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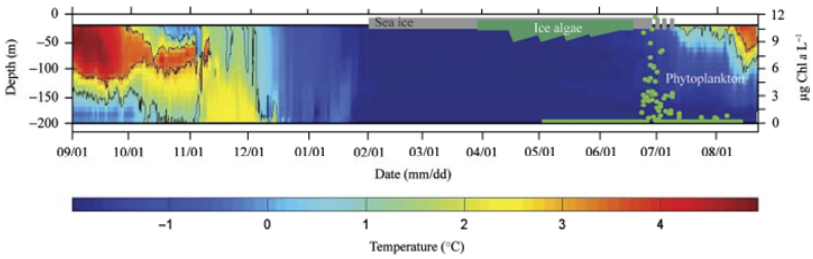
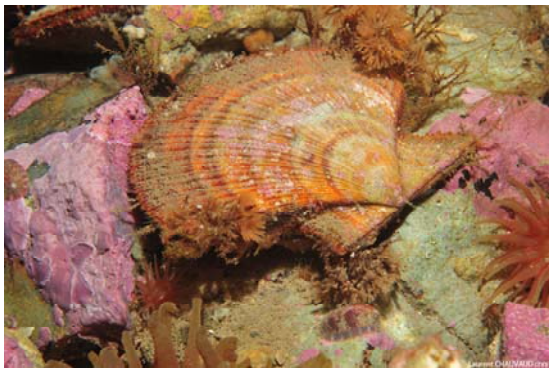
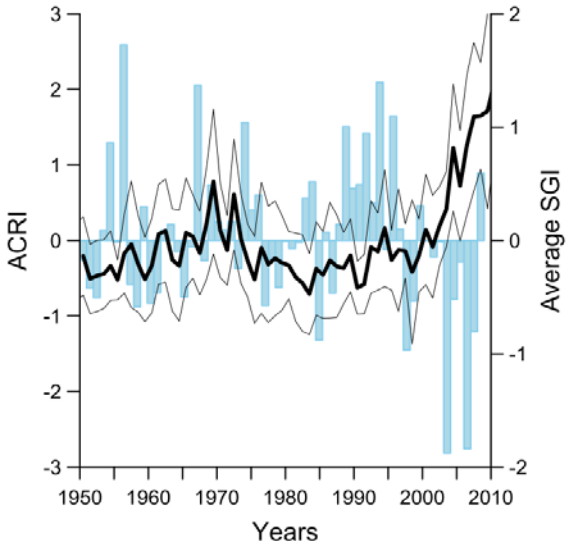
PAN-ARCTIC BIVALVES AS POLAR BIOARCHIVES
BIVALVES PAN-ARCTIQUES COMME BIOARCHIVES POLAIRES
B.B. POLAR

Research project proposed to the TOTAL Foundation

Laurent CHAUVAUD
LEMAR UMR6539







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PROJECT DESCRIPTION

***Abstract (300 words)*:**
In the B.B. polar project, we propose a scientific project using marine invertebrates as biological archives of the Arctic environmental variations. Tools will be implemented to monitor environmental parameters of the Arctic ecosystem at different time scales (from the daily to the decadal scales) by using two bivalves species, *Chlamys islandica* and *Astarte spp*., and at different spatial scales (from the single fjord to a pan-arctic view). Moreover, research in ecology will serve the visual and plastic design. This project will be the occasion for scientists and artists to work together around the climate change issues, transgressing the limits of each discipline.

***Keywords*:**
Arctic bivalves; climate; growth; proxy; biology; marine ecology

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Context and issues:

Research to calibrate Arctic bivalves as indicators of environmental variations has been underway for the last decade. In the Observatory at the European Institute of Marine Studies (IUEM), we have demonstrated since 1994 that the King scallop (*Pecten maximus*) provides exceptional biological archives of the temperate environment[1]. Our group uses routine sclerochronology and sclerochemistry techniques, which allow us to depict the high frequency (daily) variations of the ecological conditions in the coastal waters of different areas of the planet. Recently, two Arctic bivalves have been added: another Pectinidae species, *Chlamys islandica*, and the *Astarte spp*. complex. For Astarte spp., we work in collaboration with our Canadian colleagues from ISMER/UQAR (Institut des Sciences de la Mer/Université du Québec à Rimouski). The originality of this project lies in the alliance of these two pan-Arctic species, allowing us depicting environmental variations at two different time scales. Indeed, *Chlamys islandica* has a life time of a couple of decades and can record the environmental variations at the daily scale whereas *Astarte moerchi* can live as long as a century and record these variations at the annual scale.

The B.B. Polar project proposes to apply the methods of describing the recent past environment in order to obtain:

1. A calibration of the descriptors (so-called "proxies") in the sites already instrumented;
2. An accurate description of the environmental modifications occurred during the last century;
3. The establishment of an inexpensive observatory based on the calibrated method.

B.B Polar is part of programmatic and financial framework already well underway. The oceanographic monitoring equipment already deployed is provided by the platform PLATIM of the European Institute of Marine Studies. Norwegian (from University of Svalbard, UNIS) and French (Laboratoire d'Océanographie et du Climat, LOCEAN) teams are in charge of the deployment of deep-sea probes in the sites of study. For the Canadian part of the project, the ISMER/UQAR and the MNHN (Museum National d'Histoires Naturelles) are in charge of the *Astarte spp*. sampling and of the related chemical and biochemical analyses (SCLERARCTIC project; EC2CO-INSU 2012). The SCALA project (LEFE-INSU 2012) will apply the same approach on *Chlamys islandica* in Svalbard.

Yet, to be able to gather both type of studies and to go much further in realizing the first description of the environmental modifications at the Pan-Arctic scale, we are soliciting from the TOTAL Foundation the support to extend the project on both species within two geographical areas in the Arctic Region.

[1] http://www-iuem.univ-brest.fr/observatoire/evecos.php

INTRODUCTION

It is now commonly accepted that the Arctic Ocean is the region where changes in climate, hydrography and ecology, related to global warming, are expected to be strongly expressed hence, ***the Arctic can serve as a harbinger of global change*** (IPCC, 2007; ACIA, 2004). The vast Arctic shelves are likely to be particularly sensitive because of their shallowness, their seasonally varying ice cover, and their dependency upon inflowing waters from the southward oceans and continents (Piepenburg, 2005).

Pelago-benthic coupling has repeatedly been demonstrated as a key process of marine ecosystems, as it ultimately determines the level of food supply to the benthos. In polar waters, sea-ice cover strongly influences the strength of pelago-benthic coupling. Leu *et al*. (2011) suggested that the timing of primary production is probably the single most essential factor deciding the recruitment success or failure in pelagic secondary producers, and hence, the efficiency of transfer of biomass and energy to higher trophic levels. However, the quantity and quality of the algal food available, together with seawater temperature, have also been shown to be crucial for optimal reproduction and development.

The potential for sea ice to recede with climate change highlights the need to develop a predictive understanding of how Arctic marine ecosystems will evolve with changes in sea ice distribution and thickness (Clarke & Harris, 2003; Smetacek & Nicol, 2005). This requires a good understanding of ecosystem structure and functioning and how it relates to environmental drivers.

Even given the proposed resilience and adaptability of Arctic systems in general (Dayton, 1990), a climate change being so drastic that it results in a shift from a "cold/abundant ice" to a "warm/limited ice" mode will probably have profound ecological consequences propagating through all trophic levels, as sea-ice dynamics is the prime physical factor driving marine Arctic biology from cellular physiology and biochemistry to food web and habitat structure. ***In general, there would be a shift in the relative importance of sea-ice, pelagic and benthic biota in the overall carbon flux from "sea-ice algae-benthos" to "phytoplankton-zooplankton" dominance*** (Carroll & Carroll, 2003). It is also hypothesized that in shallow areas, microphytobenthos production will be enhanced. ***Yet, it remains unclear how key pelagic and benthic organisms will respond to those changes in food sources (phytoplankton, sea ice algae and microphytobenthos) and environmental conditions (Figure 1)***.

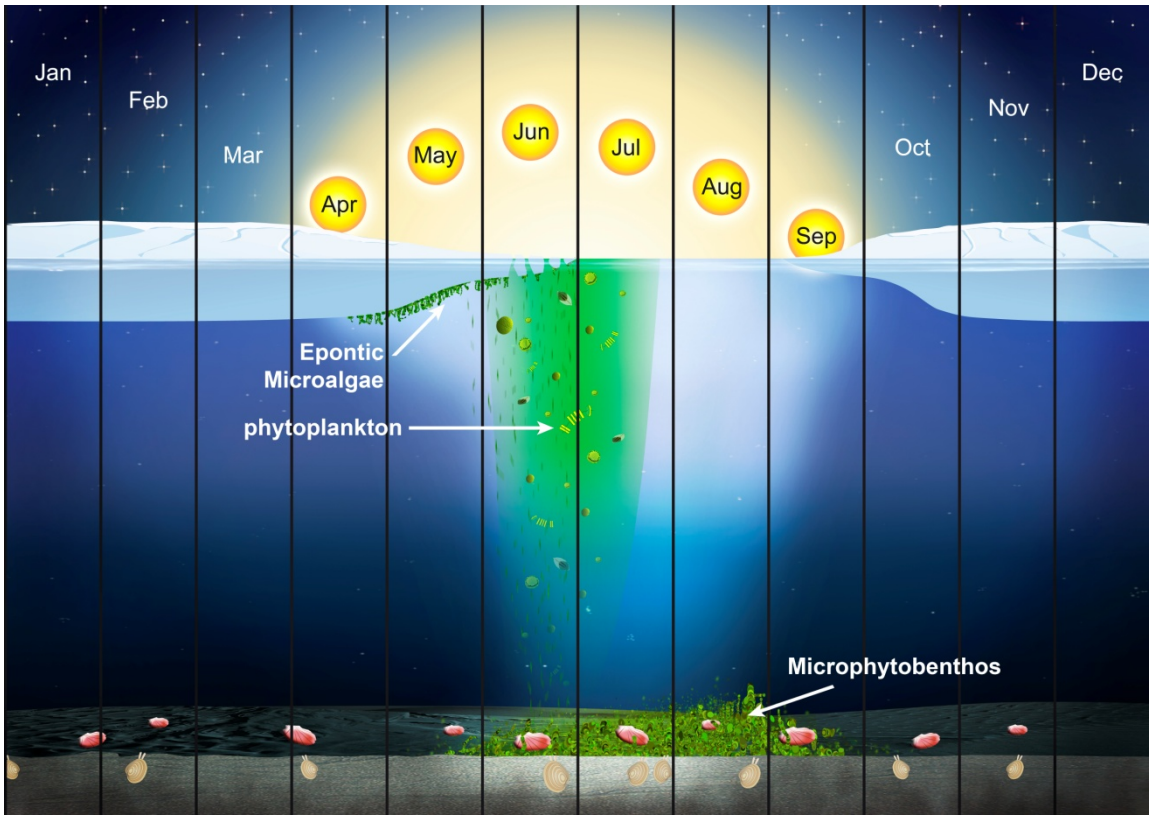


Figure 1: Schematic illustration of the seasonal timing of the three primary food sources in an Arctic ecosystem.

Seafloor communities are ideal to examine the changes in the environmental responses of marine ecosystems to climatic forcing. Many benthic organisms are long-lived, and sessile, therefore they must experience and endure changes in the biotic and abiotic conditions of the overlying waters through time.

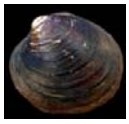
Many studies on Arctic benthic communities have proven their sensitivity to environmental changes over decadal scales (Grebmeier *et al*., 2006; Renaud *et al.,* 2008; Wassmann, 2011; Weslawski *et al*., 2011). While these studies provide insight into the long-term changes taking place in the benthos in response to different overriding physical conditions, most lack a strong temporal component, i.e. their data is from sampling in discreet and widely separated points in time. Thus, while studies can provide evidence of an effect, they cannot elucidate the mechanisms by which these changes take place (Carroll *et al*., 2011a). ***In the present era of changing climate in the Arctic, it is essential to understand not only the composition of benthic communities, but also how they are linked to environmental processes if we hope to be able to anticipate the potential responses of these systems to climate change*** (Carroll *et al*., 2011b).

Bivalves dominate the benthic biomass of many Arctic shelves (Gulliksen *et al*., 1985; Dayton, 1990). These organisms form their external calcium carbonate skeleton periodically, controlled by the organism and function of environmental conditions. It leads to the formation of growth lines that can be used as chronological landmarks (sclerochronology). High latitude bivalves have life spans of decades (Ambrose *et al*., 2006; Sejr & Christensen, 2007; Carroll *et al*., 2009, 2011a) to centuries (Schöne *et al*., 2005, 2011a; Witbaard *et al*., 1999; Wanamaker *et al*., 2011). ***Deciphering environmental proxies incorporated within biogenic archives during their growth thus provide records of environmental conditions over decades to centuries, which is critical to understand the response of Arctic benthic communities to climate change given the paucity, in this region, of long-term data on community structure and dynamics***. The studies cited above produced intriguing results suggesting that inter-annual variations in bivalve shell growth indeed reflects variability in local ecological conditions, with potential for retrospectively examining ecologically relevant effects of climatic variations over decades to even thousands of years. The important link between climate and ecosystem processes suggested by clam growth patterns however depends on uninvestigated direct links between growth and simultaneously collected environmental data (Ambrose *et al*., 2012). The approach used till now to address these questions focused on two species in the Svalbard Archipelago (*Serripes groenlandicus* and *Clinocardium ciliatum*) and consisted in looking at the inter-annual variations in shell growth to explore the relationship between benthic communities and environmental variations associated with decadal climate oscillations in the Arctic as the Arctic Oscillation (AO) and the Arctic Climate Regime Index (ACRI) (Ambrose *et al*., 2006, 2012; Carroll *et al*., 2009, 2011a, 2011b). ***The last conclusions in Ambrose et al. (2012) called for the need: i) to understand the factors affecting growth in bivalves and what they may tell us about the influence of climate change on benthic communities in general, ii) to determine the relative importance of biotic and abiotic factors on the bivalves' growth and iii) to understand taxon-specific responses to environmental variables before bivalves can be used to their full potential as bioarchives for high-latitude environmental conditions***.

Pectinidae, a bivalve family, are good candidates to address these questions. Most of them form annual rings (time stamp) and many species even produce daily rings, thus providing an excellent high-resolution calendar landmark. For instance, *Pecten maximus* shells are already used as "environmental bioarchives" in the Observatory of the European Institute for Marine Studies (IUEM; see the website for more details on the EVECOS series: http://www-iuem.univ-brest.fr/observatoire/evecos.php). This time-series is completed with the "St Jacquothèque" archiving *Pecten maximus* shells coming from different sites covering all the distribution range of the species (from North Africa to North of Norway), as well as many other scallop species studied worldwide by our research group. In the Arctic, the same methodologies and techniques will be applied on *Chlamys islandica*. In addition, to include a long-lived species in this study is important to be able to look at the long term trend of the Arctic ecosystem. Preliminary results by our group (collaboration between UQAR, MNHN and LEMAR) have shown that bivalves from the Astartidae family can be good candidates. They are present all around the Arctic Ocean and live in the sediment from the coastline to 2000 meter depth (Saleuddin, 1965).

In this context, based on our well-established experience on the use of bivalves as biological archives (Chauvaud *et al*., 1998, 2005, 2011, 2012; Lorrain *et al*., 2004, 2005; Thébault *et al*., 2006, 2007, 2008, 2009a, 2009b; Poulain *et al*., 2010, 2011; Thébault & Chauvaud, 2012; Royer *et al*., 2012;), ***we propose to develop a coupled approach of sclerochronology - sclerochemistry and physiology methods in order to establish the link between biotic and abiotic factors and the bivalves' growth at the pan-Arctic scale using two bivalves species: the Iceland scallop*** **Chlamys islandica** ***and the*** **Astarte spp.** ***(Table 1). Using this couple of species will enable us to work at different time scales: from daily to annual scale for*** **Chlamys islandica** ***and from seasonal to decadal scale for*** **Astarte spp.**

Table 1: Characteristics of the two selected species

Parameters	***Chlamys islandica*** 	***Astarte spp.*** 
Life time	Couple of decades (Max. 27 years)	Up to a century
Trophic strategy	Suspension-feeder	Suspension-feeder
Life cycle	Sex separated (dioecious) Pelagic larvae	Hermaphroditic Holobenthic life-cycle
Distribution	Widespread boreal-arctic	Widespread boreal-arctic
Habitat	Epifaunal on sediment or attached to rocks From coastline to 250 m	Infaunal in silty sediment From coastline to 2000 m

The main objective of this project is to depict the environmental signal within the shells of these two bivalves' species. The signal incorporated in the shell results, indeed, partly from the environment but also from metabolism. A phase of calibration is necessary to uncouple these two signals. The different issues addressed in this project will be investigated at different geographic scales, from the fjord to a pan-Arctic view.

Objective and expected results:

B.B. polar proposes to apply the methods of describing the recent past environment in order to obtain:

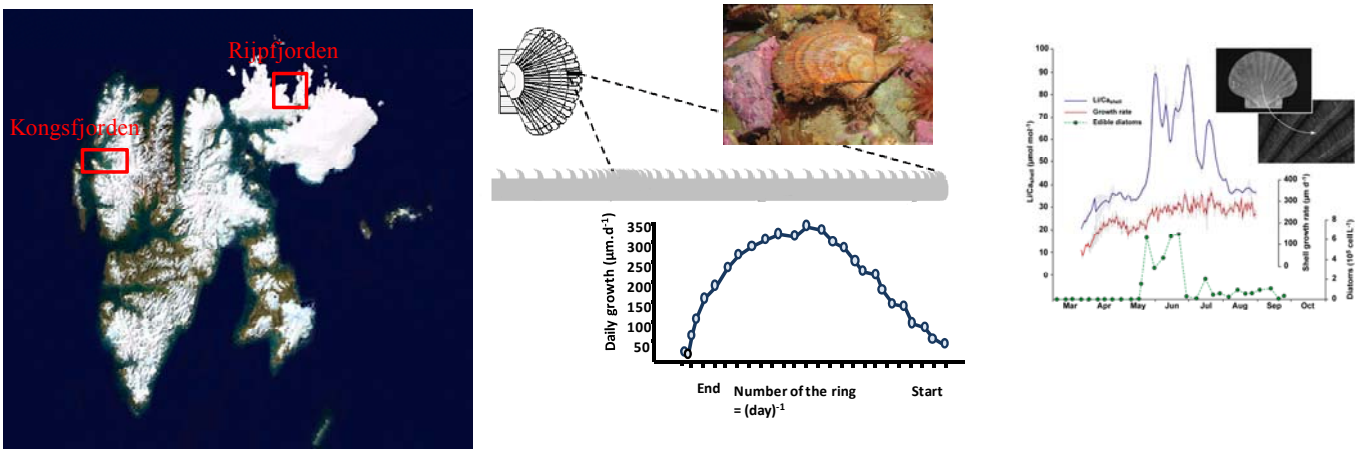
1. A calibration and validation of the environmental descriptors of the sites already instrumented (Kongsfjorden and Rijpfjorden in Svalbard)
2. A description of the environmental variations during the last decades coupling data on *Chlamys islandica* and the long-lived species *Astarte spp*.
3. A description of the environmental variations at the Pan-Arctic scale by enhancing the geographical area to non instrumented sites in the Greenland and Canadian Arctic.

Comparison of the same type of data obtained with the two bivalves' species sampled in different Arctic regions will allow us bringing into light the biological responses (growth) and the environmental variations (proxies) at the time scales at which the anthropogenic climate variations are expressed.

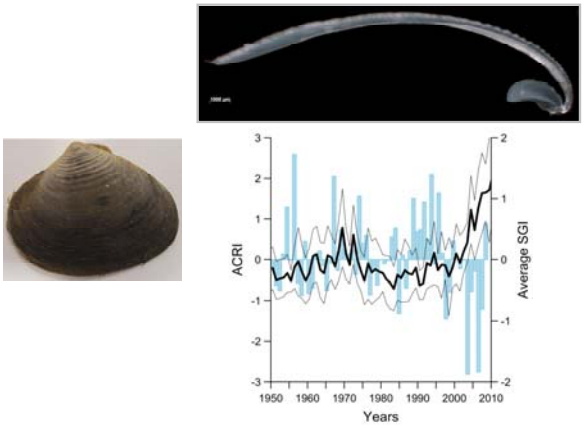
At the end of this project, we will have implemented tools to monitor environmental parameters of the Arctic ecosystem at different time scales (from the daily to the decadal scales) by using two bivalves species and at different spatial scales (from the single fjord to the pan-arctic view). We will also have transferred the techniques and methodologies well-tried on species living in temperate regions (EVECOS series of the Brest Observatory) to Arctic species. From this, we will get an image of the past evolution of the Arctic marine ecosystems, corresponding to the recent period of climate variations caused by human activities. In addition, beyond this project, we aim to be able to carry on the implemented observations on a routine basis in order to be able to monitor the coming ecosystems evolution in the frame of an Arctic Benthic Observatory. It will be part of the French national research strategy (“Chantier Arctique” driven by INSU-CNRS on behalf of the French Research Ministry) and as such, integrated into the international

effort for setting up a global Arctic Observatory (SAON - Sustaining Arctic Observing Network, initiated by the Arctic Council in 2007).

Obj. 1: Proxies' calibration and validation on *Chlamys islandica*



Obj. 2: Long-term environmental description



Obj. 3: Pan-Arctic environmental description

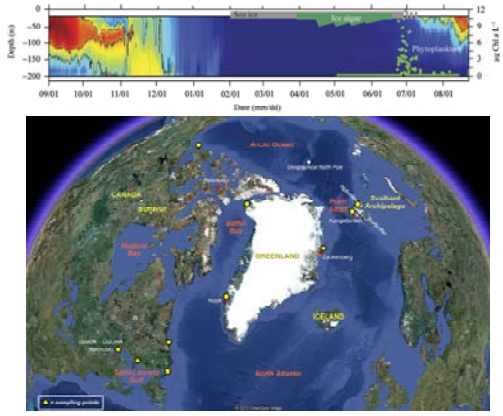


Figure 2: Schematic illustration of the project's objectives

Methodology:

To be able to calibrate the environmental proxies contained in the archived carbonates, the following steps are needed:

1. Calcein marking of *Chlamys islandica* and $\Delta^{14}C$ analysis in the shell of *Astarte spp*. to calibrate the rhythm of growth lines formation;

Measurements of the metabolism:

2. Calcification measurements to understand the archiving periods of the environmental signals;
3. $\delta^{13}C$ measurements of the carbon breathed by the organisms to quantify the part of the metabolic carbon incorporated in the carbonates;
4. Measurements of the filtration rate to calculate the amount of food ingested by the organisms;
5. Determination of the food sources assimilated by the organisms to be able to know which signal is recorded in the calcite of the scallop in term of primary production;
6. Measurements of the energetic costs of the swimming activity of *Chlamys islandica* free-living on the sediment.

The sclerochemical analyses will be performed on shell carbonate samples of the two selected species. Different chemical elements and stable isotopes will be measured and compared to the measured environmental parameters to depict different suitable proxies of the Arctic environment (see Table 2). These relevant proxies will then be applied to describe the non instrumented sites.

Table 2: Review of proxies used in bivalves' shell

Parameter	Proxy for	References
$\delta^{13}C$	Metabolism Primary production Salinity	Chauvaud *et al.*, 2011 Schöne *et al.*, 2011a Gillikin *et al.*, 2006a
$\delta^{18}O$	Temperature Salinity	Chauvaud *et al.*, 2005 Sampei *et al.*, 2005
Mg/Ca	Temperature	Takesue & Van Geen, 2004 Schöne *et al.*, 2011b
Sr/Ca	Growth Temperature	Lorrain *et al.*, 2005 Schöne *et al.*, 2011b
Ba/Ca	Phytoplankton biomass Salinity	Thébault *et al.*, 2009a Gillikin *et al.*, 2006b
Li/Ca	Phytoplankton biomass Growth	Thébault & Chauvaud, 2012 Thébault *et al.*, 2009b
Mo/Ca	Phytoplankton dynamics	Thébault *et al.*, 2009a

Positioning of the project compared to other programs in France, Europe or worldwide:

With rising concerns about environmental changes over the last decades, important multidisciplinary programs have taken place worldwide, improving knowledge on polar marine ecosystems. The focus on polar environment is becoming more and more important due to the fact that in polar oceans, temperatures are changing more than twice faster than the global average.

Traditionally, the study of the Arctic Ocean has mainly been carried out by countries surrounding the Arctic Ocean, i.e. Canada, USA, Norway, Denmark and Russia. However, since climate change is felt first and foremost in the Arctic, growing concerns for Arctic ecosystems and native populations living there have brought other countries to join these research efforts. The willingness of the European Union to get more involved in Arctic activities was recently reinforced by asking to be part of the Arctic Council.

The willingness of the European Union to get more involved in Arctic activities was recently reinforced by asking to be part of the Arctic Council. The EU recently funded, under FP7, a new project for studying the opportunity of an integrated observatory in Svalbard (SIOS, Svalbard Integrated Arctic Earth Observing System). As an ESFRI project, SIOS is a preparatory phase. Yet, contacts have been made so the future Arctic Benthic Observatory we aim to establish at the end of this project could be part of this initiative.

Even before the directives given by the EU for being involved in Arctic research, France has expressed its concern about the Arctic Regions through different reports since 2008. In particular, a mission letter was addressed in 2009, in order to request CNRS to integrate the SAON initiative and to define the conditions of this insertion. France, which carries out important polar research activities in Antarctica, has recently extended its polar marine ecosystem research efforts in the Arctic, with projects such as MALINA (Beaufort Sea), DAMOCLES or the Tara Expedition (Barents Sea). CNRS has strengthened collaborations with Canadian researchers (University of Laval in Québec), experts in Arctic research, by creating an international combined research unit (UMI – Unité Mixte Internationale).

Therefore, the B.B. Polar project aims to be part of these French and international efforts. Indeed, it is built on the knowledge obtained by its participants on Arctic ecosystem functioning during various Arctic programs (Life in a Changing Ocean[2], Circumpolar Monitoring Biodiversity program[3], ARCTICNET[4], HERMES Program[5], Pré-APOLOBIS and ANR ECOTAB).

[2] http://lifeinachangingocean.org/
[3] CAFF, Conservation of Arctic Flora and Fauna, http://www.arctic council.org/index.php/en/biodiversity/cbmp
[4] http://www.arcticnet.ulaval.ca/index-fr.php
[5] The Kongsfjord – HAUSGARTEN – transect case study: Impact of climate change on Arctic marine community structures and food webs

Duration and planning:

Schedule

	2013 (Year 1)												2014 (Year 2)												2015 (Year 3)												
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Preparation field work																																					
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Sclerochemistry																																					
Ecophysiological analysis																																					
Tissue analysis																																					
Coupling data analysis																																					
Postdoctoral contract																																					
Meetings																																					
Publication writting																																					
Magnum diffusion																																					…

Other partners involved:

Laurent CHAUVAUD, director of the Marine Observatory of the European Institute for Marine Studies and Research director CNRS at the LEMAR, is leader of the project in tight collaboration with other members of the LEMAR, national and international partners.

- Laboratoire des Sciences de l'Environnement Marin (LEMAR - UMR6539, France): Julien Thébault, Jacques Clavier, Joëlle Richard, Aurélie Jolivet, Christine David-Beausire and Erwan Amice.
- Biologie de Organismes et Ecosystèmes Aquatiques (BOREA - UMR7208, France): Frédéric Olivier and Tarik Meziane
- Institut des Sciences de la Mer de Rimouski (ISMER/UQAR, Canada): Réjean Tremblay, Philippe Archambault, Gesche Winkler and Blandine Gaillard.
- Canadian Museum of Nature (CMN, Canada): André Martel
- Bates College (University, USA): William Ambrose
- Greenland Institute of Natural Resources (GINR, Greenland): Søren Rysgaard and Martin Blicher
- Akvaplan-niva, Polar Environmental Centre (PEC, Norway): Michael Carroll
- Institute of Marine Research (IMR, Norway): Øivind Strand and Tore Strohmeier
- Agence MAGNUM PHOTOS (France): Jean Gaumy and Sandrine Paumelle

	LEMAR	**BOREA**	**ISMER/UQAR**	**CMN**	**Bates College**	**GINR**	**IMR**	**PEC**	**MAGNUM**
Bivalves sampling (Svalbard)									
Bivalves sampling (Canada and Greenland)									
Sclerochronology									
Sclerochemistry									
Biological analysis									
Ecophysiological analysis									
Artistic production									

Other LEMAR researchers or partners are not directly involved in this project but will contribute to the acquisition of environmental parameters and to bivalves sampling in their own projects:
- Nathalie Morata (LEMAR): ANR ECOTAB (2011-2014)
- Frédéric Vivier (LOCEAN - UPMC Paris): ANR OPTIMISM (2009-2012), Ice-Dyn (IPEV)
- Haakon Hop (University of Tromsø)
- University of Svalbard

Outreach and communication associated with the project / results:

In our point of view, it is important to bring closer art and sciences as it was the case in the beginning of the 20th century because they nourish reciprocal influences. We propose to the TOTAL Foundation a scientific project about information recorded in the marine invertebrates linked together with an artistic project. The research in ecology will serve the visual and plastic design.

Aren't artistic creativity and scientific discovery proceeded with the same rigor? Aren't they enrolled in a similar objective which leads everyone to go beyond knowledge and past achievements? Around these issues, we will look forward for transgressing the limits of each discipline to question both scientists and artists in a strong societal context. It is around the climate change issues, so visible in the Artic, that scientists and artists involved in the B.B Polar project will pursue their contrasting objectives: artists search and discover in order to create, whereas scientists in their researches make assumptions, infer scenarios, and test them in order to achieve a new discovery or a new paradigm... unless fate sometimes becomes the unexpected companion of creation?

Two artists are involved in the project[6]. Jean Gaumy, photographer from MAGNUM Photos Agency, will conduct a photographic mission project and also a project of art-house film. Sandrine Paumelle, visual artist, will reconstruct her art studio on site in order to perform her plastic creations and installation around the concept of "safe haven".

Thus, the images made by the B.B. Polar scientific group during their dives under the ice, will be brought face to face with images made by the artists. This transdisciplinary approach will mutually grow richer from the daily cohabitation between artists and scientists and from their own way of understanding research and creation. This exciting human laboratory will permit to "*share and strengthen expertise to broaden collective knowledge*" which is one of the objectives supported by the TOTAL Foundation. We thus plan to implement it in the frame of this project, which covers two fields of activities supported by the TOTAL Foundation: marine biodiversity and contemporary creation.

The IUEM-LEMAR already owns underwater camera equipments. Erwan Amice, SCUBA diver at LEMAR and member of B.B. Polar, has been many times awarded for the great quality of his underwater pictures, including pictures made in the Arctic and in the Antarctic. The pictures made during B.B. Polar will be available online on the CNRS website via the CNRS image database (http://phototheque.cnrs.fr/).

The approached partners for the exhibitions are: Musée des Confluences, Lyon, France; Musée des arts et métiers, Paris, France; Plateau des Capucins, Brest, France; Perpektivet Museum, Tromsø, Norway; Musée d'art contemporain de Montréal, Canada.

B.B. Polar members commit to make themselves available to the media for communicating on the project, to write scientific papers and also popular papers to sensitize the public, by this original action, to the protection of the environment.

Detailed global budget:

	INSU	INSU	IPEV	TOTAL Foundation		Global budget
	SCLERARCTIC	SCALA-LEFE	SCALA-IPEV	B.B.POLAR	Percentage	
Equipment	6 000 €	35 000 €	4 000 €	23 600 €	*34*	68 600 €
Analysis	24 885 €	28 065 €		60 000 €	*53*	112 950 €
Missions	29 400 €	7 940 €	45 040 €	90 000 €	*52*	172 380 €
Salary		3 000 €		62 000 €	*95*	65 000 €
Publications fees		3 000 €			*0*	3 000 €
Artistic production				60 000 €	*100*	60 000 €
Global budget	60 285 €	77 005 €	49 040 €	295 600 €	*61*	481 930 €

Percentage and budget required from the Foundation:

The budget required from the TOTAL Foundation is **295 600€** which corresponds to **61%** of the global budget of the project (see Table above for details).

[6] http://www.iuem.univ-brest.fr/observatoire/observation-cotiere/faune-flore/coquilles-st-jacques/

Publications and references:

References cited in the text:

Ambrose Jr. W.G., Carroll M.L., Greenacre M.L., Thorrold S., McMahon K. (2006). Variation in *Serripes groenlandicus* (Bivalvia) growth in a Norwegian high-Arctic fjord: evidence for local- and large-scale climate forcing. Global Change Biology 12:1595-1607

Ambrose Jr. W.G., Renaud P.E., Locke V W.L., Cottier F.R., Berge J., Carroll M.L., Levin, B., Ryan S. (2012). Growth line deposition and variability in growth of two circumpolar bivalves (*Serripes groenlandicus*, and *Clinocardium ciliatum*). Polar Biology 35:345-354

Arctic Climate Impact Assessment (ACIA) (2004). Impact of a warming Arctic. Cambridge University Press, Cambridge, 139pp

Carroll M.K., Carroll J. (2003). The Arctic seas. In: Black KD, Shimmield GB (eds) Biogeochemistry of Marine Systems. Blackwell, Sheffield, pp. 127-156

Carroll M.L., Johnson B., Henkes G.A., McMahon K.W., Voronkov A., Ambrose Jr. W.G., Denisenko S.G. (2009). Bivalves as indicators of environmental variation and potential anthropogenic impacts in the southern Barents Sea over multiple time scales. Marine Pollution Bulletin 59:193-206

Carroll M.L., Ambrose Jr. W.G., Levin B.S., Ryan S.K., Ratner A.R., Henkes G.A., Greenacre M.J. (2011a). Climatic regulation of *Clinocardium ciliatum* (Bivalvia) growth in the northwestern Barents Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 302:10-20

Carroll M.L., Ambrose Jr. W.G., Levin B.S., Locke V W.L., Henkes G.A., Hop H., Renaud P.E. (2011b). Pan-Svalbard growth rate variability and environmental regulation in the Arctic bivalve *Serripes groenlandicus*. Journal of Marine Systems 88:239-251

Chauvaud L., Thouzeau G., Paulet Y.-M. (1998). Effects of environmental factors on the daily growth rate of *Pecten maximus* juveniles in the Bay of Brest (France). Journal of Experimental Marine Biology and Ecology 227:83-111

Chauvaud L., Dunbar R., Lorrain A., Paulet Y.-M., Thouzeau G., Jean F., Guarini J.-M., Mucciarone D. (2005). The shell of the Great Scallop *Pecten maximus* as a high frequency archive of paleoenvironmental change. Geochemistry Geophysics Geosystems 6:Q08001

Chauvaud L., Thébault J., Clavier J., Lorrain A., Strand Ø. (2011). What's hiding behind ontogenetic $\delta^{13}C$ variations in mollusk shells? New insights from the great scallop (*Pecten maximus*). Estuaries and Coasts 34:211-220

Chauvaud L., Patry Y., Jolivet A., Cam E., Le Goff C., Strand Ø., Charrier G., Thébault J., Lazure P., Gotthard K., Clavier J. (2012). Variation in size and growth of the great scallop *Pecten maximus* along the latitudinal gradient. PLoS ONE 7:e37717

Clarke A., Harris C.M. (2003). Polar marine ecosystems: major threats and future change. Environmental Conservation 30:1-25

Dayton P.K. (1990). Polar benthos. In: Smith Jr WO (ed) Polar oceanography, Part. B: Chemistry, biology, and geology. Academic, San Diego, pp. 631-685

Gillikin D.P., Lorrain A., Bouillon S., Dehairs F., Willenz P. (2006a). $\delta^{13}C$ in *Mytilus edulis* shells: relation to salinity, DIC, phytoplankton and metabolism. Organic Geochemistry 37:1371-1382

Gillikin D.P., Dehairs F., Lorrain A., Steenmans D., Baeyens W., André L. (2006b). Barium uptake into the shells of the common mussel (Mytilus edulis) and the potential for estuarine paleo-chemistry reconstruction. Geochimica and Cosmochimica Acta 70:395-407

Grebmeier J.M., Overland J.E., Moore S.E., Farley E.V., Carmack E.C., Cooper L.W., Frey K.E., Helle J.H., McLaughlin F.A., McNutt S.L. (2006). A major ecosystem shift in the northern Bering Sea. Science 311:1461-1464

Gulliksen B., Holte B., Jakola K.J. (1985). The soft bottom fauna in Van Mijenfjord and Raudfjord, Svalbard. In: Gray J.S., Christiansen M.E. (Eds.), Marine Biology of Polar regions and Effects of Stress on Marine Organisms. Proceedings XVIIIth European Marine Biology Symposium. J. Wiley and Sons, New-York, pp. 199-215

Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp., 2007

Leu E., Søreide J.E., Hessen D.O., Falk-Petersen S., Berge J. (2011). Consequences of changing sea ice cover for primary and secondary producers in the European Arctic shelf seas: timing, quantity, and quality. Progress in Oceanography 90, 18–32

Lorrain A., Paulet Y.-M., Chauvaud L., Dunbar R., Mucciarone D., Fontugne M. (2004) $\delta^{13}C$ variations in scallop shells: Increasing metabolic carbon contribution with body size? Geochimica and Cosmochimica Acta 17:3509-3519

Lorrain A., Gillikin D.P., Paulet Y.-M., Chauvaud L., Le Mercier A., Navez J., André L. (2005). Strong kinetic effects on Sr/Ca ratios in the calcitic bivalve *Pecten maximus*. Geology 33:965-968

Piepenburg D. (2005). Recent research on Arctic benthos: common notions need to be revised. Polar Biology 28:733-755

Poulain C., Lorrain A., Mas R., Gillikin D.P., Dehairs F., Robert R., Paulet Y.-M. (2010). Experimental shift of diet and DIC stable carbon isotopes: Influence on shell $\delta^{13}C$ values in the Manila clam *Ruditapes philippinarum*. Chemical Geology 272:75-82

Poulain C., Lorrain A., Flye-Sainte-Marie J., Amice E., Morize E., Paulet Y.-M. (2011). An environmentally induced tidal periodicity of microgrowth increment formation in subtidal populations of the clam *Ruditapes philippinarum*. Journal of Experimental Marine Biology and Ecology 397:58-64

Renaud P., Morata N., Carroll M.L., Denisenko S.G., Reigstad M. (2008). Pelagic-benthic coupling in the western Barents Sea: processes and time-scales. Deep-Sea Research II 55:2372-2380.

Royer C., Thébault J, Chauvaud L., Olivier F. (*in press*). Structural analysis and paleoenvironmental potential of dog cockle shells (*Glycymeris glycymeris*) in Brittany, northwest France. Palaeogeography, Palaeoclimatology, Palaeoecology

Saleuddin A.S.M. (1965). The mode of life and functional anatomy of *Astarte spp*. (Eulamellibranchia). Journal of Molluscan Studies 36:229-257

Sampei Y., Matsumoto E., Dettman D.L., Tokuoka T., Abe O. (2005). Paleosalinity in a brackish lake during the Holocene based on stable oxygen and carbon isotopes of shell carbonate in Nakaumi Lagoon, southwest Japan. Palaeogeography, Palaeoclimatology, Palaeoecology 224:352-366

Schöne B.R., Fiebig J., Pfeiffer M., Gleb R., Hickson J., Johnson A., Dreyer W., Oschmann W. (2005). Climate records from a bivalved Methuselah (*Arctica islandica*, Molluska; Iceland). Holocene 228:130-148

Schöne B.R., Wanamaker Jr. A.D., Fiebig J., Thebault J., Kreutz K.J. (2011a). Annually resolved $\delta^{13}C$ shell chronologies of long-lived bivalve mollusks (*Arctica islandica*) reveal oceanic carbon dynamics in the temperate North Atlantic during recent centuries. Palaeogeography, Palaeoclimatology, Palaeoecology 302:31-42

Schöne B.R., Zhang Z., Radermacher P., Thébault J., Jacob D.E., Nunn E.V., Maurer A.-F. (2011b). Sr/Ca and Mg/Ca ratios of ontogenetically old, long-lived bivalve shells (*Arctica islandica*) and their function as paleotemperature proxies. Palaeogeography, Palaeoclimatology, Palaeoecology 302:52-64

Sejr M.K., Christensen P.B. (2007). Growth, production and carbon demand of macrofauna in Young Sound, with special emphasis on the bivalves *Hiatella arctica* and *Mya truncata*. Carbon cycling in Arctic Marine Ecosystems: Case Study Young Sound, Vol 58: In: Rysgaard S., Glud R.N. (Eds.), Medd. om Grønl., Biosci. Special Issue, 58, pp. 121-137

Smetacek V., Nicol S. (2005). Polar ocean ecosystems in a changing world. Nature 437:362-368

Takesue R.K., van Geen A. (2004). Mg/Ca, Sr/Ca, and stable isotopes in modern and Holocene *Protothaca staminea* shells from a northern California coastal upwelling region. Geochimica and Cosmochimica Acta 68:3845-3861

Thébault J., Chauvaud L., Clavier J., Fichez R., Morize E. (2006). Evidence of bi-daily striae in the tropical scallop *Comptopallium radula* using calcein marking. Marine Biology 149:257-267

Thébault J., Chauvaud L., Clavier J., Guarini J.-M., Dunbar R.B., Fichez R., Mucciarone D.A., Morize E. (2007). Reconstruction of seasonal temperature variability in the tropical Pacific Ocean from the shell of the scallop, *Comptopallium radula*. Geochimica and Cosmochimica Acta 71:918-928

Thébault J., Thouzeau G., Chauvaud L., Cantillánez M., Avendaño M. (2008). Growth of *Argopecten purpuratus* (Mollusca: Bivalvia) on a natural bank in Northern Chile: sclerochronological record and environmental controls. Aquatic Living Resources 21:45-55

Thébault J., Chauvaud L., Clavier J., Jacquet S., Barats A., Peycheran C., Amouroux D. (2009a). Barium and molybdenum records in bivalve shells: Geochemical proxies for phytoplankton dynamics in coastal environments? Limnology and Oceanography 54:1002-1014

Thébault J., Schöne B.R., Hallmann N., Barth M., Nunn E.V. (2009b). Investigation of Li/Ca variations in aragonitic shells of the ocean quahog *Arctica islandica*, northeast Iceland. Geochemistry, Geophysics, Geosystems 10:Q12008

Thébault J., Chauvaud L. (*in press*) Li/Ca enrichments in great scallop shells (*Pecten maximus*) and their relationship with phytoplankton blooms. Palaeogeography, Palaeoclimatology, Palaeoecology

Wanamaker Jr. A.D., Hetzinger S., Halfar J. (2011). Reconstructing mid- to high-latitude marine climate and ocean variability using bivalves, coralline algae, and marine sediment cores from Northern Hemisphere. Palaeogeography, Palaeoclimatology, Palaeoecology 302:1-9

Wassmann P., Duarte C.M., Agusti S., Sejr M.K. (2011). Footprints of climate change in the Arctic marine ecosystem. Global Change Biology 17:1235-1249

Weslawski J.M., Kendall M.A., Wlodarska-Kowalczuk M., Iken K., Kedra M., Legezynska J., Sejr M.K. (2011). Climate change effects on Arctic fjords and coastal macrobenthic diversity - observations and predictions. Marine Biodiversity 41:71-85

Witbaard R., Duineveld G.C.A., de Wilde P.A.W.J. (1999). Geographic differences in growth rates of Arctic islandica (Mollusca: Bivalvia) from the North Sea and adjacent waters. Journal of the Marine Biological Association of the United Kingdom 79:907-915

Publications of the group:

Ambrose Jr. W.G., **Carroll M.L.**, Greenacre M.L., Thorrold S., McMahon K. (2006). Variation in *Serripes groenlandicus* (Bivalvia) growth in a Norwegian high-Arctic fjord: evidence for local- and large-scale climate forcing. Global Change Biology 12:1595-1607

Ambrose Jr. W.G., Renaud P.E., Locke V W.L., Cottier F.R., Berge J., **Carroll M.L.**, Levin, B., Ryan S. (2012). Growth line deposition and variability in growth of two circumpolar bivalves (*Serripes groenlandicus*, and *Clinocardium ciliatum*). Polar Biology 35:345-354

Blicher M.E., **Rysgaard S.**, Sejr M.K. (2010). Seasonal growth variation in *Chlamys islandica* (Bivalvia) from sub-Arctic Greenland is linked to food availability and temperature. Marine Ecology Progress Series 407:71-86

Carroll M.L., **Ambrose Jr. W.G.**, Levin B.S., Ryan S.K., Ratner A.R., Henkes G.A., Greenacre M.J. (2011a). Climatic regulation of *Clinocardium ciliatum* (Bivalvia) growth in the northwestern Barents Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 302:10-20

Carroll M.L., **Ambrose Jr. W.G.**, Levin B.S., Locke V W.L., Henkes G.A., Hop H., Renaud P.E. (2011b). Pan-Svalbard growth rate variability and environmental regulation in the Arctic bivalve *Serripes groenlandicus*. Journal of Marine Systems 88:239-251

Chauvaud L., **Thébault J.**, **Clavier J.**, Lorrain A., **Strand Ø.** (2011). What's hiding behind ontogenetic $\delta^{13}C$ variations in mollusc shells? New insights from the great scallop (*Pecten maximus*). Estuaries and Coasts 34:211-220

Chauvaud L., Patry Y., **Jolivet A.**, Cam E., Le Goff C., **Strand Ø.**, Charrier G., **Thébault J.**, Lazure P., Gotthard K., **Clavier J.** (2012). Variation in size and growth of the great Scallop *Pecten maximus* along a latitudinal gradient: Bergmann's Rule Revisited. PLoS ONE 7:e37717

Lartaud F., **Chauvaud L.**, **Richard J.**, Toulot A., Bollinger C., Testut L., Paulet Y.-M. (2010). Experimental growth patterns calibration of Antarctic scallop shells (*Adamussium colbecki*, Smith 1902) to provide a biogenic archive of high-resolution records of environmental and climatic changes. Journal of Experimental Marine Biology and Ecology 393:158-167

Passarelli C., **Olivier F.**, Paterson D.M., Hubas C. (*in press*). Modification of microbial, meiofaunal and macrofaunal assemblages in presence of artificial biogenic structures, and cascade impacts on the benthic compartment's functioning. Marine Ecology Progress Series

Pernet F., **Tremblay R.**, Comeau L., Guderley H. (2007). Temperature adaptation in two bivalve species from different thermal habitats: energetic and remodelling of membrane lipids. Journal of Experimental Biology 210: 2999-3014

Redmond K.J., Magnesen T., Kupka Hansen P., **Strand Ø.**, Meier S. (2010). Stable isotopes and fatty acids as tracers of the assimilation of salmon fish feed in blue mussels (*Mytilus edulis*). Aquaculture 298:202-210

Richard J., Morley S.A., Thorne M.A.S., Peck L.S. (2012). Estimating long-term survival temperatures at the assemblage level in the marine environment: towards macrophysiology. PLoS ONE 7:e34655

Spilmont N., **Meziane T.**, Seuront L., Welsh D.T. (2009). Identification of the food sources of sympatric ghost shrimp (*Trypaea australiensis*) and soldier crab (*Mictyris longicarpus*) populations using a lipid biomarker, dual stable isotope approach. Austral Ecology:878-888

Strand Ø., Brynjeldsen E. (2003). On the relationship between low winter temperatures and mortality of juvenile scallops, *Pecten maximus* L., cultured in western Norway. Aquaculture Research 34:1417-1422

Thébault J., **Chauvaud L.**, **Clavier J.**, Fichez R., Morize E. (2006). Evidence of bi-daily striae in the tropical scallop *Comptopallium radula* using calcein marking. Marine Biology 149:257-267

Thébault J., Schöne B.R., Hallmann N., Barth M., Nunn E.V. (2009). Investigation of Li/Ca variations in aragonitic shells of the ocean quahog *Arctica islandica*, northeast Iceland. Geochemistry, Geophysics, Geosystems 10:Q12008

Thébault J., **Chauvaud L**. (*in press*) Li/Ca enrichments in great scallop shells (*Pecten maximus*) and their relationship with phytoplankton blooms. Palaeogeography, Palaeoclimatology, Palaeoecology

Tremblay R., **Olivier F.**, Bourget E., Rittschof D. (2007). Energetic content of *Balanus amphitrite* (Darwin) cyprid larvae determines habitat selection success. Marine Ecology Progress Series 340:1-8

Dossier (version Word) à renvoyer au plus tard le 15 octobre 2012 à
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