Final Report

Brilliant Marine Research Idea 2022

This report should be submitted <u>no later than 28 February 2023</u> via filantropie@vliz.be and consists of the following documents:

- A final report listing the work done and the problems encountered. This report will be made available online. If any of the tasks has not been completely finished, the report should clearly mention this, including a short explanation. max. 5 pages
- An overview of all expenditures including invoices.
- A set of five pictures (low resolution in this document). The five high resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be. Pictures should be free from use - to upload on the VLIZ website and to use in VLIZ communications.

Keep in mind that VLIZ should be mentioned in the acknowledgements of publications following the results of this Brilliant Marine Research Idea.

1. General information

Title of the idea	Unravelling the architecture of Chinese mitten crab burrows using non-intrusive techniques
Name PhD student	Heleen Keirsebelik
Name supervisor	Jonas Schoelynck
Flemish University or University College	Universiteit Antwerpen

2. Brilliant Marine Research Idea – Report about the activities

Abstract

The Chinese mitten crab (*Eriocheir sinensis*) is listed as one of the 100 worst invasive species globally. This species is known to have severe ecological and economic impacts. One of the impacts that is often brought up is its burrowing behaviour, although the impact of their burrows on the environment has never been studied in detail. We hypothesize that in marshes, high burrow densities increase the erosion of creekbanks (due to increased lateral erosion and mass failure) and alter the functioning of the marsh in terms of water purification, porewater fluxes and nutrient cycling.

In order to assess their effects, we first need to characterise what is there: the morphology of the burrows, their interconnectivity and the extent of crab burrow networks inside the creekbank. Typically, the morphology of burrows is studied by making epoxy casts. However, this method is not suitable to quantify the attributes of the burrow network on a larger scale. Moreover, it is very destructive to excavate the casts and therefore this method is not appropriate in the natural areas that are studied in this project.

The objective of this study is to map and measure the architecture of the burrow network in a non-intrusive manner using structure-from-motion photogrammetry and ground-penetrating radar (GPR). The methods are tested in both a natural and a restored tidal marsh in the Scheldt estuary. The soil of the restored tidal marsh was historically compacted by agricultural equipment, while the soil of the natural tidal marsh consists entirely out of tidally deposited sediments. We

hypothesized that the crab burrow network would be more extensive in the compact subsoil of the restored tidal marsh, compared to the more loosely packed soil in the natural marsh.

In each field site, six creekbank sections of 3 m length were studied. At each section, soil samples were taken to characterise the physical properties of the soil (including; dry bulk density, moisture content, grain size distribution and organic matter content). Based on photogrammetry, 3D models of every creekbank section were created in Agisoft Metashape every two months over a one year period. From the time series of 3D models of every section, the changes in the number of burrow openings, their morphology and the topography of the bank can be assessed over time. GPR is a method to image the soil subsurface based on the reflection and scattering of electromagnetic waves by the soil. The propagation velocity of the waves is determined by the relative permittivity contrast of the soil. This means that a change in soil properties (e.g. the presence of crab burrows) alters the time that the wave travels through the soil profile, which can be used to calculate the depth of a change in soil properties. The GPR data can be processed and converted into 3D volumetric representations of the crab burrow network.

As expected, the compact soil of the restored tidal marsh can harbour larger crab burrow densities compared to the natural tidal marsh. Preliminary results indicate that photogrammetry is a suitable method to map the surface of creekbanks and allows the evaluation of temporal variation in burrow openings and topography of the bank. A downside of the technique is that it is time-consuming to construct a high-quality model. The wet and clay-rich environment of the tidal marshes proved to be a difficult set-up for the GPR, however, the first trial was successful. Further analysis of the data will provide more knowledge about the case-study of the bioturbation by the Chinese mitten crab. Ultimately, the insights gained in this project by testing the techniques in new environments can be applied to other bioturbating species as well.

Intro

The Chinese mitten crab (*Eriocheir sinensis*) is a catadromous species that spends part of its life cycle in freshwater habitats and reproduces in marine areas. Listed as one of the 100 worst invasive species globally, this species is known to have severe ecological and economic impacts. One of the impacts that is often brought up is its burrowing behaviour, although the impact of their burrows on the environment has never been studied in detail.

These burrows have been occasionally described before, but never in large detail, nor for cases with such high densities that are witnessed in Flanders (up to 100 holes/m², pers. obs.). I hypothesize that such intense bioturbation could have a significant impact on the erosion of the banks through (i) the direct effect of excavating the burrows (ii) enhanced lateral erosion due to increased surface roughness and (iii) increased mass failure due to instability of the banks. Furthermore I hypothesize that the burrows could affect the functioning of the marsh in terms of water purification, porewater fluxes and nutrient cycling. Crab burrow networks can increase soil–groundwater interactions and drain substantial amounts of porewater to tidal creeks. The morphology, interconnectivity and the extent of crab burrow networks determine both the stability of the creek banks and the performance of nutrient cycling through this groundwater discharge.

Preliminary measurements by means of resin epoxy casts of a few burrows, showed that burrows are highly interconnected and form a dense network inside the creek banks. This method is however neither practical nor fully quantitative, since large volumes of epoxy resin are needed, and burrow castings are often incomplete. Furthermore, it is extremely destructive as the creek banks need to be excavated to extract the epoxy castings. Therefore, the method is not suitable to quantify the network on a larger scale. Here, non-intrusive methods are needed.

The objective of this study is to map and measure the architecture of the burrow network in a non-intrusive manner using

Structure-from-Motion (SfM) photogrammetry and ground-penetrating radar (GPR). This will provide highly valuable knowledge about the case study of the mitten crab but will also deliver fundamental insights that can be applied to other bioturbating species such as invasive crayfish or beavers. The Chinese mitten crab is an interesting case study as its abundance and potential impact are high in Flanders. Understanding this potential impact is crucial to advance tidal marsh restoration along the Scheldt. Furthermore, this successful invader has spread worldwide, thus knowledge gained will be beneficial beyond Flanders as well.

Material & Methods

- Two study sites: Lippenbroek (a restored tidal area in Hamme) and Notelaer (a natural tidal area in Bornem)
- In each study site: six creekbank sections along the main creek, about 3 m long and 1 m high (total of twelve sections). The corners of each section were marked in the field with metal rods. The rods were used as markers for the photogrammetry models.
- At the beginning of the study all characteristics of the studied sections were recorded and measured: creek width, average depth creek, max depth creek, bank angle, sediment characteristics of the creekbank (dry bulk density, moisture content, grain size distribution and organic matter content), vegetation, … In spring and in autumn a shear vane was used to estimate the shear strength of the sediment.
- Every section was visited every two months over a one year period:
    - All burrows in each section were counted and measured.
    - Locations of the markers for photogrammetry were recorded using an RTK GPS. Distances between the markers were measured with measuring tape for validation of the photogrammetry model.
    - All sections were photographed (+- 400 pictures per section). These pictures are processed with Agisoft Metashape to create dense clouds. The dense clouds of the same plot are compared over time to assess the evolution of the burrows, erosion, etc.
- All studied sections were scanned once with a LiDAR application on an Iphone in spring (additional to the photogrammetry).
- In spring, we tested the ground-penetrating-radar (GPR) on one extra section in Lippenbroek. The GPR was used on top of the marsh (horizontally) and on the bank itself (vertically). Additionally, sediment samples were taken at different depths, all burrows were counted and measured, pictures were taken for photogrammetry and a scan of the bank was made with a laser scanner.

Results/Conclusions

- Data based on the manual measurements and counting of the burrows suggest:
    - Higher burrow densities in the restored tidal area compared to the natural tidal area
    - Burrow densities remained more or less stable in the natural tidal area
    - Burrow densities increased around May in the restored tidal area
    - Burrows openings are generally 3 to 5 cm wide and 2 to 2.5 cm high
- Producing 3D models (Fig. 1) of the topography of the creekbank through photogrammetry worked quite well and the accuracy of the models looks good. Not all pictures have been processed yet with Agisoft Metashape. Creating high-quality models is time consuming. More time is necessary to create all the models and assess their evolution over time.

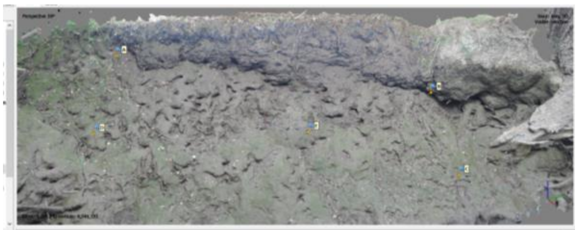

Figure 1. Screenshot of 3D model of bank produced in Agisoft Metashape.

- Trials with a LiDAR app were fast and successful, however, the models seem to lack the detail necessary for the purpose of our study.

- The GPR was not rented as indicated in the proposal, but borrowed through collaboration with Lieven Verdonck (Archéologie et Philologie d'Orient et d'Occident (AOrOc), Ecole normale supérieure, Paris). The collaboration is a big benefit because of the expertise of Lieven. The downside is that we did not do as many measurements as proposed in the proposal. So far, one trial has been conducted in the field during which we tried two different set-ups. The first set-up (horizontally on the marsh) did not deliver useful results. The second set-up (vertically on the creekbank) gave promising results (Fig. 2). Data analysis is ongoing.

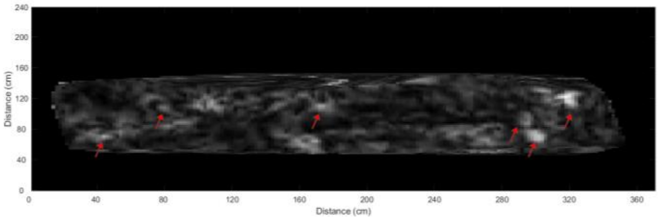

Figure 2. Cross-section of GPR results at a depth of 35 cm. Red arrows indicate potential crab burrows.

3. Overview of the expenditures

Describe in detail how the requested fund was spent within the implementation period (1 March 2022 and 28 February 2023). Be as specific as possible.

1) Consumables (total = 1302.35 euro)

Amount (euro)	What
66.62	Construction material to build wooden frame for GPR
508.9	Olympus Tough TG-6 camera (412.40 euro + 8.18 euro shipping cost + 88.32 euro VAT)
26.99	SD card sandisk
14.95	Isomo cubes as size reference for photogrammetry pictures in the field
518.22	Agisoft Metashape licence
166.67	Overhead UAntwerpen

2) Mileage (total = 563.78 euro)

Date	Distance (km)	Location	Rate (euro/km)	Amount (euro)	Who	Why
4/04/2022	82	Notelaer, Lippenbroek	0.3707	30.40	Heleen	Fieldwork (Notelaer + Lippenbroek, incl. RTK GPS)
5/04/2022	83	Notelaer, Lippenbroek	0.3707	30.77	Heleen	Fieldwork (Notelaer + Lippenbroek)
13/05/2022	70	Lippenbroek	0.3707	25.95	Heleen	Fieldwork (Lippenbroek, incl. GPR)
16/05/2022	71	Lippenbroek	0.3707	26.32	Heleen	Fieldwork (Lippenbroek, incl. GPR)
17/05/2022	82	Notelaer, Lippenbroek	0.3707	30.40	Heleen	Fieldwork (Notelaer + Lippenbroek, incl. shear vane)
18/05/2022	98	Lippenbroek	0.3707	36.33	Heleen	Fieldwork (Lippenbroek, incl. shear vane)
26/06/2022	70	Lippenbroek	0.3707	25.95	Heleen	Fieldwork (Lippenbroek)
27/06/2022	70	Lippenbroek	0.3707	25.95	Heleen	Fielwork (Lippenbroek)
1/07/2022	50.5	Notelaer	0.417	21.06	Heleen	Fieldwork (Notelaer)
25/08/2022	70	Lippenbroek	0.417	29.19	Heleen	Fieldwork (Lippenbroek)
26/08/2022	70	Lippenbroek	0.417	29.19	Heleen	Fieldwork (Lippenbroek)

29/08/2022	47	Notelaer	0.417	19.60	Heleen	Fieldwork (Notelaer)
30/08/2022	79	Notelaer, Lippenbroek	0.417	32.94	Heleen	Fieldwork (Notelaer + Lippenbroek)
21/10/2022	133	Yerseke (NIOZ)	0.417	55.46	Heleen	Get shear vane at NIOZ
24/10/2022	72	Lippenbroek	0.417	30.02	Heleen	Fieldwork (Lippenbroek, incl. shear vane)
25/10/2022	76	Lippenbroek	0.417	31.69	Heleen	Fieldwork (Lippenbroek, incl. shear vane)
26/10/2022	151	Notelaer, Yerseke	0.417	62.97	Heleen	Fieldwork (Notelaer, incl. shear vane), bring shear vane back to NIOZ
28/10/2022	47	Notelaer	0.417	19.60	Heleen	Fieldwork (Notelaer)

Overall total = 1866.13 euro

4. Pictures

A set of five pictures (low resolution in this document). The five high resolution pictures should be delivered to VLIZ by email to karen.rappe@vliz.be.