

Automated estimation of gadoid and flatfish abundance in stereo-BRUV footage using YOLO object detection – Supplementary Material

Authors

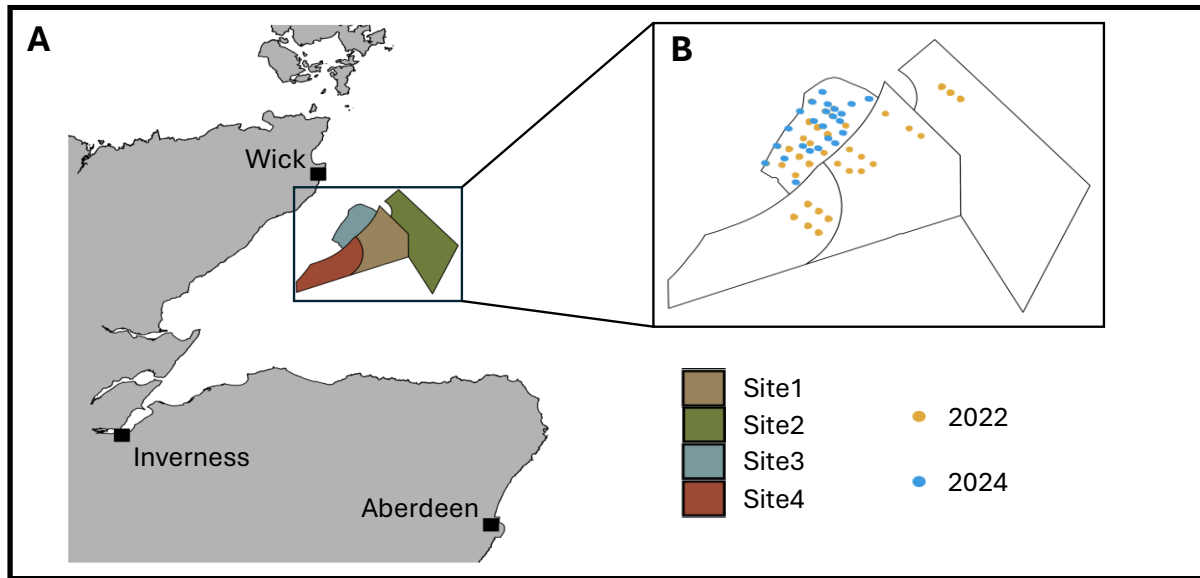
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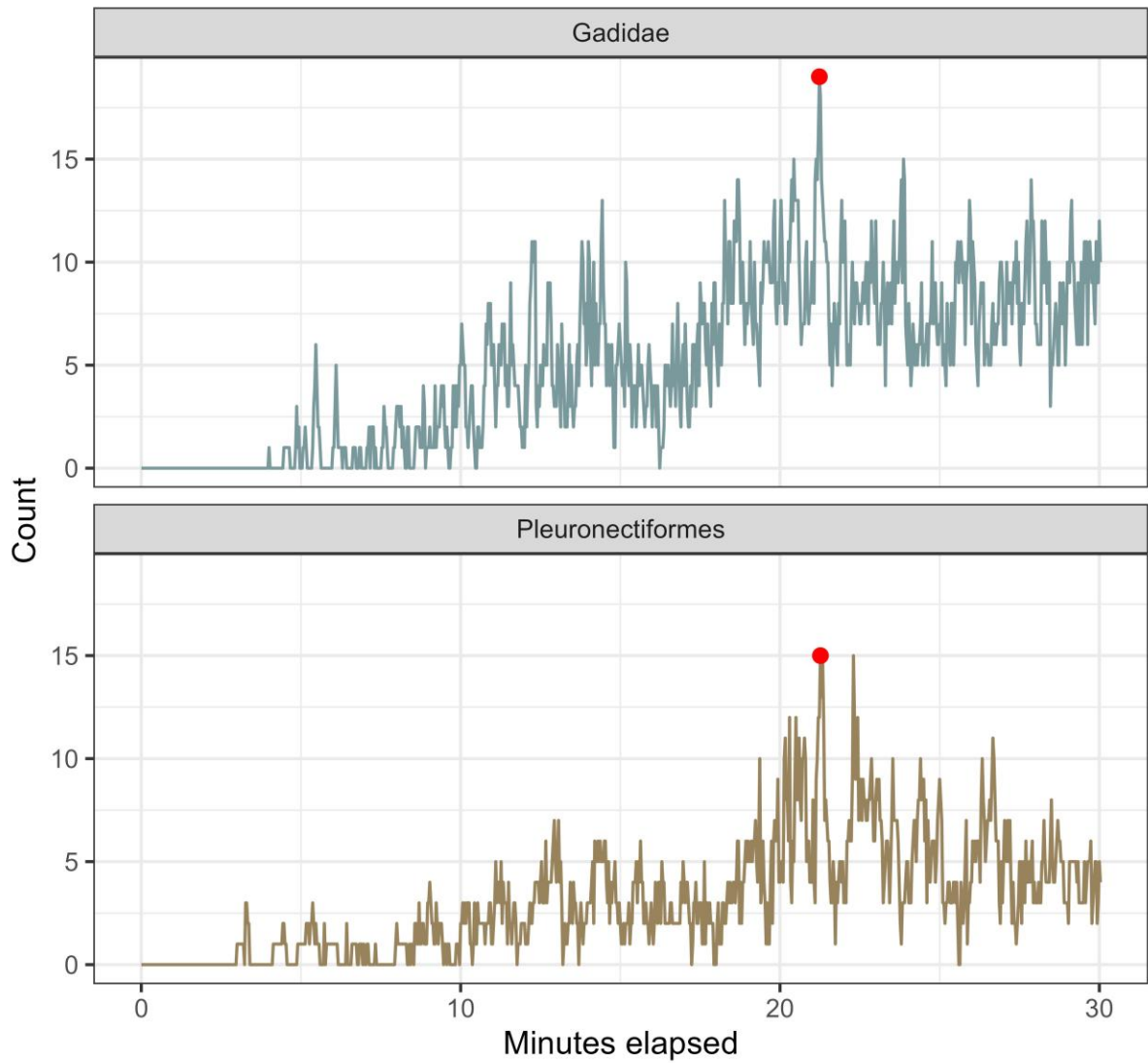
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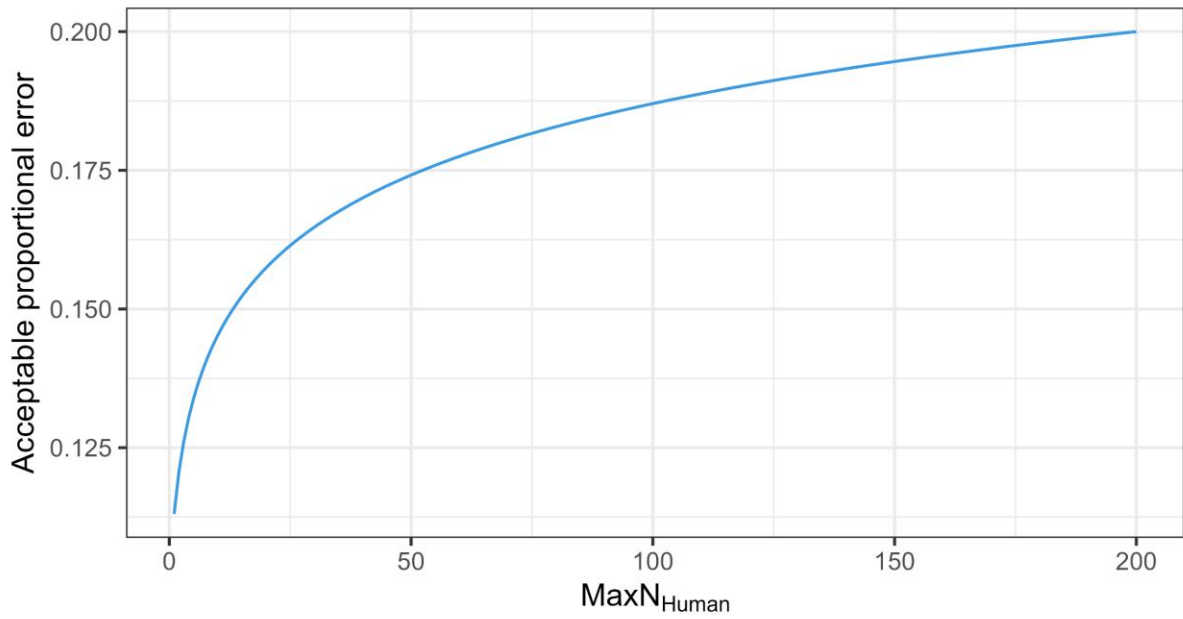
Supplementary Figures



Supplementary Figure 1: Map of the BRUV survey locations. (A) Location of the four wind farms where data were collected (Moray Firth, northeast Scotland). **(B)** Deployment locations for 2022 (gold) and 2024 (blue) within the four wind farms. For the 2022 survey each point represents three deployments in a triangle, separated by either 80 m or 150 m, while for 2024 each point represents four deployments at increasing distances from a wind turbine (30 m, 60 m, 120 m, 240 m).

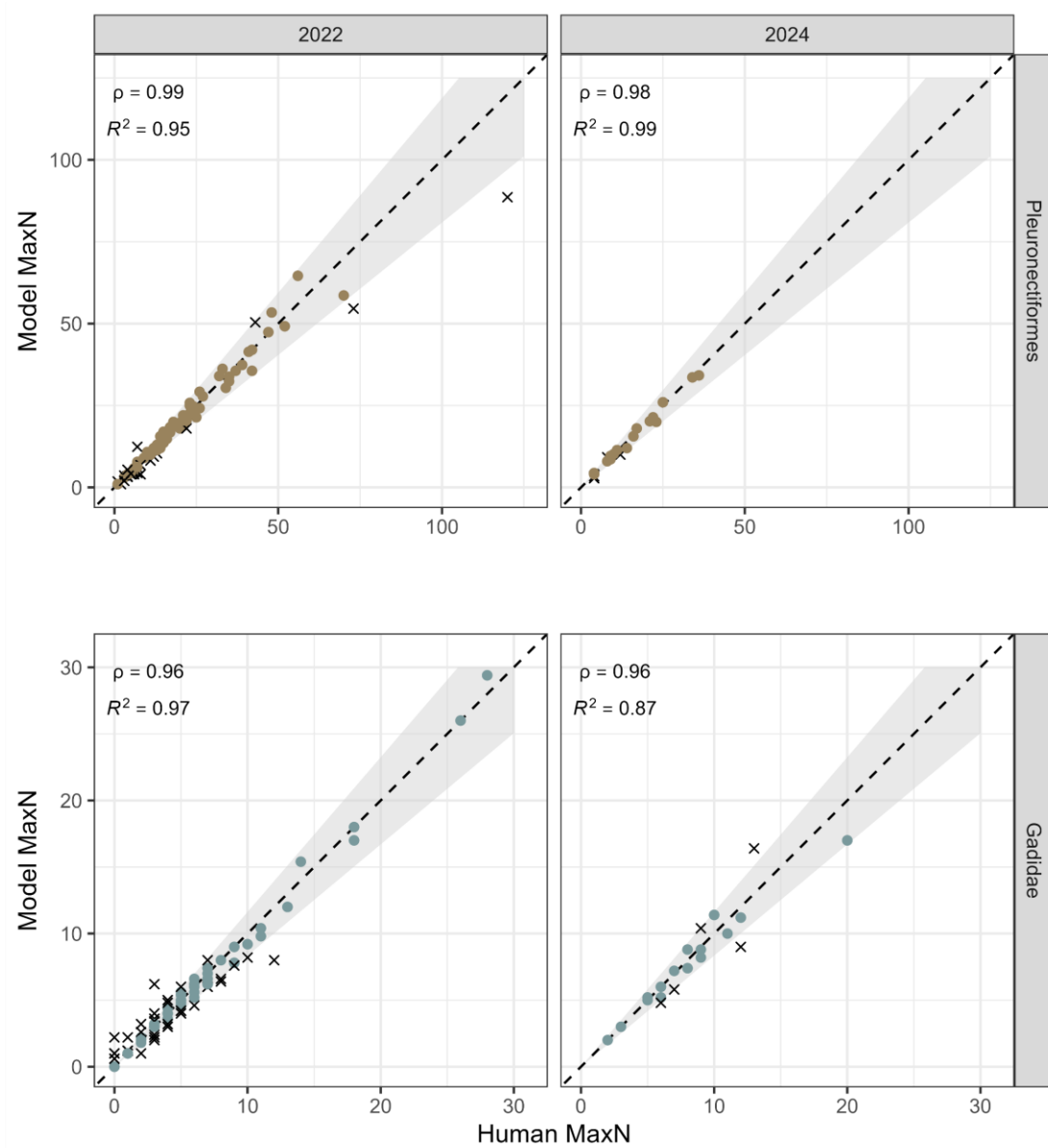


Supplementary Figure 2: *Gadidae* and *Pleuronectiformes* abundance time-series example. Time series showing the number of *Pleuronectiformes* and *Gadidae* detected by an example YOLO model in a BRUV deployment from the 2024 survey. Counts are taken from the right-hand-side camera and the MaxN value is highlighted in red.



Supplementary Figure 3: *Depiction of acceptable proportional error in MPS definition.*

Curve showing the acceptable proportional error from $\text{MaxN}_{\text{Human}}$ within which $\text{MaxN}_{\text{YOLO}}$ must fall to be considered successful.



Supplementary Figure 4: Human and Model MaxN agreement. $MaxN_{Human}$ and $MaxN_{YOLO}$ for *Gadidae* and *Pleuronectiformes* in both survey years. Coloured points denote successful $MaxN_{YOLO}$ predictions, while unsuccessful predictions are shown with a cross. Spearman's rank correlation coefficient (ρ) and the coefficient of determination (R^2) are annotated on each panel; all correlations were significant at $p < 0.001$.

Supplementary Tables

Supplementary Table 1: *Coarse search space training parameters and model performance.* Training parameters and performance metrics for models trained during the initial coarse search space optimization stage of model development.

Training parameters										Pleuronectiformes performance				Gadidae performance				Overall performance				
Model Name	YOLO Model	Classes	# Training Images	Image Size	Batch Size	Optimiser	Initial Learning Rate	Final learning Rate	Momentum	Precision	Recall	mAP	F1	Precision	Recall	mAP	F1	Precision	Recall	mAP	F1	Mean Peak Success Rate
B640_default	8s	0, 1, 2	2157	640	16	auto	0.01	0.01	0.937	0.809	0.706	0.788	0.754	0.898	0.842	0.891	0.869	0.809	0.706	0.788	0.754	0.642
NB640_default	8s	0, 2	2157	640	16	auto	0.01	0.01	0.937	0.827	0.758	0.806	0.791	0.883	0.868	0.911	0.876	0.827	0.758	0.806	0.791	0.647
B1280_default	8s	0, 1, 2	2157	1280	16	auto	0.01	0.01	0.937	0.792	0.807	0.811	0.799	0.872	0.874	0.900	0.873	0.792	0.807	0.811	0.799	0.652
NB1280_default	8s	0, 2	2157	1280	16	auto	0.01	0.01	0.937	0.797	0.784	0.809	0.791	0.871	0.869	0.893	0.870	0.797	0.784	0.809	0.791	0.652
B1280_nano	8n	0, 1, 2	2157	1280	16	auto	0.01	0.01	0.937	0.816	0.755	0.826	0.784	0.874	0.854	0.892	0.864	0.816	0.755	0.826	0.784	0.623
B1280_med	8m	0, 1, 2	2157	640	8	auto	0.01	0.01	0.937	0.807	0.756	0.785	0.781	0.899	0.868	0.899	0.883	0.807	0.756	0.785	0.781	0.647
B1280_large	8l	0, 1, 2	2157	640	8	auto	0.01	0.01	0.937	0.814	0.756	0.806	0.784	0.911	0.866	0.910	0.888	0.814	0.756	0.806	0.784	0.647
B1280_xl	8x	0, 1, 2	2157	640	8	auto	0.01	0.01	0.937	0.803	0.768	0.824	0.785	0.878	0.863	0.894	0.870	0.803	0.768	0.824	0.785	0.618
B1280_Adam	8s	0, 1, 2	2157	1280	16	Adam	0.01	0.01	0.937	0.789	0.794	0.797	0.792	0.839	0.846	0.829	0.843	0.789	0.794	0.797	0.792	0.627
B1280_AdamW	8s	0, 1, 2	2157	1280	16	AdamW	0.01	0.01	0.937	0.827	0.777	0.831	0.801	0.845	0.852	0.885	0.848	0.827	0.777	0.831	0.801	0.627
B1280_SGD	8s	0, 1, 2	2157	1280	16	SGD	0.01	0.01	0.937	0.810	0.769	0.812	0.789	0.877	0.862	0.898	0.870	0.810	0.769	0.812	0.789	0.637
B1280_NAdam	8s	0, 1, 2	2157	1280	16	NAdam	0.01	0.01	0.937	0.785	0.776	0.798	0.781	0.852	0.851	0.841	0.851	0.785	0.776	0.798	0.781	0.598
B1280_RAdam	8s	0, 1, 2	2157	1280	16	RAdam	0.01	0.01	0.937	0.846	0.768	0.830	0.805	0.874	0.829	0.861	0.851	0.846	0.768	0.830	0.805	0.637
B1280_RMSProp	8s	0, 1, 2	2157	1280	16	RMSProp	0.01	0.01	0.937	0.000	0.000	0.000	NA	0.001	0.028	0.000	0.001	0.000	0.000	0.000	NA	0.039
B1280_lr_mom_1	8s	0, 1, 2	2157	1280	16	auto	0.001	0.001	0.9	0.824	0.778	0.823	0.800	0.873	0.849	0.894	0.861	0.824	0.778	0.823	0.800	0.642
B1280_lr_mom_2	8s	0, 1, 2	2157	1280	16	auto	0.001	0.001	0.95	0.776	0.796	0.822	0.786	0.891	0.852	0.901	0.871	0.776	0.796	0.822	0.786	0.642
B1280_lr_mom_3	8s	0, 1, 2	2157	1280	16	auto	0.001	0.001	0.99	0.806	0.741	0.822	0.772	0.845	0.838	0.875	0.841	0.806	0.741	0.822	0.772	0.618
B1280_lr_mom_4	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-05	0.9	0.821	0.788	0.813	0.804	0.877	0.852	0.904	0.864	0.821	0.788	0.813	0.804	0.637
B1280_lr_mom_5	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-05	0.95	0.823	0.771	0.818	0.796	0.904	0.873	0.913	0.888	0.823	0.771	0.818	0.796	0.618
B1280_lr_mom_6	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-05	0.99	0.806	0.773	0.822	0.789	0.826	0.849	0.889	0.837	0.806	0.773	0.822	0.789	0.613
B1280_lr_mom_7	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-06	0.9	0.808	0.787	0.810	0.797	0.877	0.857	0.898	0.867	0.808	0.787	0.810	0.797	0.676
B1280_lr_mom_8	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-06	0.95	0.843	0.789	0.834	0.815	0.885	0.841	0.906	0.863	0.843	0.789	0.834	0.815	0.632
B1280_lr_mom_9	8s	0, 1, 2	2157	1280	16	auto	0.001	1.00E-06	0.99	0.844	0.738	0.818	0.787	0.907	0.832	0.901	0.868	0.844	0.738	0.818	0.787	0.662
B1280_lr_mom_10	8s	0, 1, 2	2157	1280	16	auto	0.01	0.001	0.9	0.824	0.778	0.823	0.800	0.873	0.849	0.894	0.861	0.824	0.778	0.823	0.800	0.642
B1280_lr_mom_11	8s	0, 1, 2	2157	1280	16	auto	0.01	0.001	0.95	0.776	0.796	0.822	0.786	0.891	0.852	0.901	0.871	0.776	0.796	0.822	0.786	0.642
B1280_lr_mom_12	8s	0, 1, 2	2157	1280	16	auto	0.01	0.001	0.99	0.806	0.741	0.822	0.772	0.845	0.838	0.875	0.841	0.806	0.741	0.822	0.772	0.618
B1280_lr_mom_13	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-05	0.9	0.821	0.788	0.813	0.804	0.877	0.852	0.904	0.864	0.821	0.788	0.813	0.804	0.637
B1280_lr_mom_14	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-05	0.95	0.823	0.771	0.818	0.796	0.904	0.873	0.913	0.888	0.823	0.771	0.818	0.796	0.618
B1280_lr_mom_15	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-05	0.99	0.806	0.773	0.822	0.789	0.826	0.849	0.889	0.837	0.806	0.773	0.822	0.789	0.613
B1280_lr_mom_16	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-06	0.9	0.808	0.787	0.810	0.797	0.877	0.857	0.898	0.867	0.808	0.787	0.810	0.797	0.676
B1280_lr_mom_17	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-06	0.95	0.843	0.789	0.834	0.815	0.885	0.841	0.906	0.863	0.843	0.789	0.834	0.815	0.632
B1280_lr_mom_18	8s	0, 1, 2	2157	1280	16	auto	0.01	1.00E-06	0.99	0.844	0.738	0.818	0.787	0.907	0.832	0.901	0.868	0.844	0.738	0.818	0.787	0.662
B1280_lr_mom_19	8s	0, 1, 2	2157	1280	16	auto	0.1	0.001	0.9	0.824	0.778	0.823	0.800	0.873	0.849	0.894	0.861	0.824	0.778	0.823	0.800	0.642
B1280_lr_mom_20	8s	0, 1, 2	2157	1280	16	auto	0.1	0.001	0.95	0.776	0.796	0.822	0.786	0.891	0.852	0.901	0.871	0.776	0.796	0.822	0.786	0.642
B1280_lr_mom_21	8s	0, 1, 2	2157	1280	16	auto	0.1	0.001	0.99	0.806	0.741	0.822	0.772	0.845	0.838	0.875	0.841	0.806	0.741	0.822	0.772	0.618
B1280_lr_mom_22	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-05	0.9	0.821	0.788	0.813	0.804	0.877	0.852	0.904	0.864	0.821	0.788	0.813	0.804	0.637
B1280_lr_mom_23	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-05	0.95	0.823	0.771	0.818	0.796	0.904	0.873	0.913	0.888	0.823	0.771	0.818	0.796	0.618
B1280_lr_mom_24	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-05	0.99	0.806	0.773	0.822	0.789	0.826	0.849	0.889	0.837	0.806	0.773	0.822	0.789	0.613
B1280_lr_mom_25	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-06	0.9	0.808	0.787	0.810	0.797	0.877	0.857	0.898	0.867	0.808	0.787	0.810	0.797	0.676
B1280_lr_mom_26	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-06	0.95	0.843	0.789	0.834	0.815	0.885	0.841	0.906	0.863	0.843	0.789	0.834	0.815	0.632
B1280_lr_mom_27	8s	0, 1, 2	2157	1280	16	auto	0.1	1.00E-06	0.99	0.844	0.738	0.818	0.787	0.907	0.832	0.901	0.868	0.844	0.738	0.818	0.787	0.662

Supplementary Table 2: *MPS upper threshold sensitivity testing results.* Sensitivity of *MPS* and the selected optimal confidence threshold to the upper proportional-error tolerance bound, for the 2022 and 2024 datasets. The bound was varied from 0.10 to 0.30; the 0.20 value is that used throughout the main analysis. *MPS* increases with a more permissive bound, as expected, whereas the selected confidence threshold is largely invariant.

Ceiling	2022			2024		
	<i>MPS</i>	Optimum threshold		<i>MPS</i>	Optimum threshold	
		<i>Gadidae</i>	<i>Pleuronectiformes</i>		<i>Gadidae</i>	<i>Pleuronectiformes</i>
0.10	0.549	0.5	0.4	0.650	0.4	0.2
0.15	0.613	0.5	0.5	0.675	0.6	0.2
0.20	0.667	0.5	0.5	0.775	0.4	0.2
0.25	0.716	0.6	0.5	0.850	0.4	0.2
0.30	0.770	0.5	0.4	0.900	0.6	0.2

Supplementary Files

Supplementary File 1: *Hyperparameter fine-tuning results.* YAML configuration file containing the outputs of the YOLO model fine-tuning process. The hyperparameters contained within the file are those that were used to train the 'best fitness' model during the tuning process and were used to train the models that formed the final model ensemble.

```
# 100/100 iterations complete (1025022.02s)
# Results saved to models\tuning\tune
# Best fitness=0.6375 observed at iteration 49
# Best fitness metrics are {'metrics/precision(B)': 0.84457,
#   'metrics/recall(B)': 0.81446, 'metrics/mAP
# Best fitness model is models\tuning\tune49
# Best fitness hyperparameters are printed below.

lr0: 0.00673
lrf: 0.00826
momentum: 0.98
weight_decay: 0.00034
warmup_epochs: 3.48201
warmup_momentum: 0.67469
box: 0.2
cls: 0.4279
hsv_h: 0.01575
hsv_s: 0.64895
degrees: 0.0
translate: 0.08417
scale: 0.5937
shear: 0.0
mosaic: 0.59714
mixup: 0.0
```

Supplementary File 2: Coarse search space optimisation results. YAML configuration file containing the full set of training parameters that was used to train the best model in the initial coarse search space. These parameters were used as the starting point for hyperparameter fine-tuning.

```
task: detect
mode: train
model: yolov8s.pt
data: YOLO/active_config.yaml
epochs: 1000
time: null
patience: 30
batch: 16
imgsz: 1280
save: true
save_period: 100
cache: false
device: '0'
workers: 0
project: models
name: B1280_lr_mom_7
exist_ok: false
pretrained: true
optimizer: auto
verbose: true
seed: 241593033
deterministic: true
single_cls: false
rect: false
cos_lr: false
close_mosaic: 10
resume: false
amp: true
fraction: 1.0
profile: false

freeze: null
multi_scale: false
overlap_mask: true
mask_ratio: 4
dropout: 0.0
val: true
split: val
save_json: false
conf: null
iou: 0.7
max_det: 300
half: false
dnn: false
plots: true
source: null
vid_stride: 1
stream_buffer: false
visualize: false
augment: false
agnostic_nms: false
classes:
  - 0
  - 1
  - 2
retina_masks: false
embed: null
show: false
save_frames: false
save_txt: false
save_conf: false
```

```
save_crop: false
show_labels: true
show_conf: true
show_boxes: true
line_width: null
format: torchscript
keras: false
optimize: false
int8: false
dynamic: false
simplify: true
opset: null
workspace: null
nms: false
lr0: 0.001
lrf: 1.0e-0.6
momentum: 0.9
weight_decay: 0.0005
warmup_epochs: 3.0
warmup_momentum: 0.8
warmup_bias_lr: 0.1
box: 7.5
cls: 0.5
dfl: 1.5
pose: 12.0
kobj: 1.0
nbs: 64
hsv_h: 0.015
hsv_s: 0.7
hsv_v: 0.4
degrees: 0.0
translate: 0.1
scale: 0.5
shear: 0.0
perspective: 0.0
flipud: 0.0
```

```
fliplr: 0.5
bgr: 0.0
mosaic: 1.0
mixup: 0.0
cutmix: 0.0
copy_paste: 0.0
copy_paste_mode: flip
auto_augment: randaugment
erasing: 0.4
cfg: null
tracker: botsort.yaml
save_dir: models\B1280_lr_mom_7
```