

## Article

# YOLOv8-WBF: Ensemble Learning for Reliable Detection of Endangered Medaka (Oryzias)

Rahmatullah R.<sup>1</sup> , Armin Lawi<sup>1,2,3</sup>, Muhammad Haerul<sup>1</sup>, Iman Mustika Ismail<sup>1</sup>, Irma Andriani<sup>4</sup>, Andi Iqbal Burhanuddin<sup>5</sup>, and Mario Köppen<sup>6</sup>

<sup>1</sup> Information Systems Study Program, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Indonesia

<sup>2</sup> Data Science and Artificial Intelligence Research Group, Hasanuddin University, Indonesia

<sup>3</sup> B.J. Habibie Institute of Technology, Parepare, Indonesia

<sup>4</sup> Department of Biology, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Indonesia

<sup>5</sup> Department of Fishery, Faculty of Fishery and Marine Sciences, Hasanuddin University, Indonesia

<sup>6</sup> Department of Creative Informatics, Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology, Japan

\* Correspondence: armin@unhas.ac.id

**Abstract:** Reliable detection of Medaka (Oryzias) fish is essential for ecological monitoring and conservation, particularly for tracking population trends of endangered species. This study evaluates the performance of a state-of-the-art deep learning model (YOLOv8) and an ensemble approach using Weighted Box Fusion (WBF) on a manually annotated dataset of Medaka images collected from online sources. Models were trained and validated using 5-fold cross-validation, and performance was assessed using COCO metrics, including mean Average Precision (mAP), precision, recall, and bounding box regression error. The YOLOv8-WBF ensemble achieved a mAP@0.5:0.95 of 0.578, representing an 8% improvement over the best single model. It also enhanced bounding box localization and classification reliability, particularly for small and visually challenging fish instances. These accuracy gains came at the expense of computational efficiency, with inference requiring approximately five times more operations than a single YOLOv8 model. While less suited for real-time deployment, the ensemble approach offers more reliable detection for offline ecological workflows, where accuracy is prioritized over speed. By reducing missed detections of rare or occluded fish, this work contributes to more robust biodiversity monitoring and provides a baseline for developing optimized ensemble and lightweight detection models in aquatic conservation.

**Keywords:** Medaka (Oryzias); Deep Learning; Object Detection; YOLOv8; Weighted Box Fusion; Ensemble Learning; Ecological Monitoring; Biodiversity Conservation

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## 1. Introduction

Medaka fish (Oryzias) are small freshwater fish valued as ornamental species and are significant for biodiversity studies. They are species that are under danger of extinction as declared by the International Union for Conservation of Nature (IUCN), which makes protecting them an ecological priority. Identifying Medaka apart is challenging since they have subtle morphological differences and small sizes. Not only that, but the variability of aquatic environments also makes it even more challenging. Traditionally, medaka fish have been sacrificed in taxonomy studies due to their genetic value for lineage studies [1]. Their body colour serves as a social signal and reflects environmental conditions [2], making them potential indicators of ecosystem health. Research conducted using traditional

methods, such as direct capture and then being put in an experimental tank to understand its anatomy and internal structure, can harm the organism and limit its application in long-term ecological and genetic studies. Reliable detection technologies can facilitate non-invasive conservation without the need for traditional conservation methods. This technique protects species and ecosystems while enabling effective ecological monitoring in conservation efforts.

Deep learning has evolved beyond digit identification to sophisticated object detection, facilitating applications in autonomous vehicles, medical diagnostics, agricultural automation, and environmental monitoring [3,4]. In ecological research, object detection has been utilized for monitoring insects in agriculture [5,6] and detecting wildlife in natural habitats [7–9], where precise identification is frequently challenging due to visual similarities among species and the complexity of water environments. These issues are also present in the medaka fish species, such as *Oryzias javanicus* and *Oryzias celebensis*, which have subtle morphological distinctions that complicate the reliable identification of endemic fish.

The YOLO architecture is one of the most widely used deep learning-based one-stage object detectors. Among its versions, YOLOv8 has shown a particularly good balance between speed and accuracy, as demonstrated in comparative benchmarks that evaluated YOLOv8 through YOLOv11 under real-world conditions [10]. Researchers have also proposed many variants to push YOLO's performance further, especially in challenging settings. For example, CEH-YOLO adds a high-order deformable attention (HDA) module to better highlight important spatial features, an Enhanced Spatial Pyramid Pooling-Fast (ESPPF) module for improved texture and color feature extraction, and a Composite Detection module to boost detection of small or overlapping underwater objects, along with using WIoU-v3 loss to improve bounding box regression under hard conditions [11]. [12] introduces the Softplus activation function to improve training stability, an AIFI module to strengthen intra-scale feature interactions (reducing false positives and missed detections), and lightweight neck convolution modules (GSConv, VoV-GSCSP) to reduce computational overhead while maintaining accuracy. SCoralDet focuses on underwater soft coral detection, using a Multi-Path Fusion Block (MPFB) to handle varied scales and lighting colors, lightweight modules for efficiency, and an Adaptive Power Transformation label assignment strategy to better align anchors with ground truth when coral structures are complex or blurred [13]. While these studies mainly alter the internal YOLO architecture to address trade-offs between accuracy and speed, in our work, we propose the use of an ensemble method that builds on YOLOv8 without modifying its core architecture by combining the strengths of multiple detection heads or models to improve reliability under environmental variability.

Despite its strong performance, YOLO models could still make misclassifications by detecting background regions as objects or producing duplicate overlapping predictions of the same object. By default, these redundant outputs are reduced through Non-Maximum Suppression (NMS), yet this technique has well-known limitations, particularly when objects overlap or when multiple plausible predictions exist. Recent studies have come up with a new ensemble method, Weighted Boxes Fusion (WBF), that provides a more accurate and robust alternative, since it merges bounding boxes based on confidence scores and spatial alignment rather than discarding valuable predictions outright [14]. The limitations of standard non-maximum suppression (NMS) underscore the need to investigate advanced fusion strategies in object detection. Ensemble methods are particularly effective because they combine multiple models or detection heads, thereby improving uncertainty management, reducing false detections, and increasing consistency in challenging scenarios. The primary contribution of this work is the development of an ensemble approach for YOLOv8 that incorporates Weighted Box Fusion (WBF) to improve detection reliability

in ecological monitoring applications, where accuracy is essential and misclassification significantly affect conservation outcomes.

In this work, we propose a novel Medaka fish dataset with images captured under diverse lighting colors to provide a realistic and challenging benchmark for ecological monitoring. Building on this resource MEDAKA- $\ddot{\text{e}}\text{L}$ , an ensemble-based detection framework for accurate and reliable identification of Medaka fish. By training 5 different YOLOv8n models trained across a 5-fold cross-validation of the dataset, which causes the model to learn its own unique feature of the Medaka fish. At the ensemble stage, predictions from multiple YOLOv8 models trained through cross-validation are combined using Weighted Boxes Fusion (WBF). It addresses challenges such as background misclassifications and redundant overlapping bounding boxes. Unlike traditional Non-Maximum Suppression (NMS), WBF merges bounding boxes based on confidence scores and spatial alignment, preserving valuable detections and reducing false positives that achieve higher accuracy. The key contributions of this work are as follows:

- Introduced the MEDAKA- $\ddot{\text{e}}\text{L}$  framework that uses 5 models trained across 5-fold cross-validation, and combines their outputs with Weighted Boxes Fusion (WBF) to improve detection accuracy.
- Proposed the Medaka dataset, a new collection of Medaka fish images that includes manually captured photos under different lighting colors, as well as annotated samples gathered from the internet.
- Developed an ensemble detection approach based on YOLOv8n models, where predictions are merged with WBF to keep valuable detections and reduce false positives.

## 2. Related Works

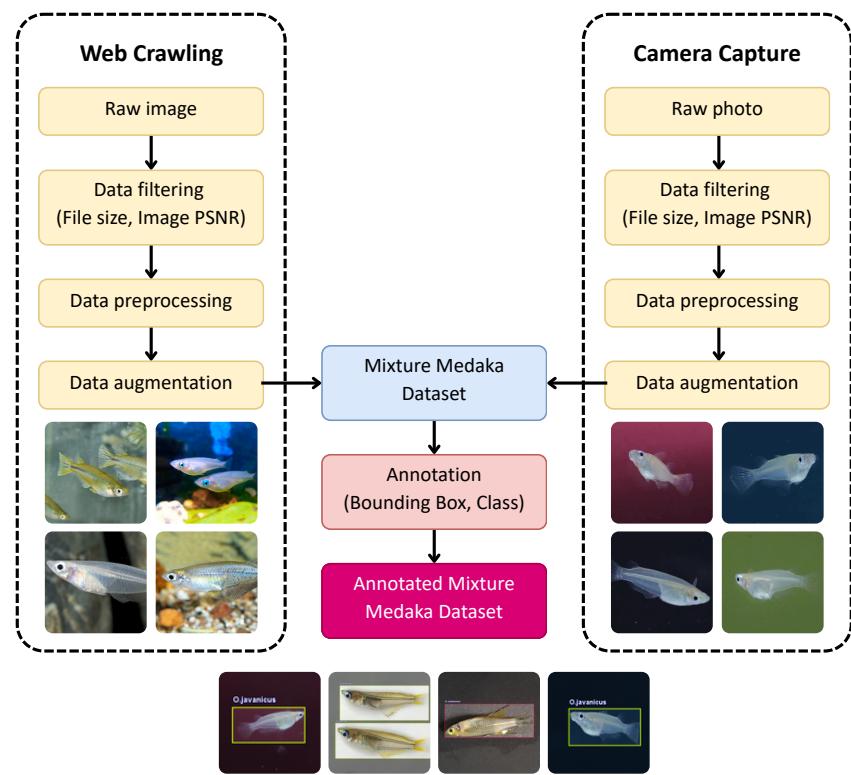
## 3. Materials and Methods

### 3.1. Data Gathering

Jelaskan karena medaka termasuk spesies yang langka, sehingga pengumpulan datanya itu dari laboratorium terkontrol yang sudah dikumpulkan semuanya. Therefore, or

Karena data yang ada di lab sedikit, dilakukan pula pengumpulan data dari internet sebagai secondary data.

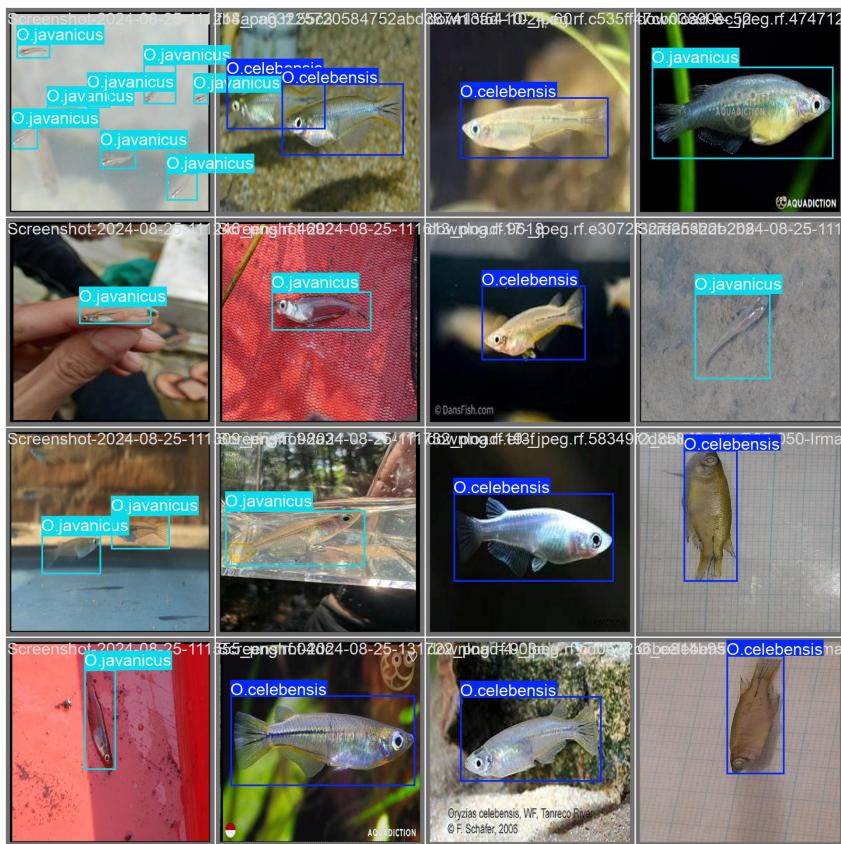
It can be seen from Figure 1 that we use two strategies to build our dataset. Our primary data were taken using ..., while our secondary data were collected from various websites.



**Figure 1.** Examples of annotated Medaka images from the mixed dataset.

A total of 1,247 high-resolution images ranging from 1920x1080 to 4096x3072 pixels of Medaka fish (*Oryzias* species) were obtained, and were annotated using ..., resulting in a total of 723 instances of *Oryzias celebensis* and 524 instances of *Oryzias javanicus*. Figure 2 shows the examples of annotated Medaka images from our dataset, both from the primary and the secondary data.

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**Figure 2.** Examples of annotated Medaka images from the mixed dataset.

### 3.2. Data Filtering, Pre-processing, and Annotation

As illustrated in Figure 1, after both of raw images and raw photos were collected, we then filtered the images based on the file size and the image PSNR.

## 4. Results

### 5. Discussion

**Author Contributions:** For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.”, please turn to the [CRediT taxonomy](#) for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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Written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Please state "Written informed consent has been obtained from the patient(s) to publish this paper" if applicable. 150  
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**Data Availability Statement:** We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at <https://www.mdpi.com/ethics>. 153  
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## Abbreviations

The following abbreviations are used in this manuscript: 174  
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MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

## Appendix A

### Appendix A.1

The appendix is an optional section that can contain details and data supplemental to the main text—for example, explanations of experimental details that would disrupt the flow of the main text but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data are shown in the main text can be added here if brief, or as Supplementary Data. Mathematical proofs of results not central to the paper can be added as an appendix. 178  
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**Table A1.** This is a table caption.

Title 1	Title 2	Title 3
Entry 1	Data	Data
Entry 2	Data	Data

## Appendix B

All appendix sections must be cited in the main text. In the appendices, Figures, Tables, etc. should be labeled, starting with "A"—e.g., Figure A1, Figure A2, etc.

## References

1. Mahmudi, A.; et al. Title of the study (please update with actual title). *Journal Name* **2022**, XX, XXX–XXX. <https://doi.org/DOLifavailable>. 189
2. Ueda, R.; Ansai, S.; Takeuchi, H. Rapid body colouration changes in Oryzias celebensis as a social signal influenced by environmental background. *Scientific Reports* **2020**. Electronic supplementary material is available online, <https://doi.org/10.6084/m9.figshare.c.7358213>. 190
3. LeCun, Y.; Bengio, Y.; Hinton, G. Deep learning. *Nature* **2015**, *521*, 436–444. <https://doi.org/10.1038/nature14539>. 191
4. Zhao, Z.; Zheng, P.; Xu, S.; Wu, X. Object detection with deep learning: A review. *IEEE Transactions on Neural Networks and Learning Systems* **2019**, *30*, 3212–3232. 192
5. Tang, L.; et al. Deep learning-based insect detection for precision agriculture: A comprehensive review. *Computers and Electronics in Agriculture* **2023**. 193
6. Ciampi, S.; et al. Automatic insect detection in sticky trap images using deep learning models. *Ecological Informatics* **2023**, *73*, 101–123. 194
7. Roy, A.; et al. WilDect-YOLO: A one-stage detector for endangered wildlife monitoring. *Ecological Informatics* **2023**. 195
8. Wenhan, Z.; et al. Enhanced YOLOv5 for wildlife detection in complex environments. *Ecological Informatics* **2024**. 196
9. Sun, J.; Zhang, H. YOLOv7 improvements for robust wildlife monitoring. *Ecological Informatics* **2024**. 197
10. Sapkota, A.; Zhang, X.; Gong, Y.; Zhang, Q. Comprehensive Performance Evaluation of YOLO11, YOLOv10, YOLOv9 and YOLOv8 on Detecting and Counting Fruitlet in Complex Orchard Environments. *arXiv preprint arXiv:2407.12040* **2024**. 198
11. Chen, M.; Hou, Y.; Li, H.; Gao, J.; Liu, W.; Gong, W. CEH-YOLO: An efficient YOLO-based detection model for underwater ecological images. *Ecological Informatics* **2024**, *79*, 102513. <https://doi.org/10.1016/j.ecoinf.2024.102513>. 199
12. Yu, X.; Liu, Z.; Xu, H.; Chen, Z.; Wu, H. YOLO-SAG: An improved YOLOv8 model for underwater target detection. *Ecological Informatics* **2024**, *80*, 102570. <https://doi.org/10.1016/j.ecoinf.2024.102570>. 200
13. Wang, R.; Zhang, X.; Chen, Y.; Li, P.; Zhang, C. SCoralDet: Efficient real-time underwater soft coral detection with YOLO. *Ecological Informatics* **2024**, *80*, 102562. <https://doi.org/10.1016/j.ecoinf.2024.102562>. 201
14. Solovyev, R.; Wang, W.; Gabruseva, T. Weighted Boxes Fusion: Ensembling Boxes from Different Object Detection Models. *Image and Vision Computing* **2021**, *117*, 104–127. <https://doi.org/10.1016/j.imavis.2021.104127>. 202

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