

Using eDNA as a baseline for assessment of environmental impacts from CCS and other anthropogenic hazards.

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1 INTRODUCTION & SCOPE OF WORK

Anthropogenic CO₂ emissions are drastically changing the global climate, with multiple consequences such as rising temperatures and ocean acidification (IPCC, 2023). These widespread changes are negatively impacting biodiversity, ecosystem functioning, and the communities that rely on them, prompting efforts to reduce current CO₂ emissions (Zawude Bakure et al., 2022; Campbell-Lendrum et al., 2023).

One proposed method for reducing CO₂ emissions and mitigating climate change is carbon capture and storage (CCS), a technology that involves injecting concentrated CO₂ into suitable geological reservoirs for long-term storage (Roy et al., 2023; Eyitayo et al., 2025). These reservoirs are often located sub-seafloor in coastal areas, which have raised concerns over potential impacts on the marine environment (Damen et al., 2006). For instance, leakage of CO₂ and brine, although unlikely, may affect local ecosystems, while the establishment of connected infrastructures may affect biodiversity on a wider scale (Blackford et al., 2009; Rastelli et al., 2016).

COREu is a pioneering Carbon Capture and Storage (CCS) project demonstrating key technologies at sites in southern and central Europe. One aim is to demonstrate full-scale CCS beneath the Prinos oil field, located in the Kavala Gulf in Greece. Although most research suggests CO₂ leakages may have minor, local and reversible environmental impacts, collection of robust baseline data is still essential for detecting potential changes in biodiversity. Therefore, a central task in COREu is to develop and demonstrate an innovative method for collection of detailed baseline data describing the marine environment prior to CCS activities, using analyses of environmental DNA (eDNA) as a sensitive and non-invasive monitoring tool.

2 METHODOLOGY

To establish a robust biodiversity baseline prior to CCS activities, sediment and water samples were collected three times over one year (summer, autumn and winter) to capture seasonal variation in biodiversity and eDNA. Sampling was carried out along a 22 km transect following the oil pipeline from the shore to beyond the planned CO₂ storage site beneath the oil extraction facilities, capturing nearshore-offshore sediment gradients and areas potentially affected by CCS activities (Figure 1a).

Environmental DNA from all samples is stored in NINAs biobank in Norway. If a CO₂ leak occurs at some point in the future, new samples can be collected after the leakage and compared with the archived baseline material. Targeted analyses using state-of-the-art genetic methods can then reveal if, and to what extent, adverse environmental impacts may have occurred.

To demonstrate the applicability of using eDNA as baseline biodiversity data, a subset of the samples was processed using high-throughput metabarcoding (Figure 1b). The assessments were performed using eDNA metabarcoding focused on benthic macroinvertebrates, Foraminifera and fish species. Both macroinvertebrates and Foraminifera (small, single-celled organisms) have been widely used as bioindicators of human impacts on ecosystems. Foraminifera are particularly useful for CCS monitoring, as they respond quickly to environmental changes such as potential CO₂ leakages. Conventional taxonomical analyses of Foraminifera were also performed to validate the representativeness of the eDNA results.

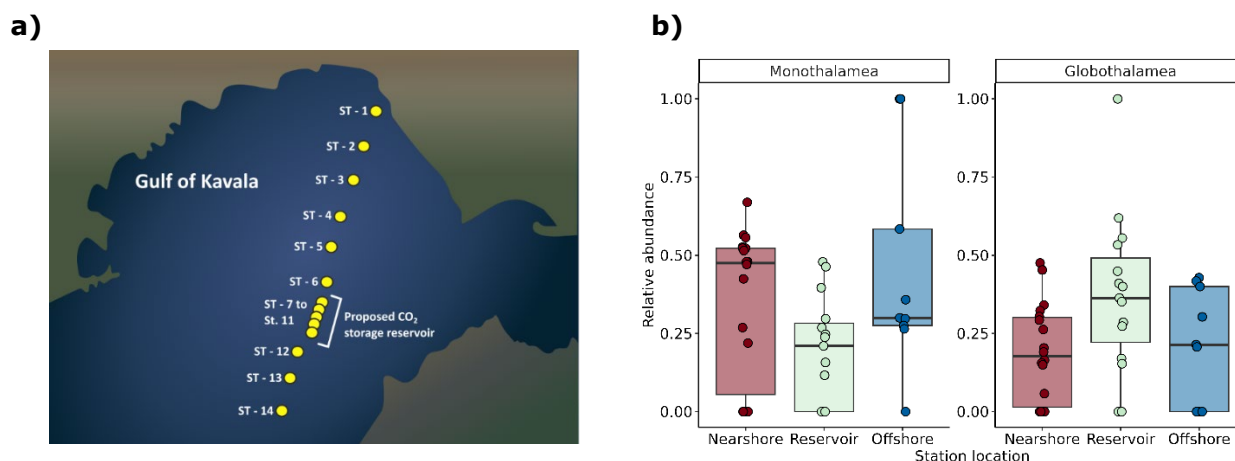


Figure 1. a) Biological and physiochemical data was collected at 14 sampling stations along a 22 km transect. b) the relative read abundance from metabarcoding of the foraminiferal classes *Monothalamea* and *Globobulimina* at stations nearshore (St-1 to St-6), stations near the proposed reservoir (green; St-7 to St-11), and offshore stations beyond the planned storage reservoir (blue; St-12 to St-14). The variation can be explained by environmental parameters, but human impacts cannot be ruled out.

3 RESEARCH OUTCOMES

All nature-based industries can produce undesired or unexpected impacts on biodiversity and ecosystems, yet such effects are often difficult to assess without robust baseline data. Even when baseline data exist, they may not adequately capture the spatiotemporal variability in biodiversity needed to reliably detect ecological change. Conventional methods for collecting biological baseline data may also have limited value for assessing unforeseen impacts that arise years or even decades later. As analytical technologies, including artificial intelligence, continue to advance, the ability to revisit and analyze preserved material becomes increasingly important.

One aim of the COREu project was therefore to develop and demonstrate an innovative eDNA-based approach to biological baseline data collection that addresses the limitations of conventional methods. The sampling design was structured to account for potential spatiotemporal variability in biodiversity when comparing baseline and post-impact data. In addition, the long-term storage of eDNA from both sediment and water samples enables future re-analysis using state-of-the-art technologies. Because eDNA contains genetic material from a wide range of organisms, the COREu approach also allows retrospective analyses targeting newly identified species of concern, an option often unavailable through conventional baseline methods.

In conclusion, the COREu approach tackles major challenges in biological baseline monitoring through a seasonal and spatially extensive sampling design capable of detecting both localized short-term effects and broader long-term regional impacts. By preserving eDNA from sediments and water the approach is effectively future-proof, allowing material to be revisited with more advanced methods as new environmental concerns emerge. This makes the COREu approach

broadly applicable for detecting ecological effects from multiple human pressures and a strong complement to traditional monitoring as molecular and AI-driven tools continue to advance.

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