INTERNATIONAL PACIFIC

HALIBUT COMMISSION

Using artificial intelligence (AI) for supplementing Pacific halibut age determination from collected otoliths

Agenda item 4.2.3:
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(B. Hutniczak, J. Forsberg, K. Sawyer Van Vleck & K. Magrane)

Purpose

- To summarize the information available on the use of artificial intelligence (AI) for determining the age of fish from images of collected otoliths
- To provide an update on the exploratory work of implementing an AI-based age determination model for Pacific halibut

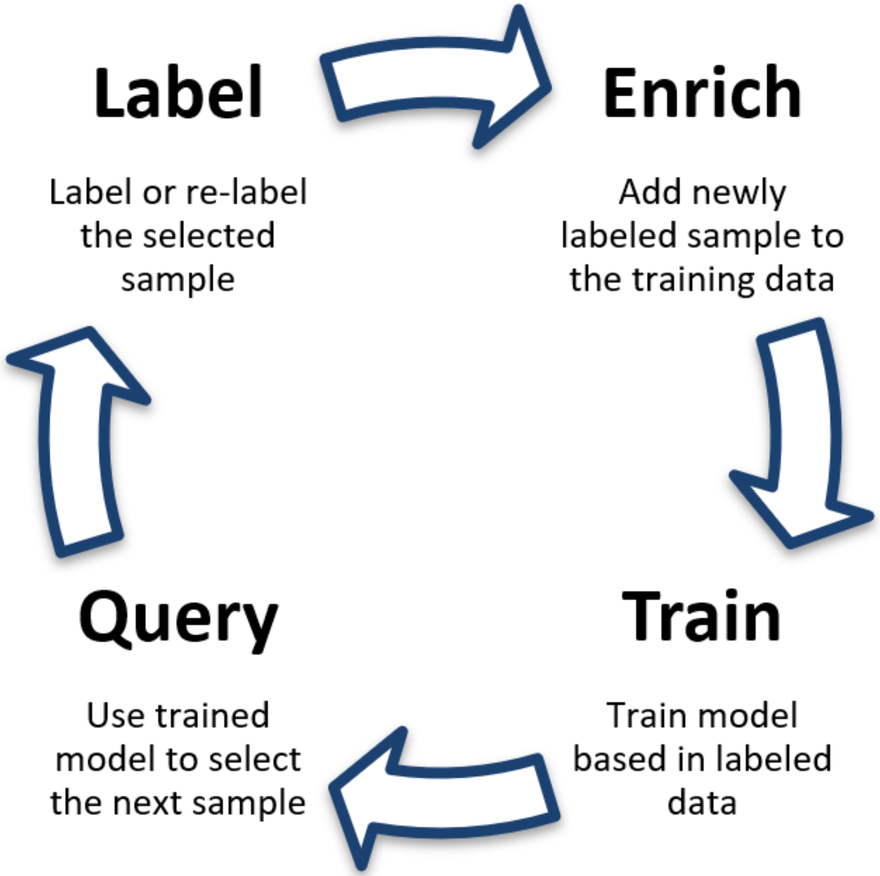
Why AI-based model?

- AI algorithms can be trained on a large dataset of otolith images with known ages to learn the patterns and variations in growth rings. Once trained, the AI model can analyze new otolith images and predict the age of the fish based on the identified patterns in the image.
- Using AI for age determination of Pacific halibut could improve consistency and replicability of age estimates, as well as provide time and cost savings to the organization, providing age data for reliable management advice.

Model framework

- The proposed approach integrates AI-based age determination and traditional ageing methods for maximum accuracy of the estimates.

Climate-readiness:
Training the model with inputs that capture temporal changes
- ➢ increasingly important in the face of changing environmental conditions and climate change



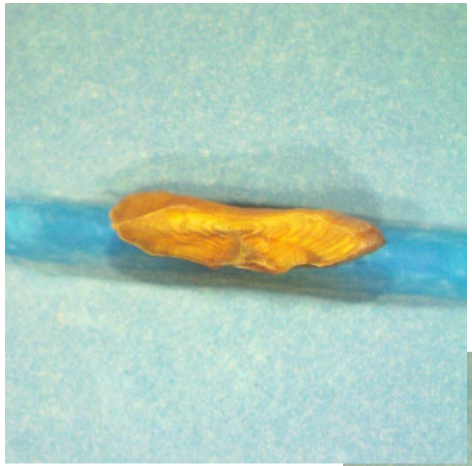
Modeling approach

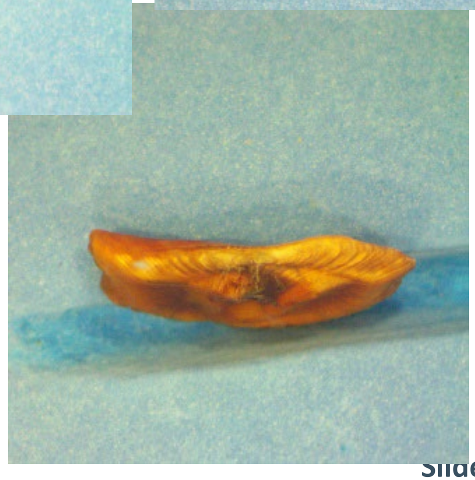
- Application of convolutional neural network (CNN) model, a type of deep learning approach
  - In CNNs, the layers are structured as stacks of filters, each recognizing increasingly abstract features in the data.
- Application of image regression - predicting a continuous variable from an image
  - Pacific halibut is a long-living species - oldest Pacific halibut on record were aged at 55 years
- Implementation - TensorFlow and Keras libraries, repurposing Inception V3 model from Google:
  - Input → InceptionV3 (feature extractor) → Regressor → Output
  - Initial modeling framework modeled on Deep Otolith project (http://otoliths.ath.hcmr.gr/) applied previously to Greenland halibut, red mullet and salmon (scales)

Database

- Since 1925, over 1.5 million otoliths have been aged and stored for potential future use. ← **unique resource for AI training**
- Aged otoliths are sectioned (broken in half) and baked to enhance the contrast between the growth rings.

- Taking pictures can be incorporated into the ageing process at relatively minor time added
- Pictures are taken with AmScope 8.5MP eyepiece cameras



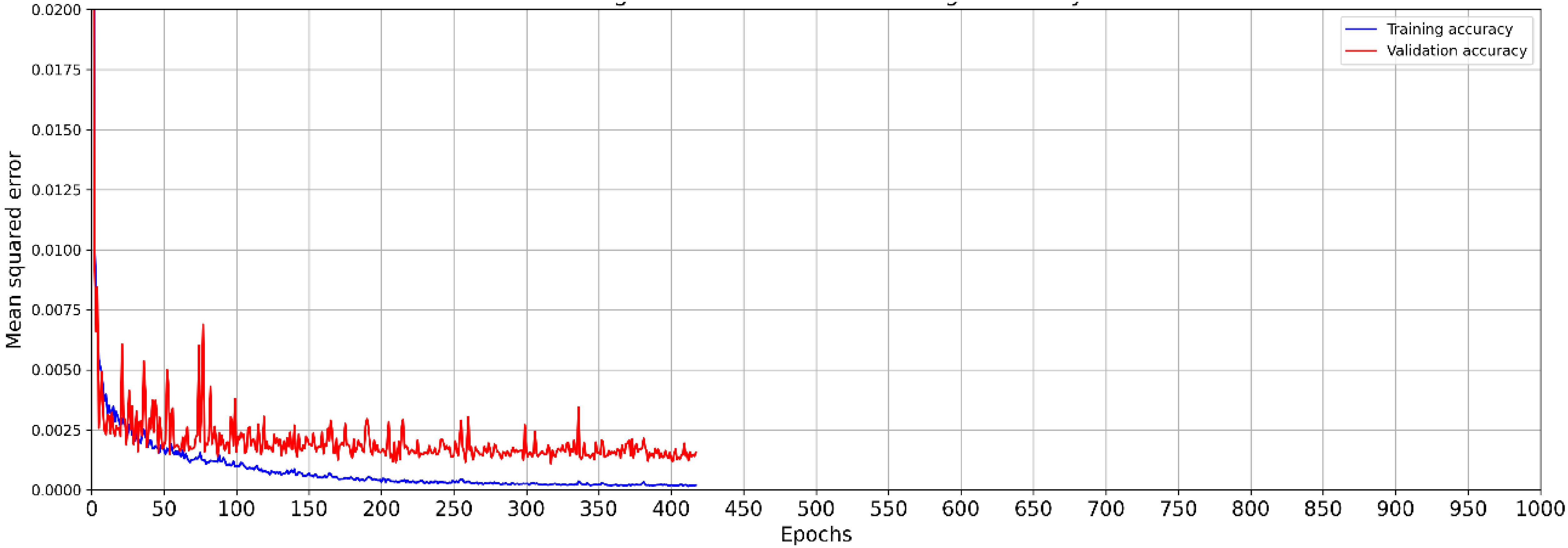


It may not be necessary to image the otoliths at resolutions sufficient for human viewers to resolve, because the CNN may be able to arrive at an age estimate without directly counting bands.

Latest run results (r9)

- 2,682 images (1,595 train, 282 validation, 805 test)
  - Test set is used to assess the performance of the model after training, providing an unbiased evaluation of its generalization capability to new, unseen data.
- Resized to 400x400 pixels, broken otoliths excluded
- Age: 4-41 (normalized)
- Epochs: 1000, patience: 100
- Learning rate: 0.0002, batch size: 16
- Normalized age MSE in training: 0.000198 and 0.0015 in validation, in 417 epochs (317 effective)

Results (1/5)

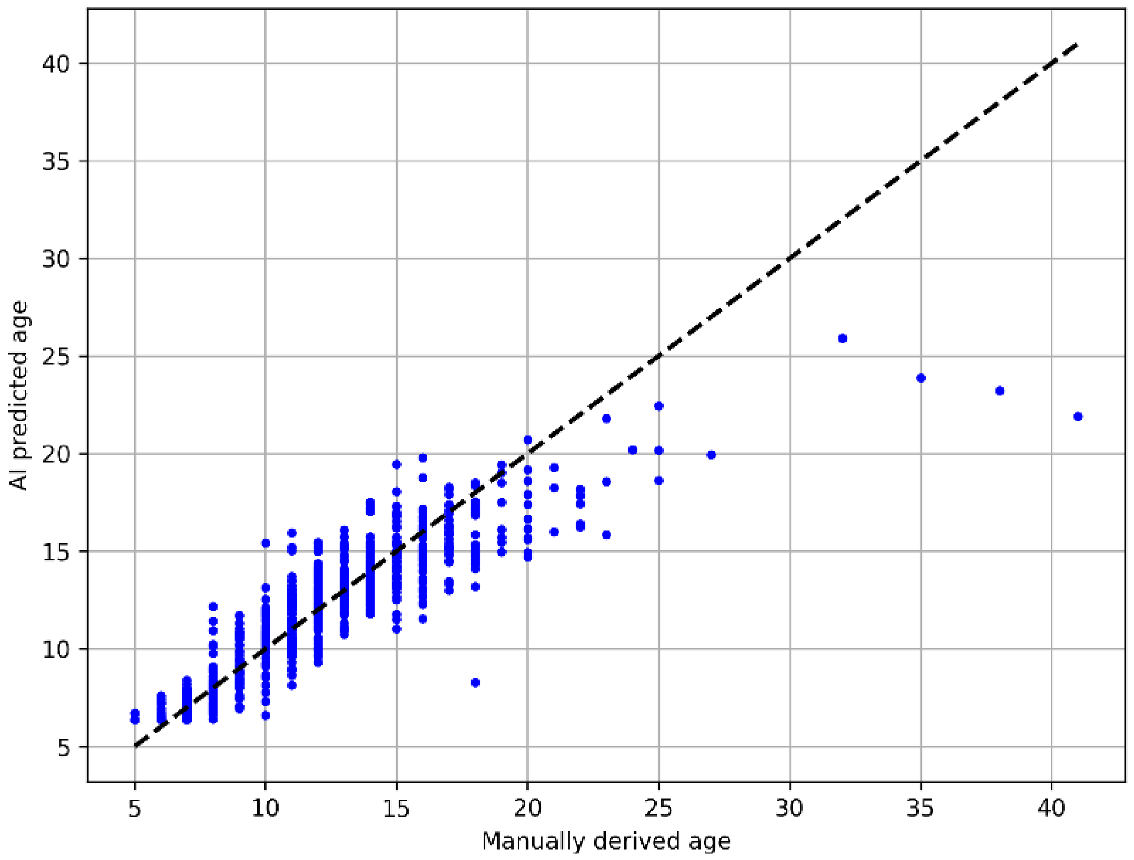


Age accuracy (measured as normalized age MSE) throughout the training process

Results (2/5)

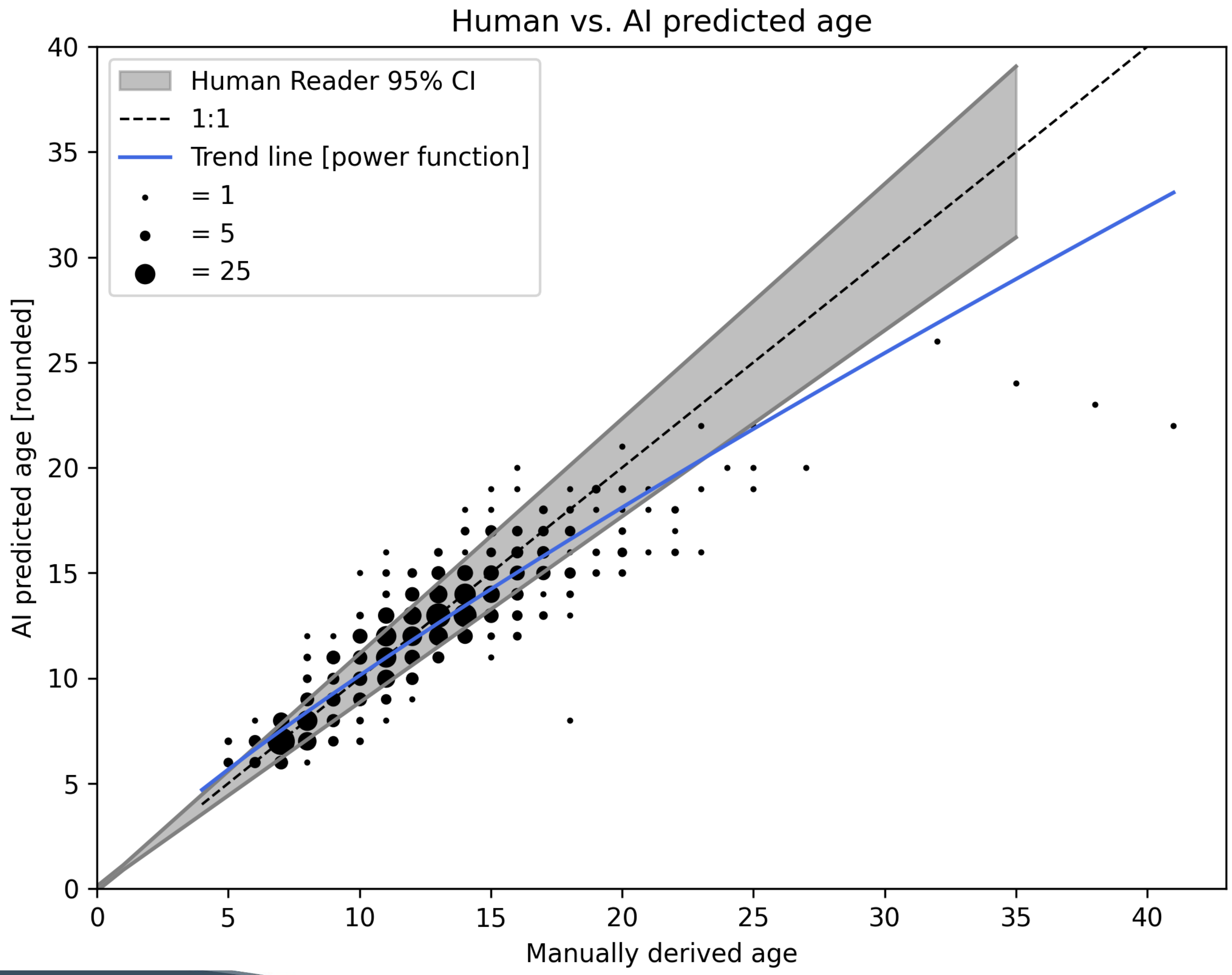
The model achieved RMSE in the test set of 1.90, and 1.94 when calculated for rounded results. Correct age was predicted for 30.3% individuals, with an additional 40.7% being within 1 year of error.

- Previous run (r7): 22% correctly predicted age on 1,311 images (RMSE = 2.11)



Comparison between manually derived age with AI predicted age.

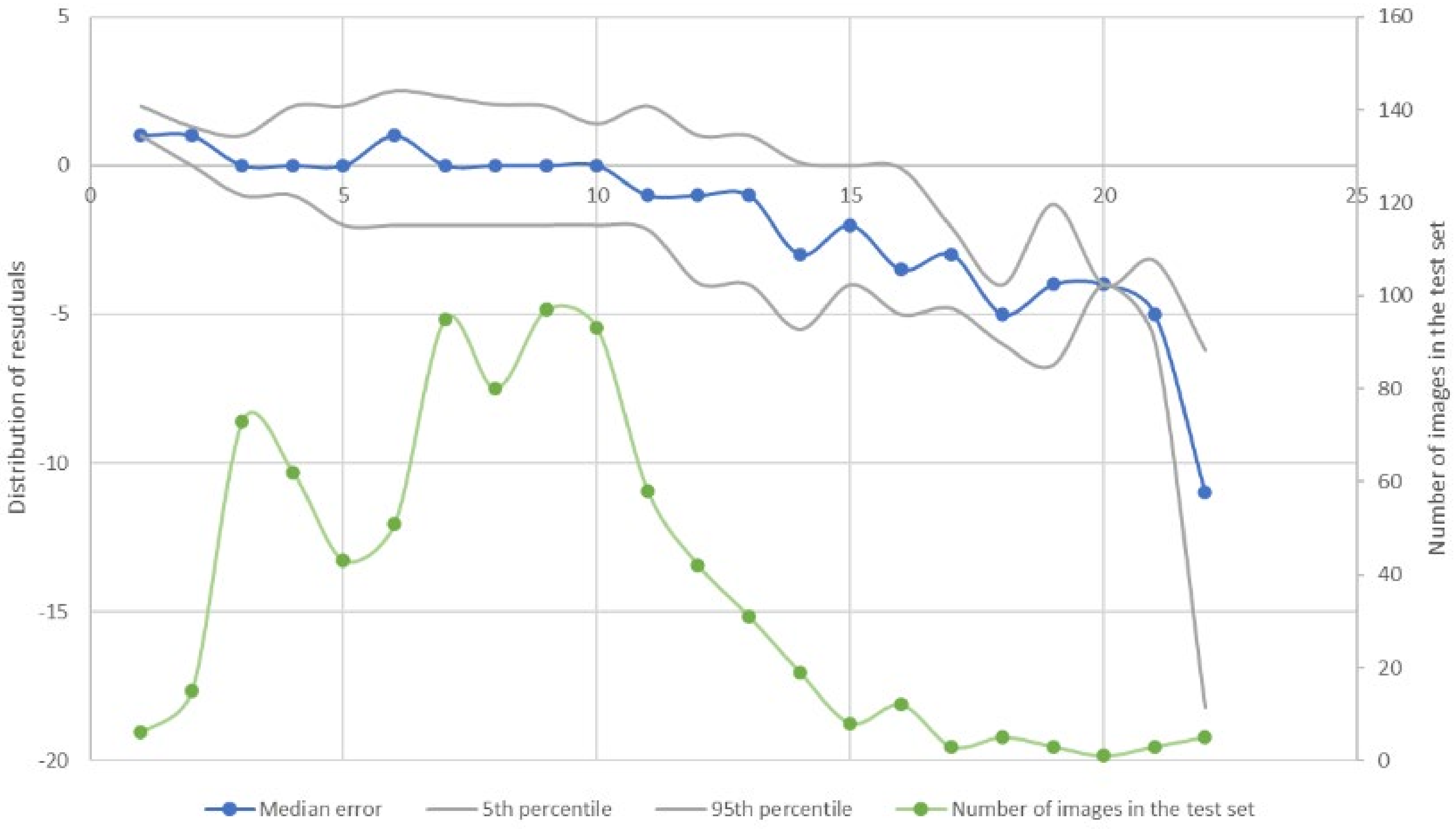
Results (3/5)



Human vs. AI predicted age
Human Reader 95% CI
1:1
Trend line [power function]
= 1
= 5
= 25
AI predicted age [rounded]
Manually derived age
0
5
10
15
20
25
30
35
40

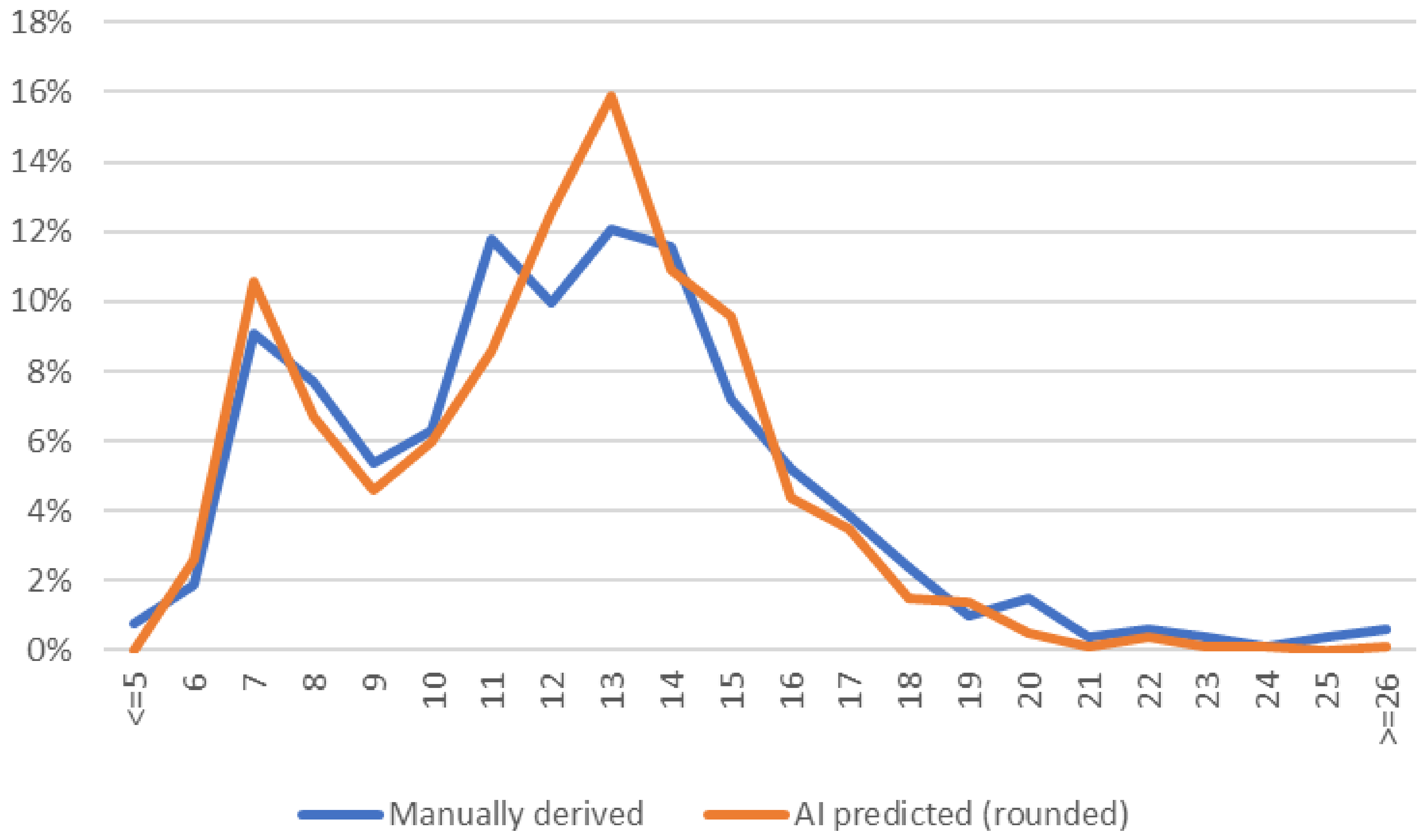
Results (4/5)

Statistically significant bias in the standard configuration was observed in age categories 16+, where the number of observations remains low despite an overall increase in sample size.



Distribution on residuals and number of images by age in the test set.

Results (5/5)

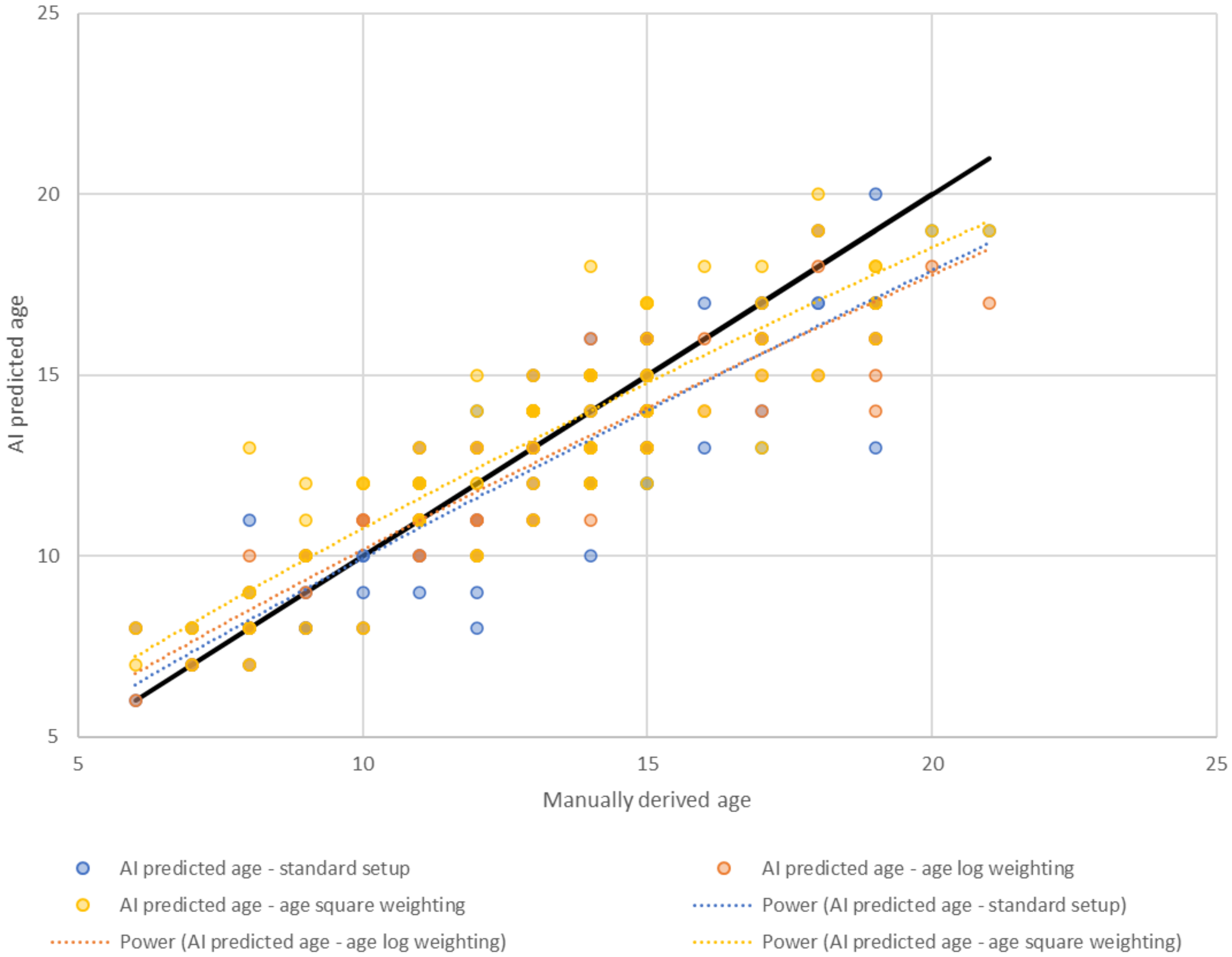


Comparison between manually derived age with AI predicted age – age composition.

Alternative model configurations

- Two separate model configurations were tested using alternative objective functions that prioritized accurate age estimation for older individuals. This was accomplished by modifying the loss function to incorporate a weighting scheme based on:
  - the logarithm of age
  - the square of age (age^2)

	RMSE [rounded]	RMSE [rounded] for ages 20+
Standard setup	1.940	6.25
Age log weighting	1.945	6.24
Age square weighting	1.767	5.53



Comparison of results between standard setup and alternative configurations derived for secondary test set.

Conclusions

- The ongoing advancement of AI technologies in the field of marine science offers considerable **potential to enhance the efficiency of age determination** of Pacific halibut using otolith images.
- Preliminary results presented here suggest that AI could serve as a **promising alternative to the current ageing protocol**, which relies entirely on manual age reading.
    - The model could benefit from further improvement by adding more images representing older age categories to the training set
- **AI is evolving rapidly**, and adapting to new developments may further improve results over time.
- **Adaptive approach** will continue to partially depend on trained readers for **capturing temporal changes**.

Next steps

- **Increase the size of the training input library** (in progress)
- Create a database comprising labelled images of otoliths both pre- and post-processing and conduct a cost-benefit analysis of processing the otoliths for ageing using AI (in progress)
- Use of auxiliary data: The project plans to explore the use of additional spatial covariates for better age prediction.
  - Other available auxiliary data include the year collected, which could be used to account for variation between cohorts and prevalent environmental conditions throughout the aged fish life histories, and the collection date, which provides insights into seasonal variation to the interpretation of the otolith edge.

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