25. Machine Learning-Assisted Photo-Interpretation as a Tool for Surveying Invasive Benthic Species in Marine Biodiversity Conservation: The Case of Caulerpa cylindracea Sonder, 1845

Sabrina Rossi1 , Elena Comino1 , Andrea Maria Lingua1 and Mariangela Norcia2

1 Politecnico di Torino University, Department of Environmental, Land and Infrastructure Engineering, c.so Duca degli Abruzzi 24, 10129, Torino (TO), Italy, email: (sabrina.rossi, elena.comino, andrea.lingua)@polito.it 2 Department of Biology, University of Naples Federico II, Via Cinthia 26, 80126 Napoli (NA), Italy, email: mariangela.norcia@unina.it

Mediterranean benthic assemblages are sensitive indicators of ecosystem condition, yet image-based monitoring is often constrained by the time required for taxonomic interpretation and cover estimation. This study develops a reproducible machine-learning workflow for benthic photointerpretation, using the invasive green alga Caulerpa cylindracea Sonder, 1845 as a challenging test case. Over three years, 1,763 photo-quadrats were acquired seasonally by SCUBA and free-diving at six shallow infralittoral sites around Culuccia Island (northern Sardinia, Italy), including three invaded and three non-invaded sites. Approximately 10% of the images were manually annotated; after quality control, 158 image-mask pairs were retained. Dense annotations included 13 benthic classes comprising C. cylindracea, other representative taxa or morphological groups, and background. A SegFormer-B0 semantic segmentation model was trained using class-balanced crop sampling, inverse-squareroot class weighting, background down-weighting, conservative image augmentation, and grouped train-validation splitting. The selected model achieved a foreground mIoU of 0.455 and a mean foreground F1/Dice of 0.584 on 47 independently held-out images. The trained model was then applied to 600 unannotated images, generating class-specific pixel counts and mean predicted imagearea fractions at image, folder, site, and whole-dataset levels. This workflow provides a practical and reproducible bridge between expert annotation and scalable quantitative monitoring of benthic communities.