바다에서 찾는 국민의 행복,
인류에 공헌하는 해양과학기술

KIOST
한국해양과학기술원

An advanced AI-based approach for spatial mapping and ecological function quantification of macroinvertebrates in tidal flats

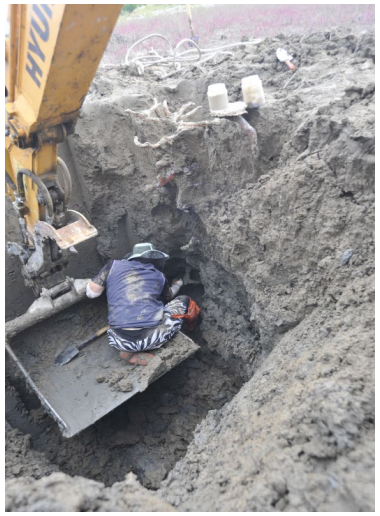
Jaehwan Seo, Chung Ho Kim, Keunyong Kim, Yeong Jae Jang, Donguk Lee, Hyeong Tae Jou, Joo Hyung Ryu, Bon Joo Koo

◦ Background









Academics

- Bc. : Environmental engineering
- M.S. : Ecological engineering
- Ph.D. : Ocean science (benthic ecology)

Careers

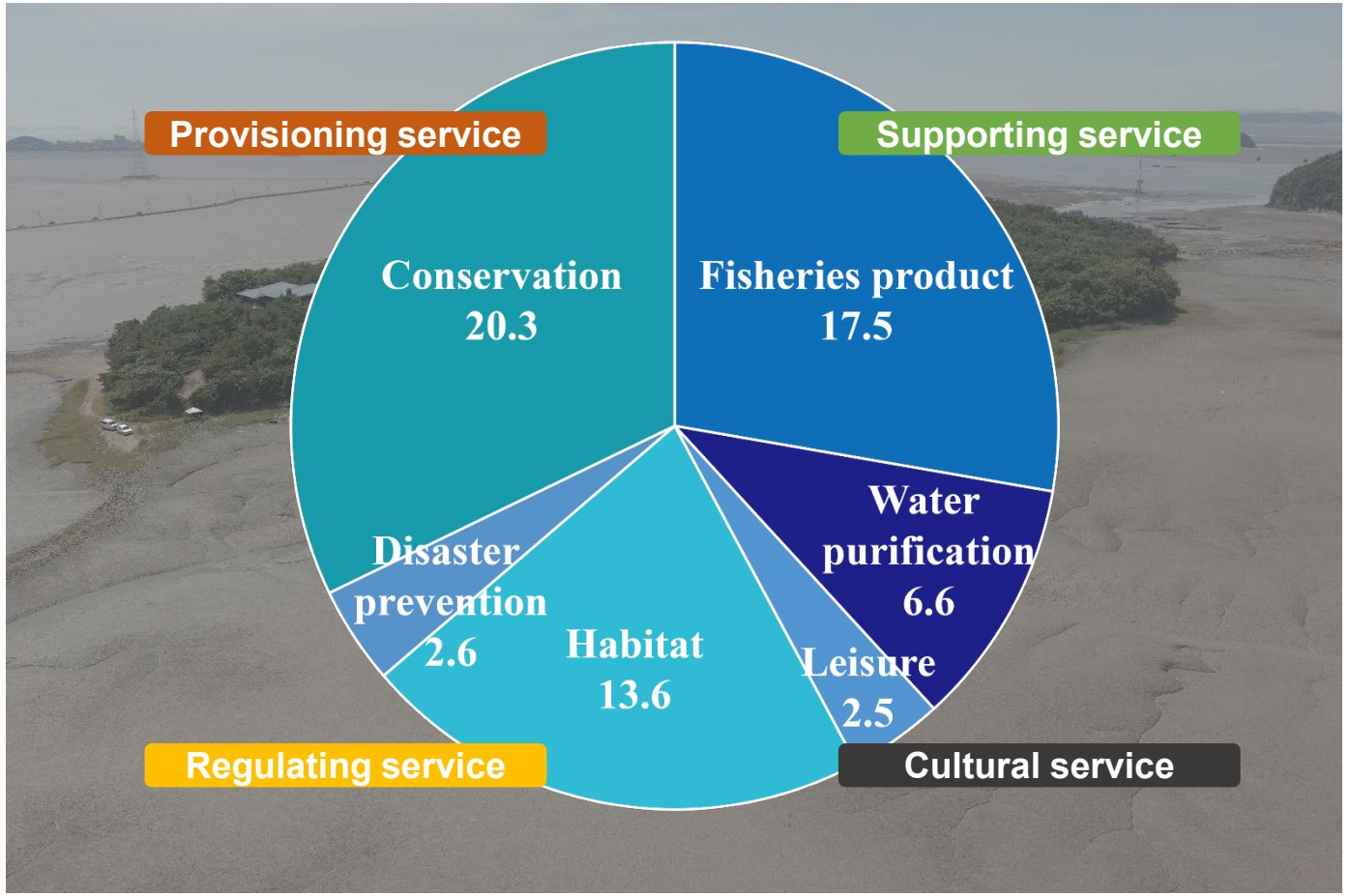
- Student researcher at research institute : 2019-2021
- Postdoctoral researcher at research institute : 2021-2026
- Senior research scientist at KIOST : 2026-current
- Associate professor at UST : 2026-current

Research skills

- Taxonomic identification of macroinvertebrates (polychaete)
- Micro- & mesocosm experiments
  (automated culture systems, aquaculture species cultivation)
- Analyzing community structure
  (ecological indices, quality assessment, statistical analysis)
- Analyzing physiological and ecological traits
  (feeding, growth, reproduction, life history, respiration)
- Analyzing ecological function (OM removal, C sequestration)
- Advanced technology (visual data, artificial intelligence)

◦ Background





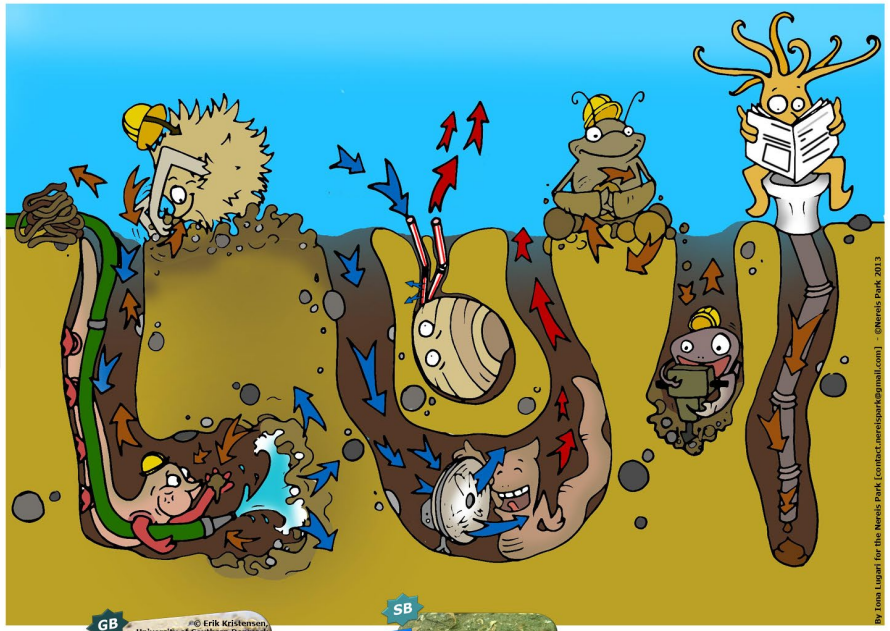
Economic value : 12 billion USD/yr (0.5 billion USD/km²)

BIOTURBATION:

The displacement of particles (sediment reworking) and water (ventilation) in sediments due to faunal activities(*).
The actors of bioturbation(#) can be regrouped in different functional groups.

(*): the definition is here restricted to aquatic fauna. Soil animals, aquatic and terrestrial plants can also generate bioturbation.

(#): only examples of marine macrofaunal species (i.e., organisms retained on a 0.5 mm sieve) are given here.





Echinocardium cordatum

Biodiffusor reworking BI
Organisms with activities that mix sediment homogeneously over short distances.
Sub-groups are epifaunal biodiffusors EB, surficial biodiffusors SB and gallery biodiffusers GB.

Upward conveyor reworking UC
Vertically oriented species that feed head-down at depth in the sediment and deposit wastes at the sediment surface.



Arenicola marina

Blind-ended burrow ventilators BV
Organisms positioned in vertical I- or J-shaped burrows. They pump oxygenated water into the burrow for respiratory purpose by body and cilia movements. Bivalve siphons may leak oxygen indirectly into the surroundings.



Hediste diversicolor



Mercenaria mercenaria

Open-ended burrow ventilators OV
Organisms that construct U- or Y-shaped galleries with 2 or more openings. They maintain breathing by circulating oxygenated water from head to tail by body undulations or by beating limbs.



Uca vocans

Regenerator reworking R
Excavators that dig and maintain burrows in the sediment by transferring sediment from depth to the surface. The excavated sediment is replaced either by surface sediment infilling or by collapse of burrow walls.



Scopimera sp.

Downward conveyor reworking DC
Vertically oriented head-up feeders that ingest particles at the surface and egest wastes deep in the sediment.



Cirriformia sp.

A collaborative work coordinated by Franck Gilbert (EcoLab).

This poster is freely inspired by the Kristensen, E., G. Penha-Lopes, M. Delefosse, T. Valdemarsen, C.O. Quintana & G.T. Banta paper: What is bioturbation? The need for a precise definition for fauna in aquatic sciences. Marine Ecology Progress Series (2012) 446: 285-302.

http://www.nereispark.org/

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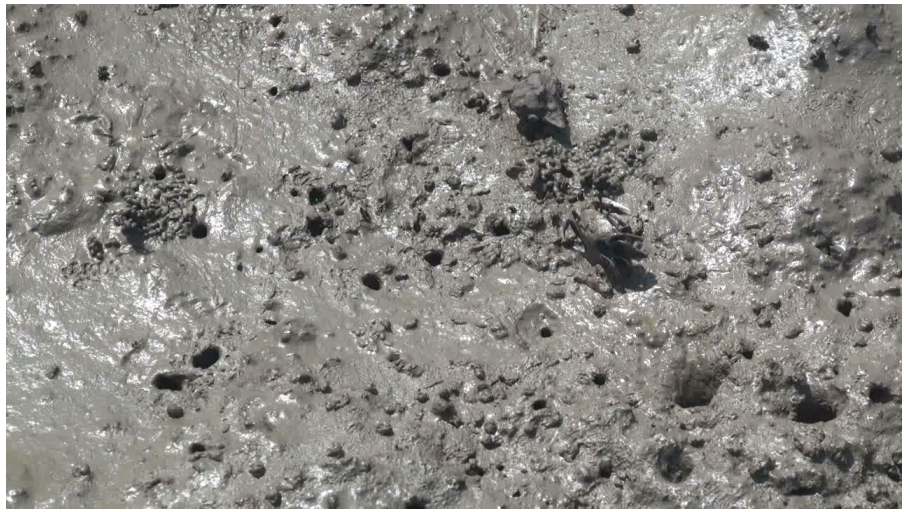
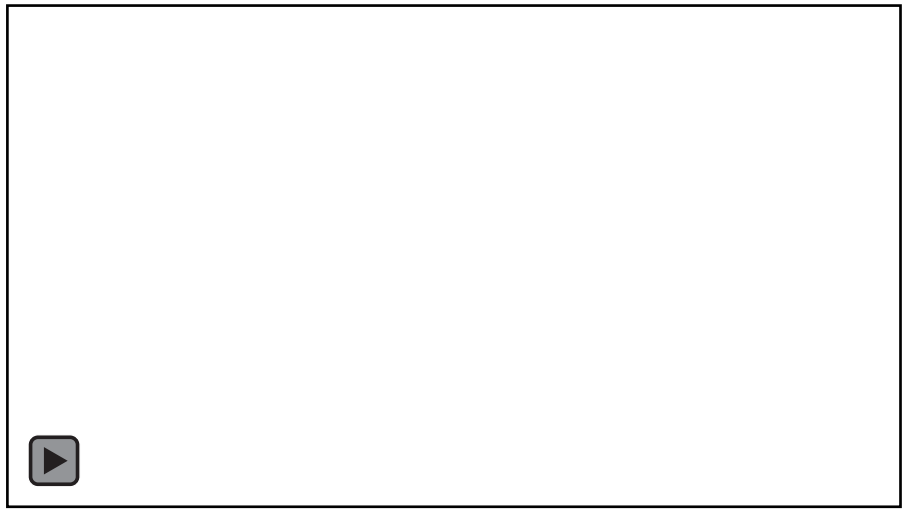
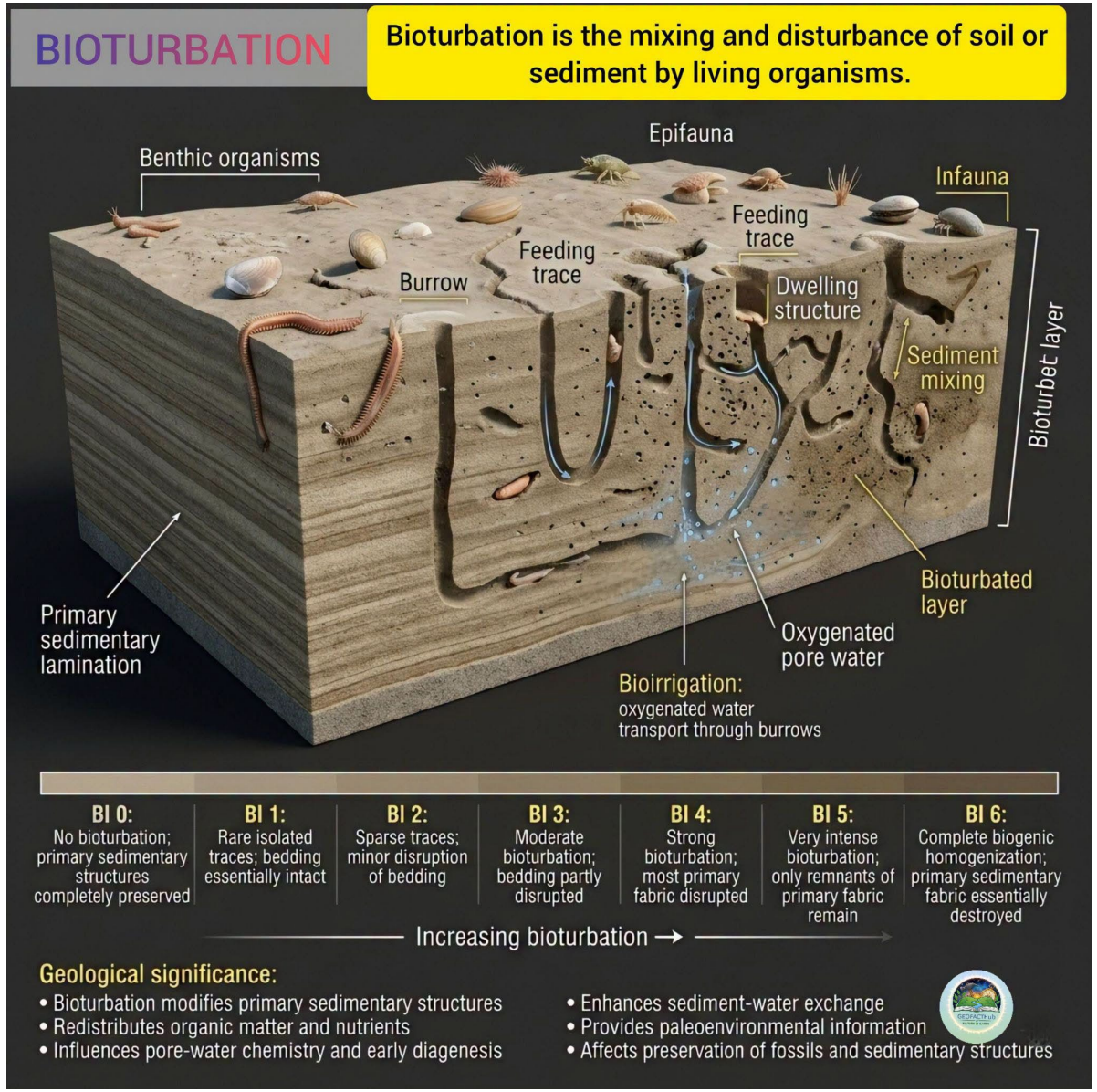




◦ Background

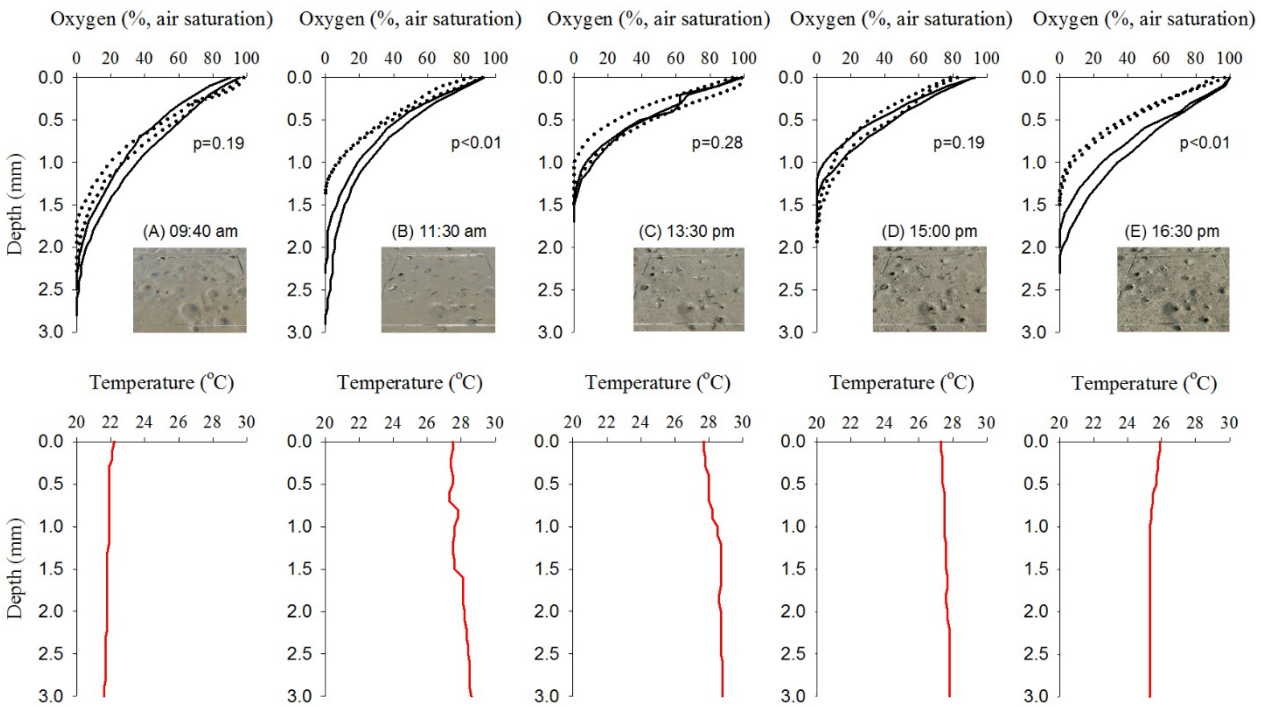


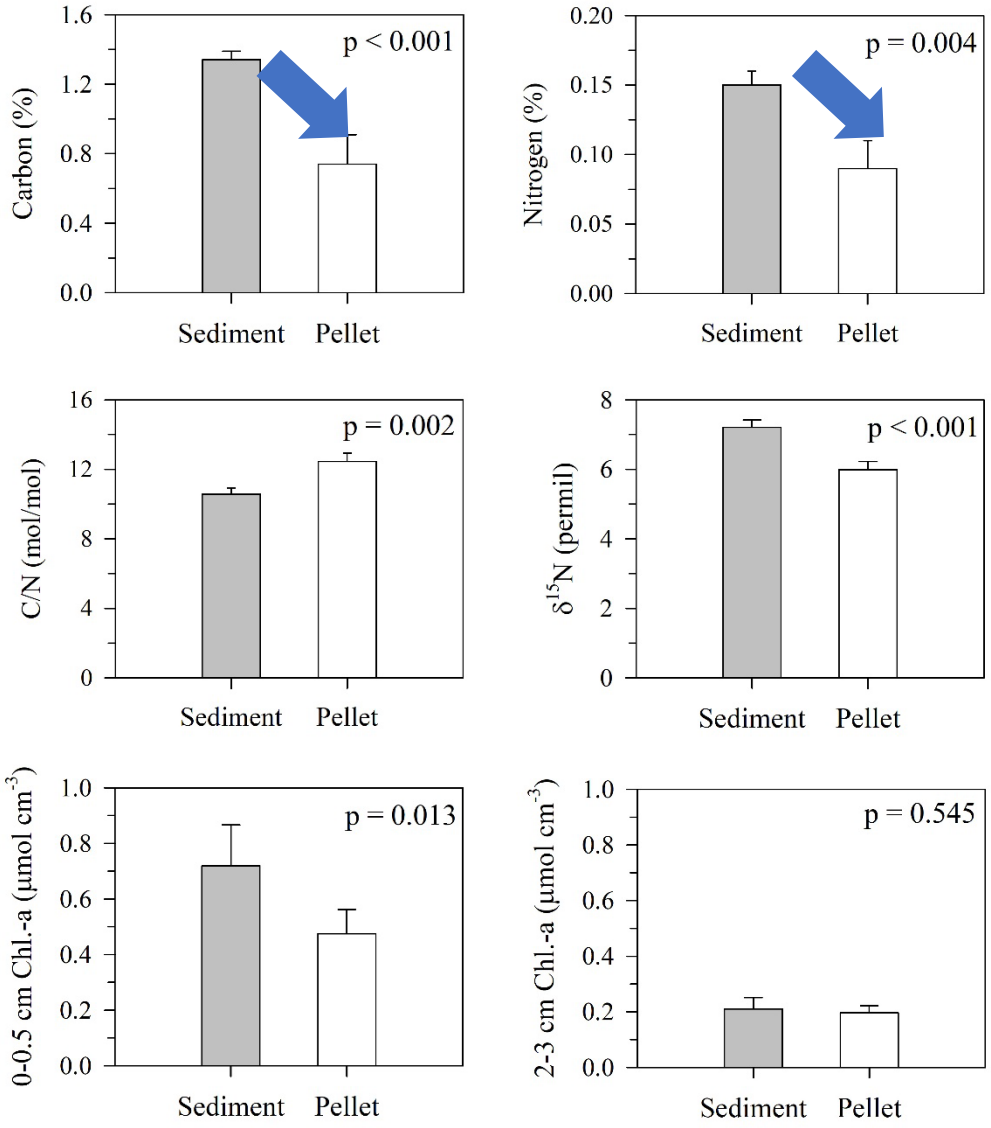
https://www.facebook.com/share/p/1M3q6GCJ93/

◦ Ecological function







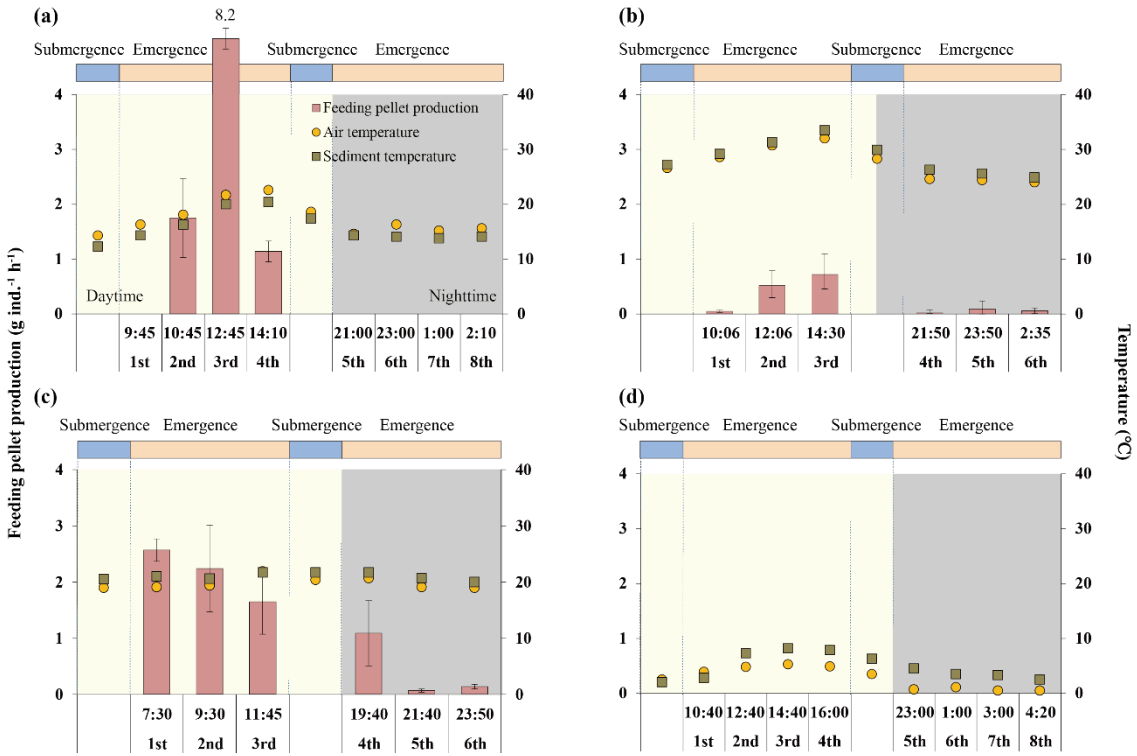


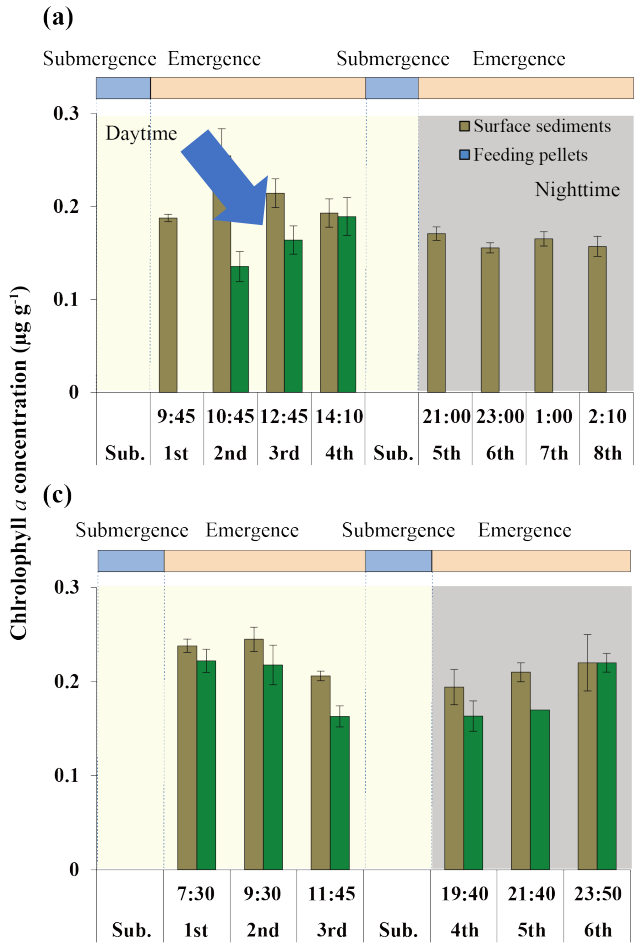
Feeding activity reduced carbon and nitrogen by 55% and 60%, respectively

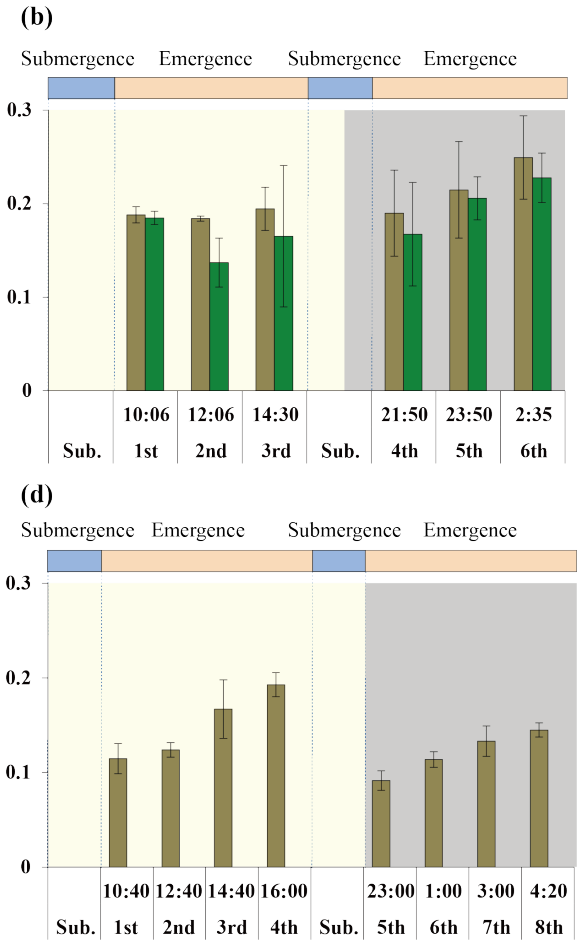
◦ Ecological function











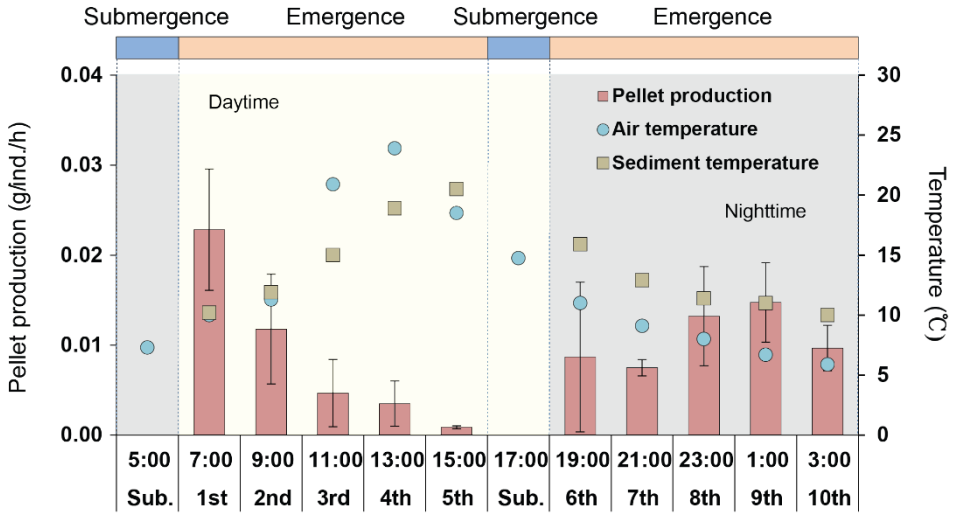
Sediments were reworked to a depth of 40 cm yr^{-1}, and feeding activity reduced chl-a by 24%

◦ Ecological function

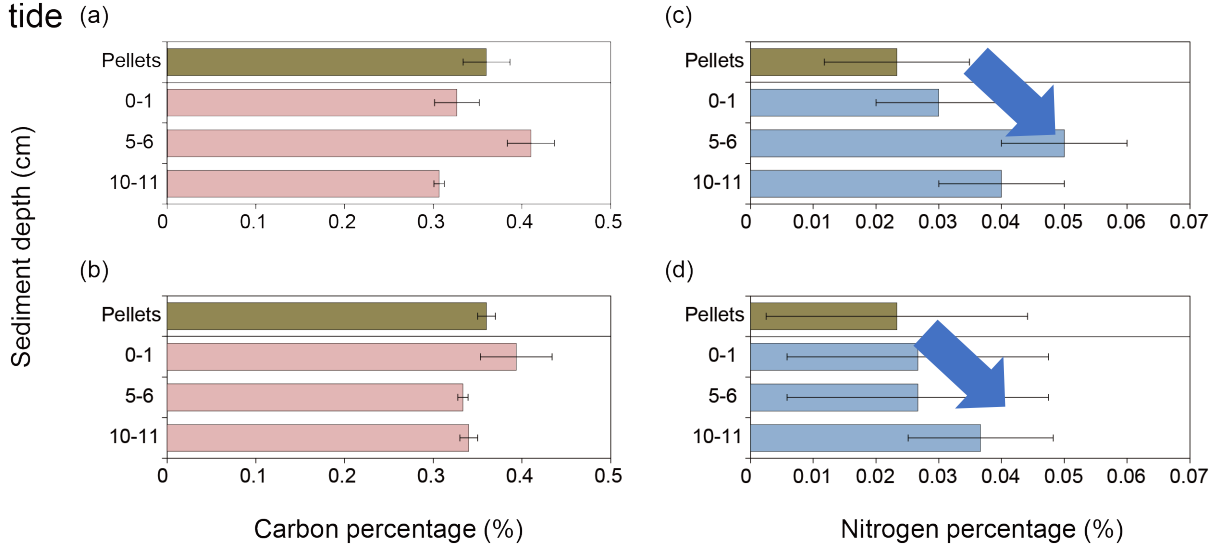




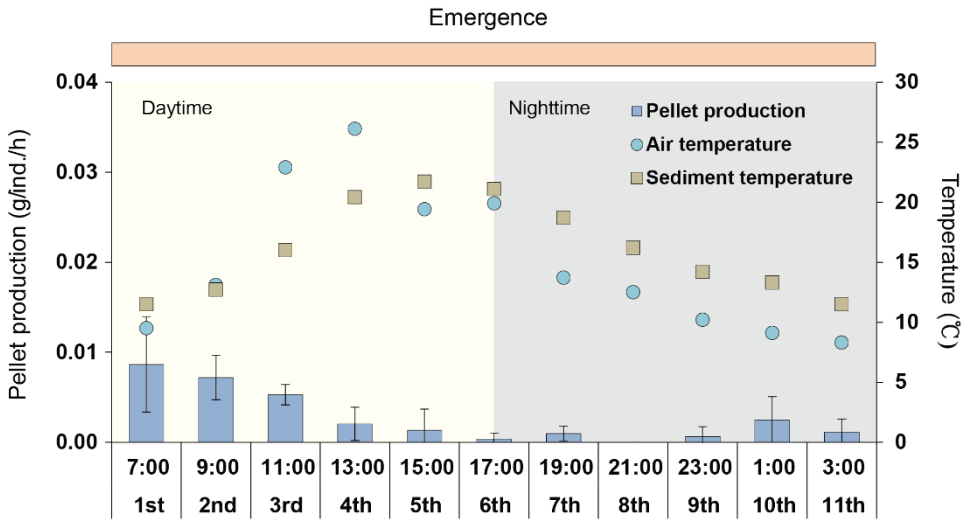
(a)



Spring tide

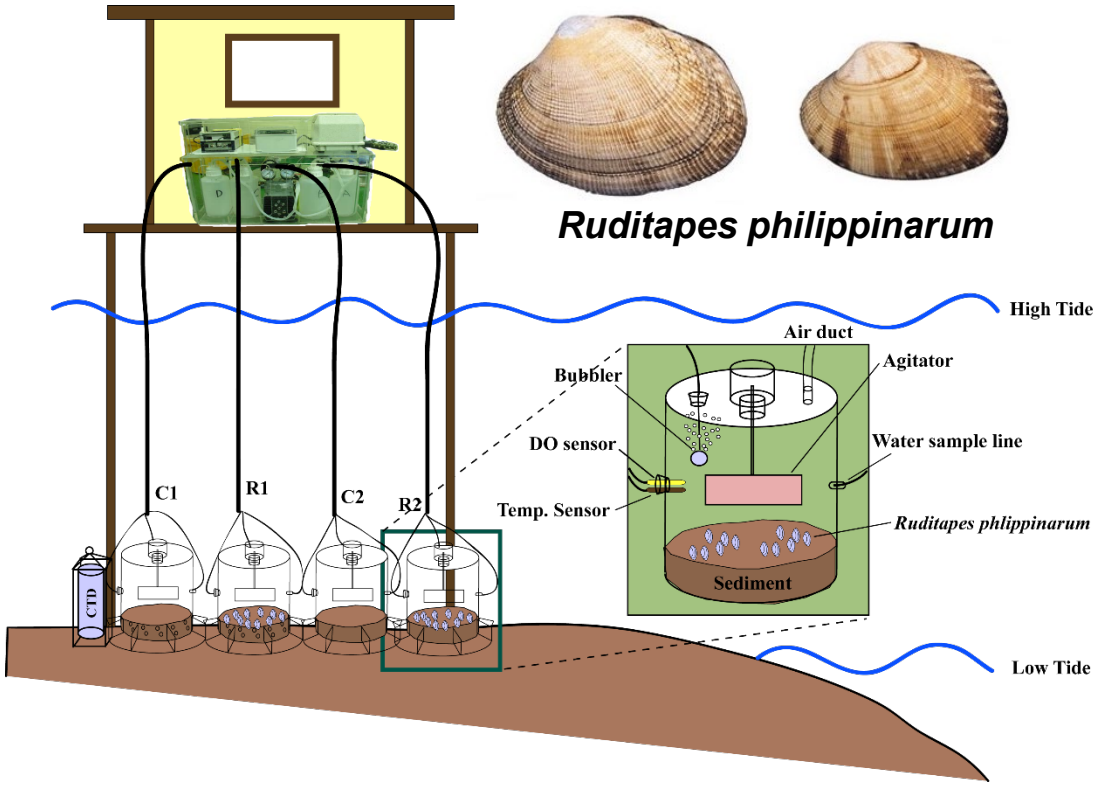


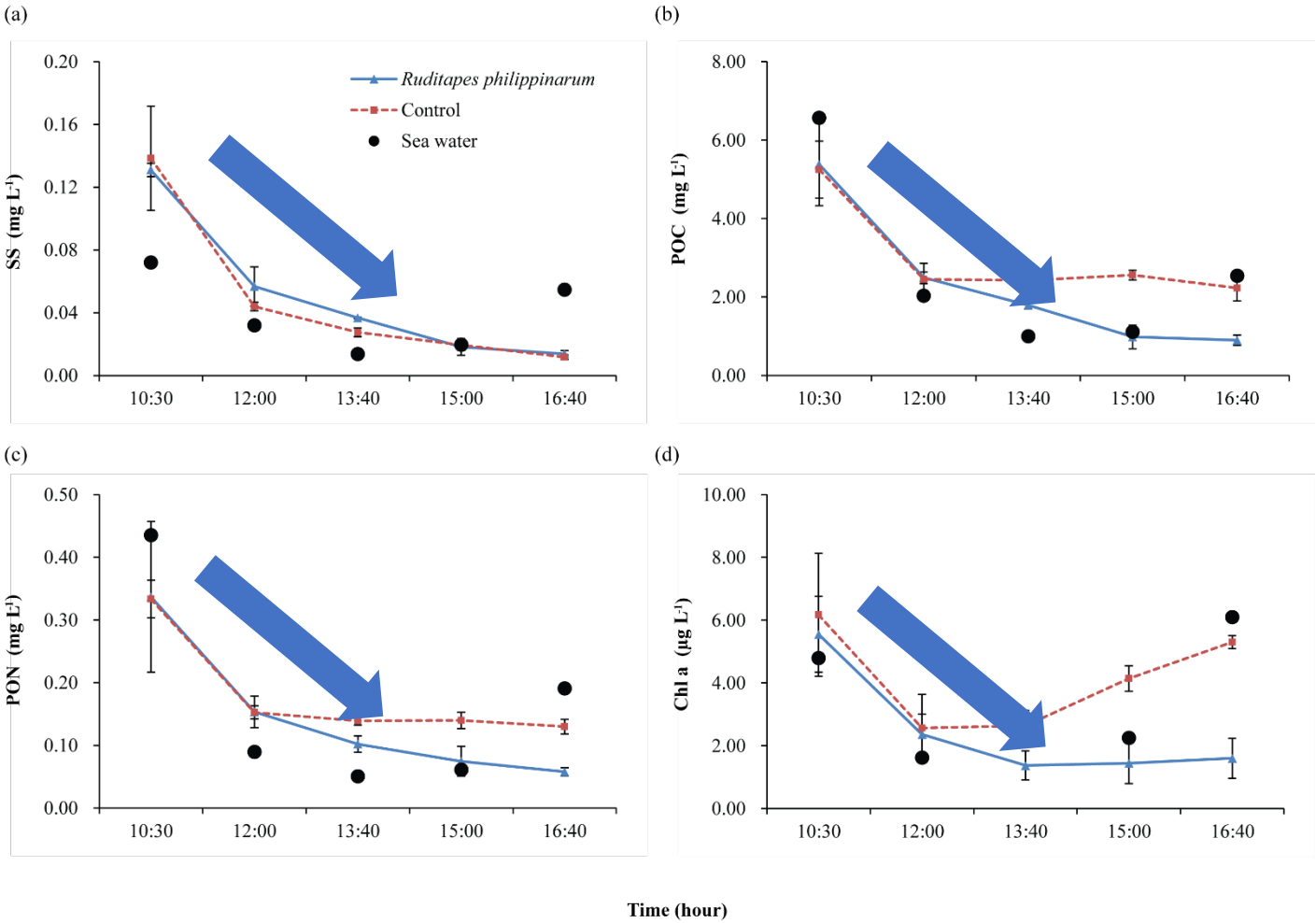
(b)



Sediments were reworked to a depth of 20 mm yr^{-1}, and feeding activity reduced carbon content by 39%

◦ Ecological function



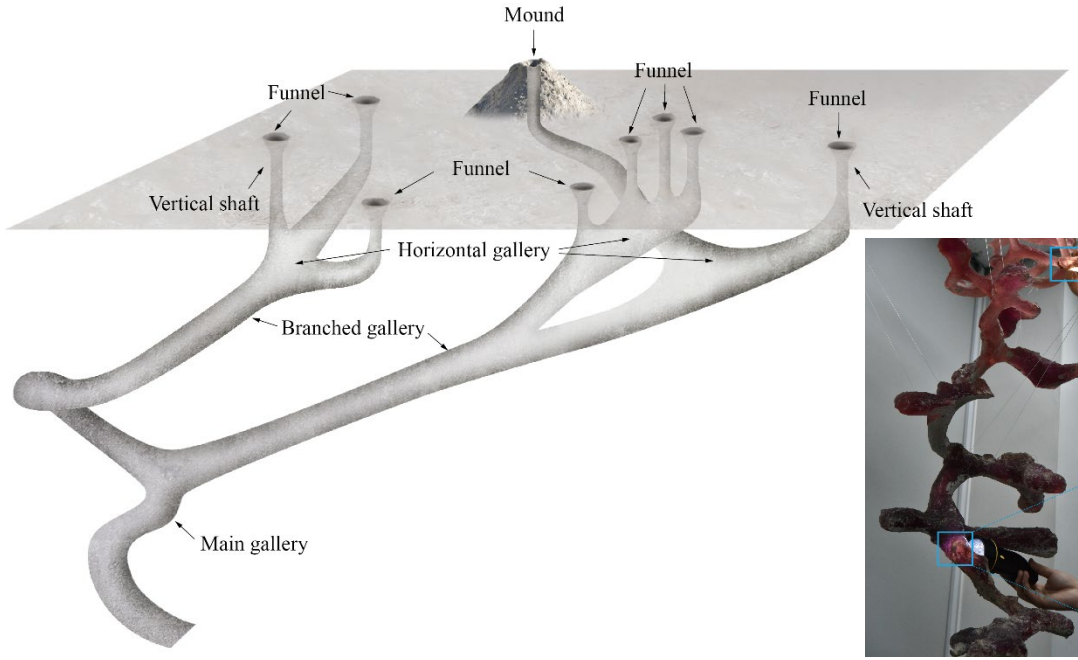


Filtering activity reduced POC and PON by 65% and 60%, respectively

◦ Ecological function









Depth : 145 cm
Surface area : 16,180 cm^2
Volume : 18,163 cm^3

Burrows increase the sediment–water interface by up to 1,511%, the most observed among marine invertebrate burrows

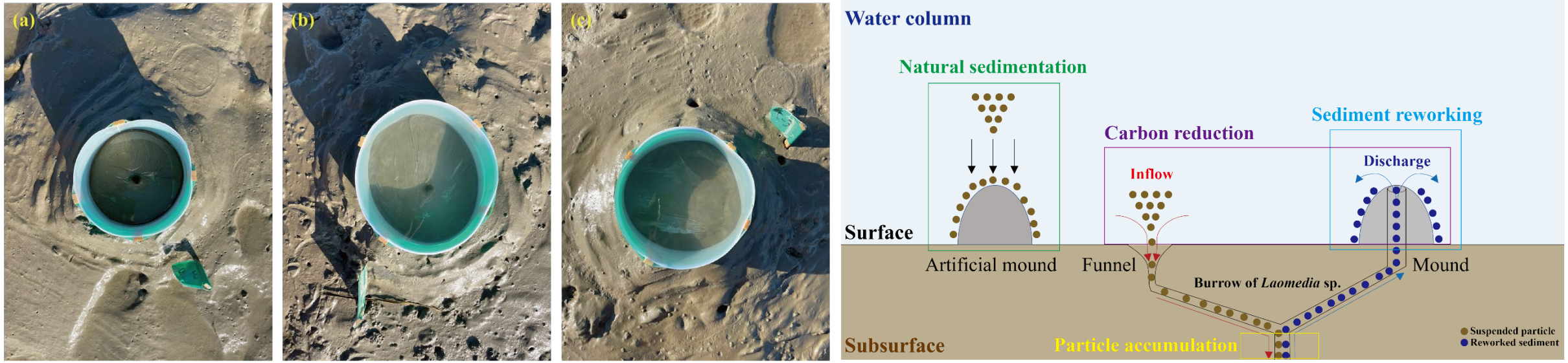


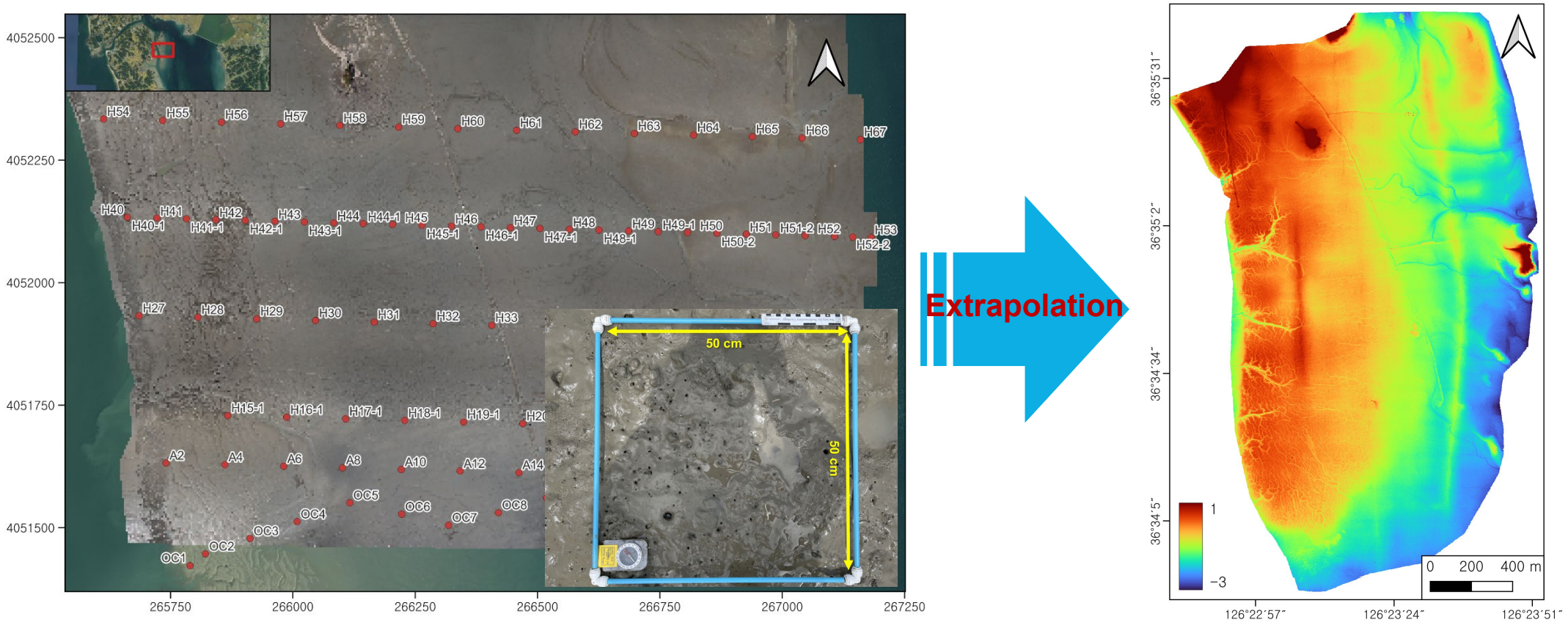
Table 4. Comparison of the organic carbon concentration between suspended particles and reworked sediments (mean ± standard deviation). Significant differences based on the *t*-test at $p < 0.05$.

	Organic Carbon Concentration over the Entire Sampling Period (mg g^{-1})					Mean Organic Carbon Concentration (mg g^{-1})
	1st	2nd	3rd	4th	5th	
SP	9.94	6.29	5.32	6.17	7.16	6.98 ± 1.78
RS	2.42	2.09	1.95	2.41	2.20	2.22 ± 0.20
p value						<0.05

SP: suspended particles, RS: reworked sediments.

Organic carbon content of suspended particles was reduced by 68% → Exploring new blue carbon potential

◦ Ongoing limitations

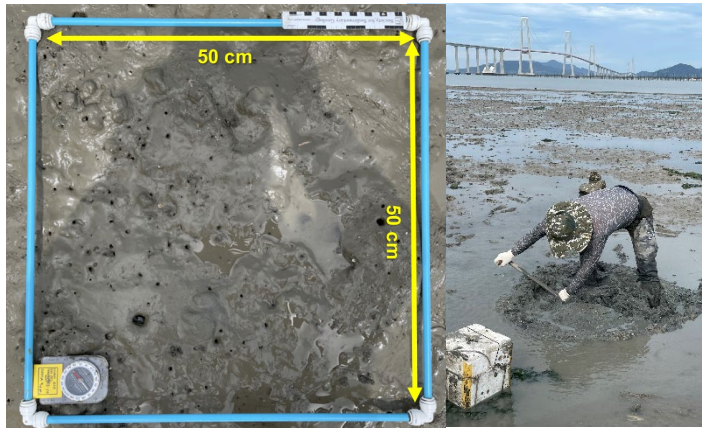


Lee et al., 2023

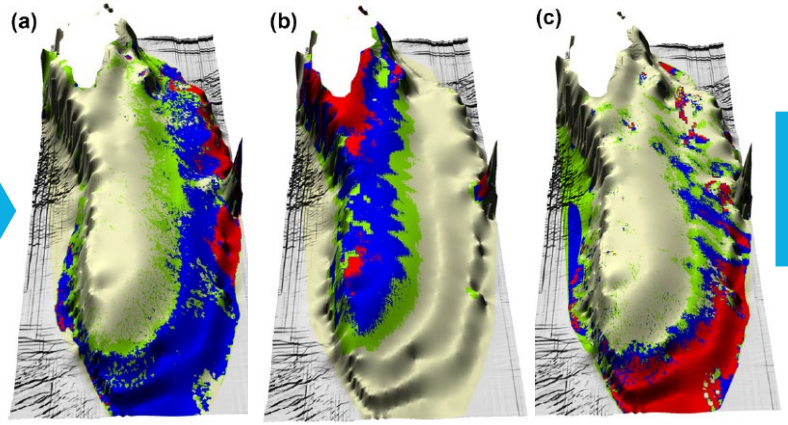
- ▶ **Inaccuracies and uncertainties that occurs when expanding point data to spatial data**
- ▶ **Lack of representativeness of limited survey stations**

◦ Ongoing limitations

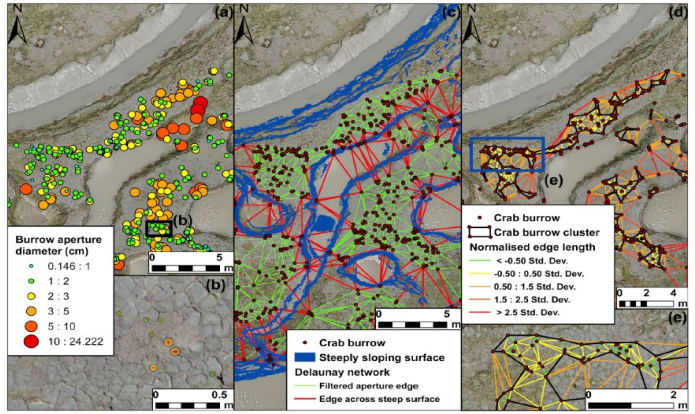
Manual counting of burrows and collection



Complex model equations



Drone and AI algorithm



- ▶ The current manual counting of burrows demands significant resources in terms of personnel, time, and effort
- ▶ A model is only an estimation technique; in many cases, it cannot reflect the natural state
- ▶ Research employing drones and AI has commenced recently; however, their utilization in the study of tidal flats remains inadequate

◦ Macroinvertebrates

Protected species



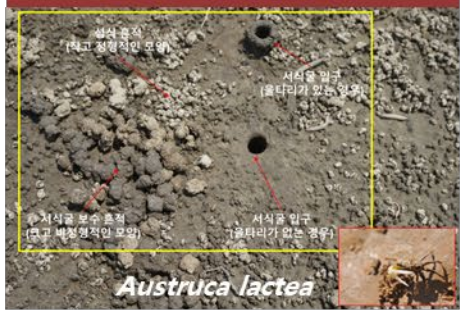
Paraleonnates uschakovi

Protected species



Ocypode stimpsoni

Protected species



Austruca lactea

Protected species



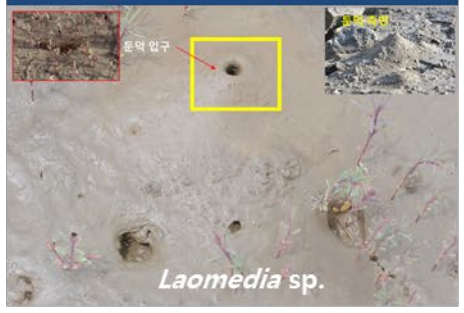
Scopimera longidactyla

Dominant species



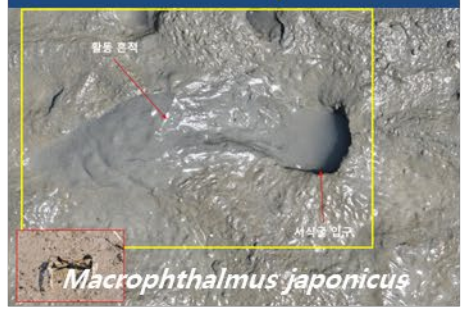
Uca arcuata

Dominant species



Laomedia sp.

Dominant species



Macrophthalmus japonicus

Dominant species



Macrophthalmus dilatatus

Dominant species



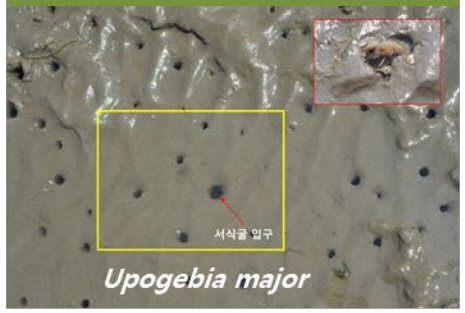
Ilyoplax pingi

Dominant species



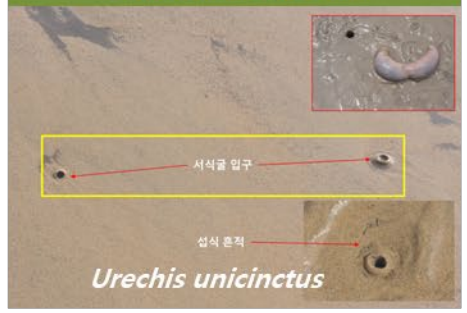
Bullacta exarata

Fisheries Species



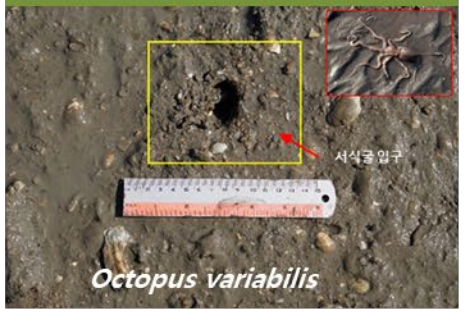
Upogebia major

Fisheries Species



Urechis unicinctus

Fisheries Species



Octopus variabilis

Fisheries Species



Sinonovacula constricta

Fisheries Species



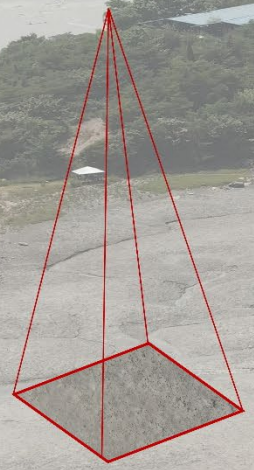
Boleophthalmus pectinirostris

Species-specific burrow opening morphology and activity traces

◦ Advanced approach

Drone image





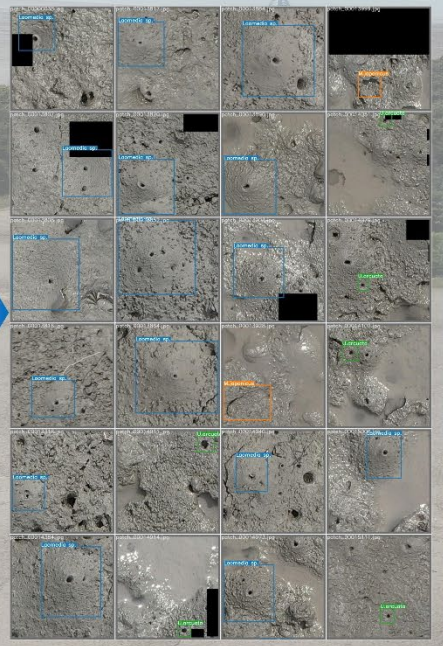
Captures high-resolution aerial images for orthograph

Orthophoto



Generates high-resolution orthographs for the training and validation datasets

AI model training



Develops an AI model trained on burrow openings using biogenic features for multiple species

Object detection

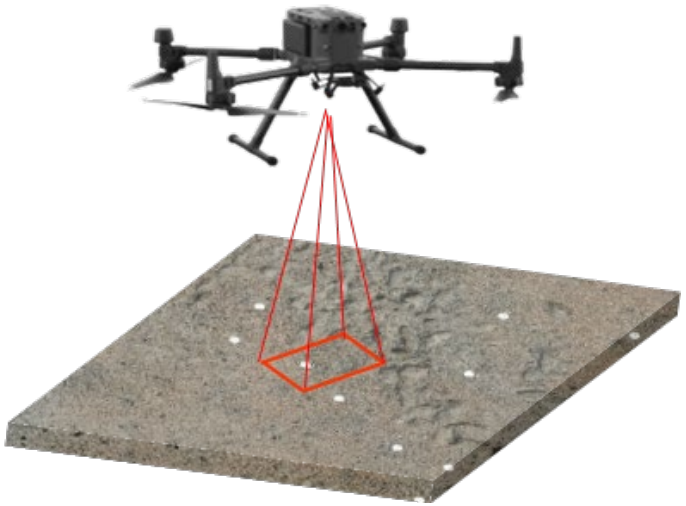


Establishes broad-area spatial data on the abundance of multiple species through burrow detection using drones and AI model

◦ Advanced approach

◦ Drone image

Low altitude flight



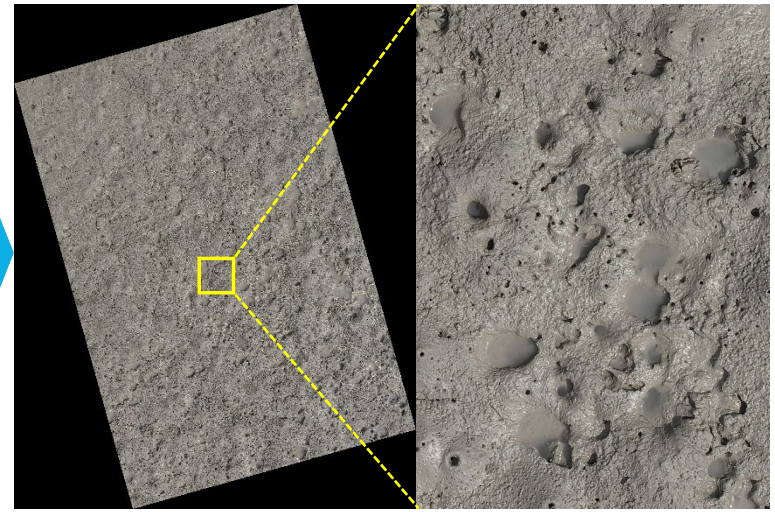
▶ Flight altitude of 5 m from the ground

High resolution image



▶ Ground Sample Distance : 0.6 mm

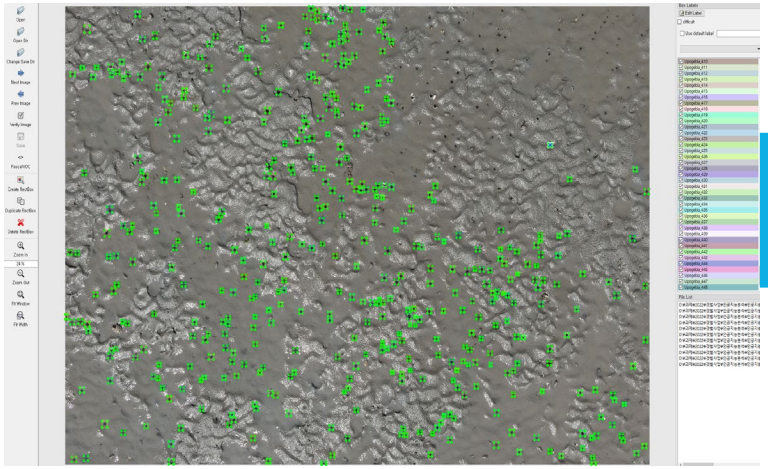
Orthograph



▶ Ground Sample Distance : 0.6 mm

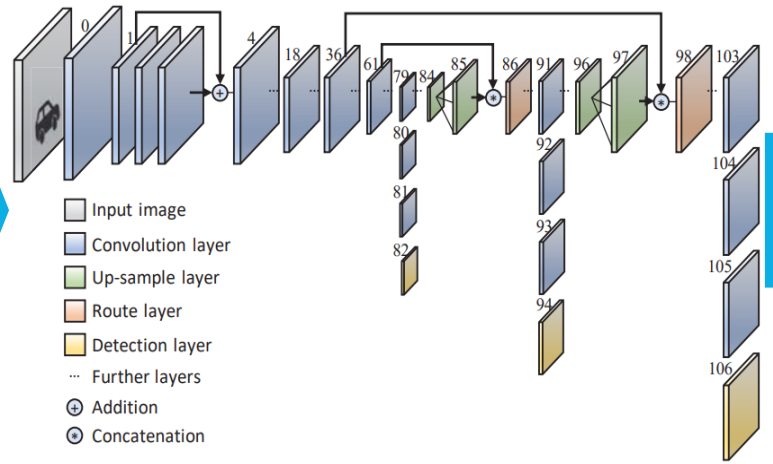
◦ Training and Prediction

Labeling



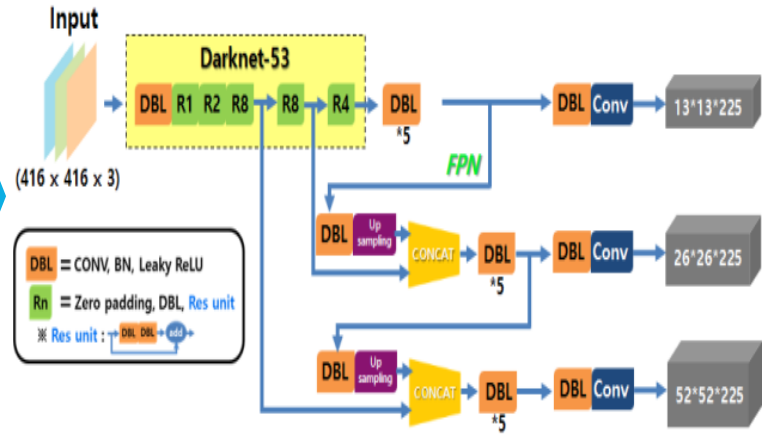
▶ Labeling of burrow opening including biogenic features using python labelimg

Training



▶ Training of labeled image using Yolo network

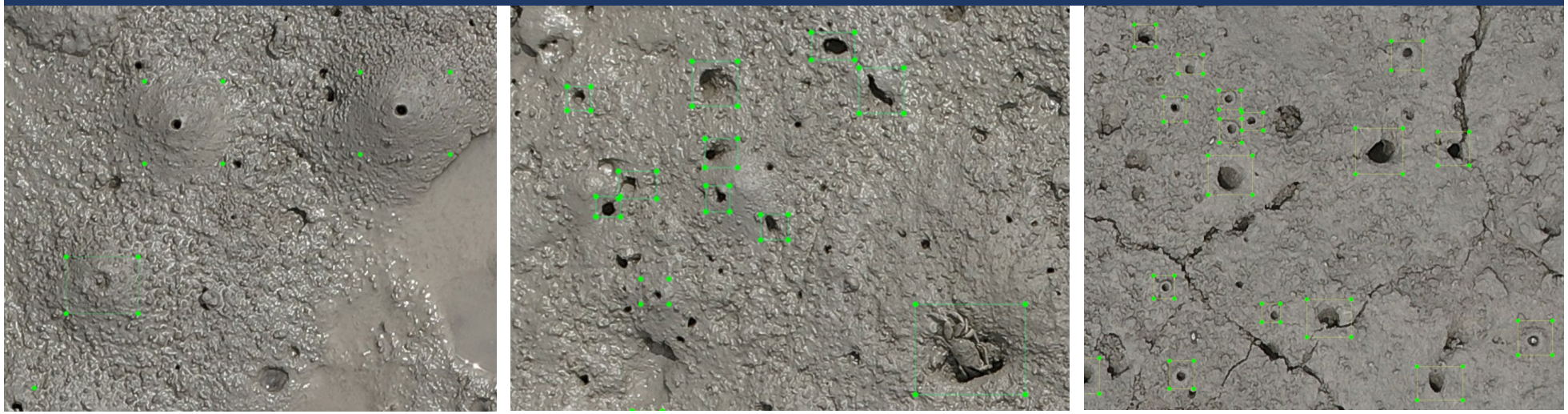
Prediction



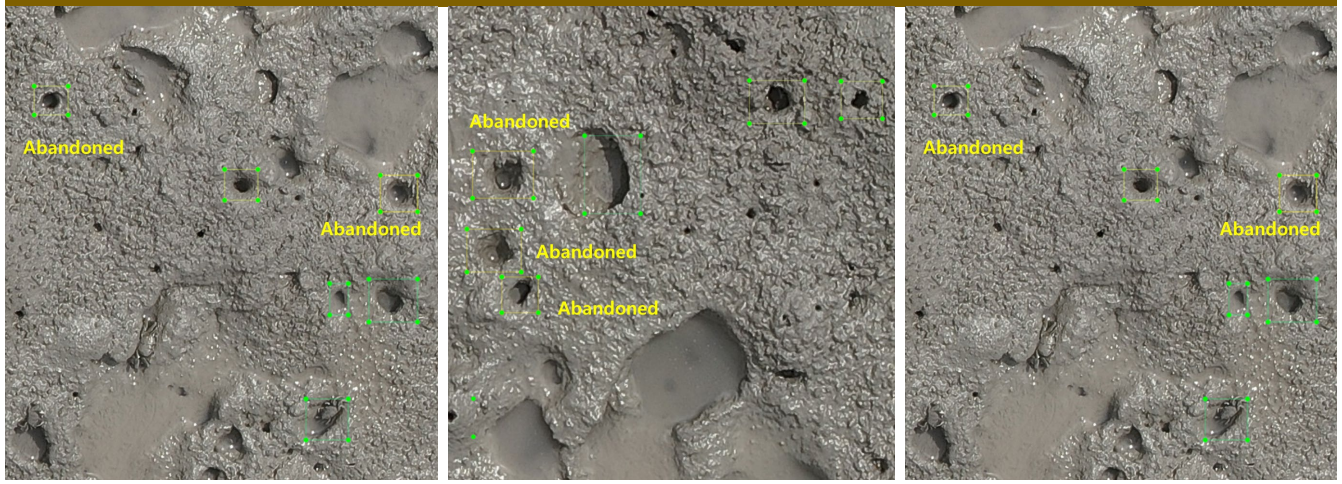
▶ Object detection with classification using Yolo network

Training dataset

Ground truth



Abandoned



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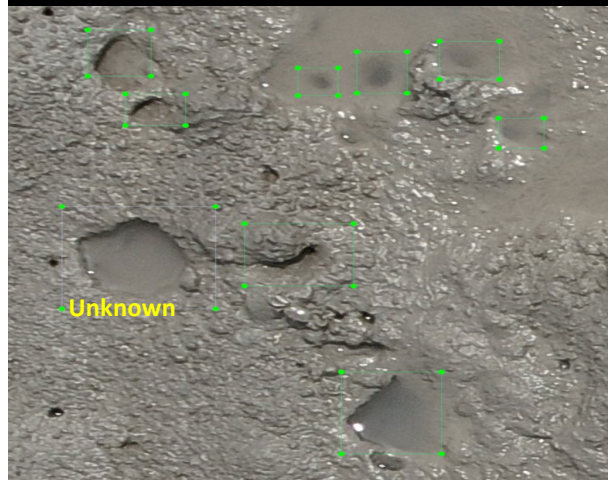
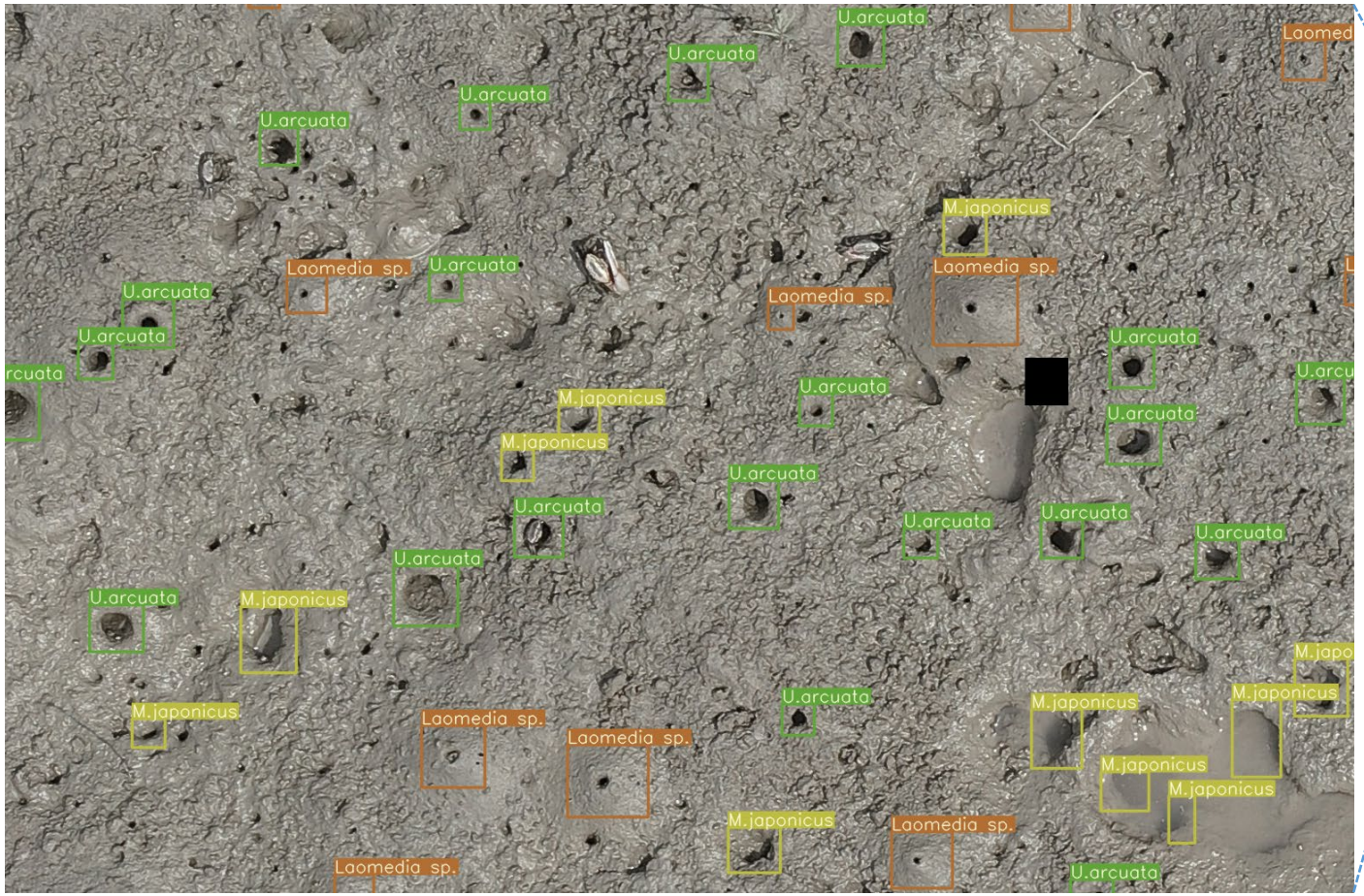


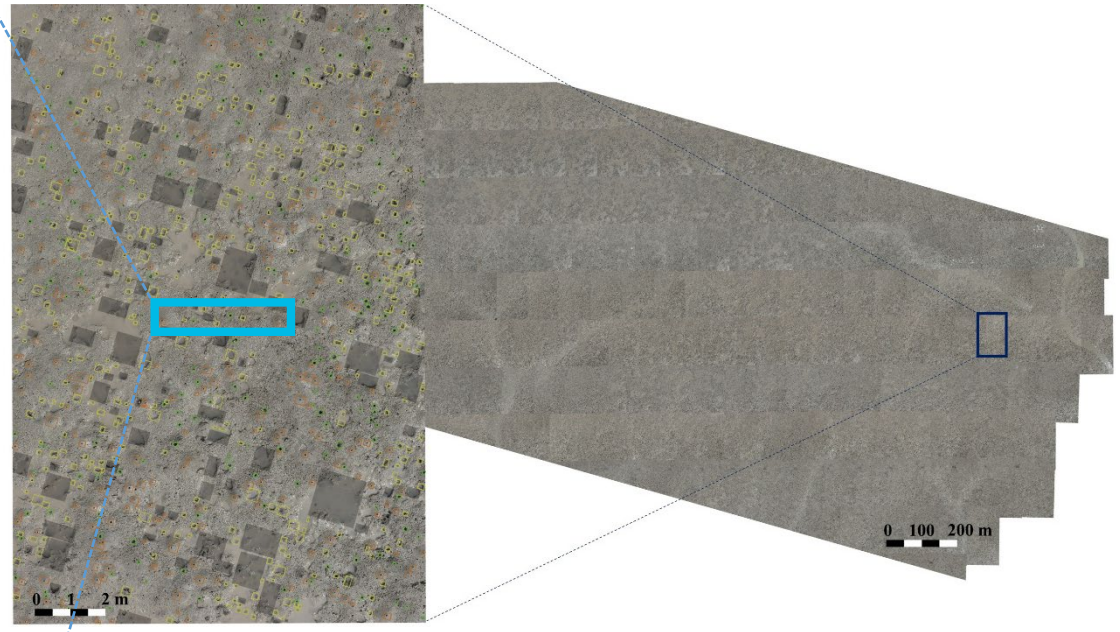
Development of diverse training datasets based on species-specific ecological characteristics

◦ Object detection and classification



◦ Object detection and classification







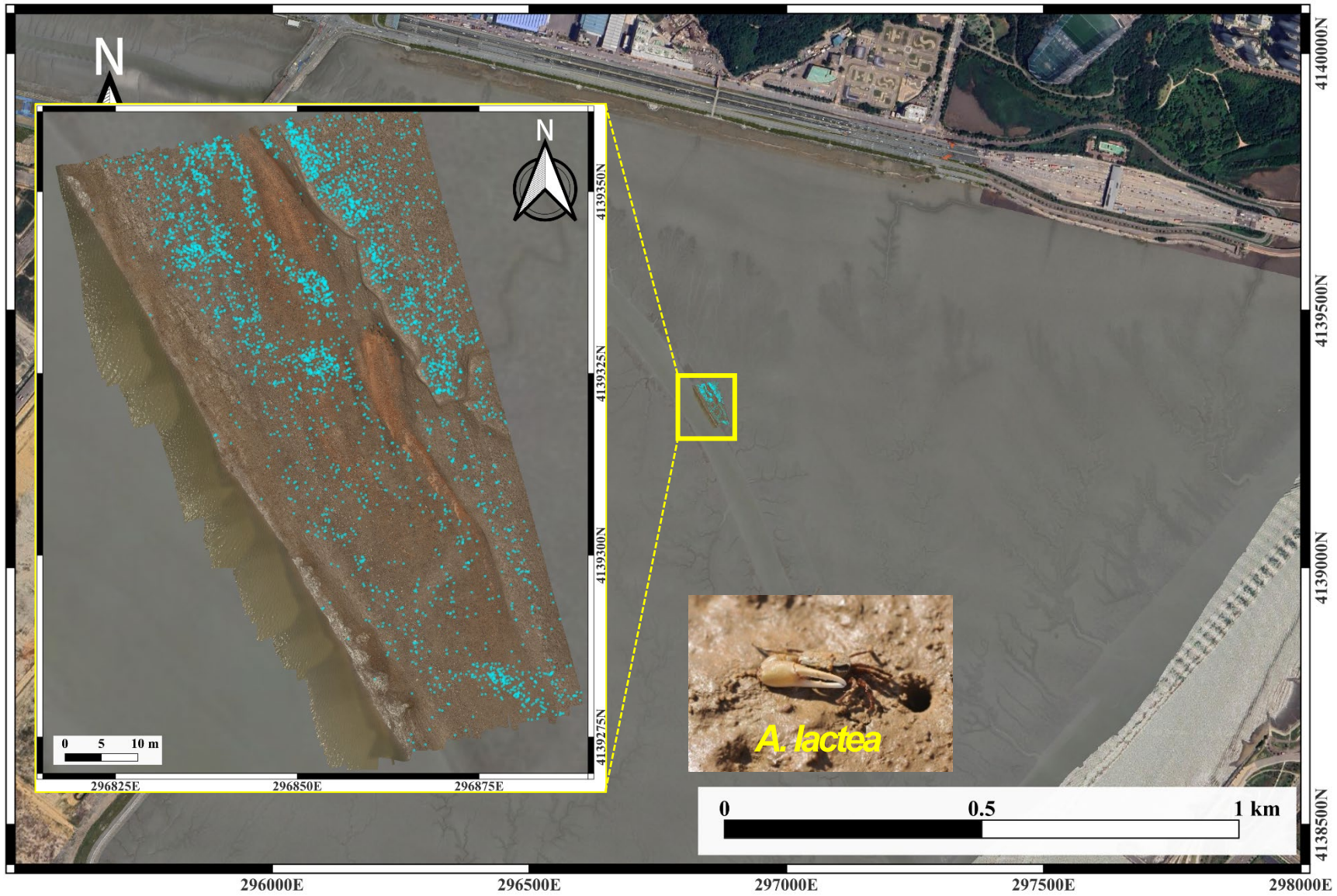




Mean detection accuracy : 85%

◦ Detection accuracy

Species	Training data	Validation data	Precision	Recall	F1-score
Sinonovacula constricta	6,700	383	0.84	0.84	0.84
Laomedia sp.	4,172	205	0.88	0.88	0.88
Urechis unicinctus	9,587	2,474	0.97	0.96	0.97
Macrophthalmus dilatatus	7,795	1,207	0.82	0.83	0.83
Uca arcuata	7,425	179	0.79	0.80	0.80
Ocypode stimpsoni	3,462	238	0.81	0.96	0.88
Upogebia major	4,810	198	0.92	0.93	0.93
Macrophthalmus japonicus	21,718	701	0.77	0.77	0.77
Austruca lactea	12,731	538	0.78	0.77	0.78
Paraleonnates uschakovi	2,544	212	0.75	0.62	0.68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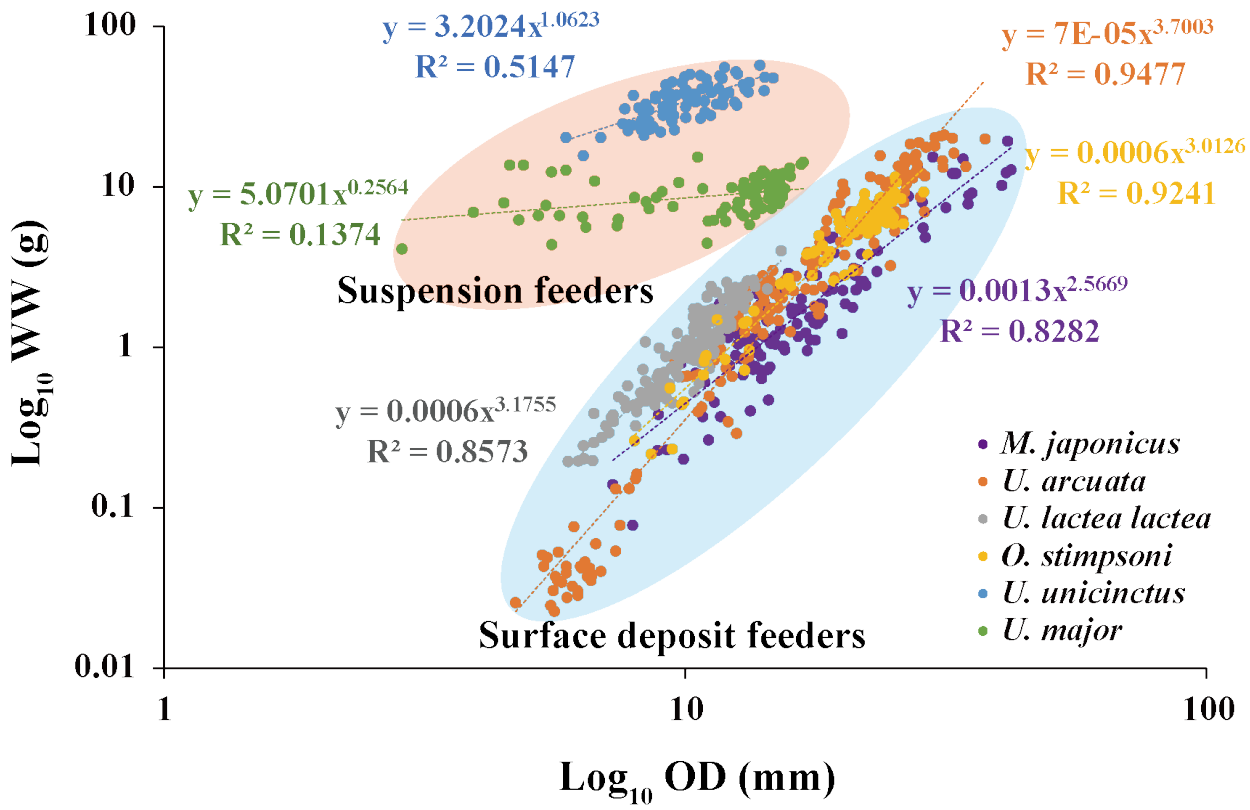
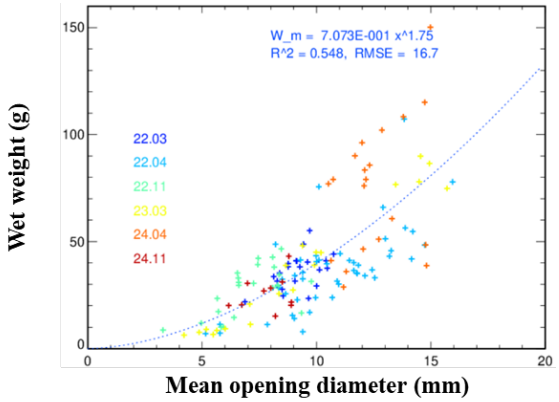
296000E
296500E
297000E
297500E
298000E
4140000N
4139500N
4139000N
4138500N

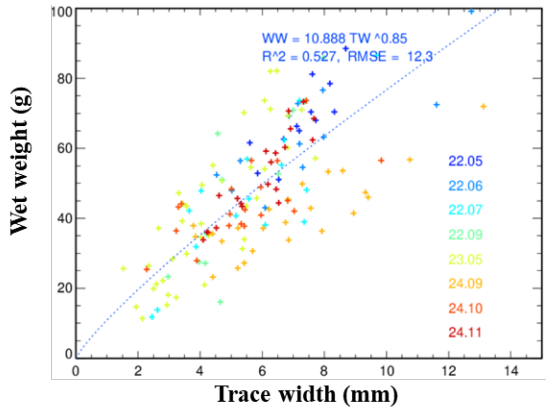

2023


2025
Habitat shift
Shift

◦ Biomass estimation







A significant correlation between the burrow opening dimension and biomass

◦ Biomass estimation

Pre-processing

Geo *.TIFF

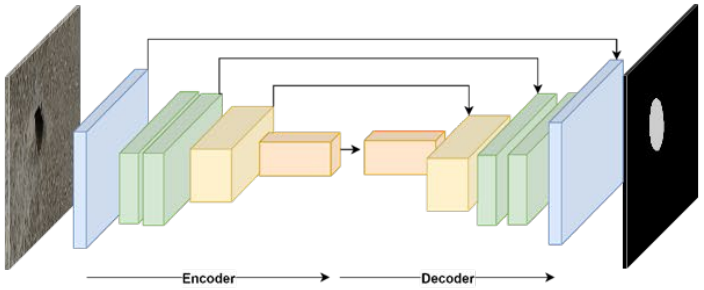
cropping

256 x 256
image Patches

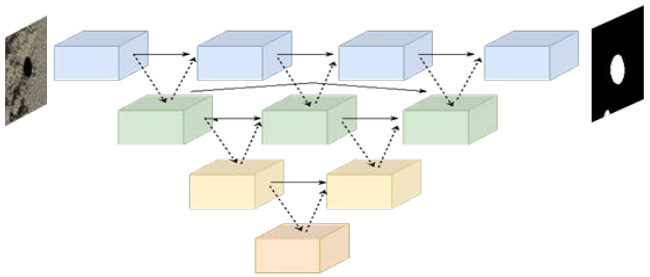
Image Labeling

Dataset

Training



U - net



U – net ++

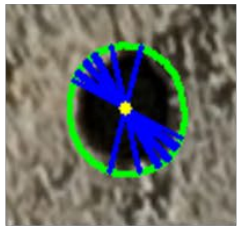
post-processing

Prediction

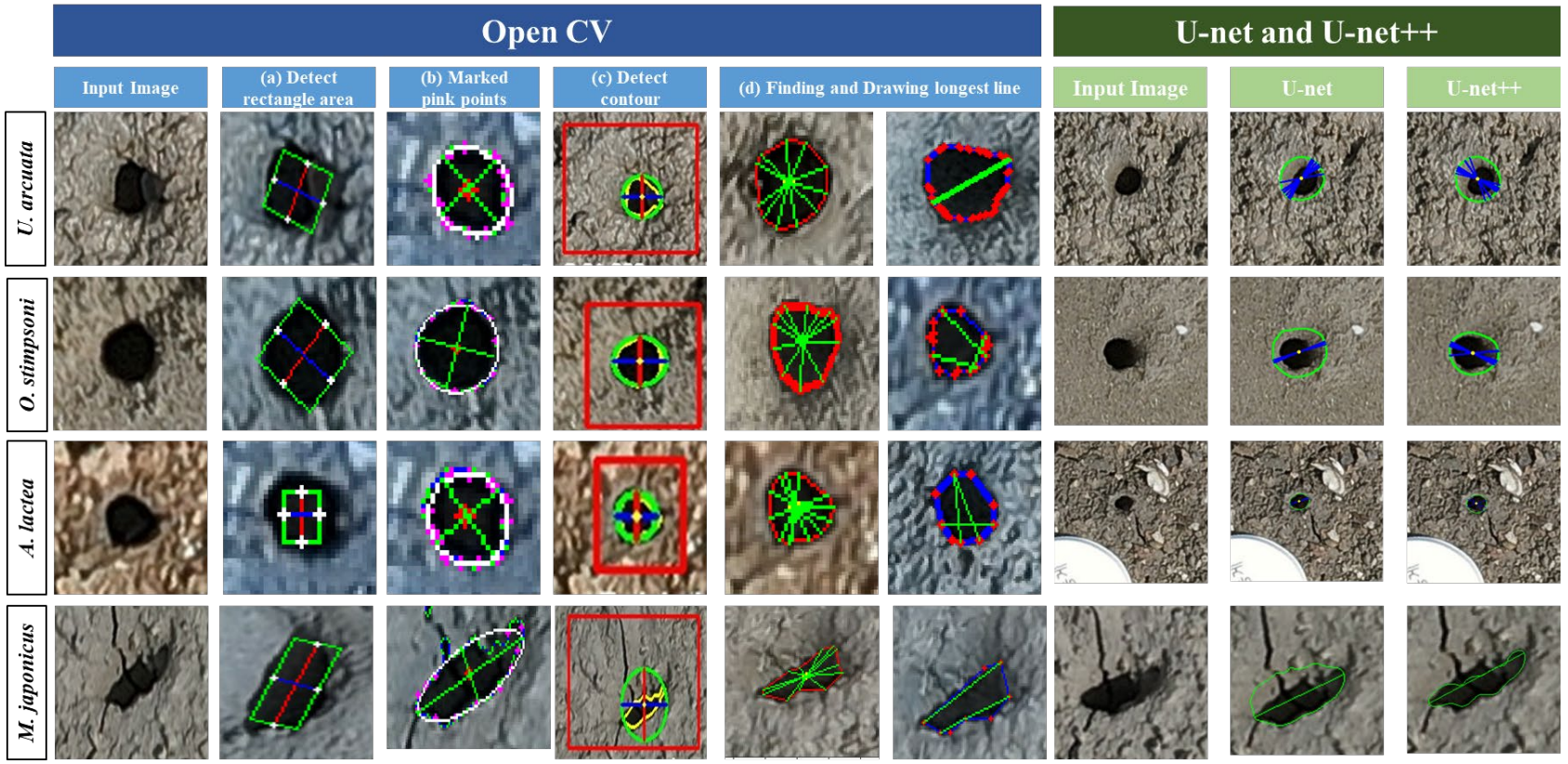
Applied OpenCV

Calculating Object Size

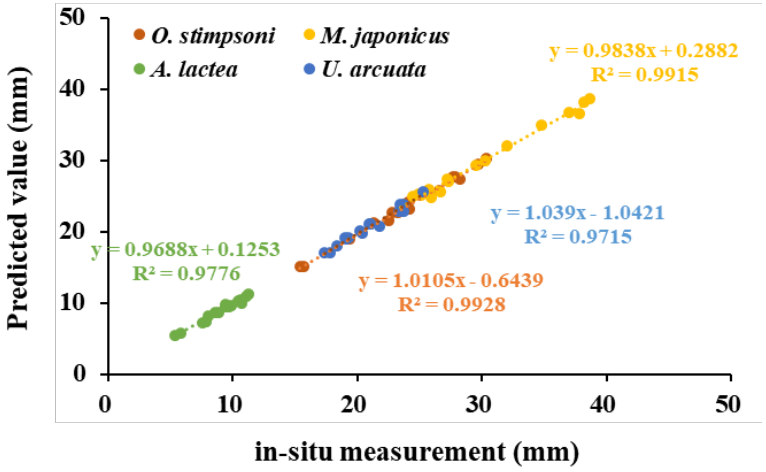
Final Output



◦ Biomass estimation

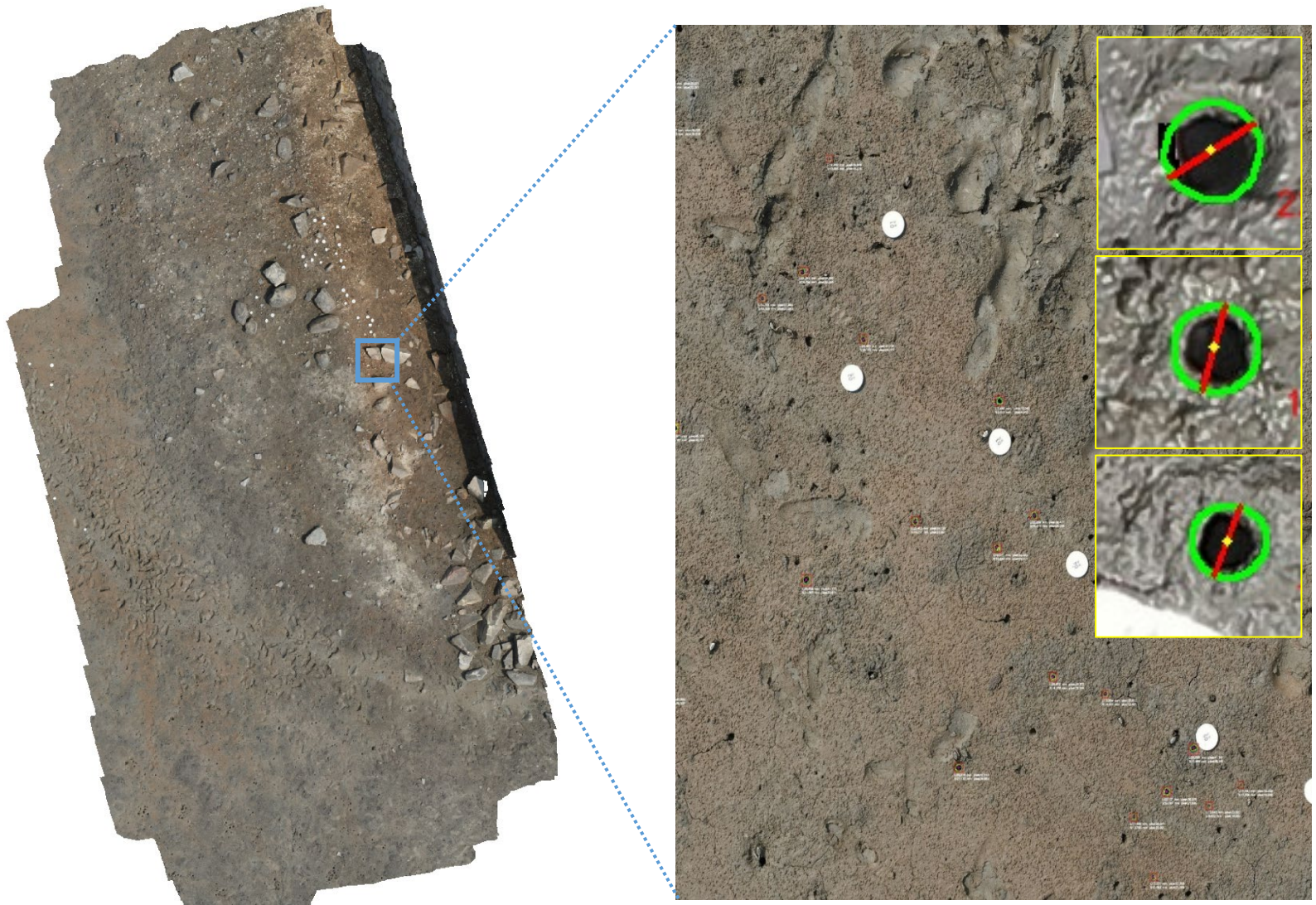


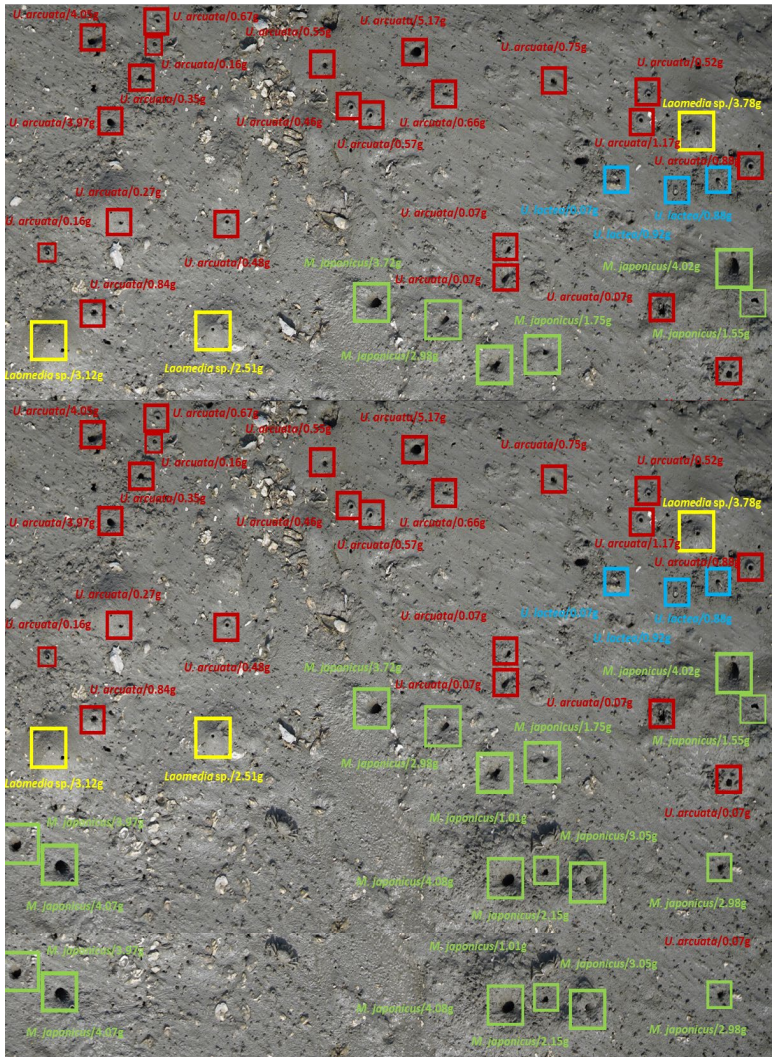
Species	Open CV	U-net	U-net++
U. arcuata	0.49	0.45	0.97
O. stimpsoni	0.73	0.55	0.99
A. lactea	0.54	0.45	0.98
M. japonicus	0.36	0.60	0.99



High accuracy in estimating species-specific burrow opening dimensions

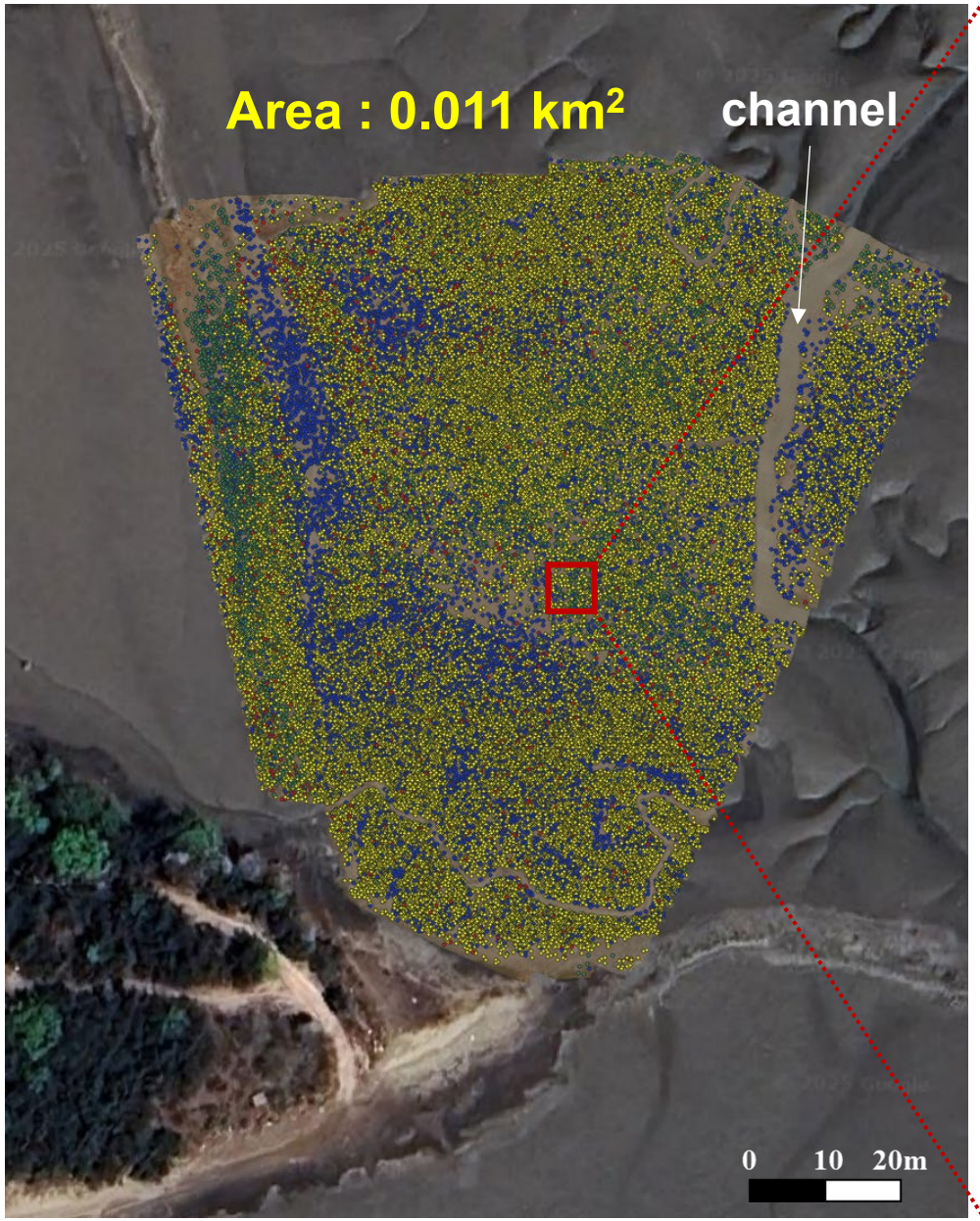
◦ Biomass estimation

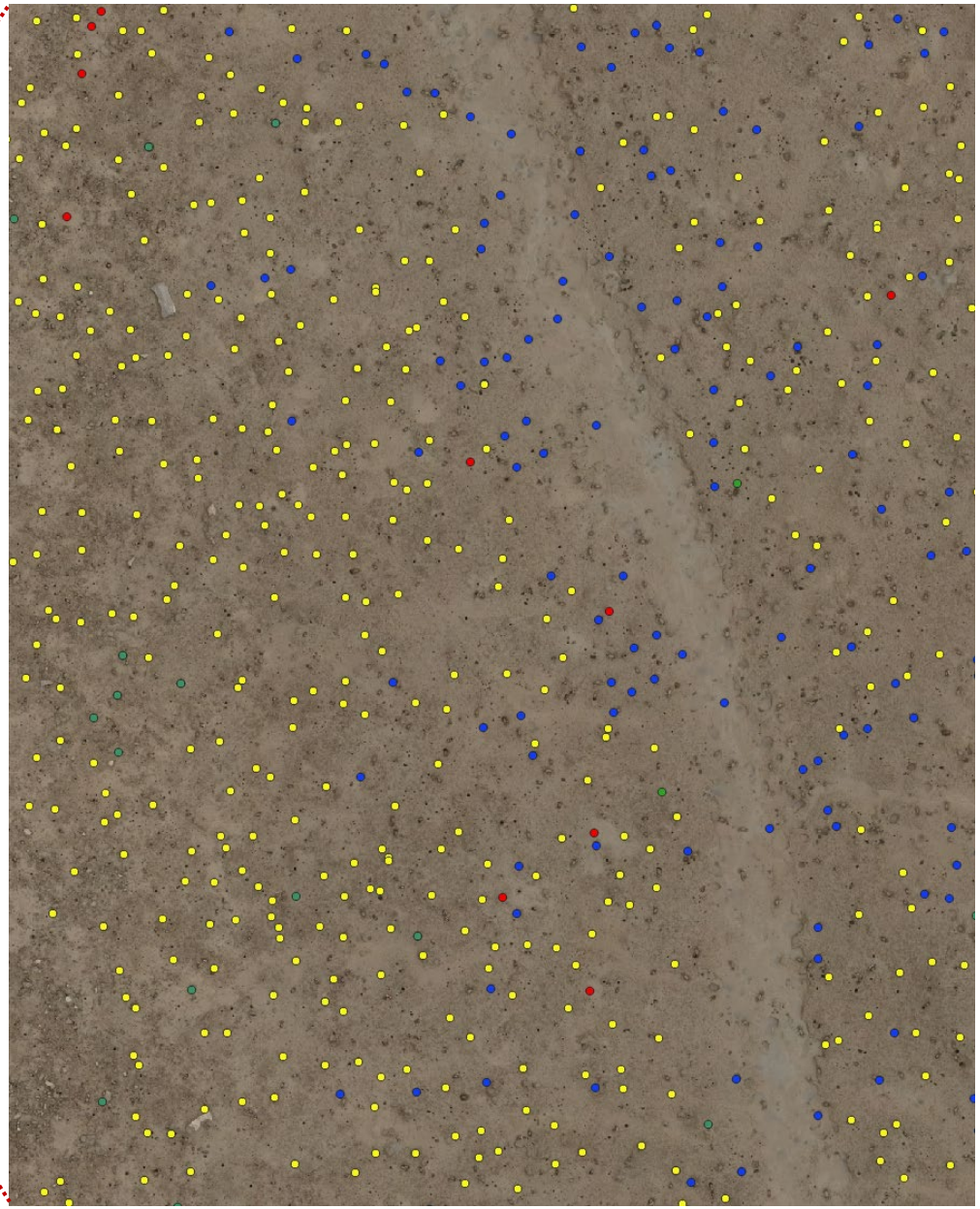




AI-based biomass estimation and spatial mapping

◦ Spatial information















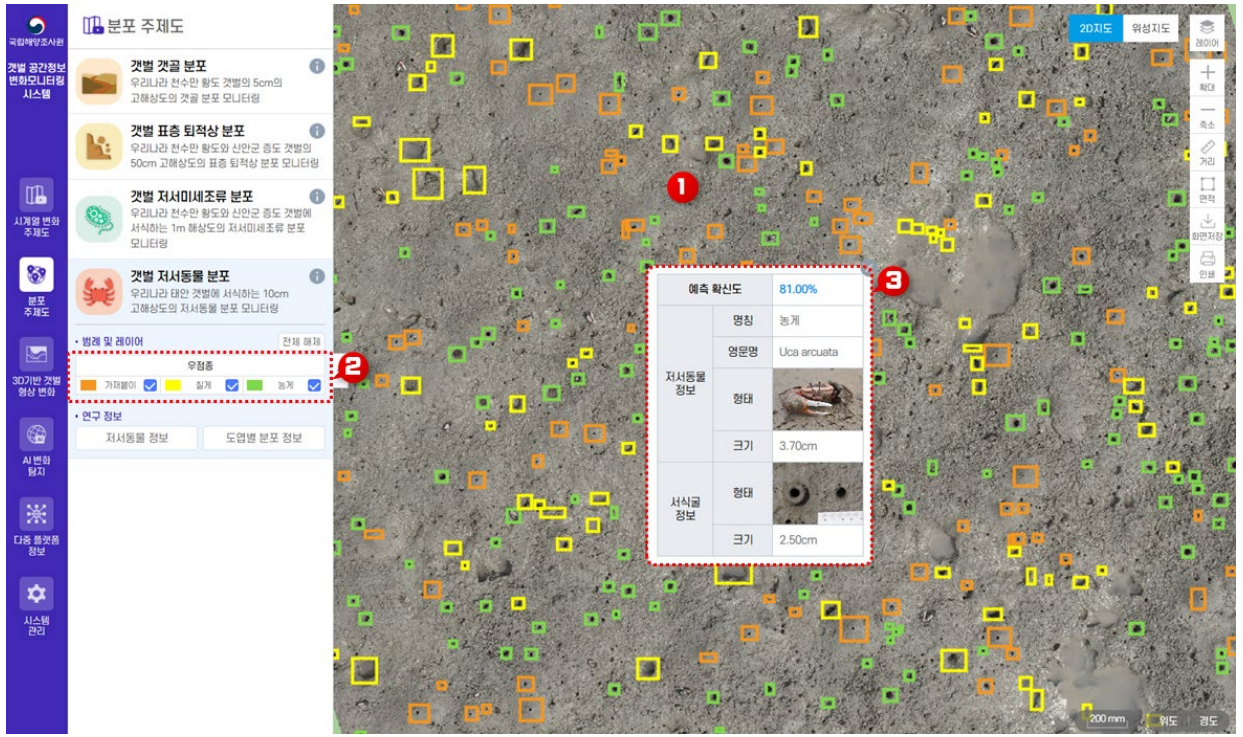
10 kgC d^{-1}, 1.4 kgN d^{-1} removal

◦ Spatial information visualization

바다에서 찾는 국민의 행복,
인류에 공헌하는 해양과학기술

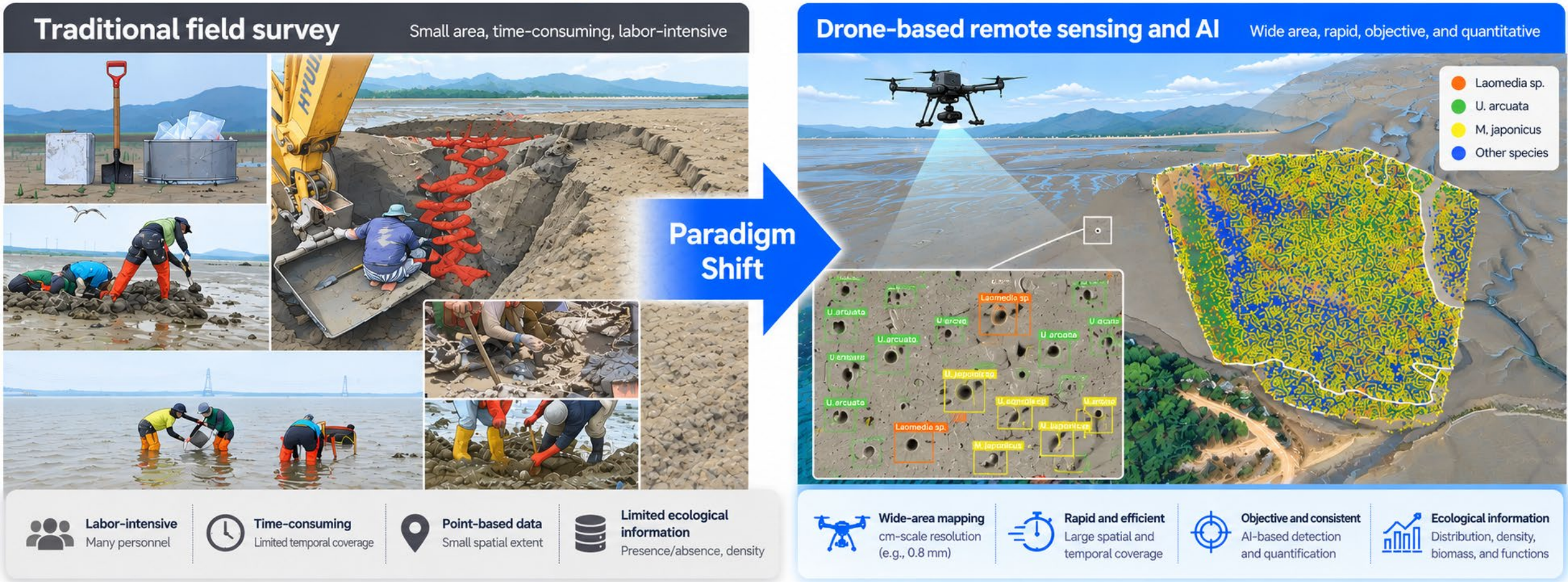
KIOST 한국해양과학기술원





Development of a web-based digital platform for tidal flat spatial information services

◦ Conclusion



AI-generated image



Thank you for your attention



playersjh@kiost.ac.kr



