

WP1: Salinity effects on proxy incorporation in foraminifera. IP: Bijma, AWI (in cooperation with WP3 partners)

The impact of salinity on the incorporation of Mg and Sr has been investigated for benthic (fig. 1) and planktonic foraminifera. For both groups a positive relationship between divalent cation incorporation and salinity could be established. It could be demonstrated that the “additional” incorporation of Mg, i.e. independent of temperature, is a direct consequence of increased salinity. This implies that a salinity increase of 2 results in enhanced Mg incorporation equivalent to 1°C temperature increase. In benthic foraminifera, the increased Sr incorporation, is not driven by salinity itself but by the concurrent increase in the saturation state with respect to calcite (Ω). For planktonic foraminifera the Sr data are inconclusive.

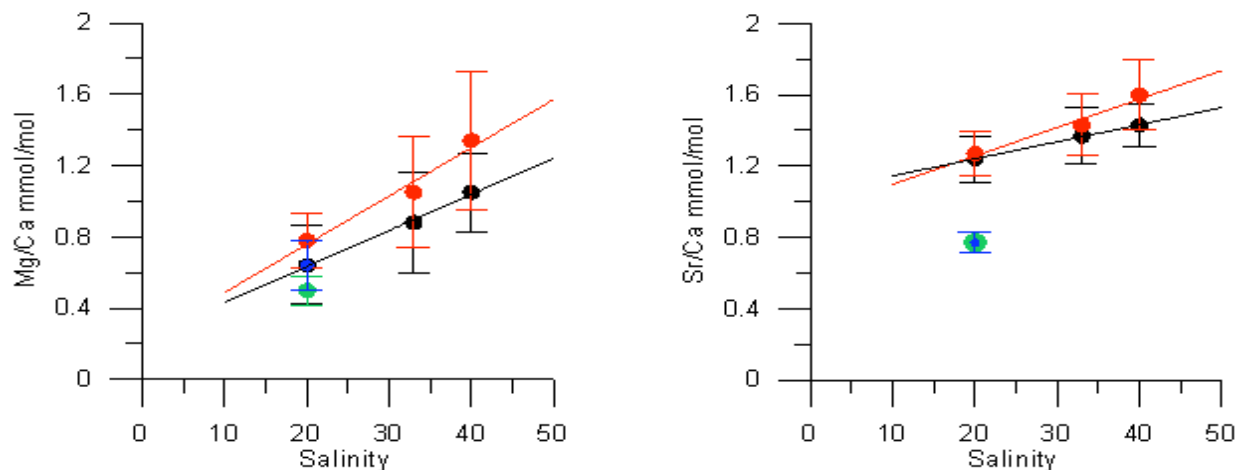


Fig. 1: Mg/Ca ratio (left) and Sr/Ca ratio (right) in *Ammonia tepida* test versus salinity. Every point is the average of specimens grown under similar experimental conditions, in red at 15°C and in black at 10°C. The results of the salinity 20+Ca experiment are plotted in green (10°C) and blue (15°C).

WP2: Ultra-high resolution element characterisation and molecular biomarkers fingerprinting in marine biogenic carbonates. IP: Arlinghaus, UMSR

- 1) 3D imaging of single foraminifera with cryo-ToF-SIMS/laser-SNMS (sample handling for 3D mapping of cells and tissues via repeated cryosectioning) was developed. A single cell organism from the North Sea (a planktonic foraminifer) with a cell diameter of a few hundred micrometers was used for optimizing 3D molecular imaging. The preparation of living foraminifera starts with adding a droplet of seawater to the gold plate in the sample holder. Then the living foraminifer is added to the droplet, then plunged into liquid propane and transferred to the cryo-ToF-SIMS/laser-SNMS instrument, where the frozen droplet is consecutively cut and analyzed with a depth of cut of 20-30 μm)
- 2) lateral variation of the Ba concentration in a coral core (together with Craig Grove, NIOZ):
 - a. the variations were found and had the expected spacing
 - b. work on expected correlation with luminescent lines in the material still in progress
- 3) alkenone mixture from *E. hux.* (provided by Marcel van der Meer, NIOZ)
 - a. all original molecules (dehydrogenated one times) in the mixture can be found with SIMS (but: relative intensity shifted compared to the corresponding GC spectrum)

- b. work on Laser-SNMS spectra (especially with fs-Laser) to be done until end of this year
- 4) cleaned shells from collected forams, issue: correlation between salinity in the habitat and metal/Ca ratios (to be done)
- 5) cross section of foraminiferal shells (embedded in resin); issue: correlation between Mg and organic compounds

WP3: Seasonality and habitat controls on benthic foraminiferal salinity proxies. IP: Reichart, UU

- 1) WP3 focused on the impact of time and microhabitat on foraminiferal growth rate and carbonate formation and thus proxy recording. Based on this main objective, the following results were obtained:
- 2) Together with PhD students from the Alfred Wegener Institute for Polar and Marine Research (AWI), Germany (WP1, Salinity effects on proxy incorporation in foraminifera) and, the Institute of Advanced Industrial Science and Technology, Japan, we successfully cultured the foraminiferal planktonic species *Globigerinoides sacculifer*. Different controlled environmental conditions, in terms of carbonate chemistry of the surrounding seawater, were used in these experiments. We determined the effects of salinity and the calcium carbonate saturation state on Mg and Sr incorporation in the foraminiferal calcite. This resulted in one manuscript.
- 3) We determined, in cooperation with the same scientific teams, ontogenic and inter-individual variations in Mg incorporation for the same species of planktonic foraminifera. Results obtained show a primary/secondary foraminiferal calcite ratio in terms of Mg content that hasn't been reported in literature before. A manuscript describing the ontogenetic effect and inter test variability is in preparation.
- 4) Laboratory culture experiments were carried out at Utrecht University using three different species of benthic foraminifera (*Bulimina sp.*, deep benthic; *Ammonia tepida*, shallow benthic; and, *Heterostegina sp.*, tropical symbiont-bearing). We determined the effect of salinity and the calcium carbonate saturation state (in terms of Ca^{2+} and CO_3^{2-}) on foraminiferal Mg incorporation. Some of these experiments are still in progress (effect of $[\text{CO}_3^{2-}]$ on foraminiferal Mg incorporation). This set of culture experiments was carried out in cooperation with a PhD student from the Centre for Marine Environmental Science (MARUM), University of Bremen, Germany (funded through EUROPROX). This resulted in one manuscript.
- 5) In close cooperation with the scientific team from the Laboratory of Recent and Fossil Bio-Indicators (BIAF) University of Angers, France (WP7, Ecologic constraints on salinity proxies in benthic foraminifera) we successfully analyzed the pore water chemistry of core top samples from the Delta of the Rhone River. Trace metal composition of foraminifera samples will be compared to the pore water chemistry in order to find any possible microhabitat effect on the foraminiferal calcite composition.
- 6) We determined ontogenic and inter-individual variations of trace metal composition in deep benthic foraminiferal calcite. Specimens used (*Cibicides pachyderma*) come from core top samples from the Bay of Biscay, North Atlantic Ocean, collected by the scientific team from the Laboratory of Recent and Fossil Bio-Indicators (BIAF) University of Angers, France (WP7).

Achievements besides scientific results:

The foraminiferal culturing groups at Utrecht University, The Netherlands and at the University of Angers, France, developed new protocols in order to maintain living stocks of benthic foraminifera in the laboratory and carry out culture experiments. New methods were also developed by the research group at Utrecht University, in order to vary and keep a constant carbonate chemistry of the seawater during the laboratory experiments.

WP4: Seasonality and habitat controls on planktonic foraminifera - Compound specific δD analysis of alkenones and particulate organic matter. IP: Schouten, NIOZ

One of the most commonly used tools to estimate palaeo-salinity variations combines reconstructions of paleotemperature and foraminiferal $\delta^{18}\text{O}$. This approach is based on the recognition that foraminiferal $\delta^{18}\text{O}$ varies as a function of temperature and ambient seawater $\delta^{18}\text{O}$ which is directly coupled to seawater salinity. The close relation between the stable hydrogen isotope ^2H (deuterium, D) and $\delta^{18}\text{O}$ in precipitation and seawater (so-called meteoric water line) enables an alternative approach to deconvolve palaeosalinity. Deuterium is incorporated into marine organic carbon during photosynthesis and can be extracted from seafloor sediments. Thus, δD analyses on marine organic carbon could provide an independent estimator that approximates seawater palaeosalinity directly and indirectly, through its salinity-specific offset from $\delta^{18}\text{O}$.

To develop this proxy we have grown cultures of *Emiliania huxleyi* and *Gephyrocapsa oceanica* and analysed their specific biomarker lipids, the long chain alkenones. We found a strong correlation between the fractionation factor $\alpha_{\text{alkenones-growth water}}$ and salinity for both *E. huxleyi* and *G. oceanica* although growth rate also had some impact. This suggested that δD of alkenones can be used to reconstruct past salinities.

We applied this newly developed proxy to a core from the Aegean Sea covering the S5 sapropel. Sapropels are organic-rich sediment layers that were intermittently deposited in the Mediterranean Sea, especially in its eastern basin, during the last 10 Myr. The associated anoxic events that gave rise to sapropel formation resulted indirectly from the impact of African monsoon maxima on the basin's hydrography. Sharp shifts in oxygen isotopes ($\delta^{18}\text{O}$) to values more depleted in the heavy isotope (^{18}O) in carbonates from surface-dwelling planktonic foraminifera, slightly preceding sapropel deposition, suggest that the Mediterranean was flooded by large amounts of freshwater leading to the development of a low salinity of the surface water and a strong density stratification of the water column. Our analysis of the δD of alkenones from last interglacial sapropel S5 from the Aegean Sea shows a large decrease in δD of 25 ‰ at the onset of sapropel formation, suggesting a drop in SSS of 6, from 39 to 33. Although the absolute SSS estimates should be interpreted with care as they are subject to relatively large uncertainties, the estimated SSS values appear quite reasonable as they, for example, yield SSS before sapropel deposition similar to that of the present day Aegean Sea. These results do illustrate the promise of a combined use of δD of alkenones, U^{k}_{37} of alkenones, and $\delta^{18}\text{O}$ of surface dwelling planktonic foraminifera, for SSS reconstructions.

We have also applied this proxy in a core covering the last 3000 yrs of the Black Sea. Approximately 2700 yrs ago *E. huxleyi* invaded the Black Sea, illustrated by the deposition of a coccolith ooze from this time on. Because *E. huxleyi* has never been observed at salinities below 11, a salinity increase to above 11 has been suggested for that time period. Our results show that the δD values of alkenones gradually decreased over the last 3000 yrs suggesting a

decrease in salinity and, therefore, a higher than present day salinity 2700 yrs ago. Relative salinity changes generated from organic walled dinoflagellate cyst (dinocyst) distributions from the same core confirms our SSS reconstruction based on δD of alkenones. This makes it likely that the invasion of the Black Sea by *E. huxleyi* is not caused by an increase in salinity.

Our results show that δD of alkenones is a promising new tool for reconstructing past salinities. To reduce uncertainties in SSS estimates, the δD -salinity relationship has to be better constrained with cultures and also be further tested in field studies.

WP5: Salinity effects on proxy incorporation in bivalves. IP: Dehaers, VUB

Shell barium and Chl-a: Ba peaks in bivalve shells do occur in spring when phytoplankton blooms are observed. However, the temporal overlap between shell Ba maxima and Chl-a maxima was not always clear (Fig. 2).

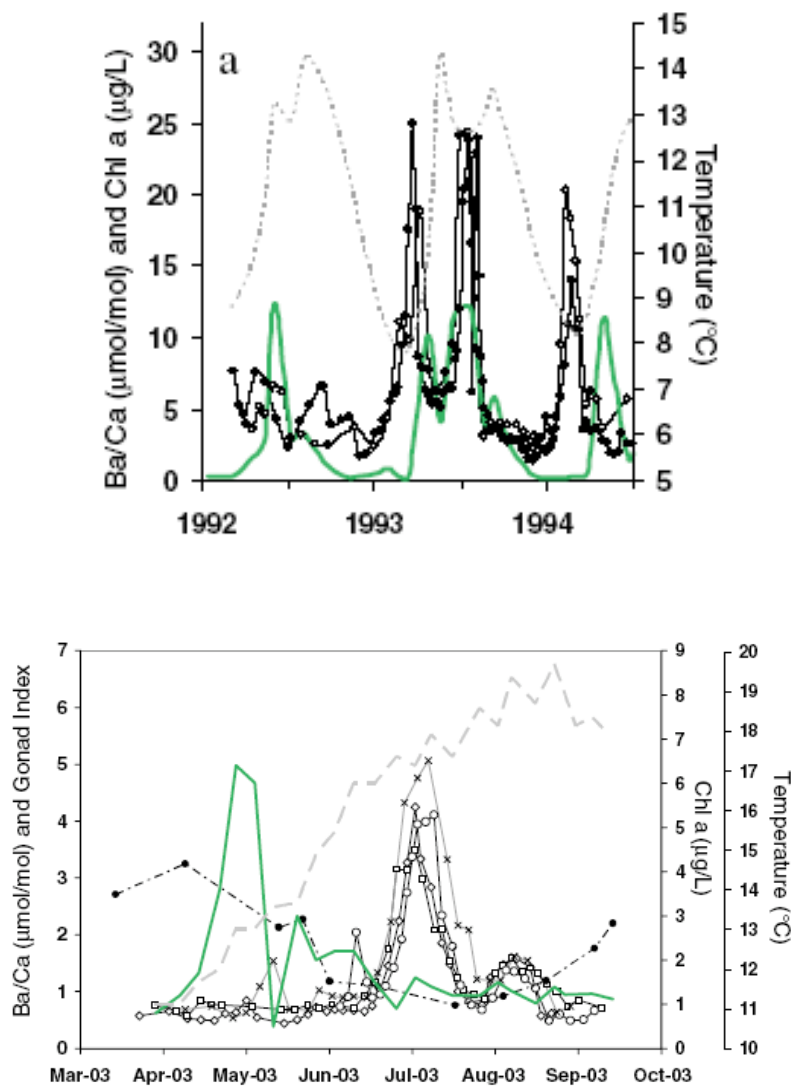


Figure 2: Top: Ba/Ca ratios in *Saxidomus giganteus* (from US east coast); dotted grey line = water temp.; green line = Chl-a reflecting phytoplankton biomass; **Bottom:** Ba/Ca ratios in *Pecten maximus* shells (Bay of Brest, France); green line = Chl-a; dashed grey line = water temp.; dashed black line with black symbols = gonad index (dry weight of the gonad divided by the shell weight, $\times 1,000$); (Gillikin et al., 2008).

Shell barium and salinity: Baseline Ba content, on the contrary, did correlate well with dissolved Ba in the medium, highlighting the potential usefulness of this element as a proxy of estuarine Ba and (site-specific) salinity (since no single Ba-salinity relationships differ between estuaries); (Figure 3).

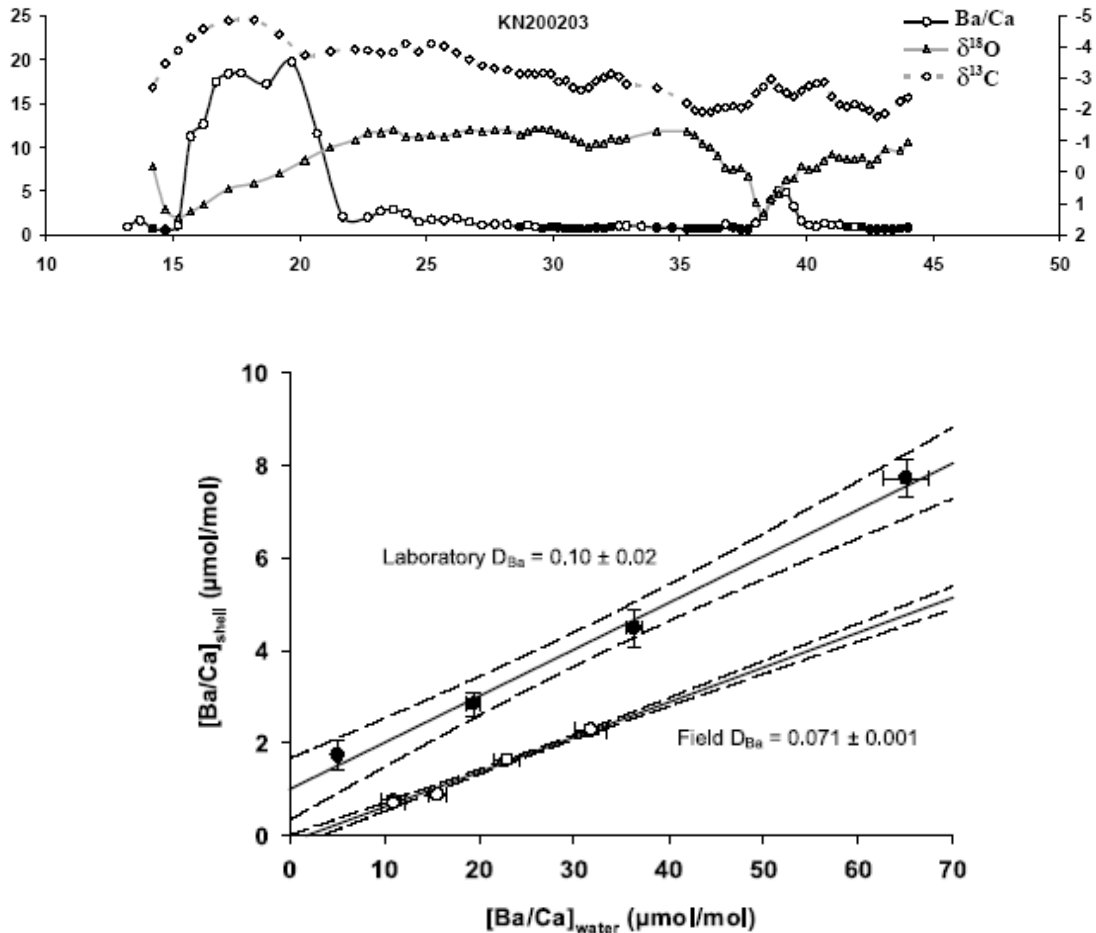


Figure 3: **Top:** example of profiles of Ba, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ along the shell growth axis for *Mytilus edulis*; the Ba peak often coincides with Chl-a maxima (spring) while baseline Ba correlates with dissolved ambient Ba; **bottom:** mean baseline $[\text{Ba}/\text{Ca}]_{\text{shell}}$ ($\pm\text{SE}$) in shells of laboratory grown (closed symbols; 28 shells, 4 treatments) and field grown (open symbols; based on multiple data from 6 shells from 4 sites along Scheldt estuary) *M. edulis* versus Ba/Ca ratios of water ($\pm\text{SE}$). The average $[\text{Ba}/\text{Ca}]_{\text{water}}$ over the whole year is used for the field regression. The solid line shows the linear least squares regressions and the dashed lines the 95% CI. Slopes are significantly different (t test) at $p < 0.0001$.

Shell carbonate $\delta^{13}\text{C}$ and salinity: Bivalve shell $\delta^{13}\text{C}$ relates well with $\delta^{13}\text{C}$ of dissolved inorganic carbon, although metabolic C clearly contributes to the shell signal. It was found that the metabolic effect on shell $\delta^{13}\text{C}$ could not easily be accounted for to allow reliable $\delta^{13}\text{C}_{\text{DIC}}$ and salinity reconstructions (Figure 4).

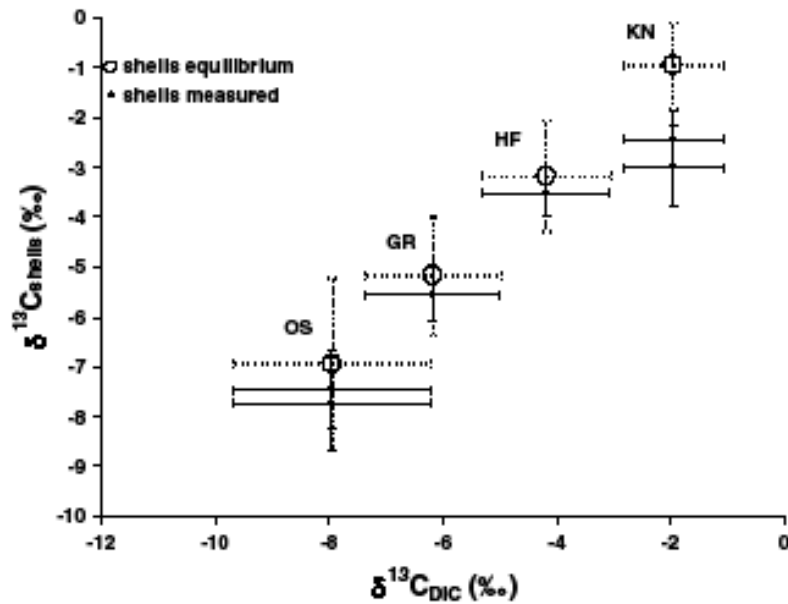


Figure 4: *Mytilus edulis*; mean $\delta^{13}C_{shell}$ and $\delta^{13}C_{DIC}$ (in ‰) averaged over the full year for four sites along the Scheldt estuary (OS= Ossenisse; GR= Griete; HF= Hoofdplaat; KN= knokke). Also plotted are the expected shell values based on the fractionation factor between $\delta^{13}C_{DIC}$ and calcite (+1.0‰; Romanek et al., 1992). Error bars represent standard deviations (Gillikin et al., 2007).

δD in shell organic matter: a new proxy: At this stage only preliminary tasks were completed. These include optimization of extraction protocols for bulk organic matter and specific biochemical compounds from bivalve shells and analysis via GC-MS (for compound identification) and GC-c-MS (only for $\delta^{13}C$ at this point). The next step will be the determination of δD in specific shell OM compounds to investigate the possible relationship between δD and salinity (Figure 5).

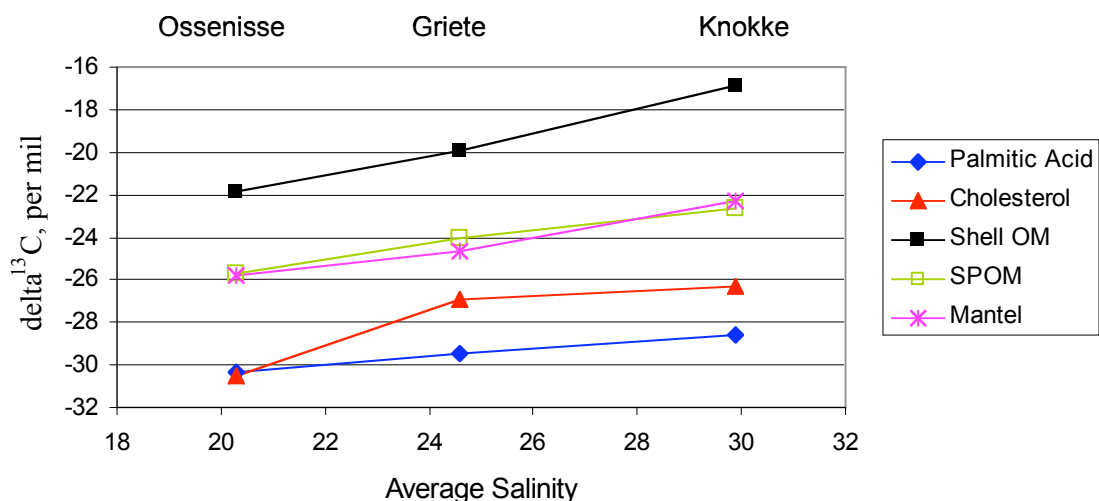


Figure 5: $\delta^{13}C$ values for suspended organic matter (SPOM); mantel tissue; bulk shell organic matter (Shell OM) and two specific compounds (palmitic acid & cholesterol) extracted from *Mytilus edulis* shell, for specimens collected along a salinity gradient in the Scheldt estuary.

Modelling

Correction for the time averaging effect: Signal profiles along an accretion axis or a growth axis of e.g. a bivalve shell may show underestimation of signal amplitude due to averaging when sampling by micro-drill or laser. A non parametric model was established enabling to correct for this underestimation, both in conditions of linear and non-linear growth rates (Figure 6).

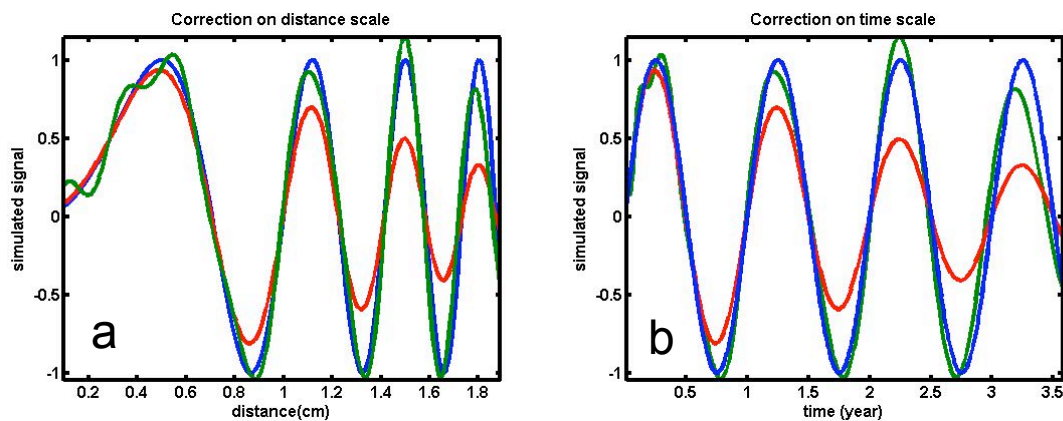


Figure 6: Correction for decreasing growth rate on a distance scale (a) and on a time scale (b). Red: measured signal, blue: true signal and green: corrected signal.

Reconstructing an environmental condition via a non-linear multi-proxy approach: A spline-model was constructed which uses the information residing in the shell profiles of proxies (elements and isotopes), (Figure 7). The first results are promising and a temperature reconstruction with a precision up to 0.45°C was achieved.

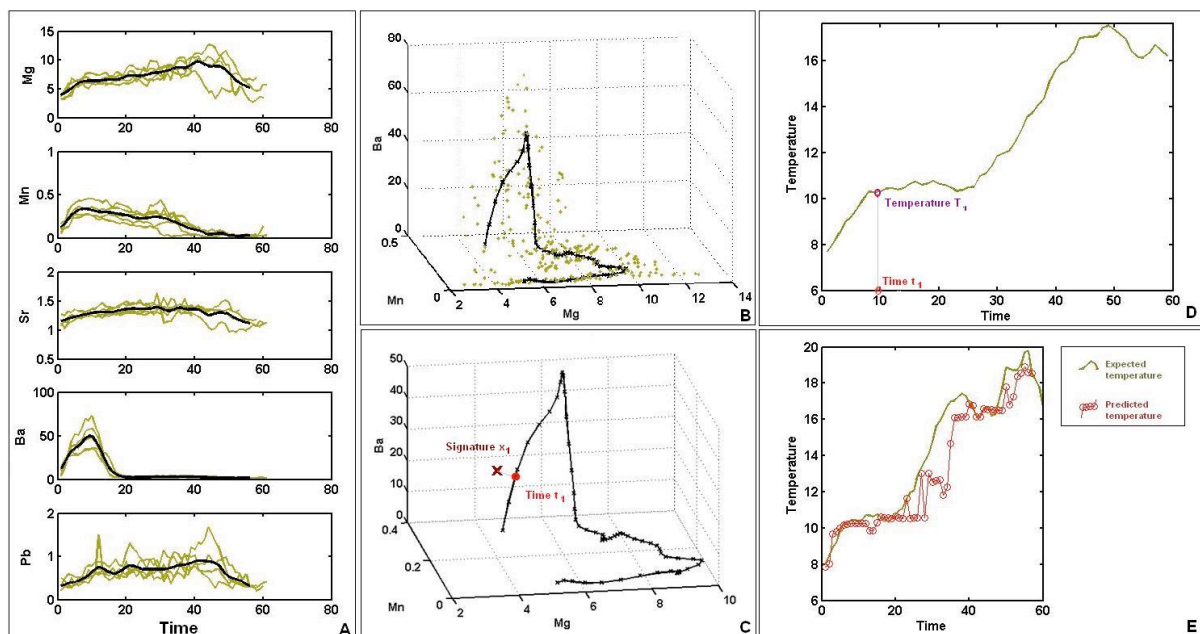


Figure 7: A: Construction of a non-linear transfer function for different proxy profile in *Mytilus edulis* shells over a time (growth) axis. B: rewriting the transfer functions in a single n-dimensional function (there are as many dimensions as proxies). C: Linking of a measurement (chemical signature) to a unique time-position. D: Linking of the time-position to the corresponding environmental parameter(s). E: Validation of the method, comparing the measured environmental parameter(s) with the predicted environmental parameter(s).

WP6: Temperature-salinity dependent uptake of Mg into biogenic carbonates: constraints from magnesium isotopes. IP: André, MRAC

Mg isotopes ($\delta^{26}\text{Mg}$) in biocarbonates: Temperature and Salinity proxy?

Mg isotopes in sea urchins and starfish skeletons: Figure 8 presents the Mg isotopic composition ($\delta^{26}\text{Mg}$) measured in sea urchins (-2.3 to -2.8‰) and starfish (-3.0 to 3.1‰) skeletons. The difference observed with fractionation produced by inorganic calcite precipitation from seawater (-3.5‰) shows a biological influence on Mg signatures in echinoderms which lower the incorporation of light Mg isotope. The biological influence is larger in sea urchin than in starfish.

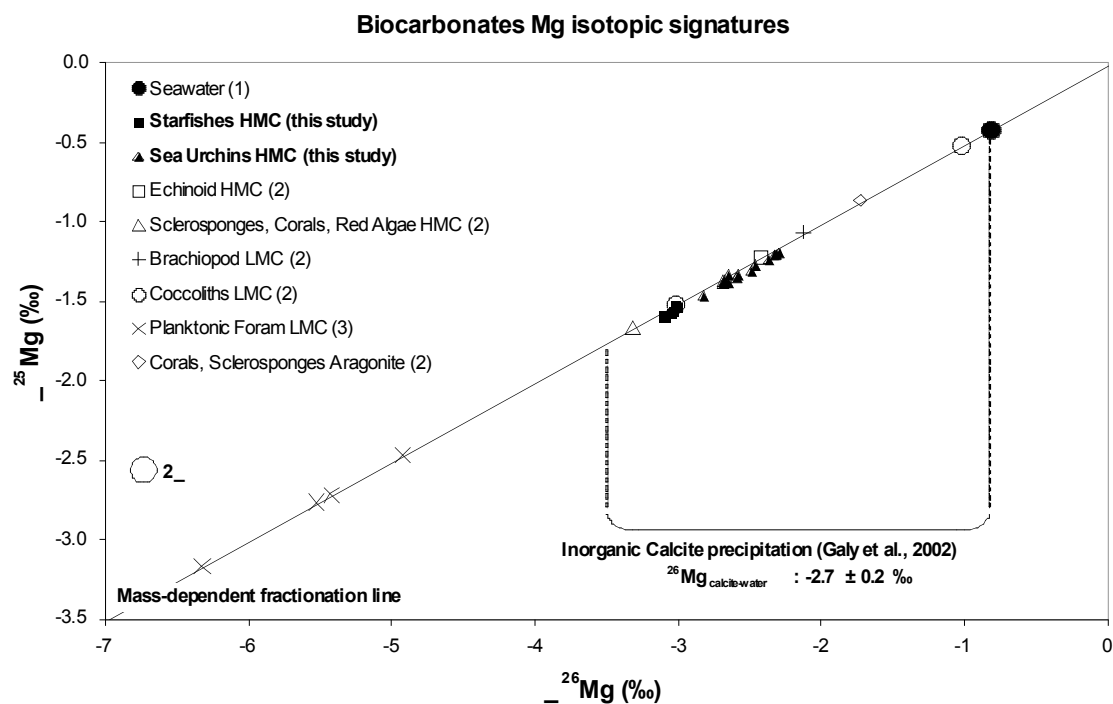


Figure 8: Three isotopes plot ($\delta^{26}\text{Mg}$ - $\delta^{25}\text{Mg}$) of Mg isotopic signatures measured in echinoderms and comparison with other marine biogenic carbonates and seawater signature: (1) Tipper et al (2006); (2) Wombacher et al, (2006) and (3) Chang et al, (2004).

Mg isotope in culture sea urchins: Culture experiment performed with sea urchin over 11°C temperature range for two salinities is presented in Figure 9. $\delta^{26}\text{Mg}$ values show a linear relationship with T with a weak salinity dependency between 36 and 39‰. The T dependency of the fractionation factor -0.03 to -0.02‰/°C is however too weak to provide a precise paleothermometer considering the global uncertainty on the measured $\delta^{26}\text{Mg}$ (0.15‰).

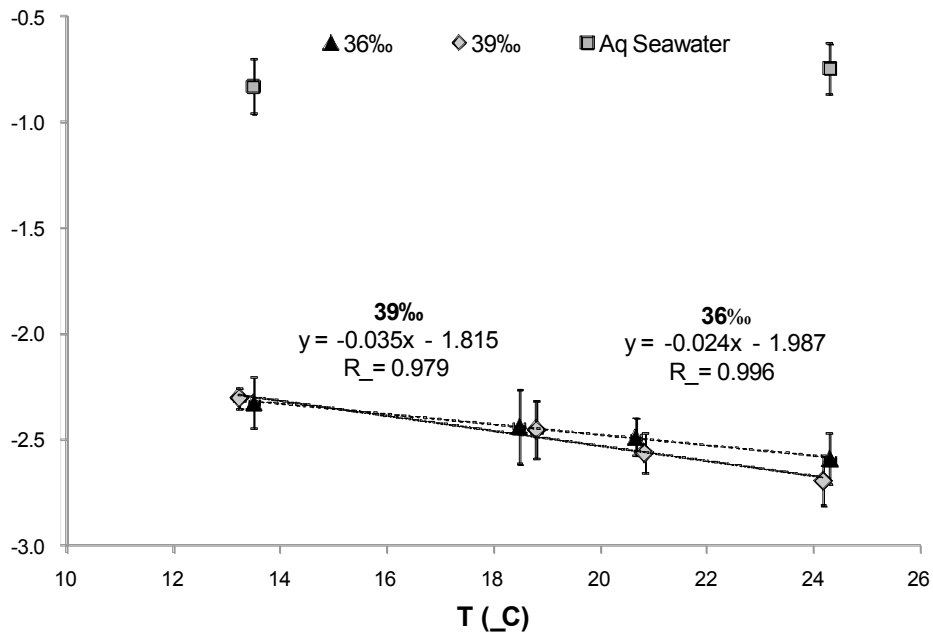


Figure 9: Mg isotopic signatures measured in cultured sea urchin under salinity and temperature controlled conditions. Sea urchin values were obtained from juvenile interambulacral plates grown during the experiment and correspond to at least three specimens cultured in similar conditions. Also plotted, the isotopic signatures of the water sampled in two distinct aquariums. Uncertainties are at 95% confidence interval.

Mg isotopes in bivalve: $\delta^{26}\text{Mg}$ in the different compartments involved in the shell formation of the manila clam (*Ruditapes philippinarum*): Mg isotopic ratios and Mg concentrations determined in the different compartments involved in the shell formation of the Manila clam are presented in Figure 10. Shell $\delta^{26}\text{Mg}$ data show strong and variable enrichments in light Mg isotope and appear to vary according to the salinity contrast encountered between the oceanic (Locmariaquer) and the estuarine site (Le Bono) subjected to tidal activity and to freshwater inputs from the Auray river. Mg isotopic compositions of the shells which can be attributed to variations in the Extra Pallial Fluid are strongly influenced by the Mg incorporation in the soft tissues (enriched in heavy isotopes). Enrichments in light isotopes of the internal fluids are a consequence of a balance effect due to incorporation of Mg in the intracellular medium. This process which is potentially related to the metabolic activity varies significantly according to salinity variations encountered between the two sites. At the oceanic site, low to moderate metabolic influence is observed contrasting with moderate to high influence at the estuarine site.

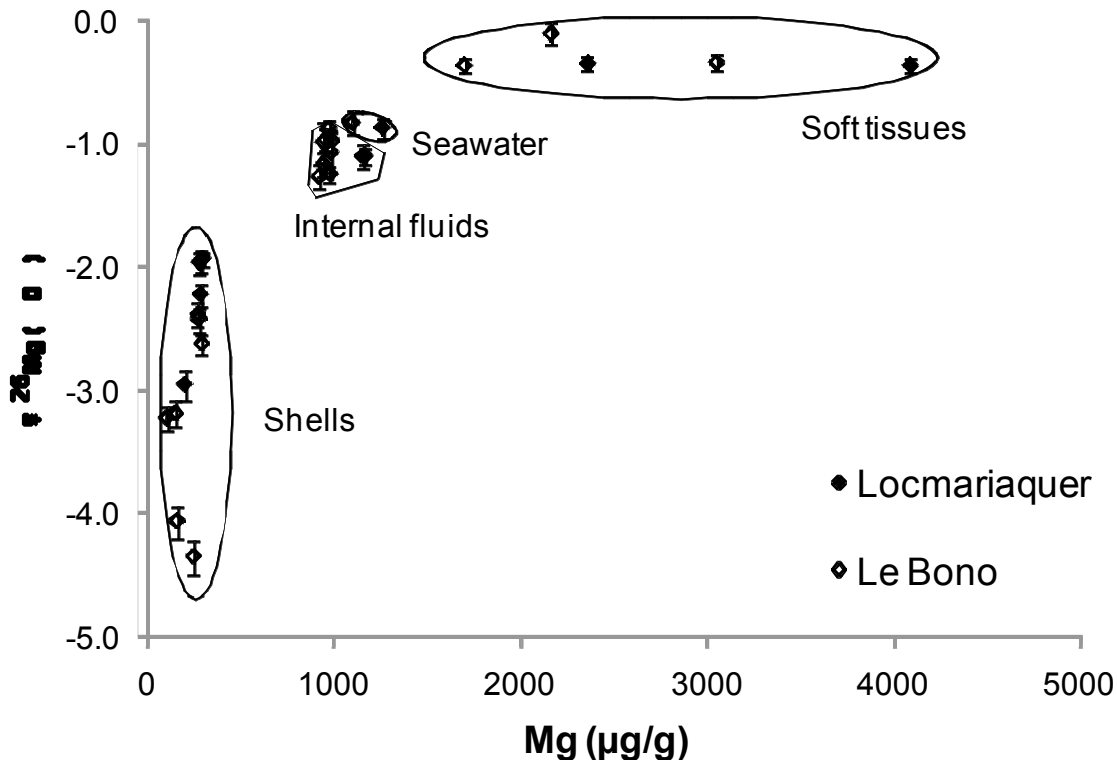


Figure 10: Comparative plot of $\delta^{26}\text{Mg}$ (in per mil) versus Mg concentrations (in $\mu\text{g/g}$) determined in the different matrices involved in the calcification process of the Manila clam (*Ruditapes Philippinarum*) and in the seawater from the two sampling sites considered (Locmariaquer and Le Bono). The Mg concentrations reported for the seawater and the internal fluids (EPF and hemolymph) are expressed in μg per gram of liquid, for the soft tissues (mantle, foot and remaining parts) in μg per gram of dry tissue and for the shells (inner nacreous part and outer prismatic part) in μg per gram of carbonate. Uncertainties associated with $\delta^{26}\text{Mg}$ represent 2σ error (95% confidence interval).

WP7: Ecologic constraints on salinity proxies in benthic foraminifera. IP: Jorissen, UA

The BIAF laboratory at Angers University was responsible for WP7: Ecological constraints on salinity proxies in benthic foraminifera. The main aim of this workpackage was to investigate how the physico-chemical and biological conditions of natural life habitats influence the geochemistry of the foraminiferal shell, more specifically, those aspects of the geochemistry that can be used for salinity proxies. In order to achieve this, we envisaged an approach combining field observations in areas with a strong salinity gradient, and laboratory experiments aiming to reduce the number of interfering parameters, which allow us to describe the influence of salinity with most other parameters remaining stable.

In practice, the contribution to the Paleosalt Project of BIAF Angers had three main components: 1) supplying living deep sea foraminiferal faunas to other laboratories, 2) study the impact of salinity on proxy carriers in a field setting, and 3) study the influence of salinity changes on the foraminiferal geochemistry in laboratory experiments. The following paragraphs explain these points in more detail.

- The BIAF team has been providing living foraminifera from continental shelf and deep sea settings to the partner of Utrecht University and AWI. These living foraminiferal faunas were essential for the culture experiments aiming at a better calibration of paleosalinity proxies. In all, live foraminiferal faunas collected in 55 multicores from 20 to 1000 m

depth have been sent to partner institutes. Three sampling campaigns, in the Bay of Biscay and in the Gulf of Lions, were necessary to collect this material.

- At the start of the Paleosalt program, it was virtually unknown how to create favourable conditions for deep sea foraminifera in experimental setups. Therefore, a large effort has been done to find out under what conditions deep sea foraminifera reproduce and add enough chambers to allow geochemical measurements of newly formed calcite. A secondary problem is to achieve all this in a laboratory setup, where the main geochemical characteristics (salinity, temperature, carbonate chemistry) can be maintained stable. At the end of the project period, all this has been achieved for *Bulimina marginata*, which reproduces, and adds chambers over a wide range of temperatures (4-19°C). A key element for obtaining successful culture experiments with this species is the food quality. It turns out that *Bulimina marginata* behaves best when fed with a mixture of living green algae and diatoms. One publication has been submitted to *Journal of Experimental Marine Biology and Ecology* (Barras et al.), a second publication will be submitted soon (Barras et al., *Journal of Foraminiferal Research*).

- In September 2007, we organised a workshop at the Laboratory of Marine Bio-Indicators (LEBIM) at Yeu Island, France. The aim of this workshop was to exchange expertise about laboratory experiments with deep sea foraminifera. Scientists of BIAF Angers, Utrecht University and Alfred Wegener Institute Bremerhaven participated.

- A study on the foraminiferal faunas in the Auray River estuary is still in progress. The Auray river has a strong salinity gradient (21–32 PSU), with a temporal variability that mainly depends on fresh water runoff and tidal inflow of marine water. The aim of our study was to investigate how the composition of the foraminiferal faunas and the geochemistry of the foraminiferal shells vary in response to these salinity changes. Six subtidal sampling stations have been selected along the salinity gradient, and the foraminiferal faunas have been studied for 2 contrasting seasons (spring 2006 and winter 2007). Continuous salinity recordings have been made at two of the sampling stations by our colleagues of Bretagne Occidentale University. Foraminiferal faunas are dominated by *Haynesina germanica* in the upper estuary, by *Ammonia tepida* in the middle and lower estuary. In the lower estuary, significant amounts of marine taxa appear (e.g. *Quinqueloculina* spp.). Stable isotope measurements (ready for the spring 2006 samples, and available in October 2008 for the winter 2007 samples) show a strong $\delta^{13}\text{C}$ gradient from the upper to the lower estuary (Fig. 11). This apparent response to salinity is probably caused by a compositional change of dissolved organic matter used for test construction, which predominantly originates from the degradation of terrestrial plant material in the upper estuary, and progressively shifts to a more marine signature towards the outer estuary. The results for the winter 2007 samples will reveal whether this trend is stable throughout the year, and can be used for salinity reconstructions.

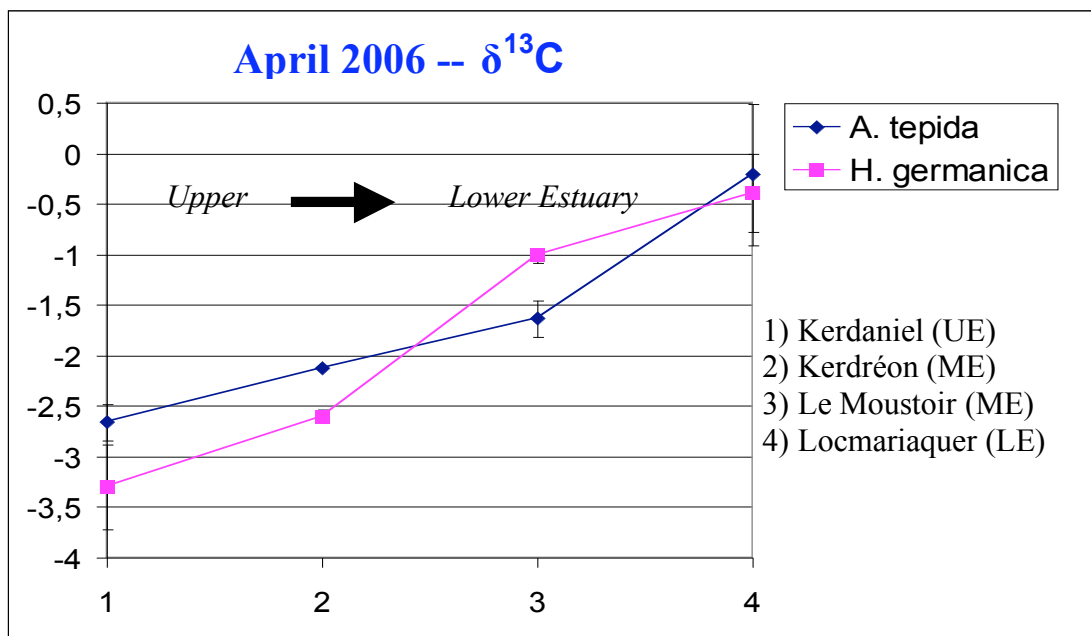


Fig. 11: Auray river estuary ; $\delta^{13}\text{C}$ of living benthic foraminifera collected at 4 sites in the upper (UE), middle (ME) and lower estuary (LE). The $\delta^{13}\text{C}$ gradient corresponds to a salinity increase of 21 to 32 ‰.

- Living *Ammonia tepida*, collected in Aiguillon Bay, have been incubated in the laboratory at 3 different salinities (30, 32.4 and 35.7 ‰). At all salinities, reproduction was obtained, and the juveniles calcified significant quantities of new chambers under the controlled conditions, until attaining a maximum test size of about 750 μm (Fig. 12). The stable isotopic composition as well as trace metal content of the shells formed at different salinities will be determined in September 2008. These measurements will allow to determine, and to describe mathematically the relationships between salinity and $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, as well as a number of sensitive trace metals. Individual isotopic measurements will be performed on 13 different size classes, ranging from 100 to 750 μm . The aim of this is to determine eventual changes during the ontogeny of the relationship between salinity, stable isotopes and trace metal concentration.

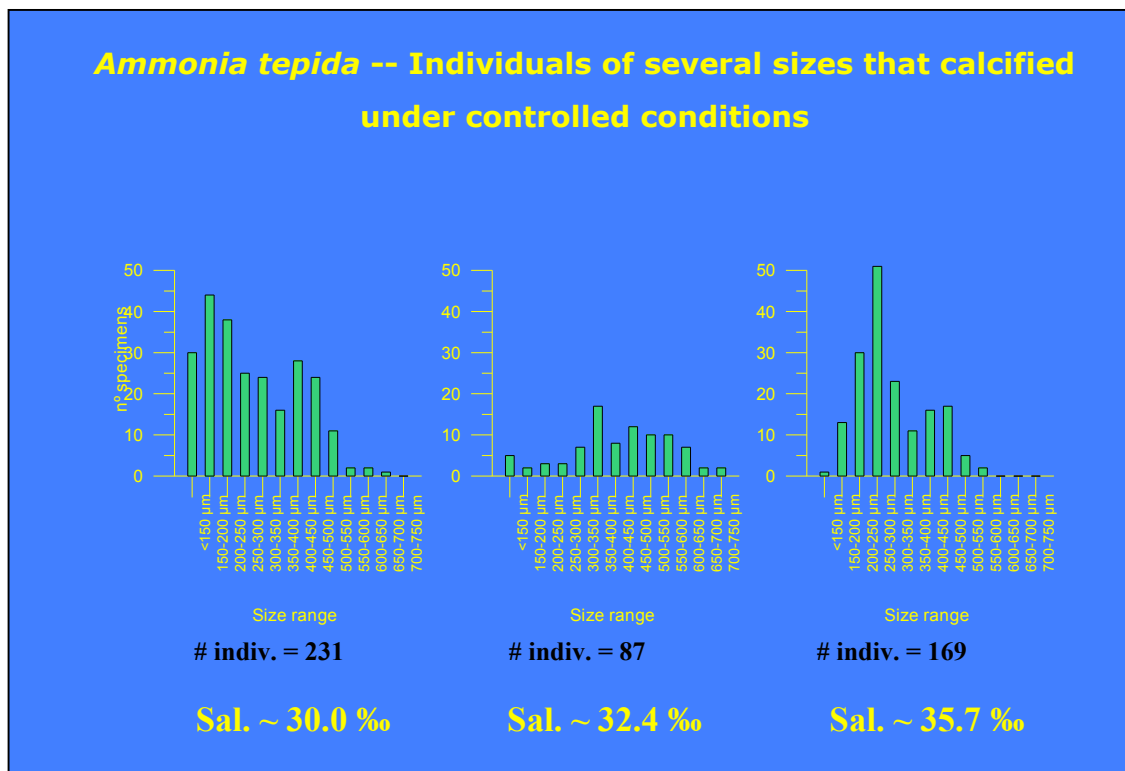


Fig. 12. Results of a culture experiments in which specimens of *Ammonia tepida* were cultured in three different salinities. For all three salinities, abundant adult specimens were obtained.

WP8: Physiologic controls on salinity proxies in bivalves. IP: PAULET, LEMAR

The aim of WP8 is to understand (1) how trace elements and stable isotopes are incorporated in bivalve shells and (2) how physiological effects can alter the environmental signal incorporated in bivalve shells. For this purpose, an euryhalin bivalve, *Ruditapes philippinarum*, living in the Auray River (France) was chosen.

1) An *in situ* monitoring was performed in the Gulf of Morbihan (France). Two stations were chosen along the Auray River: Locmariaquer, located at the mouth of the estuary and Le Bono upstream. Temperature and salinity were recorded at both stations every ten minutes using an autonomous data logger from March 2006 to July 2008. Every 2 months, water samples were collected in order to characterize dissolved and particulate chemical composition (traces elements, $\delta^{18}O_{\text{water}}$, $\delta^{13}C_{\text{DIC}}$, $\delta^{15}N_{\text{POM}}$ and $\delta^{13}C_{\text{POM}}$).

Results:

At Le Bono station, we observed a high salinity variability (between 15 and 34) at various times scales: annual, fortnightly and tidal. Inversely, at Locmariaquer salinity is nearly stable. Magnesium, strontium, calcium and barium concentration, $\delta^{18}O_{\text{water}}$ and $\delta^{13}C_{\text{DIC}}$ were highly correlated with salinity.

This record is the first step of proxy calibration. The Manila Clam, *Ruditapes philippinaum*, lives at these two stations. This will allow to work on the effect of spatio-temporal salinity variations on physiology and finally on shell composition. This monitoring will also be used by WP7 for foraminifera calibration.

2) A Sclerochronology study was performed in order to extract a precise time scale from the shell microstructures. Previous studies have focused on Manila clams from intertidal flat. In our work, a subtidal population has been studied. Calcein marking were made *in situ* by scuba diving in subtidal area using benthic chambers. These calcein marking showed that biomineralization cycles and growth lines formation in the shells occurs with tidal periodicity: one micro-increment is precipitated per tidal cycle.

This result allows to assign a calendar date to each growth increment observed in the shell of *Ruditapes philippinarum* collected at the Bono.

3) *In situ* experiment at high temporal resolution

A monitoring study was performed at a high temporal resolution in the Auray River estuary. Seawater and Manila clams were sampled in the subtidal zone by scuba diving every two hours during a 48 hours experiment at the Bono. At this location, tidally driven variations of environmental parameters (i.e. salinity, turbidity, dissolved oxygen, $\delta^{18}\text{O}_{\text{water}}$, $\delta^{13}\text{C}_{\text{DIC}}$, Mg, Sr, Ca and Ba concentration ...) were observed. Salinity varied between 20 (low tide) and 32 (high tide). The first results indicate that the osmolarity in seawater equals that in the haemolymph and extra-pallial fluids, except at low tide when osmolarity is higher in the fluids. These results show that *Ruditapes philippinarum* is an osmoconformer. However, we can hypothesize that at low tide, when salinity decreases beneath a threshold, our clams could close their valves to protect themselves from low salinity. As a consequence Manila clam may not record salinity minimum into their shells.

Trace elements analyses of the shells by electronic microprobe (WDS) show that there is no magnesium concentration variation at a tidal scale and there is a good relation between shell microstructure and strontium banding. *R. philippinarum* records strontium variation at tidal scale. Strontium variations in the shell could be explained by strontion concentration variations in water or by the biomineralization rate. Analyses of traces elements concentrations in *Ruditapes philippinarum*'s fluids (heamolymph and extra-pallial fluids) at a tidal scale are on progress

4) Organisation workshop bivalve à brest en octobre 2007

A workshop focusing on bivalve salinity proxy was held at the European Institute for Marine Sciences in Brest (France) in October 4th and 5th 2007. Fourteen talks have been proposed and two scientific round tables organised.

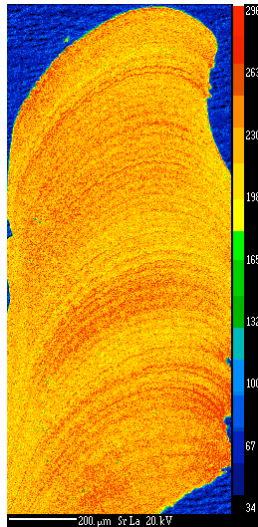


Figure 1 : Strontium distribution in a clam shell from the Bono station. Strontium concentration variation corresponds to tidal rhythm.

WP9: Thermo-*haline* controls on past ocean changes: Verification and application of salt proxies. IP: Zahn, UB

Unfortunately, this WP could not be carried out as no funding was made available.