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Marine Ecosystem Responses to Rapid Climate Change (Palmer LTER)

Hugh Ducklow (The Ecosystems Center, MBL, Woods Hole, MA, USA)

What and where is Potter Cove and what are/have we been doing there?

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Potter Cove is an inlet of Maxwell Bay on King-George Island of the South Shetland archipelago, where the Argentine military base Jubany has been built since the early 1950ies. In the beginning of the 1990ies, the Dallmann laboratory was founded as Argentine (IAA)-German (AWI) research facility. The talk will present a short summary of this collaboration both scientifically and with respect to the development of the cooperation: *How is our view of the cooperation and what do we want to improve… ? This is planned as an interactive discussion....*

Evaluation and estimation of positive degree days and melt days over the Southwest Antarctic Peninsula during the austral summer season.

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Significant increases in surface temperatures associated with recurrent glaciological changes observed in the Antarctic Peninsula (AP) during the last decades are well documented in bibliography. However, the availability of data on the Southwestern region of the AP has always been very limited. In order to gather the scarce available data about near surface temperature at this region, different data sources were consulted. Conventional weather stations San Martín (SM) and Rothera and automatic weather stations (AWS), Dismal and Kirkwood, were considered for the Antarctic summer periods 2001-2009. In the case of SM the analysis could be extended until 1979. Air temperature areal averages were also obtained for an area included in Margarite Bay from two reanalysis provided by the National Centers for Environmental Prediction/Nacional Center for Atmospheric Research (NCEP/NCAR). Monthly correlations from daily air temperature anomalies between the mentioned data sources were obtained. Data from reanalysis showed poor correlations and were left out of further analysis. Given that the most important glaciological changes occur during the summer season, only December, January and February were the months considered. Significant positive temperature trends for SM were found along the period 1980-2009. These changes are also reflected in Positive Degree Day (PDD) and Melt Day (MD), having increased 24ºC and 5.9 days per decade, respectively. In order to complete the gaps present in AWS and Rothera data series, a linear model obtained from scatterplots established between the series, which obtained best correlations, was applied. PDD and MD were analyzed for the reconstituted temperature series. The feasibility and the convenience to adapt a similar procedure to the data obtained at the northern tip of the AP and, particularly, to the South Shetlands region will be discussed.

Geomorphology and glacial-stratigraphy of James Ross Island, Northern Antarctic Peninsula

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James Ross Island is located on the rain shadow of the northeastern tip of Antarctic Peninsula. The present island's landscape consists mainly of an up to 300 m thick ice cap and related outlet glaciers covering a stacked volcanic tablemountain/tuyas-complex. Nevertheless the NW side of the island has a large ice-free area where former glaciogenic landforms -shaped on Neogene volcanic and underlying Cretaceous marine sedimentary rocks- are significantly reworked by present mass wasting, periglacial (including glacio-nival), fluvial, and marine processes. The coast line is mostly deglaciated and characterized by abrupt, erosive shorelines, with active and fossil sea-cliffs and low depositional shorelines, with dominance of marine action (beach and spits) or fluvio-marine action (deltas and tida1 flats). In this coastal area previous, Holocene and Upper Pleistocene glacial and marine activities are revealed by the morphology and stratigraphy of well preserved moraines and marine-terraces onshore. Moreover, outcrops of glacial, marine, and volcanic deposits, allows a fragmentary reconstruction of the glacier history of James Ross Island going back to the Upper Miocene. King George Island (South Shetland Islands Archipelago) located on the windward rainy side of the NW Antarctic Peninsula, offer a good opportunity to compare both morpho-structural and morphogenetic environments dominated by different tectonic and climatic regimes.

Ice mass loss on King George Island and its relation to other observations on the Antarctic Peninsula

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The knowledge on glacial changes and estimates on freshwater budgets resulting from intensified surface melt and glacier mass loss are an important boundary condition for many biological and integrated earth system science approaches. However, quantitative evidence originating from glaciological field surveys and data on concurrent glacier surface mass balance are scarce for this region. We provide an overview on recent glaciological observations from the King George Island ice cap on the northern tip of the Antarctic Peninsula and link these results on evidence for glaciological changes on the Antarctic Peninsula. The KGI glacier area loss between 2000 and 2008 amounts to about 20 km^{-2}. We observed at least 4 times higher accumulation rates 4950 mm w.e. (2007/08) and 3184 mm w.e. (2008/09) than the reported mean values from an ice core in 1995. Surface lowering is prevailing at elevations below 270 m above ellipsoid. Our 11-year DGPS record reveals a linear dependence of surface lowering with altitude with a maximum annual surface lowering of 1.44 m a^{-1} at 40 m and -0.20 m a^{-1} at 270 m above ellipsoid. Assuming persisting climate condition as during the last 11 years the small ice cap of Bellingshausen Dome would disappear in about 285 years. The estimated additional freshwater discharge due to surface lowering into Potter Cove, where major

marine biological programs are run, amounts to approximately $27.8*10^6$ m³ over the 11-year time period.

Planned glaciological measurements during IMCOAST project phase

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Main activity during the 3 year IMCOAST project will be the operation of an automatic weather station on Potter Glacier as well as an eddy-covariance system. These measurements will be combined with surface mass balance measurements along stake lines connecting to the Polish network. Both data sets will be used to drive spatially distributed mass balance models in order to estimate melt water amounts draining into the Potter Cove. Additionally, we will initiate surface elevation change measurements using differential GPS on Potter Cove and continue observations on Bellingshausen Dome. We will also calibrate a surface mass balance model using station data from Jubany and Bellingahausen stations. A time lapse camera will be installed to capture ice dynamics and if possible calving fluxes in order to separate dynamic and climatological component of glacier mass balance. Cooperation partners: R. del Valle, H. Salas, P. Skvarca (IAA)

A regional-scale estimation of meltwater run-off on the northern Antarctic Peninsula

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A positive-degree day based model was applied on the northern portion of Antarctic Peninsula aiming to estimate the total snow melt and subsequent runoff (R). The model was forced by temperature data obtained by the ERA-Interim Reanalysis project, for the time period from 1989 to 2010. Temperature data from 14 weather stations distributed on the study area were obtained to calculate the monthly mean temperature for each year of analysis. The Larsen ice shelves were excluded from the analysis in order to maintain a constant area and so make the total R comparable throughout the whole time series. For the period of study, we obtained values of R ranging between 0.29×10^{12} kg yr^{-1} and 2.78×10^{12} kg yr^{-1}. Although no good correlation coefficients were found between R and mean temperatures measured at the meteorological stations (i.e. always lower than 0.5), it is clear that high values of R are accompanied by high mean temperatures at least in one of the summer months. A specific event occurred in the summer of 2006-2007, when we found concomitantly the highest values of R, January mean temperature and February mean temperature. The east side of the peninsula produced always higher amounts of R, especially in the vicinity of the former Larsen A and B ice shelves.

Sedimentary and geochemical cycles in the Maxwell Bay cores

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In Maxwell Bay, King George Island, 100 m thick Holocene sediments have been deposited. These allow high-resolution environmental studies in the South Shetland Island area covering the recent warm climate period. Using sediment cores taken during Polarstern cruise ANT-XXIII/4 (2006), we were able to detect the impact of climate phases like the Little Ice Age on local sedimentation processes. In sediment core PS69/335-2 a cyclic pattern was found in the magnetic susceptibility (MS) parameter. High magnetic susceptibility correlates to low content in total organic carbon (TOC) and total sulfur (TS). This pattern was found in the other sediment cores as well and we suppose that lower values in MS can be related to higher biogenic productivity (TOC and TS values) or less input of terrigenous sediment. Destruction of the magnetic susceptibility signal by a reduction of ferric to ferrous iron is another alternative that need to be taken into account. The negative correlation between MS and TS possibly indicates this early diagenetic alteration. But the good correlation between XRF Fe counts and the MS does not support a destruction of high MS Fe-minerals. MS correlates to the dry bulk density (DBD) of the sediment and negatively to the biogenic opal as well as to the water content, all of this indicates a dilution of the MS signal by higher organic input. Spectral analyses of some sediment parameters of core PS69/335-2 resulted in cyclic frequencies of approximately 200 years. Similar frequencies were found in sediments from Collins Harbor and Bransfield Basin, which have been discussed as indicators for changing sea ice coverage. We are investigating additional parameters in our cores to detect comparable environmental changes.

Holocene paleoenvironmental changes at King George Island (maritime Antarctica) as recorded by lake sediment geochemistry

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A high resolution geochemical (major and minor elements) and radiocarbon analysis was conducted on sediments from Ardley Lake (Ardley Island, Western Antarctic Peninsula). Bio-elements like C, Ca, Cu, N, P, Sr, S, and Zn were used as proxies for ornithogenic soils to reconstruct alternations of local penguin populations within the last 8,760 years, which seem to be related to changes in regional climate. Furthermore, the occurrence of pyrite and the enrichment of additional proxies, like U and Mo give first evidence for early diagenetic processes under anoxic conditions and possible Mid-Holocene freshwater-marine transitions.

Climate cycles in *L. elliptica* shells from Potter Cove

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Both climate trends and climate oscillations affect the ecology of the WAP region and of Antarctica in general. Producing sound evidence, however, for mechanistic coupling of distinct ecological processes proves to be difficult, owing to the general noisiness of ecological data and to the lack of sufficiently long and reliable time series. Calcium carbonate shells and skeletons of long lived organisms may serve as archives of environmental conditions and of corresponding organism response that are reflected in morphological and biogeochemical properties of the shell/skeleton. The Antarctic bivalve *L. elliptica* attains a maximum length of > 100mm and an age of about 35 years; it shows a distinct pattern of annual growth bands in sections of the umbo reflecting strong seasonality in growth that is coupled mainly to seasonality in food availability, whereas shell oxygen stable isotope ratios (δ18O) have been shown to reflect seasonal change in melt water inflow. We analysed annual shell increments in *L. elliptica* specimens collected in Maxwell Bay (predominantly in Potter Cove), King George Island, for decadal variability and trend in shell growth and their drivers during the last 60 years.

Periods of stronger and weaker meltwater discharge into Maxwell Bay (King George Island, Antarctica) during the past two Millennia

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Presently, the Antarctic Peninsula belongs to the fastest warming regions on Earth. Meltwater discharge increases, glaciers retreat and as a consequence the coastal ecosystems change at an ever-increasing pace. The goal of our study is to reconstruct the timing and impact of historical climate phases such as the Medieval Warm Period (MWP) and the Little Ice Age (LIA) as analogs for the recent climate development, and to identify the marine sedimentary processes affected by the changing climate. Here we present results of a high-resolution gravity core taken at 461 m of water depth close to the mouth of Potter Cove, one of the tributary fjords that feed Maxwell Bay. The core reveals climate-induced fluctuations in the sedimentation pattern during the past c. 1800 years. Sedimentation at the core site is controlled by sediments from the tributary fjords entering Maxwell Bay including Potter and Marian coves and Collins Harbor. There are two sediment classes: Class 1 is characterized by two grain-size subpopulations. The coarser one represents the bedload fraction, whereas the finer one is interpreted to represent meltwater-induced suspension load. Since meltwater is restricted to the summer season, it is suggested that Class 1 sediments characterize periods of intense summer-meltwater production and thus, warmer climate phases. Class 2 samples show the same coarse grain-size mode but they lack the fine subpopulation. We suggest that these sediments indicate less intense summer-meltwater production and thus colder climatic conditions. The mean grain size suggests that average bottom current speeds were slightly higher during colder climate phases than during the warmer phases. Bioproduction at the core location and in the sediment source areas as reflected by bio-productivity proxies (TOC, bio-opal) is not always positively related to climate since warm-phase meltwater discharge adversely affects bioproduction through light attenuation by turbid waters. Furthermore, during warmer phases the TOC signal becomes diluted due to increased deposition of terrigenous fine sediment. Comparison with Antarctic,

hemispherical, and global temperature reconstructions reveals clear signals of the MWP, the LIA and the post-LIA climate recovery. Class 1 sediments dominate the warmer MWP, Class 2 sediments dominate the colder LIA. The Maxwell Bay record shows climate signals that are partly unique to either one of the hemispheres. Thus, it resembles best the global temperature reconstruction. Apparently, the MWP started earlier in the Southern Hemisphere (SH) than in the Northern Hemisphere suggesting that the source for the warming might also be in the SH. In contrast to the MWP the timing of the LIA appears to be largely synchronous between the hemispheres. Generally finer sediments clearly mark the end of the LIA. However no stronger meltwater influence can be detected; the conditions of the AD 1970s resemble those at the beginning of the MWP. Changing sedimentation processes cannot be detected in the Maxwell Bay record until after AD 1975.

Coastal geology and sedimentary environments in 25 de Mayo (KGI) Island, Antarctica

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Main objectives of this study are the characterization of sedimentary environments in Potter Cove and Peninsula at present and late Holocene, the analysis of spatio- temporal changes and its relation with dynamical processes and climate change. Methodology consists in sedimentary facies identification, statistical analysis and determination of detrital modes. Also, GPR gives complementary information to integration of cores.

Dissolved nutrients and trace metals in Potter Cove, King George Island Antarctica – Plans for upcoming campaign 2010-2011

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Since the late 1960s a reduction of sea ice and a dramatic retreat of glaciers is reported at the Western Antarctic Peninsula (WAP) that has even accelerated in the last decade. The chemistry of the dissolved load of melt waters draining from retreating glaciers into Potter Cove is poorly known. It has been suggested that the input of nutrients (N, P, Si), micro-nutrients (e.g. Cu, Ni, Zn) and suspended matter into Potter Cove may have an impact on biological processes in this semi-enclosed bay and even on the fertility of the whole Southern Ocean. Goals of this project are the geochemical characterization, quantification and transformation of the dissolved nutrient, major and minor ion composition in Potter Cove (6 stations from the glacier front to the cove entrance) and of glacial melt water draining into Potter Cove. Furthermore, by analyzing major element and trace metal input on different time scales, we intend to get assessment of the transfer of geochemical proxies from glacier retreat into sedimentary archives.

Response of Potter Cove phytoplankton dynamics to long-term climate trends

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Since 1991, two coastal stations were monitored in the inner (E1) and the outer (E2) Potter Cove (King George/25 de Mayo Island) in order to determine the departure of hydrographical characteristics and phytoplankton dynamics from long-term mean conditions. Seawater temperature and salinity, total particulate matter (TPM) and chlorophyll-a (Chl-a) concentrations were measured monthly in winter and bi-weekly during summer. Meteorological information from the adjacent Argentinean station Jubany was also gathered. Air temperature increase was evident, with rises of 0.39 and 0.48 ºC per decade for summer and winter, respectively. Positive anomalies characterised wind speeds during the decade between the mid '90 and the mid 2000 years, while negative anomalies were evident from year 2004 and on. Sea ice cover did not present any trend during the whole period. Surface water temperature increased significantly in both stations, although the increase was higher in E1. Salinity fluctuated with no clear trend. In both studied stations phytoplankton biomass average during the spring-summer season was normally around 1 mg m^{-3} Chl-a and no trend was evident for the 19 studied years. However, variability was higher in E2 than in E1. TPM was generally higher in E1. Similarly, no long term trends were evident in their concentrations. At the interannual scale, the Southern Annular Mode (SAM) signal appears as the prevalent driver of the studied variables, except for surface waters in E1, which would respond to local forcings. More observations are needed to identify potential long-term trends other than those modulated by the SAM.

Annual and spatial variability of marine bacteria and archaea from Potter Cove, South Shetland Islands, Antarctica

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Temporal and spatial variability of marine *Bacteria* and *Archaea* were studied at Potter Cove, Antarctica, during a one-year sampling cycle (December 2007-February 2009). Surface water samples were taken with Niskin bottles from three locations: S1 (inner cove), S2 (outer cove) and S3 (near the opening of the Potter Creek). Photosynthetic pigments, suspended particulate matter, salinity, temperature and meteorological parameters were also measured. Samples were filtered on cellulose acetate membranes (0.22 µm) and frozen (-80ºC) until further processing. Genomic DNA was isolated and analyzed using Denaturant Gradient Gel Electrophoresis (DGGE) followed by 16S rDNA sequencing. DGGE band sequencing revealed that most bands represented strains related to the phylum *Proteobacteria*, mostly *γ-Proteobacteria* (orders *Oceanospirillales*, *Pseudomonadales*, *Alteromonadales, Thiotrichales*) and some *α-Proteobacteria* (all these isolates showing 100% identity with the genus *Pelagibacter*, order *Rickettsiales*). Analysis of bacterial DGGE patterns showed a high

annual variability. Samples from S1 and S2 were more similar to each other, than to S3 suggesting a spatial variability probably caused by glacial melting during summer. Archaeal diversity (Shannon index) decreased during summer and showed an inverse correlation with chlorophyll-a concentration. Moreover, the mean archaeal diversity was similar for S1 and S2, both were higher than for S3 samples. This work is a first attempt to understand the changes in diversity of these marine microbial communities and to cover the actual gap in knowledge about Antarctic bacterioplankton and archaeoplankton, in particular during autumn and winter.

A phytoplankton bloom in Potter Cove during summer 2010: an exceptional feature?

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Since the early 1990's phytoplankton has been studied and monitored in Potter Cove (King George/25 de Mayo Island, South Shetlands). Phytoplankton biomass is typically low compared to Antarctic shelf and oceanic environments, with average spring - summer values below 2 mg Chlorophyll-a m^{-3}. The physical conditions in the area (intense winds, reduced irradiance induced by particles originated from the land, etc) explain the low coastal productivity at KGI. In January 2010 a first large phytoplankton bloom in almost 20 years was observed in the area, with a maximum of around 10, and a monthly average of 4 mg Chlorophyll-a m^{-3}. In the present work we analyse the physical conditions that lead to this high phytoplankton accumulation. The importance of such blooms in future climate scenarios is discussed.

Melt water and oxidative stress in coastal Antarctic phytoplankton

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Increased ice melting due to global climate warming drives changes in salinity in Antarctic coastal surface waters. This might expose phytoplankton cells to osmotic stress, which leads to the production of reactive oxygen species (ROS) and lipid peroxidation. Different phytoplankton groups react differently to this stress. Here we analysed the cell content of ROS, TBARS, which are indicators of free radical formation and accelerated lipid peroxidation, and liposoluble antioxidants in two different phytoplankton assemblages, one dominated by the diatom *Porosira glacialis* and the other one by picoplankton which was experimentally exposed to different salinties.The treatment mimicks variable salinities fronting melting glaciers. ROS concentration in picoplankton was significantly lower than in the diatom, both before and after exposure to osmotic stress, while soluble antioxidants (□-tocopherol y □-carothenes) concentrations were higher in picoplankton than in *P. glacialis*. Oxygen consumption was measured in both isolates in the dark, and we observed a higher consumption in *P. glaciales* exposed to low salinity compared with picoplankton maintained at the same salinity. Our

results suggest a species specific response to osmotic stress which could affect the carbon cycle in coastal Antarctic phytoplankton.

Chemical mediation of predator-prey and mutualistic interactions between macroalgae and invertebrates on the WAP

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Macroalgae dominate hard bottom areas along the western Antarctic Peninsula to depths of up to 40 m or more. Most of the macroalgae are chemically defended from a variety of macro- and mesograzers but harbor very high densities of amphipod mesograzers. These amphipods do not consume most of the macroalgal species, but benefit the macroalgae by keeping them relatively clean of epiphytic microalgae and filamentous macroalgae. They do, however, appear to have selected for a relatively high incidence of filamentous endophytes in the larger macroalgae. The amphipods benefit from living on the large, chemically-defended macroalgae because they gain refuge from fish which are their primary predators. Hence this represents a community-scale mutualistic relationship between the dominant macroalgal assemblage and the abundant amphipod assemblage that is mediated, at least in part, by the macroalgal chemical defenses.

Is macroalgal distribution expanding in response to climate-induced glacier retreat at Potter Cove (South Shetland Island)?

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Climate warming has been related to glacial retreat along the Western Antarctic Peninsula. Over the last years, a visible melting of Fourcade Glacier (Potter Cove, South Shetland islands) has exposed new hard bottom ice-free areas available for benthic colonization. However, these sites are expected to present an alteration of the water column (due to an increase of sediment input and salinity changes) and on the ice disturbance patterns. Studies performed seventeen years ago showed that the coastal sites close to the glacier cliffs in the inner Cove, characterized by soft substratum, were practically devoid of macroalgae. Are the new ice free areas suitable for macroalgal colonization? To tackle this question, underwater video transects were performed at six new ice-free areas of the inner Cove, from the waterline down to 12-15 m. Macroalgae were found colonizing all studied areas, even in close proximity to the retreating glacier. *Palmaria decipiens* was one of the most abundant macroalgal species at the most disturbed sites. *Himantothallus grandifolius* was present at relatively shallow depths, where a decrease in light penetration caused by sediment input might have caused a shift in the vertical distribution of this species. Our results show an expansion of the macroalgal distribution in Potter Cove. As macroalgae are probably one of the main energy sources that support a large fraction of the secondary production of the benthos in the inner Cove, these results can be expected to affect the energy and matter flux in this ecosystem.

Impact of UV radiation and grazers on the colonization of marine benthic primary producers in Antarctica (part i: intertidal communities)

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How are benthic Antarctic communities affected by changing environmental conditions such as UV radiation (UVR)? UVR is known to affect many biological processes but almost no information exists whether these effects, visible on the molecular and cellular level, impair polar ecosystem structure. In order to obtain more information we studied the colonization of benthic primary producers in the Antarctic rocky intertidal and subtidal over a period of 106 and 70 days, respectively. 32 experimental units were installed at each site in a two-factorial design (UVR, three levels and grazers, two levels). Intertidal communities were dominated by single cell diatoms and green algal propagules. Limpet grazing reduced the algal biomass and macroalgal recruit density and further introduced a shift in both macro- and microalgal species composition. There were no negative UVR effects on the diatom assemblage. In contrast, significant UVR effects on the macroalgal assemblage were detected. UVAR (315-400nm) negatively impacted density and richness of recruits, whereas additional UVBR (280-315nm) caused a shift in species composition and led to a lower diversity of the macroalgal community by the end of the intertidal experiment. Effects were species-specific and showed that particularly young propagules were sensitive to UVR. No interactive effects of UVR and grazing were found. It is postulated that UVR has the power to change ecosystem structure in intertidal Antarctic macroalgal communities, which might have consequences for higher trophic levels. The effects of UVR and grazers on the subtidal community and a comparison of both field experiments are presented by Campana et al.

Impacts of UV radiation and grazers on the colonization of marine benthic primary producers in Antarctica (part ii: Subtidal communities)

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Ultraviolet B radiation (UVBR, 280-315 nm) is known to be a stress factor for Antarctic benthic algae and invertebrates. However, there is almost no available information regarding these effects at the community level. A two-factorial colonization experiment (UVR, three levels and grazing, two levels) was performed at an intertidal and a subtidal site on King George Island/I. 25 de Mayo. Structural parameters of the community were followed for fifteen and ten weeks, respectively. The effects on the intertidal community are presented in detail in Zacher et al. Subtidal communities were dominated macroscopically by colonial diatoms and green algal filaments. Ultraviolet radiation (UVR,

280-400nm) did not affect diatoms but exerted a group-specific effect on the macroalgal assemblage. Overall, red algal cover was negatively impacted by UVR whereas for green algal filaments a significant interaction between grazing and UVR was detected. Grazers introduced a shift in both micro- and macroalgal species composition and reduced the community biomass, with stronger effects when UVBR was absent. When comparing intertidal and subtidal experiments, community architecture and biomass production was markedly different at both sites, with higher biomass and more complex diatom composition at the subtidal spot. However, UVR and grazing affected both sites in a similar pattern. Our findings suggest that UVR and grazing play a key role in shaping the subtidal and intertidal benthic algal communities in Antarctica. UVR impact on subtidal communities seemed to be more complex than in the intertidal, exerting both direct and indirect effects on the community structure.

Ultraviolet radiation influences the feeding behaviour and grazing rate of a common Antarctic benthic amphipod (Poster presentation)

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The effects of ultraviolet radiation (UVR, 280-400nm) as a modulator of herbivore-algal interactions have been poorly studied in Antarctic benthic communities. In this study, we investigated the impact of UVR on the feeding behaviour and feeding rate (FR) of the common amphipod Gondogeneia antarctica. Two short-term feeding assays were performed: i) Multiple-choice experiments. Individuals were added to a square aquarium that received photosynthetically active radiation (P treatment, >400nm), PAR + ultraviolet A radiation (PA treatment, >320nm) and PAR+UVR (PAB treatment, full spectrum). Cut-off filters were placed on one quarter of the aquarium to manipulate the underneath light conditions; the fourth quadrant did not receive a filter (control). Four algal pieces were fixed in the centre of each quadrant (N=5) ii) No-choice experiments. Amphipods were exposed to a single irradiance treatment (P, PA or PAB) (N=8). FRs of intertidal and subtidal amphipods were calculated, as the consumption of Palmaria decipiens. Multiple-choice experiments showed that intertidal organisms presented higher FRs when UVR was absent (ANOVA, $p<0.05$). In contrast, the FRs of subtidal organisms were not affected by the radiation treatment. When confined to a single light treatment, the FRs of both intertidal and subtidal amphipods were reduced in the PAB treatment (ANOVA, $p<0.05$). The algal palatability was not altered by UVR. Our findings indicate that a short-term exposure to ultraviolet B radiation causes a direct negative effect on amphipods by depressing their feeding activity. However, more research is needed to improve the knowledge of the dynamics of the observed effects.

Macroalgal photosynthetic light requirements in relation to their vertical distribution in Potter Cove, South Shetland Island, Antarctica

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The aim of this study is to understand the macroalgal vertical zonation at Potter Cove (Isla 25 de Mayo/ King George Island) in five selected areas with different degree of glacial influence, and thus a different degree of sedimentation, from a physiological point of view. From December 2009 to March 2010, five macroalgal species (*Desmarestia anceps, Himantothallus grandifolius, Ascoseira mirabilis, Iridaea cordata* and *Palmaria decipiens*) were sampled at 5, 10, 20 and 30 m depth. After collection, photosynthetic parameters and chlorophyll a content were determined. In areas with high glacial influence the maximal vertical distribution limit of all species was 10 m depth, while in areas with intermediate and low/none glacial impact, it was 20 and 30 m depth, respectively. Areas with high glacial influence presented limiting light conditions below 20 m depth coinciding with the absence of macroalgae. In intermediate and low disturbed areas, light intensities were not limiting. Palmaria decipiens was the only studied species showing lower light saturation points at deeper depths. Chl a content did not show significant differences with increasing depth. Our first results show that the vertical zonation of the studied species is positively correlated to the light penetration which decreases as the glacial influence (as production of sediment input) increases. A further increase of sedimentation due to global warming will undoubtedly lead to an elevation of the lower distribution limit of the studied species and will probably have a great effect on macroalgal primary productivity in Potter Cove.

Impact of global climate changes on geographic and depth distribution of seaweeds – where are we now?

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The geographic distribution of seaweeds is primarily determined by the temperature requirements of their different life history stages. In contrast, their lower and upper depth distribution limits are - beside several other factors - mainly determined by the radiation conditions. Due to global climate changes (greenhouse effect, stratospheric ozone depletion) both the temperature and radiation conditions are changing.

A strong rise of water temperatures is expected until the end of this century in the Arctic sector of the North Atlantic. In contrast, the temperature rise will be much lower in the Antarctic Peninsula region. Under this scenario, North Atlantic polar to cold temperate seaweeds will extend their distribution into the high Arctic, but retreat on the northeastern Atlantic coastline. By contrast, selected Antarctic seaweeds will probably not significantly alter their latitudinal distributions.
Due to increasing inflow of turbid meltwater in polar fjords the water transparency and, hence, the light conditions in the sublittoral will decrease strongly. Data on net daily carbon assimilation relative to daily respiratory C losses indicate that several seaweeds from Potter cove (King George Island, Antarctica) are presently unable to inhabit depths ≥30 m. Under conditions of increasing turbidity the lower depth distribution limit of seaweeds will undoubtedly rise to an unknown extent.

Stratospheric ozone depletion leads to enhanced UV-B radiation at the earth's surface and in the water column affecting seaweeds from the intertidal and upper sublittoral strongly. The deleterious effects of UV-B radiation are not only apparent on the physiological and molecular, but also on the organism and community level. Recent data indicate that the susceptibility of algal propagules to UV radiation determines the upper depth distribution limit of seaweeds. The future changes are difficult to predict as it is unclear to which levels the stratospheric ozone concentration will recover and how water transparency will change due to changing meltwater inflow. Clearly, the shift in underwater radiation conditions must be characterized more clearly to predict changes in both the lower and upper depth distribution limit of seaweeds.

The role of physical isolation and migration in achieving and maintaining adaptations in the Antarctic benthos

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Fast evolving molecular markers are increasingly becoming available also for non-model organisms and allow a much more detailed understanding how genetic variants within a species are distributed in space and time. Continued survival in the Southern Ocean requires that an organism be adapted in some ways to the extreme conditions of this marine environment. Natural selection can only result in adaptedness if the traits are at least in part heritable, i.e. have a genetic basis. However, migration of specimens between locations represents a natural dilemma: On the one hand migration is a prerequisite to colonization of new habitats but on the other it may result in the influx of alleles that are adapted to different environmental conditions, thus reducing the adaptedness of the receiving population.

Using microsatellites in combination with coding genes from the mitochondrial and nuclear genomes we studied selected marine invertebrates from the Southern Ocean and adjacent waters. Our results indicate that timing and geographic position of genetic discontinuities coincided in some, but not all, of our case studies with major oceanographic and topological barriers. Physical isolation alone is therefore a poor predictor of genetic similarity and by extension also the adaptability to local environments. The situation improves dramatically when the effects of (1) environmental changes in the evolutionary past of the species (glaciations) and (2) the differences in making use of their environment of different species are considered.

Newly ice free areas: an opportunity for colonization or a lost garden for old inhabitants?

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Glacier retreatment consistently registered along the Antarctic Peninsula, caused by its rapid warming, is affecting coastal ecosystems by increased ice calving, sedimentation rates and fresh water input. Factors that together with water temperature increase can severely impact on Antarctic biota. This retreating process also opened newly ice free areas available for colonization and establishment of benthic communities. Potter Cove presents an excellent opportunity to assess the effects of these processes on coastal ecosystems, due to long-term data availability and the high retreatment experienced by Fourcade glacier surrounding the cove. Although mayor ecosystem shifts

were observed in "old" areas where typical Antarctic epibenthic filter feeders communities with complex 3rd dimensional structures are being replaced by infaunal and flat forms of suspensivorous together with other functional groups as predators, scavengers and necrophagous. On newly ice free areas, striking dense and abundant communities dominated by those species that are in rapid decline in "old" areas of the cove were observed. Whether these "new" communities were developed in such a short time or if they were already established under the glacier in ice pockets and refugia, are the topics that will be discussed considering available data and current knowledge on development of Antarctic benthic communities.

Physiological response of Antarctic solitary ascidians to increased sedimentation erosion

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In the last 15 years the benthic community of Potter Cove have suffer important shifts in the abundance and distribution of different groups of filter feeders. The main objective of our work is to understand, how sensitive/tolerant different filter feeders are to the local change scenario in Potter Cove, to be able to model the future perspectives of the benthic community within the current climate trend. In the beginning of our investigation the focus on the consequences of hydrographic change and especially increased coastal sediment run-off on benthic filter feeders. We investigated the effect of different concentrations of natural sediment on metabolic rate ($mgO_2\ g^{-1}$ dry mass d^{-1}) of three ascidian species, simulating the in-situ sedimentation conditions. We also compared the metabolic capacity of the ascidians with and without sediment coverage including aerobic, (citrate synthase (CS) activity) and anaerobic capacities (lactate (LDH), opine dehydrogenases (ODH) activity), as well as their tissue energy content in terms of glycogen. We can see clear differences in the tolerance of different species to sedimentation, both functionally and metabolically founded, and are now trying to align these results with the observed shift in communities and species abundance.

Investigating the responses of meiofauna in Potter Cove from a climate change perspective: an experimental approach

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In this study we report results from a feeding experiment performed on Potter cove shallow water meiofauna. In controlled laboratory conditions we added 13C-labeled bacteria and phytoplanktonic diatoms (*Thalassiosira weissflogii*) on top of soft sediment cores retrieved at 15 m depth in front of the Fourcade glacier. We investigated the uptake of the given food sources by nematodes, copepods and cumaceans after 5 days and 10 days of incubation time. A preference for the phytoplankonic food source ($p<0.05$) compared to bacteria was detected for all taxa. Cumacea showed the fastest

response (higher individual uptake values at 5 days) in providing with the food source probably because being good swimmers are free to access the food while it is still settling through the water column. Once the food had settled completely (5-10 days) on the sediment surface, copepods and nematodes, which are morphologically adapted for moving in between the sediment particles, could reach the food dispersed within the sediment more easily and proved to be more efficient in taking up the food than Cumacea. In this experiment, copepods are the more important meiofaunal group in terms of uptake efficacy relative to their community biomass. Global warming is known to affect the phytoplanktonic communities and may lead to enhanced bacterial degradation rates. If the microbiota becomes more important in the sediments, the freshly settled phytoplankton could be degraded more rapidly and hence, become less available for the meiofauna. This would lead to unpredictable changes in the benthic compartment functioning.

Nacella concina, phenotypic plasticity or genetic differentiation: divergent opinions and supporting evidences.

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Nacella concinna is one of the dominant and most abundant shallow waters invertebrates of the Antarctic, and one of the few inhabiting the intertidal zone. This species presents two morphotypes: littoral (migrant) and sublittoral (non-migrant). The first attempt to establish whether these differences were due to separate gene pools was conducted by allozyme electrophoresis; no genetic differences were found and it was hypothesized that such differences were due to phenotypic plasticity. However, using ISSR-PCR as molecular markers genetic differences between the two morphs in populations of Potter Cove were found as was in Admiralty Bay using AFLP, other dominant marker. But later, in Adelaide Island populations using also AFLP there was found no evidence of differentiation between morphs and again the differences were attributed to the phenomenon of phenotypic plasticity. Therefore the question is still open and although the later study was using a higher samples number, it is also true, that together with morphological differentiation, including more advance techniques as Elliptical Fourier Analysis, it has been observed physiological and behavioral differences, suggesting that some degree of genetic differentiation, not fully revealed yet, can be possible. The question acquires more relevance under the current warming process where shallow water and intertidal systems will be especially affected.

Will an increasing permeability of the Antarctic Circumpolar Current trigger faunal invasions into the Antarctic? Lessons from the shallow-water limpet *Nacella*

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The isolating effect that the Opening of the Drake Passage and the creation of the Antarctic Circumpolar Current (ACC) about 35 Mya before present had is largely considered to be the ultimate reason that has caused the high degree of endemic species on the Antarctic shelf. A molecular

phylogenetic tree based on mitochondrial and nuclear gene sequences (16S, COI, 18S) of South American and Antarctic members of the shallow-water limpet *Nacella* confirms the existence of genetically isolated clades on either side of the potential barrier. However, the calculated age of divergence between these two clades is significantly younger than the age of the forming of the ACC (COI: 6.52 Mya, CI 0.61 - 14.76; even younger estimates in 16S and 18S). Extensive genetic exchange must have taken place well after the Drake Passage and the ACC had already been fully established. The disappearance of this exchange and the final divergence into the two clades occupying Patagonia and the Antarctic Peninsula took place in the late Miocene when the strong cooling of the Antarctic Continent increased the selection for physiological and genetic adaptation and specialisation. This unexpected finding forces us to reject the hypothesis that the mere physical presence of the Drake Passage and the ACC erected an effective barrier to faunal exchange between Antarctica and South America. Our findings are particularly relevant now as the climate change is quickening its pace in Antarctica and may change the parameters that still protect the uniqueness of the Southern Ocean fauna very soon.

Phylogenetic relatioships of the ascidian *Synoicum adareanum*: first insights using COI (cytochrome-oxidase 1)

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The colonial ascidian *Synoicum adareanum* (family Polyclinidae) has an exclusively Antartic distribution range and presents two morphotypes, one green with elongated colonies and the other orange and round colonies. In this study, we attempted to explore the relationships among morphotypes and populations of this species using the mitochondrial gene cytochrome oxidase I (COI). We sequenced COI in 56 individuals from five populations with different composition of morphotypes: King George (25 de Mayo) Island (orange), Livingston Island (unknown), Low Island Site 1 (green and orange), Low Island Site 2 (green and orange) and Melchior (orange). COI sequences from other ascidian species were retrieved from GenBank for comparisons. Fifteen haplotypes were detected, all of them translated to a protein sequence, without premature stop codons. A maximum parsimony tree separated them into two, highly divergent groups. The first group consisted of four haplotypes found in green individuals from Low (Sites 1 and 2) and Livingston Islands that joined with ascidian species of the genus *Aplidium*. The second group consisted in highly divergent haplotypes found in the orange individuals and in a few green individuals from Low Island. We will discuss several hypothesis explaining the high nucleotide divergence observed among this last group.

Physiological stress response of the Antarctic bivalve *Laternula elliptica* to climate change

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Increasing temperatures and glacier-melting at the Western Antarctic Peninsula (WAP) currently alter environmental conditions in shallow shelf areas. Sessile benthic species like the Antarctic soft shell clam *Laternula elliptica* experience first effects of these changes e.g. increased sediment input from melt water run-off and higher iceberg-scouring frequencies. Environmental stress and changing food conditions are anticipated to influence *L. elliptica* physiology including the immune system. We investigated behavioural, physiological and biochemical responses towards different stressors in individuals of different physiological states (age/size) from two stations with different scales of

environmental disturbance. Further a first characterization of the *L. elliptica* cellular immune system was undertaken. Marked differences in stress response between smaller and larger individuals were found. Smaller individuals coped better with sedimentation (stable respiration rate), ice-scouring (faster re-burrowing ability) and hypoxia (slower decrease in energy charge) and showed higher survival rates after injury. Lower *L .elliptica* abundance on the higher disturbed station was found but also first indications of adaptation to the investigated disturbance factors were observed i.e. faster re-burrowing in the sediment and a respiratory response to sediment. Cellular immune functions in *L. elliptica* are comparable to other bivalves. Hemocytes were able to phagocytise particles and generate reactive oxygen species (ROS). In vitro stimulation of hemocytes indicated a generally low immune capacity (ROS generation) especially in larger/older animals. Injury and starvation modulated the cellular immune capacity (hemocyte concentration).

L. elliptica seems to tolerate high environmental disturbances and thus might be able to survive large environmental changes however a shift towards younger/smaller individuals can be expected.

Why models, and which ones should be used to study Antarctic ecosystems.

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Models are not only tools to fit data or predict scenarios. They are the seed for ecological theory. In consequence, it is not irrelevant which kind of models we choose for a given problem. I will intend to show how the choice of a model can be made in order to maximize the benefits. Models should be simple, general and intelligible. It is not convenient to complicate models looking for realism, because our understanding could be less. Models should be used to establish new theories and concepts.

Data archiving in PANGAEA - preparation and policy

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The open access Publishing Network for Geoscientific & Environmental Data PANGAEA® was developed at AWI as a data archive that allows sustainable data storage. All data entries are linked to the principal investigators, institutions, and publications, and receive a digital object identifyer (DOI number). Hence, data can be made publicly available without losing their origin and the meta-data. Since IMCOAST data will be archived in PANGAEA® the data bank will be introduced to the

community of scientist involved. The goal is, to agree on a mandatory policy on how to handle published and yet unpublished data.