A - Timetable

February			
Week 5	Week 6	Week 7	Week 8
Project description	Background, writing: UAVs, sensors, computer vision, Legislation	Background, writing: UAVs, sensors, computer vision, Legislation	Background, writing: UAVs, sensors, computer vision, Legislation
	Exploring Open Cv, create templates	Exploring Open Cv, create templates	Exploring Open Cv, create templates
	Research habitat types for survey	Research habitat types for survey	Flightplan
		Materials and methods, writing	Materials and methods, writing

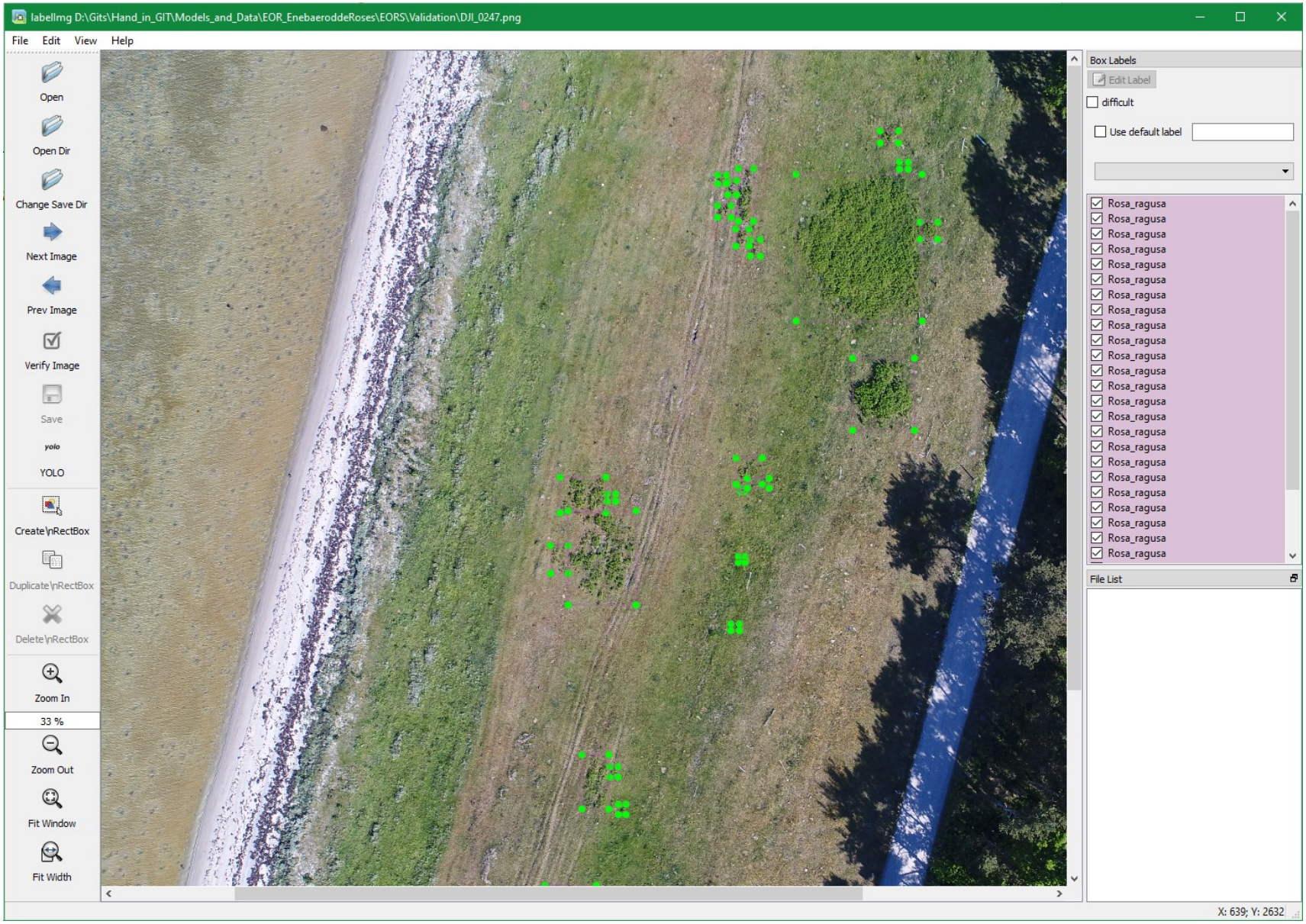
March				
Week 9	Week 10	Week 11	Week 12	Week 13
Flight and data preparation*	Flight and data preparation*	Flight and data preparation*	Flight and data preparation*	Flight and data preparation*
Data processing; computervision	Data processing; computervision	Data processing; computervision	Data processing; computervision	Data processing; computervision
Background writing: Habitats	Background writing: Habitats	Background writing: Computer vision	Background and introg; wrapping up	Background and intro; wrapping up
Materials and methods, writing	Materials and methods, writing	Materials and methods, writing	Materials and methods, writing	Materials and methods, writing
				Hand-in Background

April			
Week 14	Week 15	Week 16	Week 17
Data processing	Data processing	Processing presentable results	Processing presentable results
Results	Results	Results	Results
Materials and methods; wrapping up	Materials and methods; wrapping up	Materials and methods; wrapping up	Materials and methods; wrapping up
	Flightplan*	Flight and data preparation*	Flight and data preparation*
		Hand-in Materials and methods	

May			
Week 18	Week 19	Week 20	Week 21
Results; wrapping up			
Discussion	Discussion	Discussion, wrapping up	
		Conclusion	
		Completion of thesis	Completion of thesis
Hand-in Results		Hand-in report (Discussion)	

*Timetable for the study spanning from February to May. The timetable is the one approved upon submitting the project description. Orange cells constitute practical and computational tasks, light green research and writing tasks, green pure writing tasks, and blue hand-in of works to revision by supervisor. An asterisk * denotes activities that can be prone to change. A flight in April was scheduled to collect supplementary data and video material.*

B - LabelImg.py Interface



LabelImg is an interface based on python, providing a workflow for labeling images with bounding boxes. By panning and zooming, bounding boxes can be drawn around objects and labeled accordingly. Annotations are saved in either YOLO or Pascal format.

C - Data sets table extended with labeled subjects

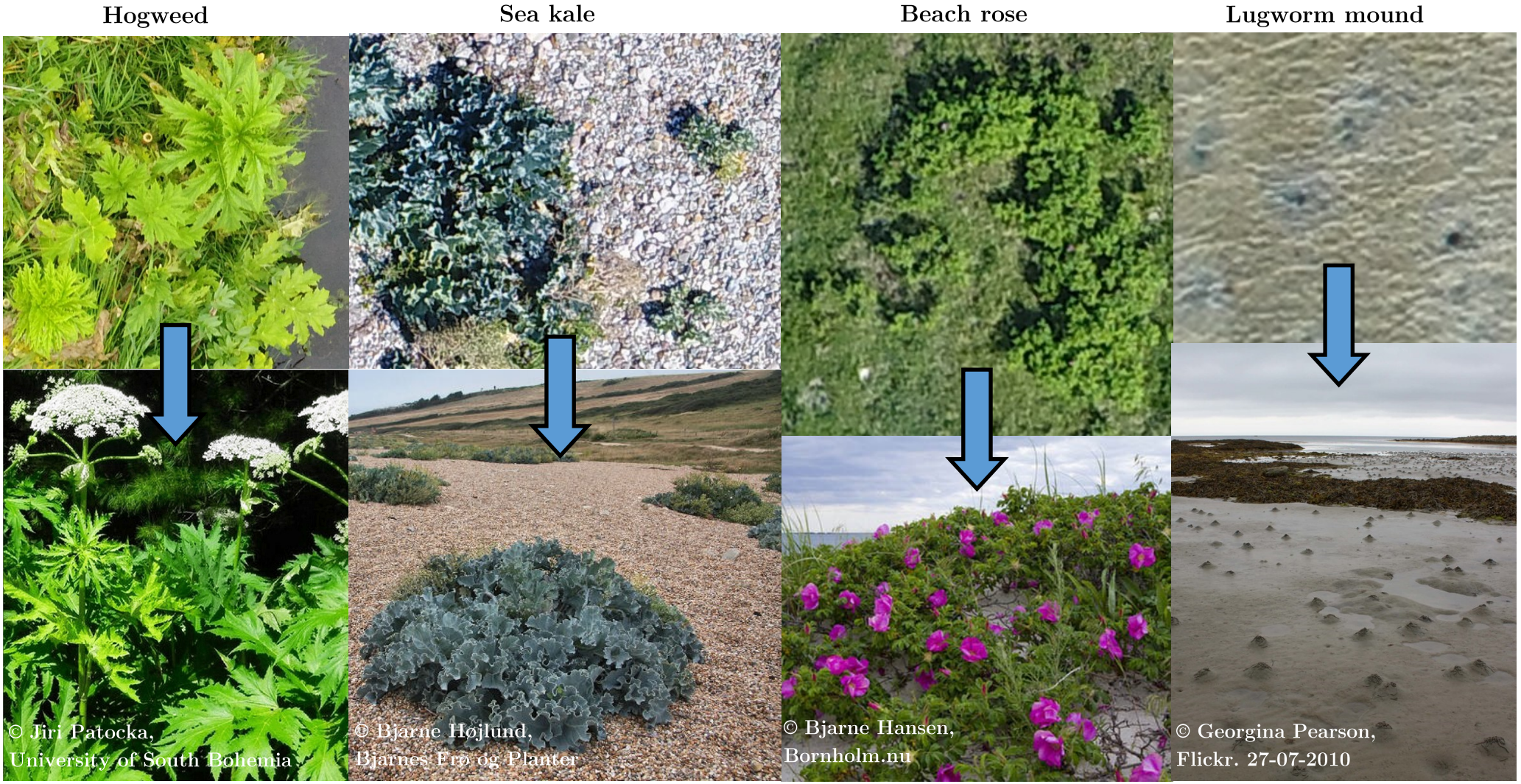
Table of data sets used for YOLOv4 models split into two tables. The upper table, equivalent to Table 1, has sets provided with IDs. For each set, the location of the data gathering, a brief description otherwise detailed in the main text, and the subject in focus within the set are listed. The resolution of images in the train, test, and validation split is listed along with the number of objects labeled within each set split, respectively (#Train, #Test, #Val). The number of images in each split (#Images) is listed as "Train - Test - Validation". For the set EORS, two validation splits are present, a single image equivalent to the one used for EOR and EORE, and seven images being smaller cutouts of the aforementioned validation image. Due to this, Resolution is marked by an asterisk as validation imagery differs from train and test. Four out of the seven images can be computed, housing an increasing number of objects under #Val.

The lower table: Sets are provided with IDs. For the training test and validation split, the number of objects of each given class is denoted. "-" marks classes where no such subject is present in each data splits. In the validation split for EORS," NA" indicates no lugworm mounds were present at computable image resolutions.

ID	Location	Description	Subject	Resolution	#Images	#Train	#Test	#Val
DPS	Daltofterenden	Parameter search	Hogweed sp	5472x3648	5-1-1	470	69	127
BNK1	Bøjden Nor	Three subclasses	Sea kale	3840x2160	8-3-1	862	235	193
BNK2	Bøjden Nor	One main class	Sea kale	3840x2160	8-3-1	862	235	193
BNK3	Bøjden Nor	flower + shadow	Sea kale	3840x2160	8-3-1	862	235	193
BNK4	Bøjden Nor	flower + free	Sea kale	3840x2160	8-3-1	862	235	193
BNK5	Bøjden Nor	shadow + free	Sea kale	3840x2160	8-3-1	862	235	193
BNK6	Bøjden Nor	No shadow	Sea kale	3840x2160	8-3-1	579	194	105
BNR1	Bøjden Nor	Refined main class	Sea kale	3840x2160	8-3-1	396	115	78
BNR2	Bøjden Nor	Refined subclasses	Sea kale	3840x2160	8-3-1	792	215	158
EOR	Enebærodde	Cluster labeling	Beach rose	4864x3648	10-3-1	254	129	29
EORE	Enebærodde	Segmenting labels	Beach rose	4864x3648	10-3-1	494	162	106
EORS	Enebærodde	Input size matching	Beach rose	608x608	241-15-1/7	945	61	29/3,11,19,20

	Training split							**Test split**							**Validation split**						
ID	Hogweed	Free standing kale	Sea kale flower	Shadowed kale	Combination of kale subclasses	Worm mounds	Beach roses	Hogweed	Free standing kale	Sea kale flower	Shadowed kale	Combination of kale subclasses	Worm mounds	Beach roses	Hogweed	Free standing kale	Sea kale flower	Shadowed kale	Combination of kale subclasses	Worm mounds	Beach roses
DPS	470	-	-	-	-	-	-	69	-	-	-	-	-	-	127	-	-	-	-	-	-
BNK1	-	197	447	218	-	-	-	-	87	118	30	-	-	-	-	19	86	88	-	-	-
BNK2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BNK3	-	197	-	-	665	-	-	-	87	-	-	148	-	-	-	19	-	-	174	-	-
BNK4	-	-	-	218	644	-	-	-	-	-	30	205	-	-	-	-	-	88	105	-	-
BNK5	-	-	447	-	415	-	-	-	-	118	-	117	-	-	-	-	86	-	107	-	-
BNK6	-	195	384	-	-	-	-	-	87	107	-	-	-	-	-	19	86	-	-	-	-
BNR1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78	-	-
BNR2	-	346	446	-	-	-	-	-	89	126	-	-	-	-	-	71	87	-	-	-	-
EOR	-	-	-	-	-	-	254	-	-	-	-	-	-	129	-	-	-	-	-	-	29
EORE	-	-	-	-	-	-	494	-	-	-	-	-	-	162	-	-	-	-	-	-	106
EORS	-	-	-	-	-	495	450	-	-	-	-	-	41	20	-	-	-	-	-	NA	29/3,11,19,20

D - Subject classes at nadir- and frontal view



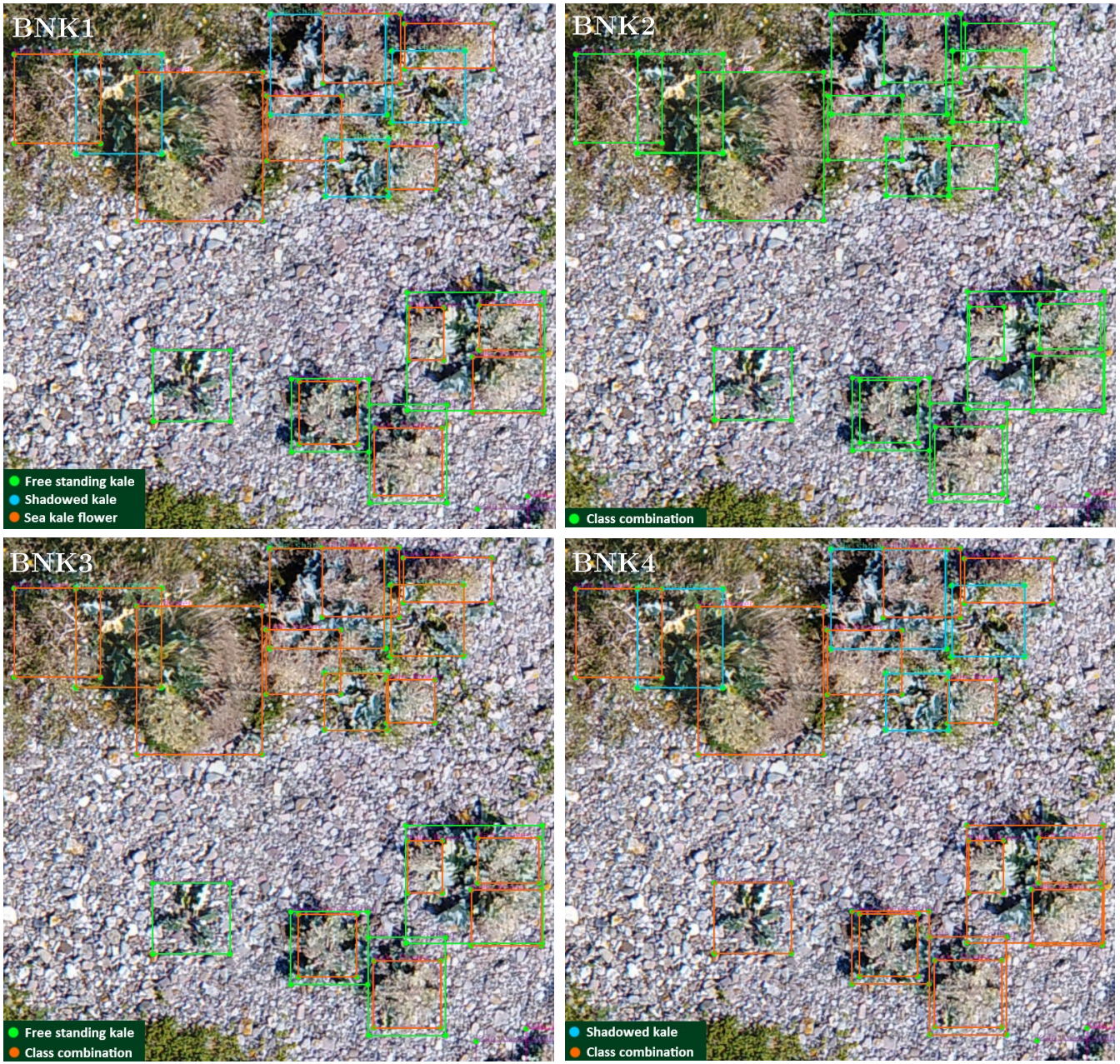
Hogweed, sea kale, beach rose, and lugworm mounds are illustrated at nadir and frontal view. Arrows point to each class's corresponding frontal view to the nadir view. All imagery at nadir view derives from the data sets utilized in the study with hogweed, beach rose and lugworm mounds photographed by ©Niels Svane and sea kale by the study's author © Jakob Jaensch Rasmussen. Imagery in frontal view has copyrights listed within the image frame.

E - Labeling hogweed

Labeling of giant hogweed in the Daltofterenden data set using the LabelImg interface. Bounding boxes are highlighted in a photo editor to make bounding boxes easily identifiable.

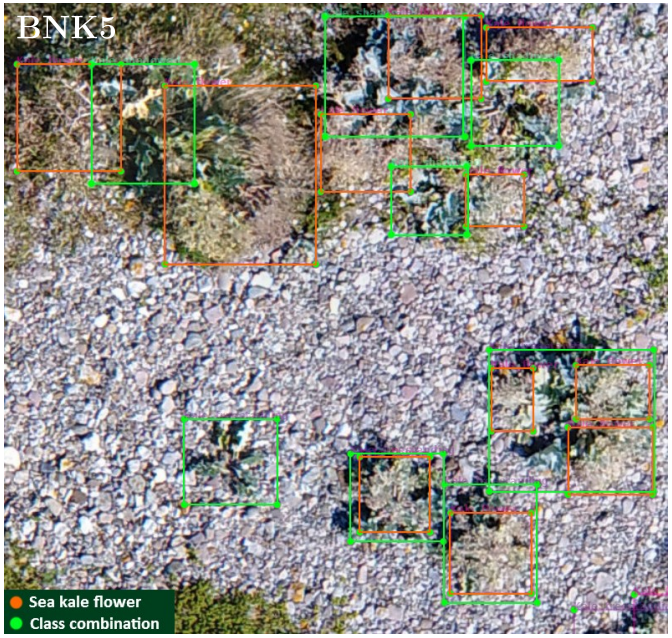
F1 - Labeling sea kale

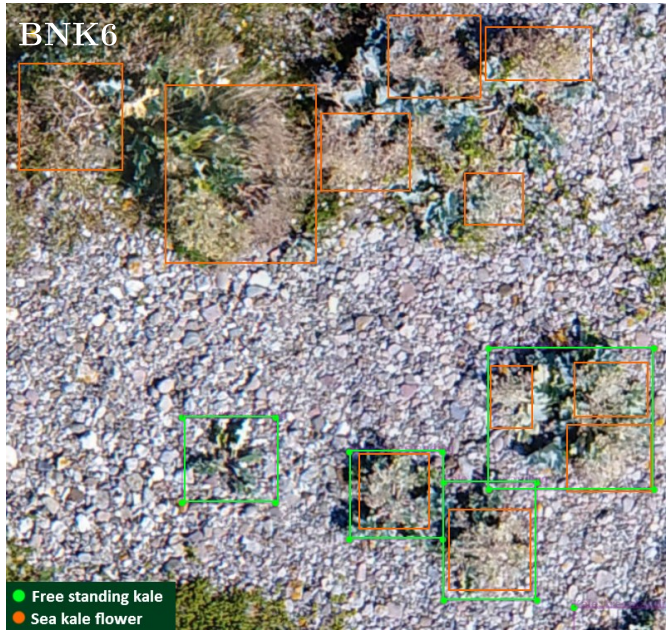
Labeling of sea kale in the Bøjden Nor data set using the LabelImg interface. Bounding boxes are highlighted in a photo editor to make bounding boxes easily identifiable. A legend in the lower left corner denotes colorations correlation to classes. Eight labeled sets are presented, all displaying the same image cutout with identical subjects. Figures span across appendix F1-2.

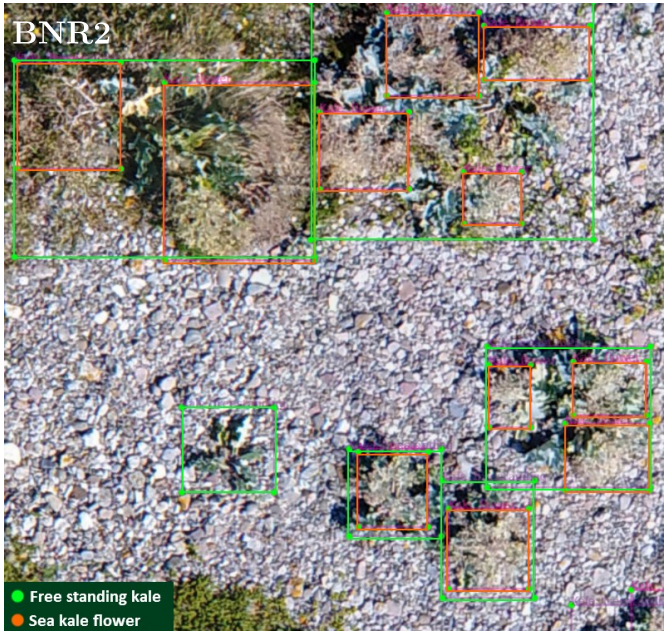


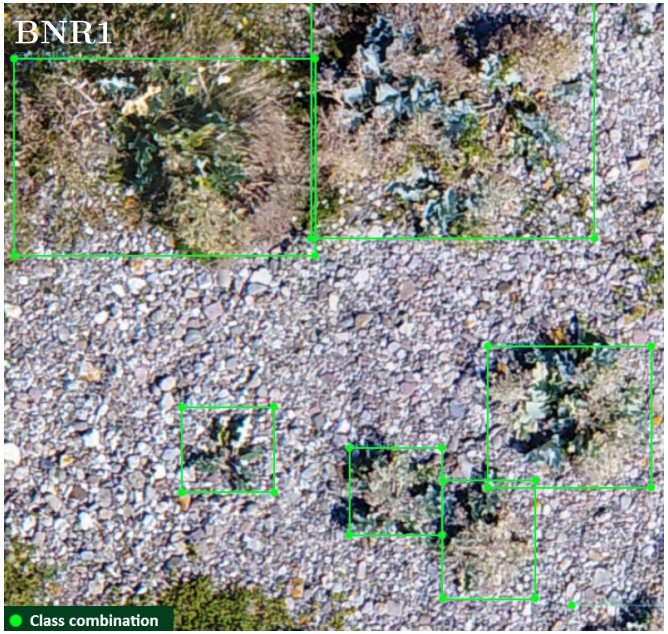
F2 - Labeling sea kale

Labeling of sea kale in the Bøjden Nor data set using the LabelImg interface. Bounding boxes are highlighted in a photo editor to make bounding boxes easily identifiable. A legend in the lower left corner denotes colorations correlation to classes. Eight labeled sets are presented, all displaying the same image cutout with identical subjects. Figures span across appendix F1-2.

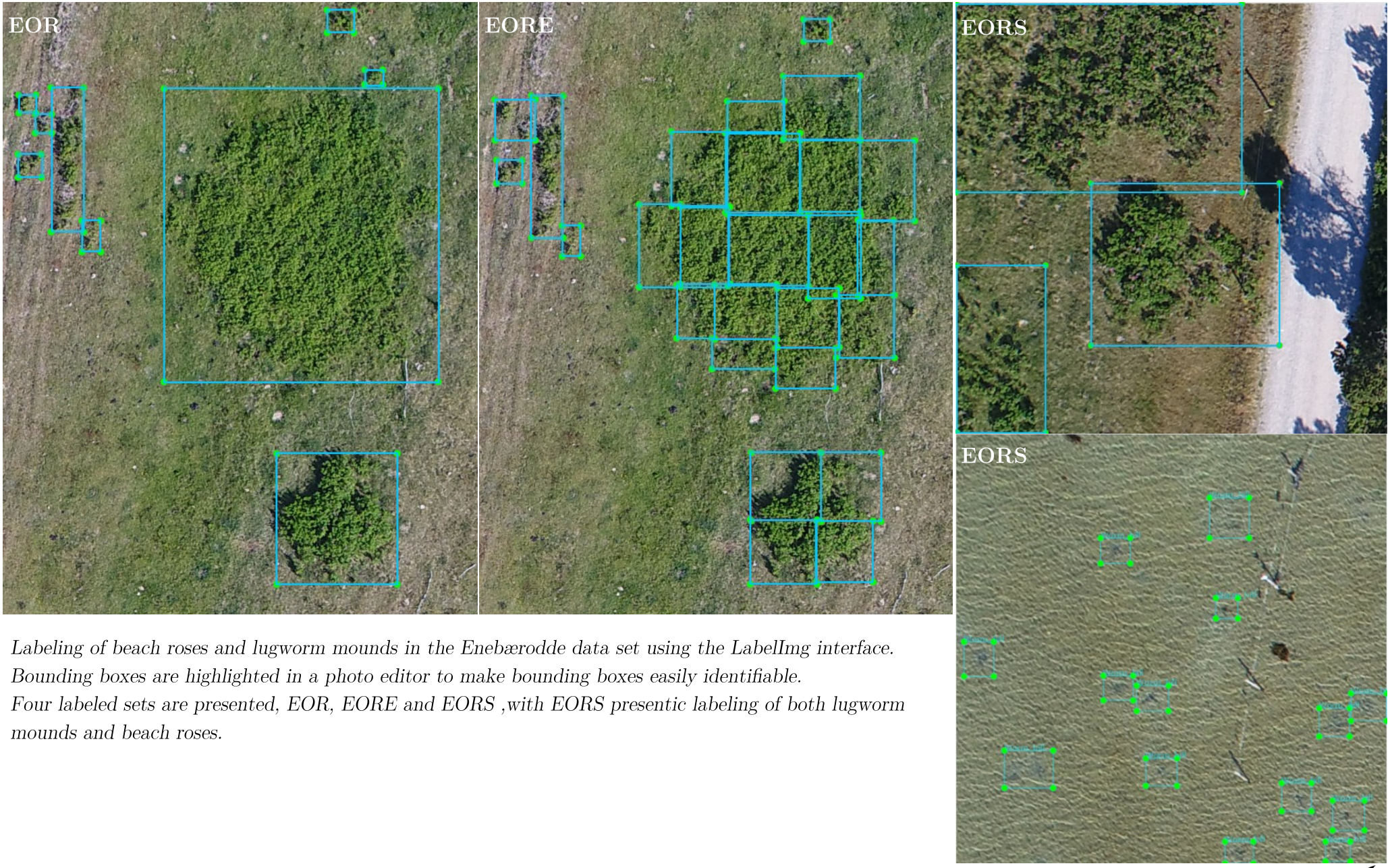






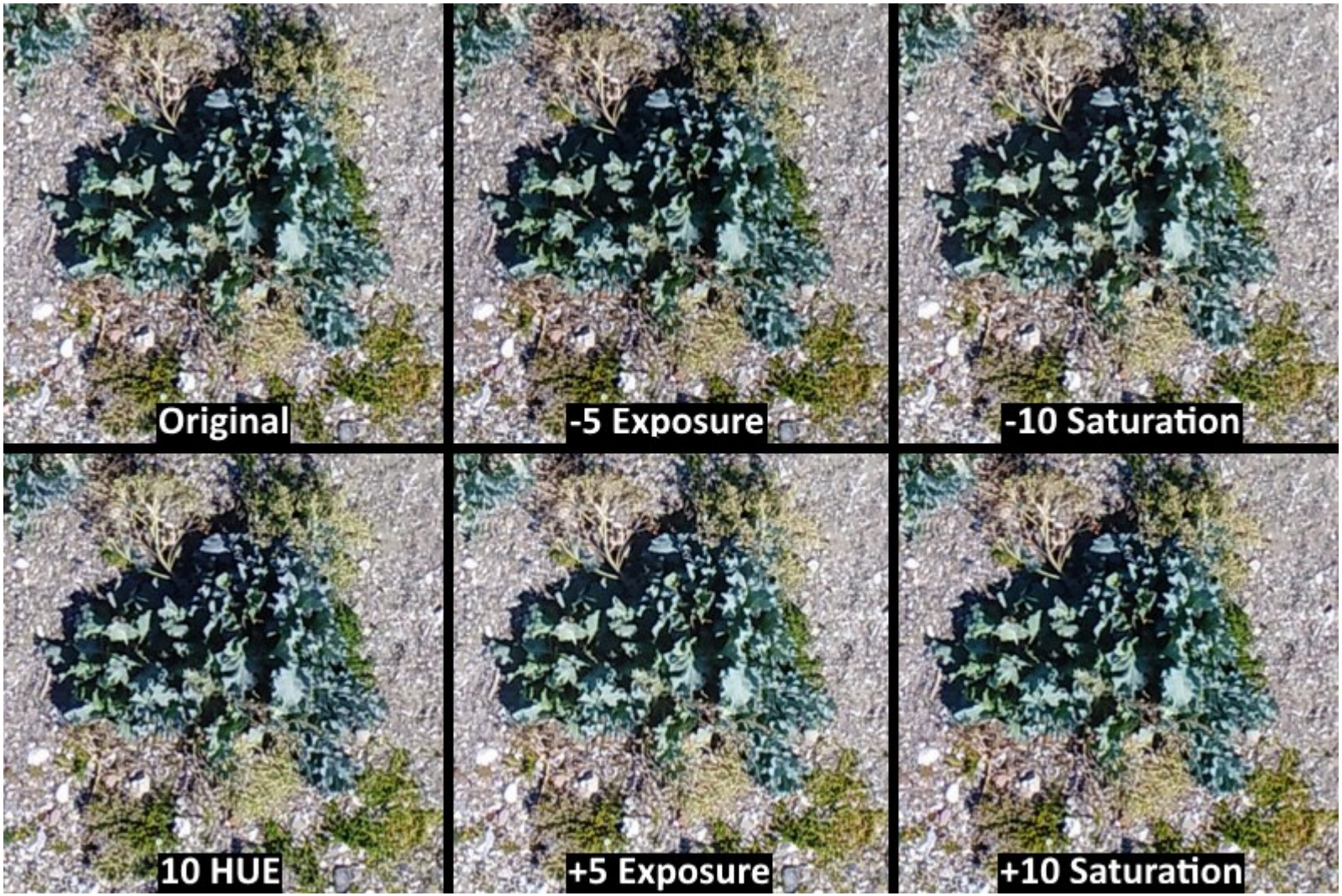


G - Labeling beach roses and lugworm mounds



Labeling of beach roses and lugworm mounds in the Enebærodde data set using the LabelImg interface. Bounding boxes are highlighted in a photo editor to make bounding boxes easily identifiable.
Four labeled sets are presented, EOR, EORE and EORS ,with EORS presentic labeling of both lugworm mounds and beach roses.

H - Pixelmodifiers



YOLOv4 augmentation for pixel modifiers HUE, exposure and saturation visualized for an instance of sea kale at nadir view in 20m altitude. Displayed pixel values are of those applied in the study and can be referenced to the Original unaltered image cutout. Pixel modifiers are set to values deemed realistic as per human standards when representing subjects within imagery.

I1 - Coverage evaluations, python script

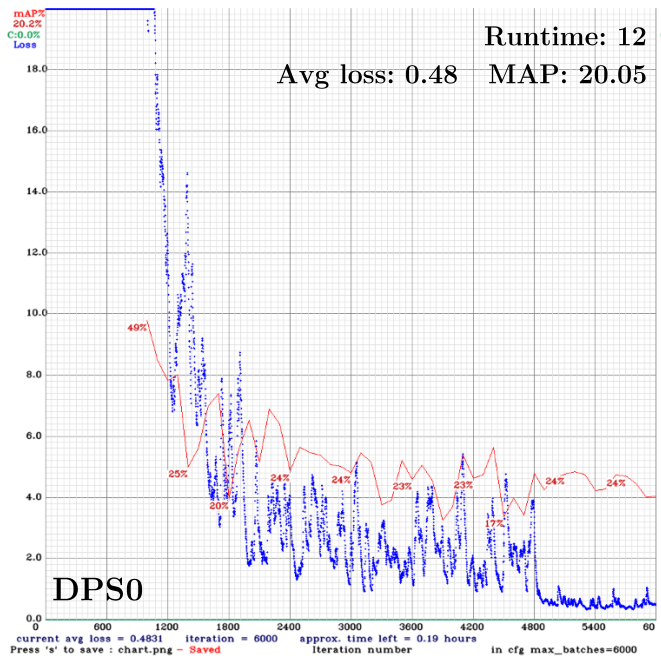
Appendix I1 depicts the output from the python evaluation script evaluating YOLOv4 detectors on their ability to cover the validation sets bounding boxes. The subject investigated is hogweed. Detections are conducted with NMS and IoU set to 0.5 at 0.8 in required detection confidence. The script outputs the validation image along with visualized overlap, green, validation boxes missed resulting in an underestimate, orange, and red visualizing where the detector overestimates coverages or produce false positives. The Script counts true positives (TP), false positives (FP), and false negatives (FN) to calculate precision, recall, and F1 score. Coverages are calculated in spatial metrics relying on an input of the imagery's spatial resolution. Coverages are further evaluated as accuracy, underestimate, overestimation, and precision.
Coverage precision is used as the leading assessment measure in evaluating detector performance in the study.

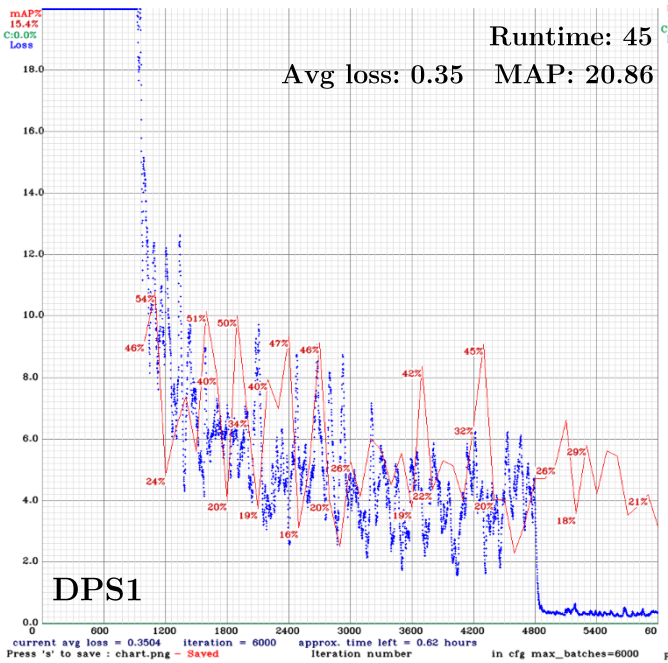
Appendix I2 visualizes the validation bounding boxes, yellow, along with the detector's detections of subjects, blue. Bounding boxes are marked with the class and confidence level.

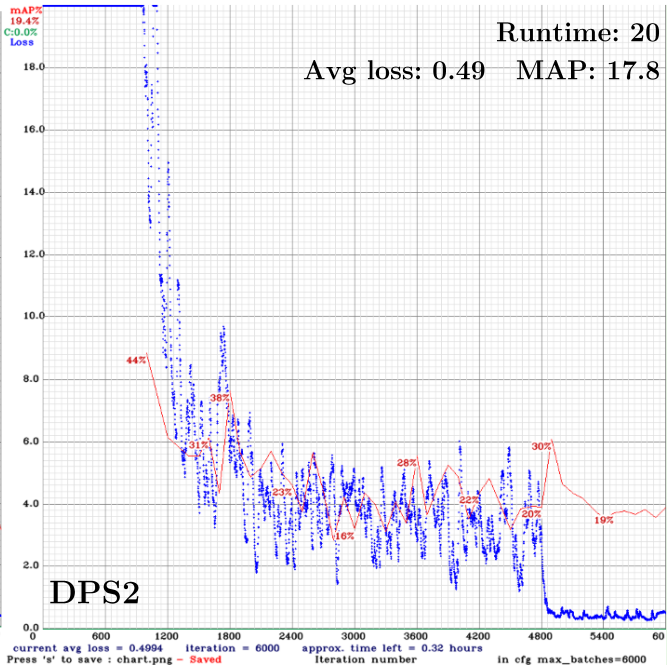
```
>>Confusion matrix<<
TP (IoU >  0.5 ): 108    FP (IoU <  0.5 ): 8
FN (Groundtruthing outside detections): 2
Precision: 0.931         Recall: 0.982   F1 score: 0.956

>>Coverages<<
Groundtruth coverage:  72.87 m2.
Detection coverage:  74.45 m2.
Intersecting coverage/IoU:  68.8 m2.
Groundtruthing coverage missed:  4.08 m2
Error/overestimated coverage:  5.65 m2 of detection not part of the IoU.

>>Evaluation metrics on coverage<<
Accuracy, fraction of IoU coverage relative to groundtruthing:  94.4 %
Underestimate, fraction of invalid detection relative to IoU coverage:  5.6 %
Precision, fraction of IoU coverage relative to the sum of invalid- and groundtruthing coverages:  87.6 %
Overestimate, fraction of the detection not part of the IoU coverage:  7.6 %

>>Visualizing IoU assesment<<
[Green == Accuracy, Valid detection coverage(IoU between groundtruthing- & detection mask)
[Orange == Underestimate, Missed groundtruthing (Groundtruthing mask)]
[Red == Overestimate, Invalid detection coverage (Detection mask)]
```

I2 - Coverage evaluations, python script

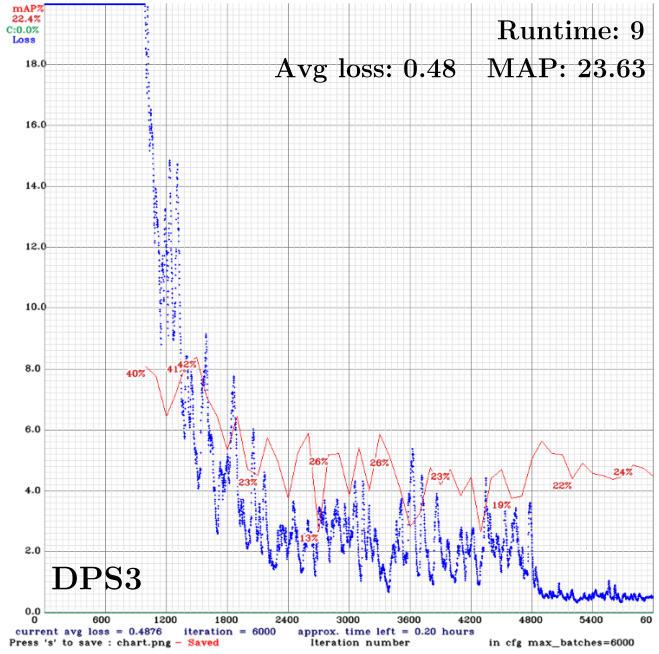
J1 - MAP curves, Daltofterenden

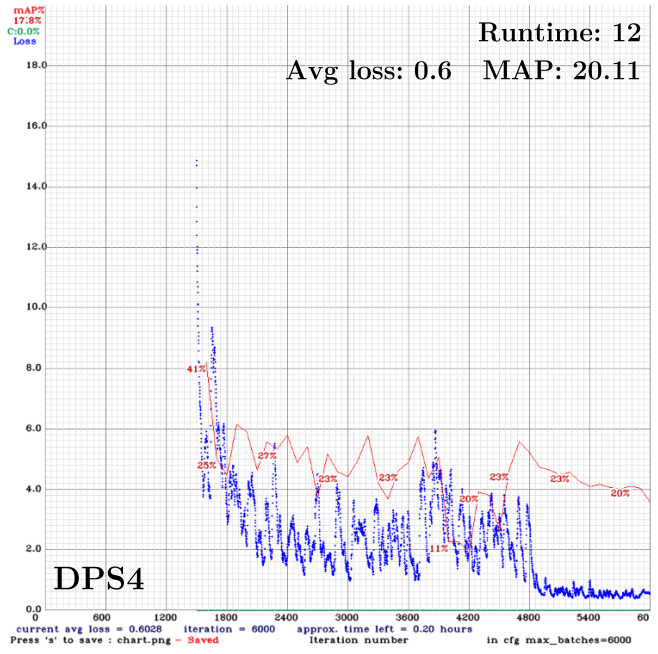




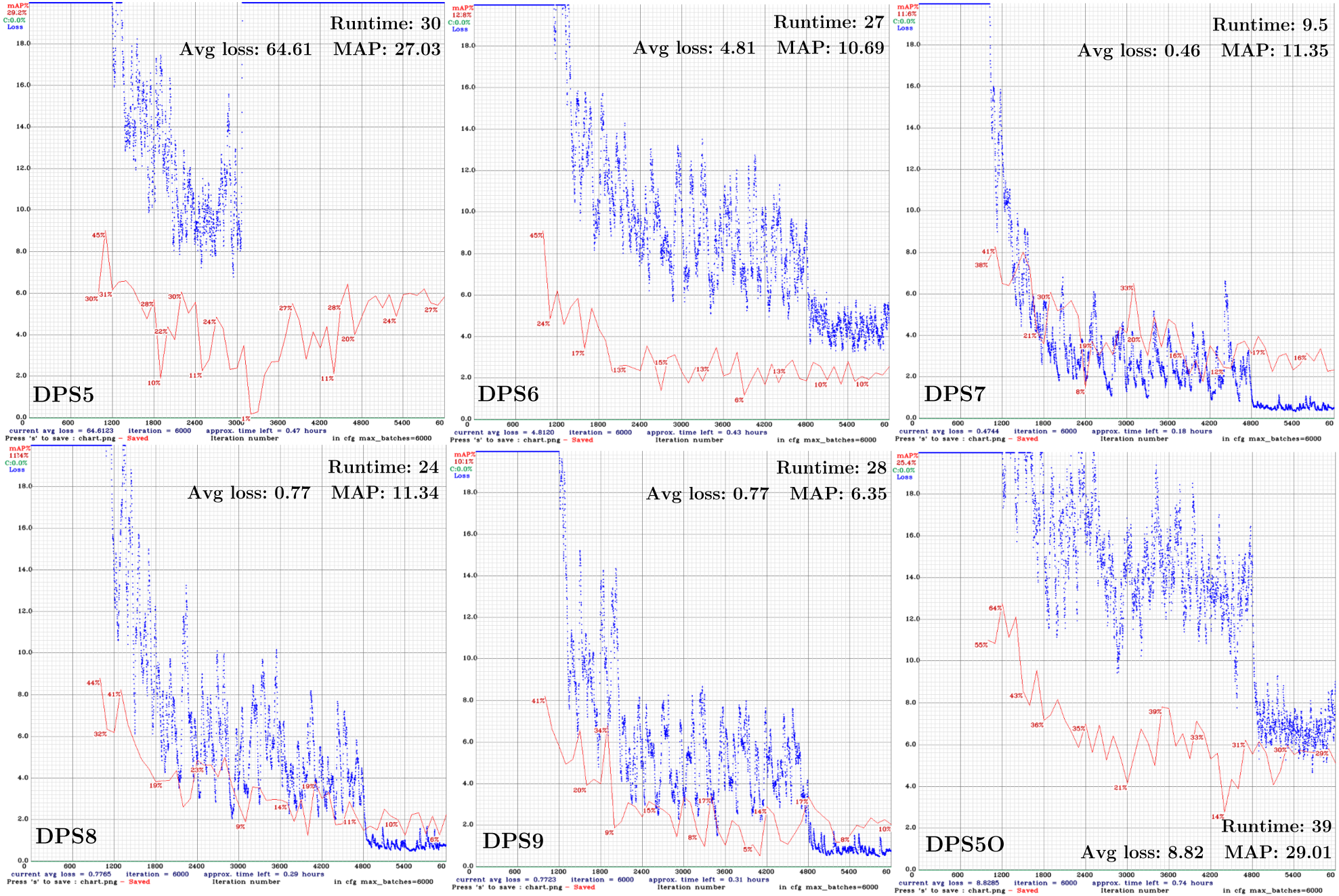


Training curves of YOLOv4 detectors trained on a data set of Daltofterenden capturing a population of giant hogweed. Loss is visualised as blue points and mean average precision (MAP) as a green curve across 6000 training epochs. The runtime of training is listed in hours along average loss and final MAP for the detector. Each graph is listed with the model ID in the lower left corner. Graphs span from appendix J1 to J2.





J2 - MAP curves, Daltofterenden



K - Detectors for Bøjden Nor, setup and evaluation

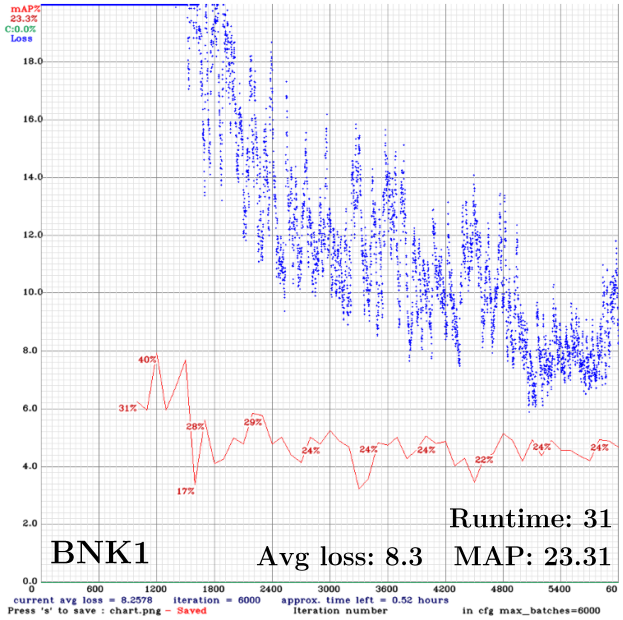
The upper table displays YOLOv4 detectors trained on detecting Crambe maritima, sea kale. Configuration of YOLOv4 parameter settings is listed. Mean average precision at 50% overlap (MAP50) is calculated on the test set and listed for the weights after training for classes sea kale(AP K), flowers (AP F), shadowed kale (AP S), and combinations thereof (AP C) if present.

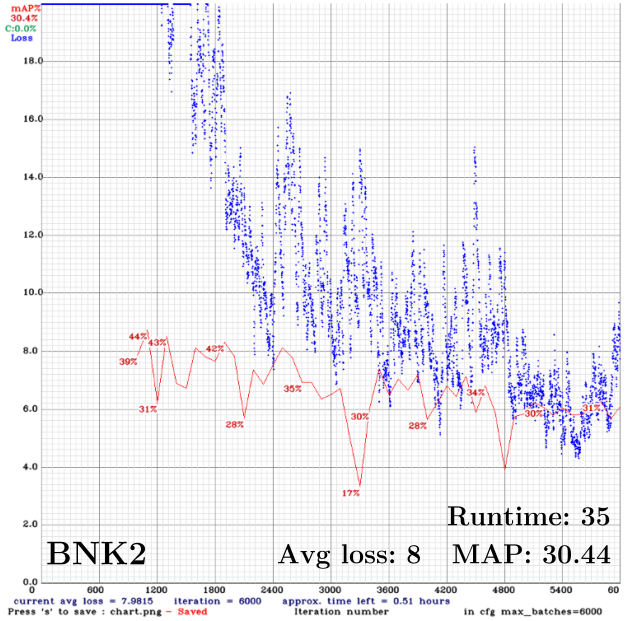
The lower table displays coverage accuracy (CA), coverage underestimate (CU), coverage precision (CP), coverage overestimate (CO), and F1 score as calculated on the validation set with IoU and NMS threshold set to 0.5 at a confidence level of 0.8. Evaluation measures are presented for every class and as an average of measures. "NA" are entries omitted for the given model, and "-" marks entries for classes part of the present subclass combination.

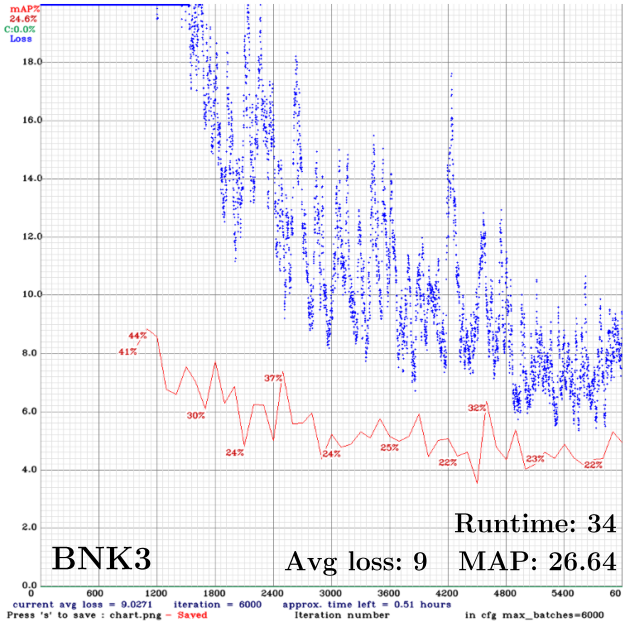
ID	Input	Sub division	MAP, validation	APk	APf	APs	APc
BNK1	416	16	23.31	41.73	26.25	1.94	NA
BNK2	416	16	30.44	-	-	-	30.44
BNK3	416	16	24.64	34.18	-	-	15.1
BNK4	416	16	16.28	-	-	1.68	30.87
BNK5	416	16	25.3	-	17.17	-	33.44
BNK6	416	16	27.86	42.61	13.1	NA	NA
BNK6O	800	64	33.77	40.93	26.6	NA	NA
BNR1	416	32	37.02	-	-	NA	37.02
BNR1O	800	64	41.74	-	-	NA	41.74
BNR2	416	32	24.88	35.79	13.97	NA	NA

	Freestanding sea kale					Sea kale flowers					Shadowed sea kale					Combination of subclasses					Measures averaged				
ID	CA	CU	CP	CO	F1	CA	CU	CP	CO	F1	CA	CU	CP	CO	F1	CA	CU	CP	CO	F1	CA	CU	CP	CO	F1
BNK1	45.3	54.7	24.8	64.5	0.428	10.1	89.9	9.9	13.9	0.132	1.4	98.6	1.4	18.9	0.023	NA	NA	NA	NA	NA	18.9	81.1	12.0	32.4	0.19
BNK2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.5	71.5	26.8	17.7	0.304	28.5	71.5	26.8	17.7	0.30
BNK3	45.6	54.4	24.1	66.2	0.467	-	-	-	-	-	-	-	-	-	-	9.9	90.1	9.7	16.2	0.151	27.8	72.3	16.9	41.2	0.31
BNK4	-	-	-	-	-	-	-	-	-	-	2.2	97.8	2.2	14.8	0.024	21.3	78.7	19.9	25.7	0.291	11.8	88.3	11.1	20.3	0.16
BNK5	-	-	-	-	-	10.5	89.5	10.1	26.7	0.132	-	-	-	-	-	13.2	86.8	12.1	41.5	0.126	11.9	88.2	11.1	34.1	0.13
BNK6	53.4	46.6	23.6	70.3	0.588	17.8	82.2	17	21.9	0.313	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35.6	64.4	20.3	46.1	0.45
BNK6O	46	54	37	34.6	0.2	7.1	92.9	7.1	13.5	0.113	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	26.6	73.5	22.1	24.1	0.16
BNR1	-	-	-	-	-	-	-	-	-	-	NA	NA	NA	NA	NA	56.6	43.4	52.8	11.3	0.75	56.6	43.4	52.8	11.3	0.75
BNR1O	-	-	-	-	-	-	-	-	-	-	NA	NA	NA	NA	NA	46.4	53.6	43.6	12.2	0.595	46.4	53.6	43.6	12.2	0.60
BNR2	45.4	54.6	41.9	15.3	0.485	14.9	85.1	14.3	21.2	0.248	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	30.2	69.9	28.1	18.3	0.37

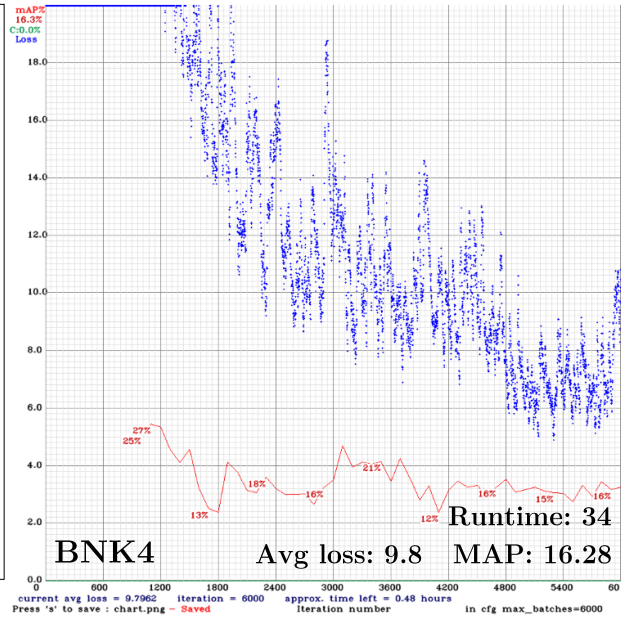
L1 - MAP curves, Bøjden Nor

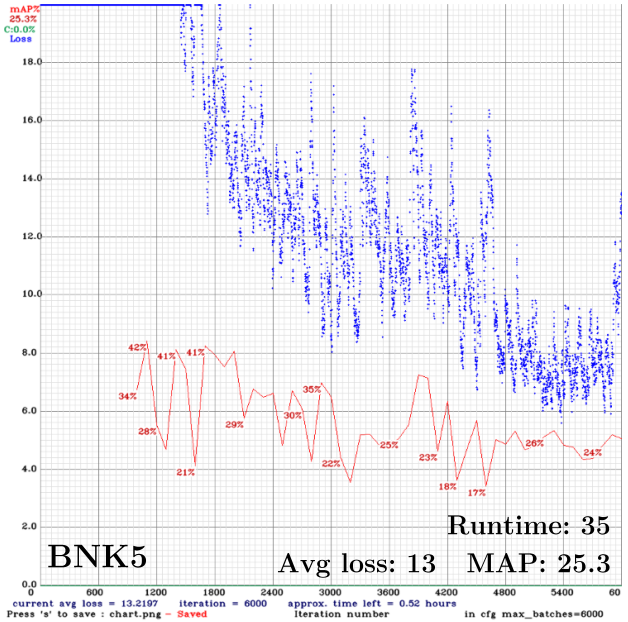




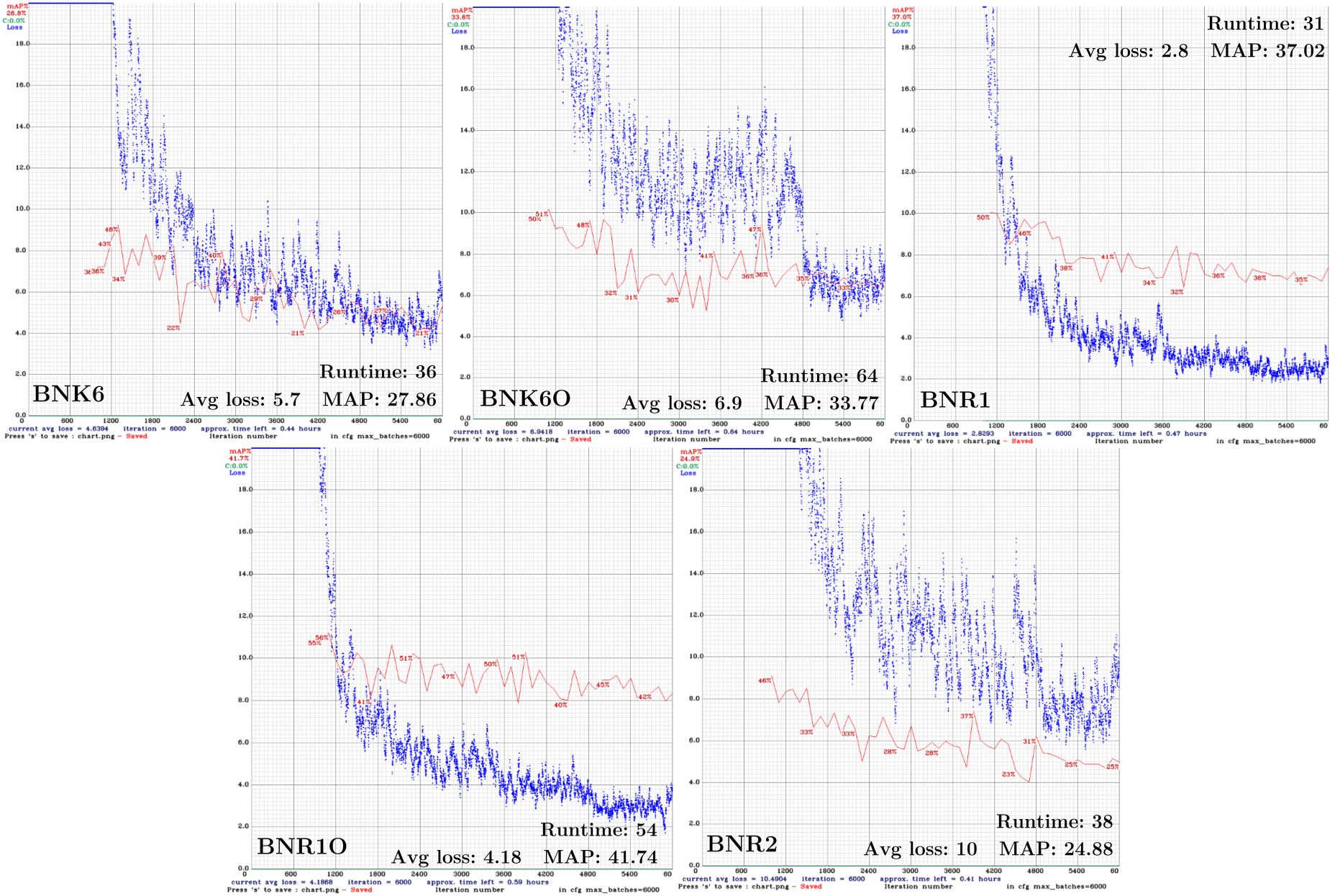


Training curves of YOLOv4 detectors trained on a data set of Bøjden Nor capturing a population of sea kale. Loss is visualised as blue points and mean average precision (MAP) as a green curve across 6000 training epochs. The runtime of training is listed in hours along average loss and final MAP for the detector. Each graph is listed with the model ID in the lower left corner. Graphs span from appendix L1 to L2.

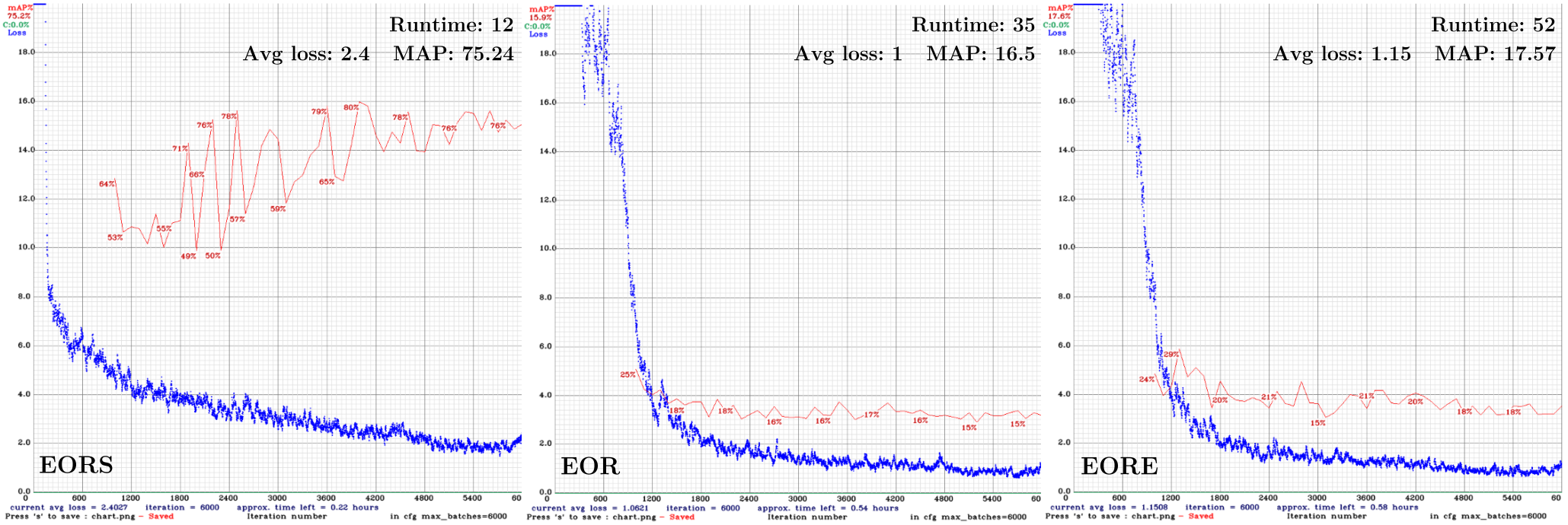




L2 - MAP curves, Bøjden Nor



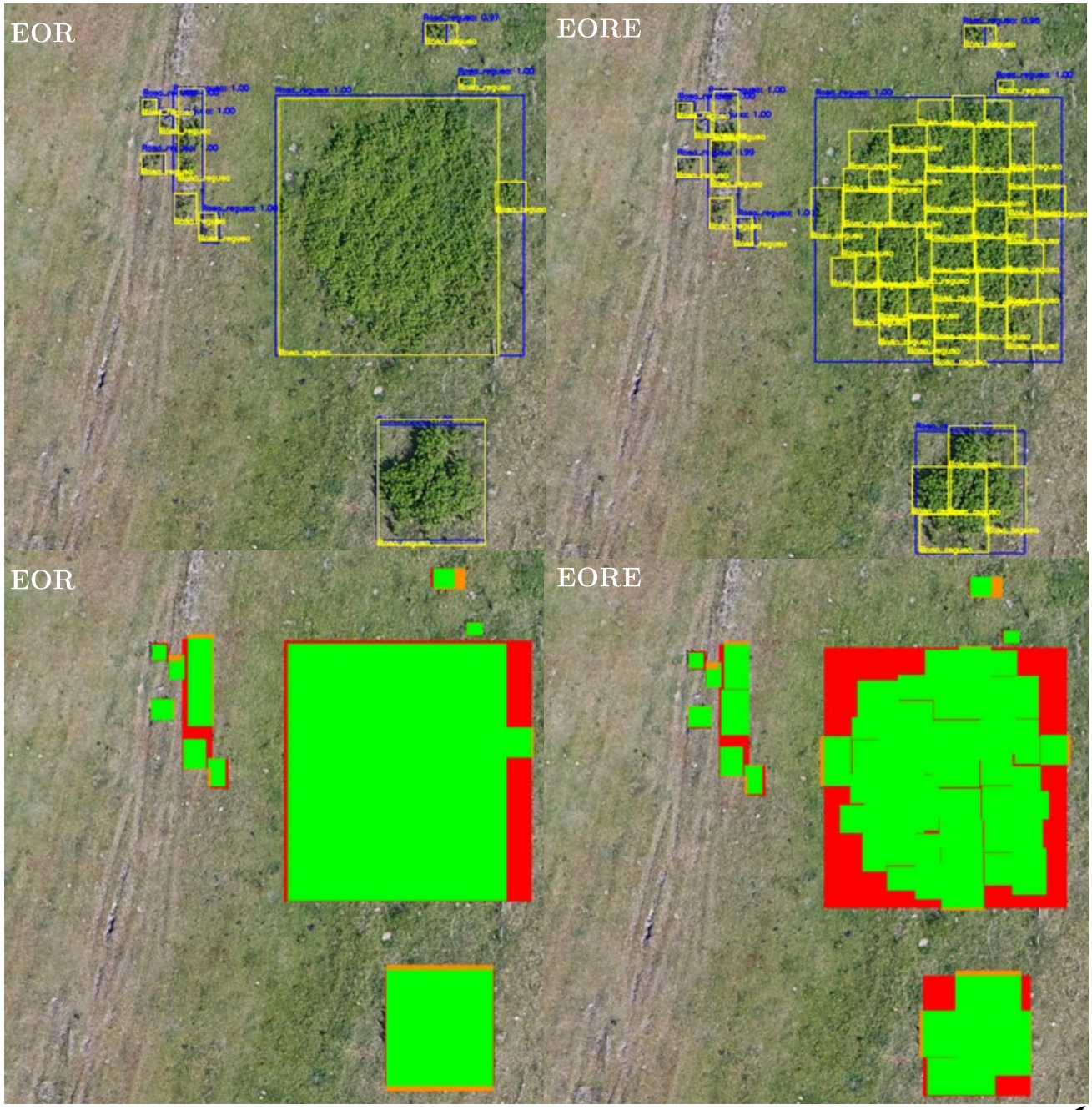
M - MAP curves, Enebærodde



Training curves of YOLOv4 detectors trained on a data set of Enebærodde capturing a population of beach roses and lugworm mounds. Loss is visualized as blue points and mean average precision (MAP) as a green curve across 6000 training epochs. The runtime of training is listed in hours along average loss and final MAP for the detector. Each graph is listed with the model ID in the lower left corner.

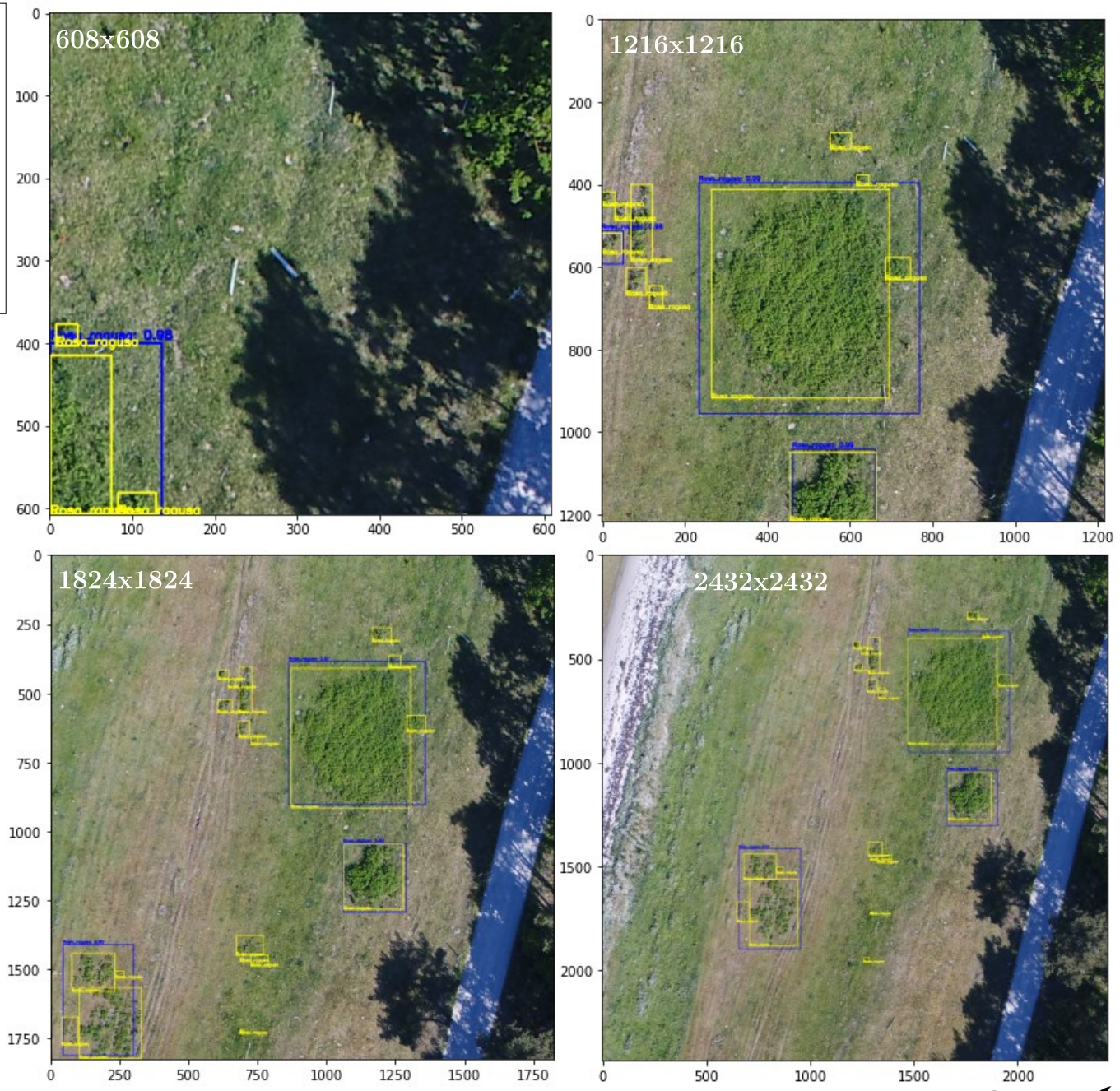
N - EOR and EORE validation, detection strategy

Detections and coverage evaluation output for Enebærodde Roses (EOR) and Enebærodde roses edges (EORE). The subject investigated is beach roses. Detections are conducted with NMS and IoU set to 0.5 at 0.8 in required detection confidence. In the top half, outputs display detector detections, blue, overlaying validation bounding boxes, and yellow. The lower half is an output of the validation with visualized overlap, green, and validation boxes missed resulting in an underestimate, orange, and red, visualizing where the detector overestimates coverages or produces false positives



O - EORS validation across variable resolutions

For detector EORS validation, image cutouts are visualized. The subject investigated is beach roses. Detections are conducted with NMS and IoU set to 0.5 at 0.8 in required detection confidence. The validation bounding boxes, yellow, along with the detectors detections of subjects, blue, is presented within imagery. Bounding boxes are marked with the class and confidence level.



P - Detectors trained for the study

Table of all trained detectors for the study. Detectors are denoted by their ID in accordance to presented detectors in the report. ID is sorted alphabetically. For each detector it is denoted if (Y) or if not (N) the detector is presented in the study. Detectors sharing the same ID are triplicates and duplicates of one another. Image resolution and detector input size is listed. Runtime in hours is listed, accompanied by mean average precision (MAO) and average loss calculated at the conclusion of training.

ID	Presented	Image Resolution	Input Size	Runtime (h)	Avg. Loss	MAP	ID	Presented	Image Resolution	Input Size	Runtime (h)	Avg. Loss	MAP
BNK1	Y	3435x2160	416	31	8.25	23.31	DPS2	Y	5472 x 3648	608	20	0.49	17.8
BNK2	Y	3435x2160	416	35	7.98	30.44	DPS3	N	5472 x 3648	416	8	0.48	15.08
BNK2	N	3435x2160	416	29	4.84	26.81	DPS3	Y	5472 x 3648	416	9	0.48	23.63
BNK3	Y	3435x2160	416	34	9.02	24.64	DPS4	Y	5472 x 3648	800	12	0.6	20.11
BNK4	Y	3435x2160	416	34	9.79	16.28	DPS5	Y	5472 x 3648	416	30	64.61	27.03
BNK5	Y	3435x2160	416	35	13.21	25.3	DPS5O	Y	5472 x 3648	800	39	8.82	29.01
BNK6	Y	3435x2160	416	?	5.69	27.86	DPS5O	N	5472 x 3648	800	63	7.34	19.76
BNK6	N	3435x2160	416	?	4.63	26.84	DPS5O	N	5472 x 3648	800	45	7.62	25.88
BNK6	N	3435x2160	416	36	6.22	24.62	DPS6	N	5472 x 3648	416	30	5.41	8.36
BNK6O	N	3435x2160	800	75	8.12	33.33	DPS6	Y	5472 x 3648	416	27	4.81	10.69
BNK6O	Y	3435x2160	800	64	6.94	33.77	DPS7	Y	5472 x 3648	416	9.5	0.46	11.35
BNK6O	N	3435x2160	800	66	8.71	33.8	DPS8	Y	5472 x 3648	416	24	0.77	11.34
BNR1	Y	3435x2160	416	31	2.82	37.02	DPS9	Y	5472 x 3648	416	28	0.77	6.35
BNR1	N	3435x2160	416	27	2.93	34.38	EOR	Y	5472 x 3648	800	35	1	16.5
BNR1	N	3435x2160	416	26	2.56	32.22	EOR	N	5472 x 3648	800	35	1.06	15.86
BNR1O	Y	3435x2160	800	54	3.56	41.49	EOR	N	5472 x 3648	800	35	1.15	14.34
BNR1O	N	3435x2160	800	52	3.53	40.48	EORE	N	5472 x 3648	800	56	3.65	4.8
BNR1O	N	3435x2160	800	54	4.18	41.74	EORE	N	5472 x 3648	800	49	1.14	17.1
BNR2	Y	3435x2160	416	38	10.49	24.88	EORE	Y	5472 x 3648	800	52	1.15	17.57
DPS0	N	5472 x 3648	416	10.4	0.44	19.38	EORS	N	608x608	608	12	2.2	69.75
DPS0	Y	5472 x 3648	416	11.9	0.48	20.05	EORS	Y	608x608	608	12	2.4	75.24
DPS1	Y	5472 x 3648	800	45	0.35	20.86	EORS	N	608x608	608	12	2.26	70.83

Q - YOLACT, detection visualization

Fig. 7: **YOLACT** evaluation results on COCO's `test-dev` set. This base model achieves 29.8 mAP at 33.0 fps. All images have the confidence threshold set to 0.3.

The figure derives from "YOLACT++: Better Real-time Instance Segmentation" by D.Bolya, C.Zhou, F. Xiao & Y. Lee, 2019, arXiv:1912.06218