research into impacts & safety in CO_2 storage

Our progress on marine sites

Most research on the risks of carbon capture and storage (CCS) focuses on the possibility of release of CO_2 from storage and how that can be minimised. Although this is a good strategy, it is also important to be aware of potential effects to the ecosystem in the unlikely event that CO_2 is released. Understanding how a leak of CO_2 into the marine environment disperses is important, not only in order to understand subsequent potential impacts on marine species but also to plan effective and efficient monitoring strategies. Therefore, at this stage in RISCS offshore work is focused on the quantification of the ecological risk as a function of elevated CO_2 levels, identification of the response and recovery of individual species after exposure to CO_2 (laboratory experiments), 1D numerical experiments of seawater ecology and benthic species, the dispersion of CO_2 plumes in seawater and on field work at the Panarea natural test site.

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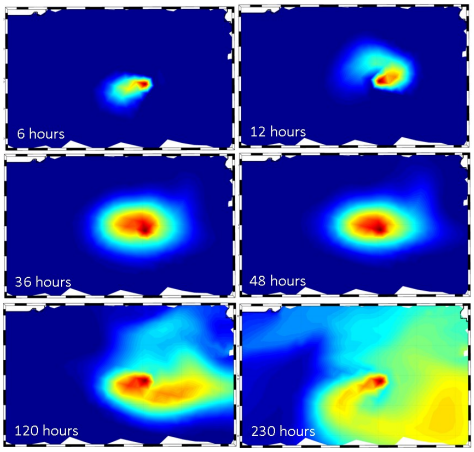
Modelling

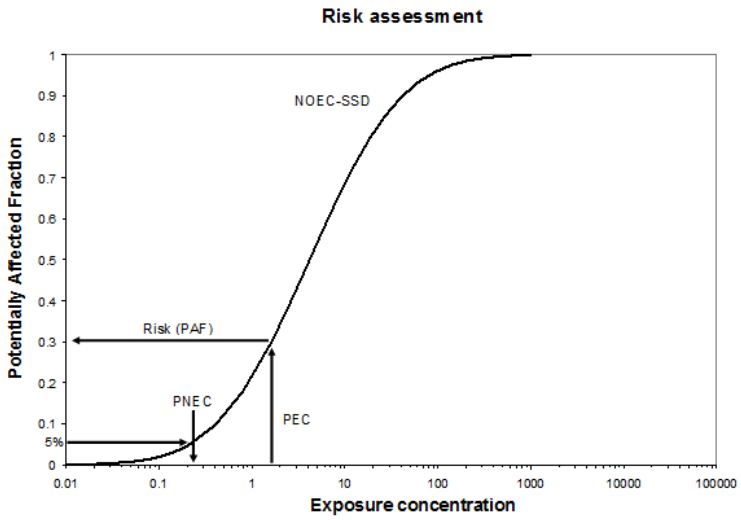
It is clear that any leak event will be unique, depending on flux rates, tidal state, currents and season. In RISCS we have explored the behaviour of a CO_2 leak using the FVCOM (Finite Volume Coastal Ocean Model) coupled to a carbonate system model that reflects the chemical changes associated with the influx of CO_2 at depth. We are investigating a subset of the generic scenarios identified in the early stages of the RISCS project.

The dispersion of a leak will be complex. The reason for this is the strong tidal mixing in NW European shelf seas. This implies that design of suitable monitoring strategies require careful consideration.



Dispersion of an idealized plume over a few days

To assess the impact of CO_2 an eco-toxicology technique known as Species Sensitivity Distribution (SSD) was used which estimates the Potentially Affected Fraction (PAF) of species at a specific CO_2 exposure level.



The Predicted No Effect Concentration (PNEC) level usually corresponds to a PAF of 5%. CO_2 effect data were collected from the literature for 67 species, which was used to generate an SSD. The experimental conditions for these tests were, however, highly variable, complicating the interpretation of the SSD. The uncertainty of the risk was therefore also estimated. Furthermore, more standardised data are required for a proper quantitative risk assessment

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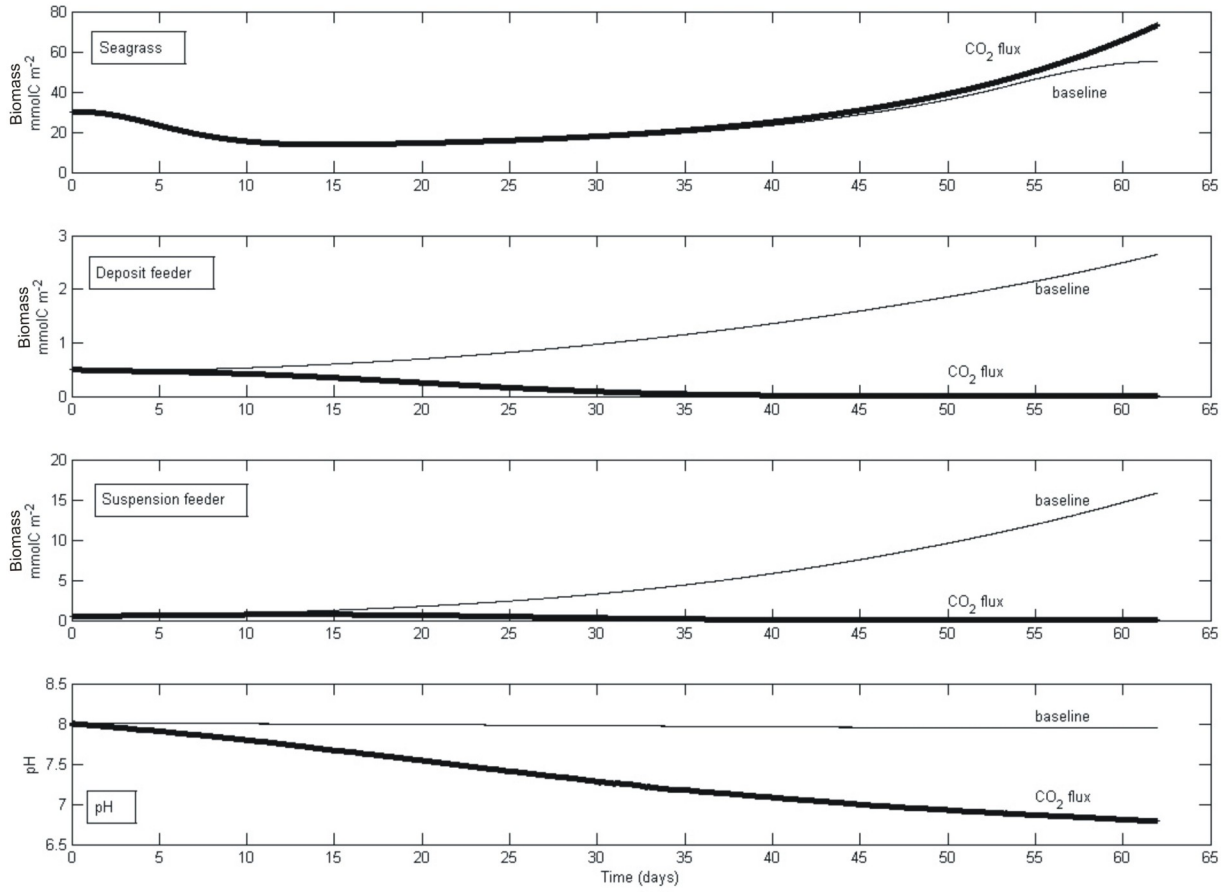
SEVENTH FRAMEWORK PROGRAMME

A series of hypothetical scenarios which describe seawater ecology and benthic species are also being modeled (1D) to help inform the impact studies. The models take into account inorganic nutrients: nitrate, total ammonium, phosphate, dissolved inorganic carbon. The evolution of total alkalinity determines the acidification levels.

The model handles the conversion of pelagic particulate organic matter, produced by plankton and seagrass, to benthic detritus reaching the sea floor. The nutrient cycles interact with dissolved oxygen to estimate the oxygen amount produced by the seagrass.

The conceptual scheme of the different components links to form a food web consisting of four targeted species: fish, meiobenthos, deposit feeders and suspension feeders that is directly impacted by CO_2 emissions.



The CO_2 emission results, from simulations with a constant flux of 0.002 mmolC m^{-2} s^{-1} over 62 days, are compared to the baseline evolution given in the figure (above). Acidification is shown by the lowering of pH values (above) which in turn reduces the biomass of the deposit and suspension feeders to almost zero; the sea grass biomass, which is not directly affected by the pH in the water column, increases due to reduced grazing pressure.

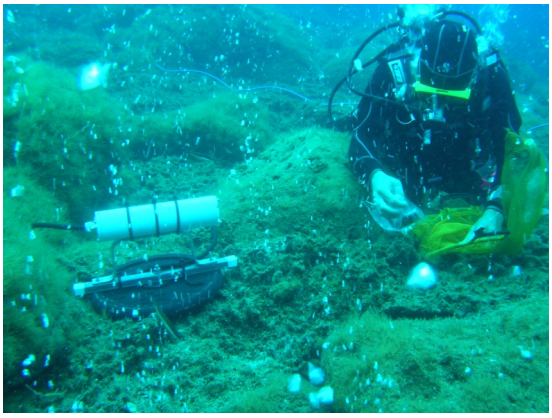
Field analogues

Field work has been completed at the Panarea natural test site, where geological CO_2 is leaking from the sea floor into the overlying water column. We have conducted four field campaigns, one each season, during which chemical, biological, and physical oceanographic parameters were measured and monitored to better understand the spatial and temporal impacts of the leaking CO_2 on the marine ecosystem. The work was focused on:

* Sampling for the examination of the scale at which chemical/biochemical modifications can be observed
* Continuous monitoring of pCO_2 (photo below)
* Current monitoring
* Benthic chamber measurements

Interim results indicate the highly variable nature of the measured parameters. Most significant is how the various mixing processes rapidly dilute the chemical/ biochemical/ biological CO_2-leakage signals as one moves a short distance away from what can be considered a very large source. This is lending support to initial results from the FVCOM simulations described above. Future work will involve the completion of the remaining chemical and biological analyses, followed by an integrated interpretation of the entire collected data set.

Researchers collecting water samples for biological and chemical analyses. The main Island of Panarea can be seen in the background.



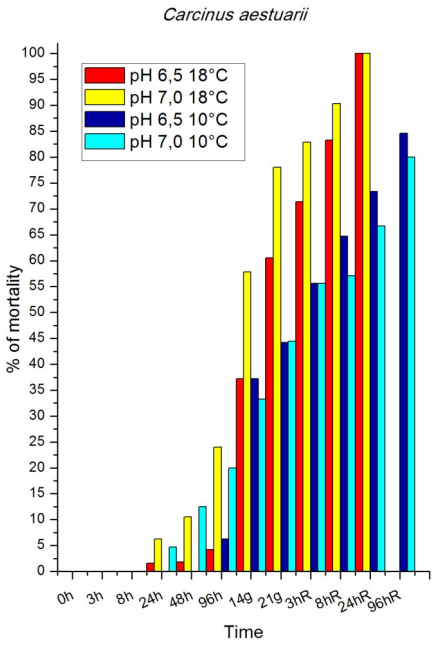
Autonomous probes (developed by the University of Rome) deployed on the sea floor for the continuous monitoring of dissolved CO_2 concentrations.

Experimental work

The laboratory experimental work aims to determine and quantify the response and recovery of the individual species after exposure to elevated levels of CO_2. The physiological and immunological response of two crustacean species *Carcinus aestuarii* and *Palaemon elegans,* to reduced pH (6.5 and7.0) were tested at two temperatures: 18°C (spring-summer conditions) and 10°C (autumn and winter conditions).

To define the effect of modified pH and temperature, mortality and a set of hemolymph parameters were measured at each pH level and temperature: glucose as a general indicator of stress, lactate concentration and pH for acid balance regulation; total protein concentration and density for its role in osmoregulation and finally total haemocyte count to asses the general health of the animals.

The graph (right) shows mortality of the crab *Carcinus aestuarii* over time under the different experimental conditions.



In general, the mortality of this species is time dependant with mortality increasing under the spring - summer conditions (18°C).

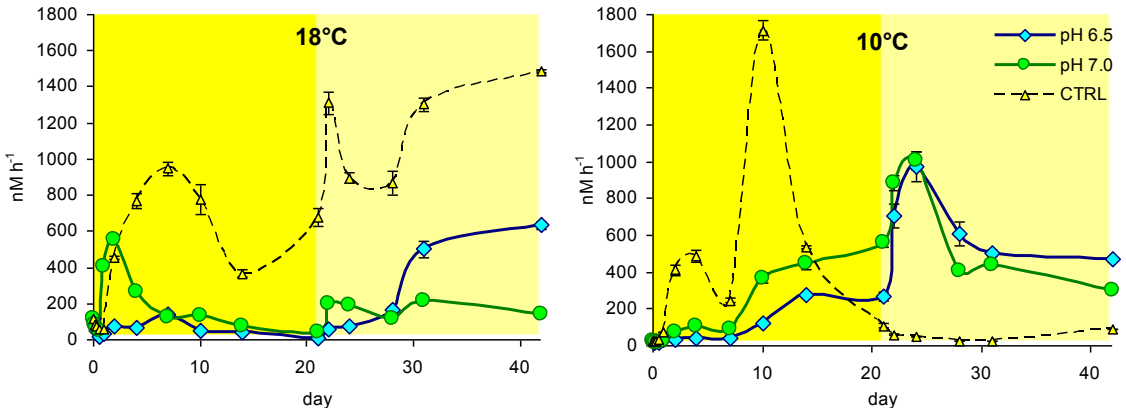
Four mesocosm experiments have been carried out, during two different seasons, (concluding in March 2011) to evaluate the effect of CO_2 induced pH decrease on microbial communities collected from the Gulf of Trieste (northern Adriatic Sea) seawater and sediment (see graphs below).

Every experiment was made up of 3 stages: a) short-term effect, b) long-term effect and c) recovery.

The analyses focussed on prokaryotic abundance and metabolism (degradation processes, carbon production and respiration).

In both experiments (plankton and benthos) benthic diatoms seemed to be stimulated at pH 7.0 and inhibited at pH 6.5. The highest and lowest abundances were observed at these pH values. At both temperatures, the microalgal assemblages were dominated by *Navicula*, *Nitzschia* and *Gyrosigma*.

In the graph (in continuation) are the photophase results relative to plankton experiments.



Phosphatase activity within the mesocosm experiments at 18°C and 10°C. The yellow background outline the CO_2 treatment stage; the light yellow background indicates the recovery stage.

Past Events

Characterise a CO_2 storage site up to the final stage of licensing: how to get started?(SiteChar meeting)

Date & place: 01 March 2012, IFP Energies nouvelles - Rueil Malmaison, France

* Assessing Impacts of CO_2 leakage on the ecosystem - An overview and early results from the RISCS project Jonathan Pearce, BGS and the RISCS project team

Discussion Laboratory on CO_2 storage impacts organised by the RISCS project

Date & place: 14th March 2012 - Bruxelles

This was an open dialogue between the RISCS researchers, EC officers from DG RTD and stakeholders from major power companies and NGOs as to discuss opinions and aspects to be included in the Guide of Impacts Appraisal.

One of the key issues raised at the event was the role CCS would play as a technology for a sustainable use of fossil fuels and the need to provide balanced, valid and accessible information to communicate CCS.

Communicating the CO_2 storage impacts with stakeholders and EU representatives

7th CO2GeoNet Open Forum

date & place: 17-19 April 2012, San Servolo Island, Venice, Italy

This year' s CO2GeoNet Open Forum counted more than 130 participants from 30 different countries. The forum provided a picture of the wide landscape of European and national research projects on CO_2 Geological Storage. This allowed participants to debate and pinpoint outstanding challenges through fruitful general discussions.

* RISCS - Research into Impacts and Safety in CO_2 Storage Dave Jones, BGS - CO_2GeoNet and the RISCS project team

Upcoming Events

Euroscience Open Forum (ESOF)

date & place: 11-15 July 2012, Dublin, Ireland

Europe's largest general science meeting ESOF is an interdisciplinary, pan-European meeting, which showcases the latest advances in science and technology; promotes a dialogue on the role of science and technology in society and public policy; and stimulates and provokes public interest, excitement and debate about science and technology.

* What is the impact of sustainable energy technologies? RISCS team

GHGT11, 18th - 22nd November 2012, Kyoto, Japan

Accepted abstracts for poster presentations:

* *Modelling dispersion of CO_2 plumes in sea water as an aid to monitoring and understanding ecological impact*. J.C. Blackford, R. Torres
* *Hypothetical Impact Scenarios for CO_2 Leakage from Storage Sites* A. Paulley, R.Metcalfe, M. Egan, P. R. Maul, L. Limer, A. A. Grimstad, and the RISCS Project Team
* Systems analysis of field and laboratory experiments considering impacts of CO_2 leakage in terrestrial systems A.E. Bond, R. Metcalfe, N. Chittenden, P.R. Maul, P. Suckling, K. Thatcher, R. Walke, K. Smith, D. Rasse, D.G. Jones,
* *Environmental impacts of CO_2 leakage: recent results from the ASGARD facility, UK.* K.L. Smith, M.D. Steven, D.G. Jones, J.M. West, P. Coombs, K.A. Green, T.S. Barlow, N. Breward, S. Gwosdz, M. Krüger, S.E. Beaubien, A. Annunziatellis, S. Graziani and S. Lombardi
* *Simulated CO_2 leakage experiment in terrestrial environment: Monitoring and detecting the effect on a cover crop using ^{13}C analysis*. C. Moni, D.P. Rasse, and the RISCS Project Team

Accepted abstract for oral presentation:

* *Potential environmental impacts of CO_2 leakage from study of natural analogue sites in Europe* F. Ziogou, V. Gemeni, N. Koukouzas, D. de Angelis, S. Libertini, S.E. Beaubien, S. Lombardi, J.M. West, D.G. Jones, P. Coombs, T.S. Barlow, M. Krüger and S. Gwosdz