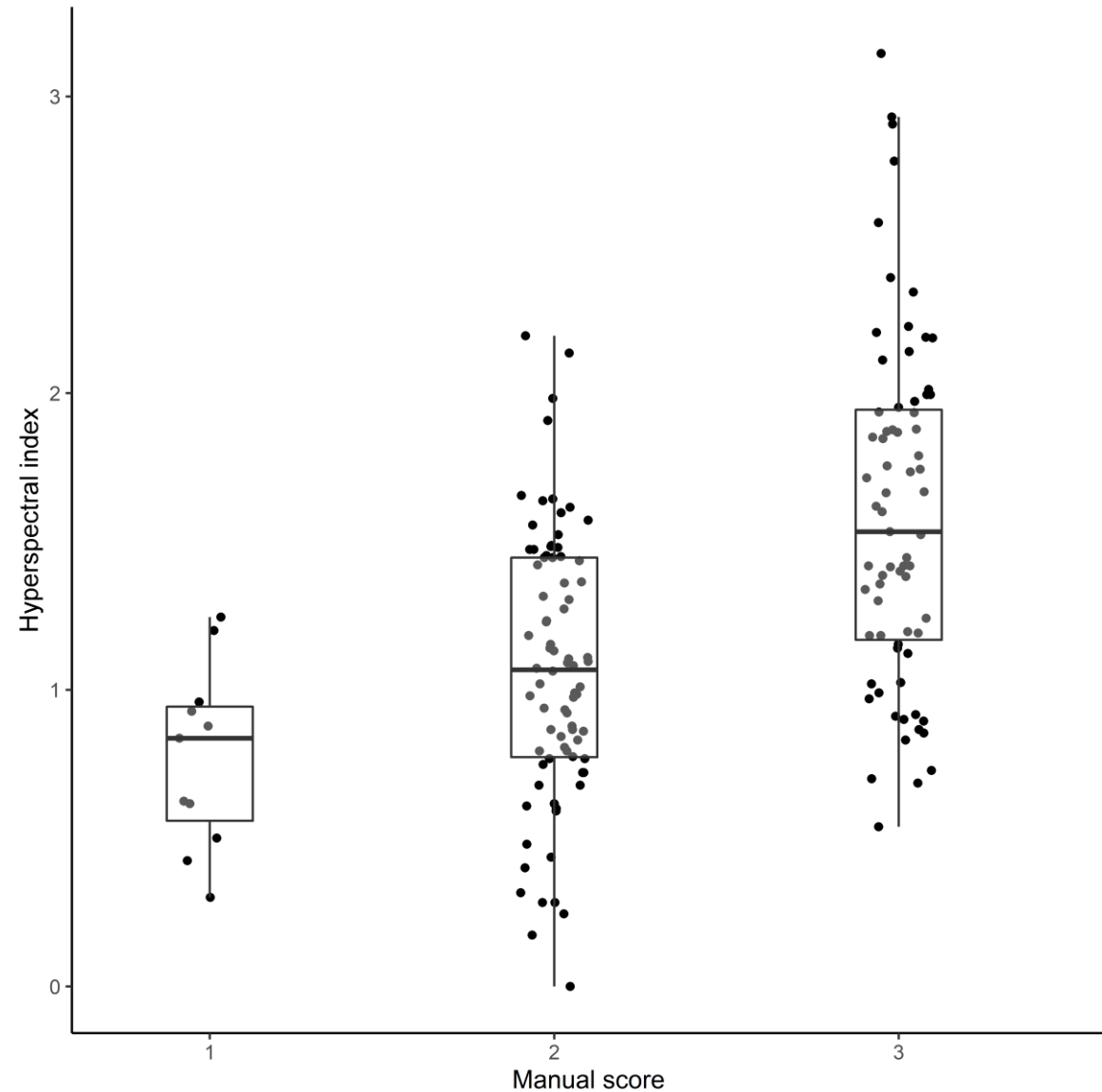
Spearman's correlation: 0.56

Interrater agreement: 0.66

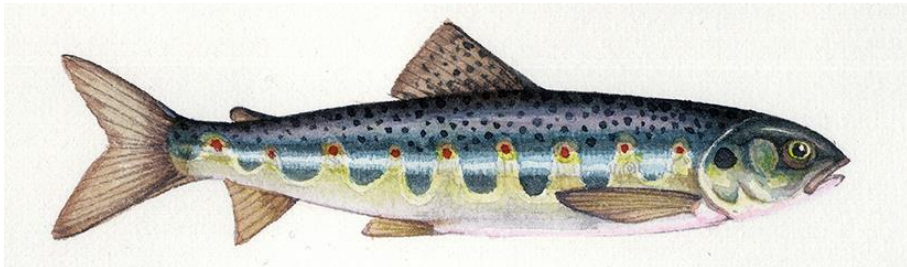
Cohen's kappa: 0.40

### Manual scores and camera output

Polychoric correlation: 0.54

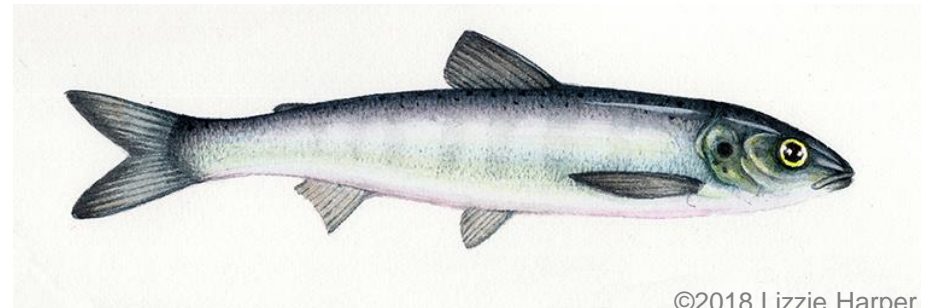


# Trial 2: Smoltification



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Parr



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Smolt



Debes et al., 2020



### Parr vs Smolt

Odei et al., 2020

| Characteristic    | Index (point) <sup>a</sup> |             |             |                  |
|-------------------|----------------------------|-------------|-------------|------------------|
| 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:

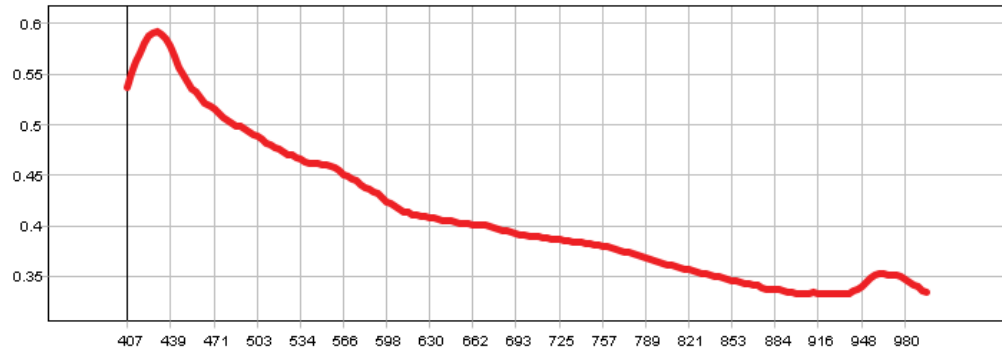
<sup>a</sup>The transition of Atlantic salmon parr to smolt is indicated in the gradual increasing score from 1 to 4.

Khaw et al., 2021

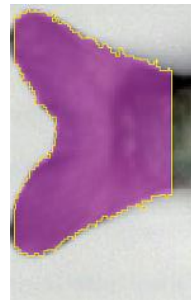
# Experimental setup

- 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

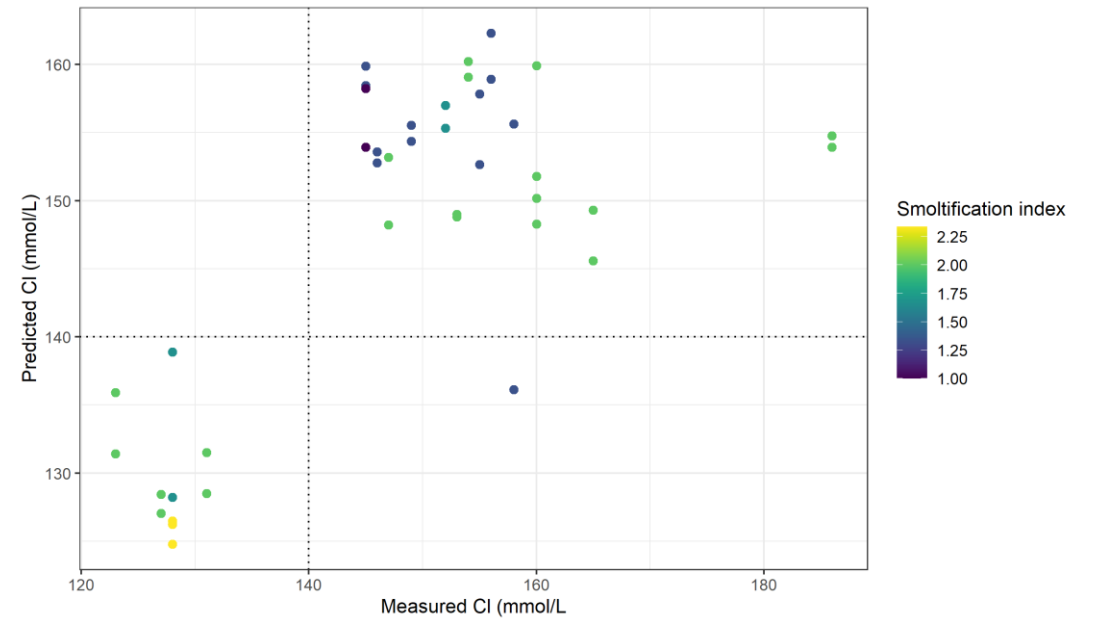
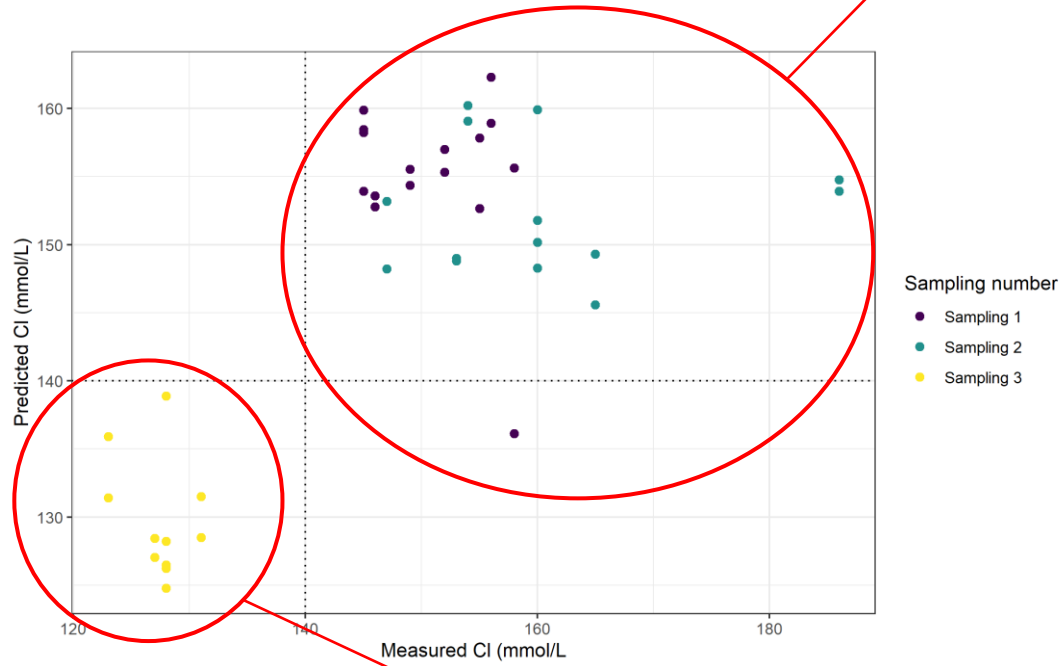
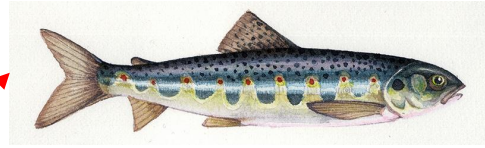


**Type**

- 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

