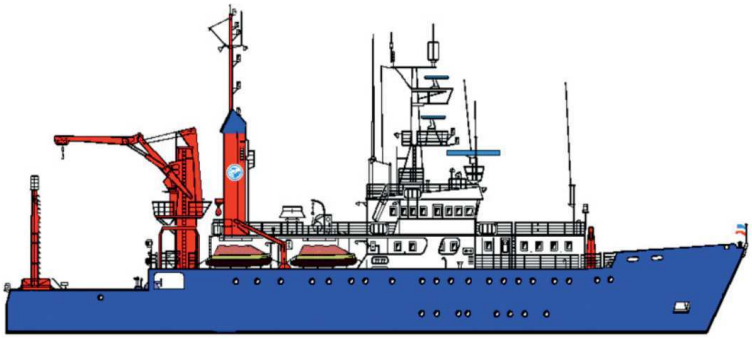
GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

RV POSEIDON

Cruise Report POS420

C O W A C S S



Biological observation and sampling of cold-water corals to investigate impacts on climate change

Trondheim – (Kristiansund) – Kiel

08. – (25.) – 30.09.2011

Content

Note:

The Leibniz-Institute of Marine Sciences, IFM-GEOMAR has changed to **GEOMAR | Helmholtz Centre for Ocean Research Kiel** with beginning of 2012. However, in order to avoid confusion with administrative documents (e.g. permissions) we have used the "old" name in the following report.

1. Scientific crew

Name	Participation	Function	Institute / Affiliation
Form, Armin	08. – 30.09.	Chief Scientist	IFM-GEOMAR
Riebesell, Ulf	08. – 11.09.	Scientific advisor	IFM-GEOMAR
Herzig, Peter	08. – 10.09.	Observation	IFM-GEOMAR
Rietschel, Ernst	08. – 10.09.	Observation	Leibniz-Gemeinschaft
Rauner, Max	08. – 10.09.	Observation	ZEIT Wissen
Gilson, Dirk	08. – 11.09.	Multimedia	WDR
Lederer, Mario	08. – 11.09.	Multimedia	WDR
Begas, Rene	08. – 11.09.	Multimedia	WDR
Zankl, Solvin	08. – 30.09.	Documentation	SZWP
Botros, Mona	08. – 11.09.	Multimedia	WDR
Hissmann, Karen	08. – 30.09.	JAGO-Team	IFM-GEOMAR
Schauer, Jürgen	08. – 30.09.	JAGO-Team	IFM-GEOMAR
Lich, Barbara	10. – 11.09.	Observation	GEOLINO
Yogeshwar, Ranga	10. – 11.09.	Observation	WDR
Nicolai, Maike	10. – 25.09.	Documentation	IFM-GEOMAR
Büscher, Janina	11. – 30 .09.	Coral cultivation	IFM-GEOMAR
Roberts, Murray	11. – 25.09.	Resp. & growth exp.	HWU
Hennige, Sebastian	11. – 25.09.	Resp. & growth exp.	HWU
Müller Christina	11. – 30 .09.	Foodweb exp.	NIOO
López Correa, Matthias	11. – 30 .09.	CTD	Geozentrum Nordbayern

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2. Research Programme

2.1 Short introduction – Research Background

Form, A.

As a result of the raising CO_2-emissions and the resultant ocean acidification (decreasing pH and carbonate ion concentration), the impact on marine organism that build their skeletons and protective shells with calcium carbonate (e.g., mollusks, sea urchins, coccolithophorids, and stony corals) becomes more and more detrimental. In the last few years, many experiments with tropical reef building corals have shown, that a lowering of the carbonate ion concentration significantly reduces calcification rates and therefore growth (e.g., Gattuso *et al.* 1999; Langdon *et al.* 2000, 2003; Marubini *et al.* 2001, 2002). In the middle of this century, many tropical coral reefs may well erode faster than they can rebuild.

Cold-water corals are living in an environment (high geographical latitude, cold and deep waters) already close to a critical carbonate ion concentration below calcium carbonate dissolves. Actual projections indicate that about 70% of the currently known *Lophelia* reef structures will be in serious danger until the end of the century (Guinotte *et al.* 2006). Therefore *L. pertusa* was cultured at IFM-GEOMAR to determine its long-term response to ocean acidification. Our work has revealed that – unexpectedly and controversially to the majority of warm-water corals – this species is potentially able to cope with elevated concentrations of CO_2. Whereas short-term (1 week) high CO_2 exposure resulted in a decline of calcification by 26-29 % for a pH decrease of 0.1 units and net dissolution of calcium carbonate, *L. pertusa* was capable to acclimate to acidified conditions in long-term (6 months) incubations, leading to slightly enhanced rates of calcification (Form & Riebesell, 2012).

For the continuation of our laboratory experiments, living fragments of the hermatypic cold-water coral *Lophelia pertusa* and a few branches of *Madrepora oculata* were collected during this POSEIDON cruise. We also conducted experiments *in situ* and on-board in order to complement laboratory studies.

2.2 Major cruise objectives

The scientific main objectives and methods of the POS420 cruise were:

- To make photo and video documentations of cold-water coral ecosystems suitable for scientific habitat mapping and documentation purposes.

- To collect live cold-water coral *Lophelia pertusa* and associated reef fauna for subsequent laboratory measurements embedded in the BMBF funded project BIOACID (sub project 3.1.2).

- To analyse the physical and chemical water mass properties (temperature, salinity, oxygen, light transmission, chlorophyll fluorescence, dissolved inorganic carbonate, total alkalinity, neodynium, nitrate, nitrite, silicate and phosphate) bathing the cold-water coral reefs.

3. Narrative of the cruise

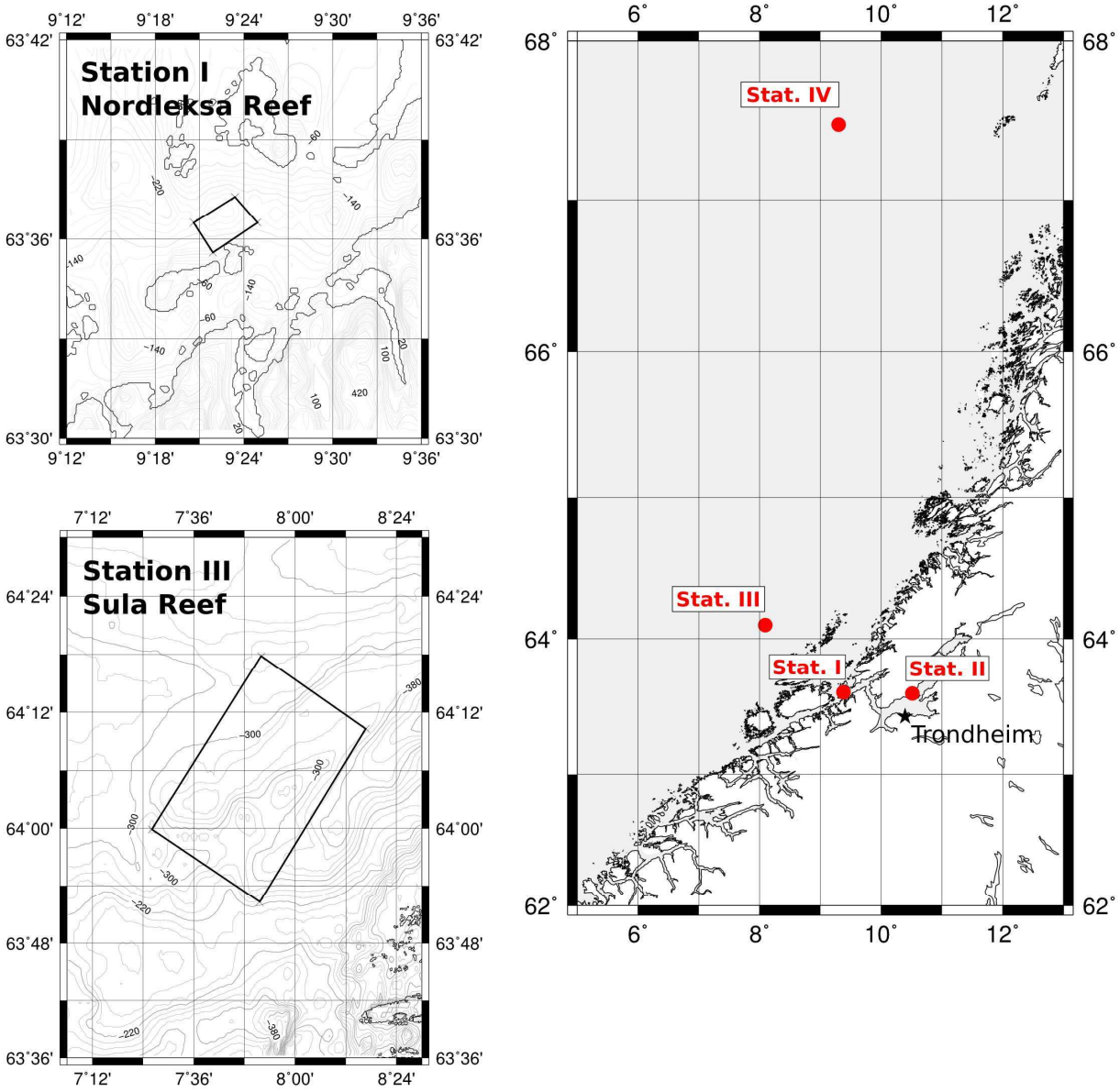

Figure 1 Overview of stations as planned for cruise POS420 (right map) and area maps of the both stations where JAGO dives were conducted, Nordleksa Reef (I) and Sula Reef (III). See Appendix 1 for stationlist with ship position coordinates.

Note: In the following narrative of the cruise all times are reported in local time for Norway (CEST; UTC+02:00).

7th September 2011

Loading of submersible JAGO and scientific equipment in Trondheim (part I).

8th September 2011

Loading of scientific equipment (part II). Embarkation of the scientific crew (see 1. for details). At 7.00 p.m. RV POSEIDON has left the port and headed towards station I (Nordleksa). Arrived at station during the night.

9th September 2011

At 6.10 a.m. a first CTD for characterising the water column was conducted. Afterwards, a JAGO handling and training manoeuvre was performed. At 10.00 a.m. the first JAGO visual observation dive of cold-water coral bioherms was conducted (# 1, station I / 694-1). At 4.00 p.m. a second JAGO visual observation dive (# 2, station I / 695-1) was realised. During the dive, a plankton net was taken for documentation purposes (station I / 696-1). After JAGO was back on deck (6.40 p.m.) RV POSEIDON headed to the port of Trondheim (arrival at 10.36 p.m.).

10th September 2011

Partial exchange of the scientific crew (see 1. for details). At 1.12 p.m. the vessel departed from the harbour and headed back to station I (Nordleksa). After arrival in the evening (6.00 p.m.), a JAGO visual observation and video documentation dive was conducted (# 3, station I / 697-1).

11th September 2011

After a CTD cast in the morning (station I / 698-1) a visual observation dive with JAGO (# 4, station I / 699-1) was performed at 11.20 a.m.. A short surface dive (# 5, approx. 10 m water depth) was carried out for filming and documentation purposes directly thereafter. In the early afternoon RV POSEIDON headed towards port of Trondheim (arrival at 7.12 p.m.) for a final partial scientific crew exchange (see 1. for details) in the evening.

12th September 2011

At 12.00 a.m. the vessel departed from the harbour and headed towards station II (Selligrunnen). A CTD was downcasted at 14.00 p.m. (station II / 700-1). The CTD was lowered to 50m depth (ca. 16 m above ground) and water samples were taken at different depths (mainly for carbonate chemistry). Afterwards, RV POSEIDON headed to Nordleksa (station I), where another CTD cast was done at 7.30 p.m (station I / 701-1). Water samples were taken from different depths again with 160 m (ca. 10 m above ground) as the deepest location. Start of a 24 h CTD survey around the Nordleksa reef with an interval of three hours: CTD was

downcasted at 10.00 p.m. (station I / 703-1). In between two CTD casts a plankton net was lowered to 100 m in order to get samples for photo documentations (station I / 702-1).

13th September 2011

At 3.45 a.m. the next CTD of the 24 h survey was carried out to 170 m water depth (station I / 703-3). At 7.00 a.m. the next CTD started and was lowered to 165 m water depth (station I / 703-4). At 9.00 a.m. a plankton net followed (station I / 703-5) which was lowered to 150 m depth. After three additional CTDs at 10.00 a.m., 1.00 p.m. and 3.15 p.m. a JAGO test dive was carried out at 6.05 p.m (dive # 6, station I / 704-1). The CTD survey was cancelled due to technical problems with the sensors.

14th September 2011

Due to bad weather conditions and maintenance work on JAGO, the vessel stayed position.

15th September 2011

At 9.00 a.m. a JAGO visual observation dive was conducted (# 7, station I / 705-1). At 2.00 p.m. another JAGO visual observation and video documentation dive (# 8, station I / 706-1) was realised. At about 6.00 p.m. the RV POSEIDON headed towards station III (Sula Reef).

16th September 2011

At 10.00 a.m. the RV POSEIDON arrived the Sula Reef area . As the waves remained relatively strong, JAGO dives were postponed to better conditions and the day was used for CTD and plankton net activities. At 12.15 a.m. the first CTD station was conducted (station III / 707-1). Water samples were taken for neodynium and total alkalinity measurements. Another CTD (station III / 708-1) was performed only for seawater column profile data. At around 2.30 p.m., the CTD was downcasted above a reef mount (station III / 709-1). Samples were taken for measurements of trace elements and the carbonate chemistry and nutrients from near bottom and the surface. Afterwards, a plankton net was casted down three times to different depths at this station. One next location was occupied with another plankton net for photographies and a CTD (station III / 710). A series of CTD casts was conducted during the night in order to follow a planned transect (station III / 711 – 716).

17th September 2011

Due to high waves, the early announced JAGO dive (at 8.00 a.m.) in the Sula Reef was cancelled. At 12.00 a.m. JAGO dive # 9 took place (station III, 718-1). After JAGO submerged, seawater was pumped from 50 m water depth (station III, 718-2). During the dive, clod cards were deployed at two different reef locations (see 4.4.1) and afterwards corals were collected.

At around 2.30 p.m. JAGO surfaced and coral samples were transferred to POSEIDON with the aid of a rubber boat. After transferring the samples JAGO submerged again (dive # 10) without going on deck. After the dive JAGO was lifted back on deck. Several small pieces for on-board respiration and growth experiments as well as few samples for isotope measurements could be sampled during both dives.

18th September 2011

Some on-board experiments or preparations for experiments went on. Diving was not possible anymore due to an incoming low and high waves.

19th September 2011

Around midday the RV POSEIDON headed towards Nordleksa (station I). On-board experiments went on.

20th September 2011

After getting the permission from the Norwegian Fiskeridirektoratet to collect coral samples in Nordleksa a JAGO sampling dive was conducted at 9.00 a.m. (# 11, station I / 719-1). Another dive followed at 14.00 p.m. (# 12, station I / 719-2).

21st September 2011

At 8.30 a.m. a JAGO sampling and photo documentation dive was carried out (# 13, station I / 720). Another dive (# 14) followed at the early afternoon. During this dive clod cards were deployed at one reef location (see 4.4.1).

22nd September 2011

At 8.30 a.m. a JAGO sampling dive was conducted (# 15, station I / 721-1). In the meantime, starting at around 9.00 a.m., water was pumped from 50 m depth into two 1000 l water containers. At 2.30 p.m. another JAGO sampling and video documentation dive (# 16) was carried out.

23rd September 2011

At 9.30 a.m. the last JAGO dive of this cruise took place (# 17, station I / 723-1). Because of strong bottom currents sampling of labelled corals and accompanying organisms failed (see 4.4.1). Station work was finished at 6.00 p.m. and the RV POSEIDON headed to station III (Sula Reef).

24th September 2011

At early morning the RV POSEIDON arrived at station III. After breakfast, four 1000 l water containers were filled with water from 50 m water depth for water renewal (see 4.2). A JAGO dive for collecting labelled corals (see 4.4.1) was considered as too risky due to a strong swell. At 6.15 p.m. the vessel left the Sula Ridge and headed towards Kristiansund.

25th September 2011

At around 7.30 a.m. the RV POSEIDON arrived in Kristiansund and docked at the pier. Three scientists left the vessel after customs clearance. Declaration of sampled cold-water corals with the customs according to CITES regulations. Leaving Kristiansund at 1.00 p.m. and heading towards Kiel, Germany. Finishing of last on-board experiments.

26th to 30th September 2011

Transfer towards Kiel and packing. End of scientific cruise POS420 / COWACSS after docking at the IFM-GEOMAR pier on 30th September at 7.42 a.m. and customs clearance.

4. Measurements and sampling

4.1 Submersible JAGO

Hissmann, Karen & Schauer, Jürgen

The manned submersible “JAGO” (IFM-GEOMAR) has an operational depth range of 400 m and can accommodate two persons, the pilot and a scientist/observer. The highly manoeuvrable vehicle has two large acrylic dome ports, one at the front (diameter 70 cm) and one at the top (45 cm). It is electrically driven and moves autonomously under water within the reach of the navigation and communication systems of the support vessel. The vehicle is equipped with USBL navigation and positioning system, fluxgate compass, vertical and horizontal sonar, underwater telephone, digital video (HDV) and still cameras, CTD and a manipulator arm for collecting and handling various sampling devices.

Because of its compact construction (3 x 2 x 2.5 m LWH) and small weight of 3 tons JAGO can be launched and recovered from nearly every larger boat and vessel with sufficient crane capacity (min. 5 tons SWL). The RV POSEIDON is one of the most suitable support vessels for the submersible. She has a low working deck with a free board of less than 2 metres and a powerful crane with sufficient outreach for save handling.

During POS420 the submersible was mainly used for video documentation and to collect live and death coral fragments. Dive sites were selected based on previous submersible cruises and on charts kindly provided by Jan Helge Fosså (IMR, Bergen, Norway).

Live corals and dead coral fragments were carefully sampled with the manipulator arm of the submersible and stored in a sampling basket attached to the lower front of the submersible. Water samples were taken in close vicinity to the bottom with a 5 litre Niskin bottle attached to the port bow of the submersible. A CTD (SAIV A/S SD204 Norway) at the stern of the submersible continuously recorded depth, temperature, salinity and density during each dive.

Table 1 Detailed dive log of JAGO dives during RV POSEIDON cruise POS420. JAGO pilot: Jürgen Schauer; All times in UTC.

Dive #	**Date**	**Location**	**Time** submerged	**Time** surfacing	**Total dive time** (min)	**Touch down position (N/E)**	**Lift off position (N/E)**	**Min - Max Depth** (m)	**Observer**
1	09/09/11	Nordleksa-Reef	9:58?	12:22?	144	N 63°36 .11'	N 63°36.31'	195-213	Rietschel, E.
						E 09°21.89'	E 09°22.58'		
2	09/09/11	Nordleksa-Reef	14:15	16:21	126	N 63°36.4 8'	N 63°36.48'	150-223	Rauner, M.
						E 09°23.24'	E 09°23.14'		
3	10/09/11	Nordleksa-Reef	16:02	17:31	89	N 63°36.55 '	N 63°36.53'	147-170	Lich, B.
						E 09°23.22'	E 09°23.21'		
4	11/09/11	Nordleksa-Reef	9:28	11:32	124	N 63°36.40 '	N 63°36.50'	160-220	Yogeshwar, R.
						E 09°23.61'	E 09°23.08'		
5	11/09/11	Nordleksa-Reef	12:13	12:19	6	N 63°36.73'	N 63°36.73'	10	Yogeshwar, R.
						E 09°23.26'	E 09°23.26'		
6	13/09/11	Nordleksa-Reef	16:17	18:02	105	N 63°36.4 7'	N 63°36.40'	143-230	Pregler, H.
						E 09°22.46'	E 09°23.64'		
7	15/09/11	Nordleksa-Reef	7:24	9:25	121	N 63°36.59'	N 63°36.67'	200-237	Roberts, J.M.
						E 09°23.53'	E 09°23.88'		
8	15/09/11	Nordleksa-Reef	12:22	14:54	152	N 63°36.3 7'	N 63°36.48'	147-225	Nicolai, M.
						E 09°22.90'	E 09°22.80'		
9	17/09/11	Sula-Reef	10:10	12:29	139	N 64°06.11'	N 64°06.11'	293-295	Müller, Chr.
						E 08°06.05'	E 08°06.15'		
10	17/09/11	Sula-Reef	12:41	15:33	172	N 64°06.05'	N 64°06.19'	296-347	Müller, Chr.
						E 08°06.61'	E 08°06.30'		
11	20/09/11	Nordleksa-Reef	7:45	10:01	136	N 63°36.4 6'	N 63°36.45'	153-180	Form, A.
						E 09°22.60	E 09°22.76'		
12	20/09/11	Nordleksa-Reef	12:17	14:20	123	N 63°36. 51	N 63°36.48'	160-187	Henninge, S.
						E 09°22.86'	E 09°22.87'		
13	21/09/11	Nordleksa-Reef	6:45	10:14	209	N 63°36.5 0	N 63°36.47'	145-200	Zankl, S.
						E 09°22.74'	E 09°22.71'		
14	21/09/11	Nordleksa-Reef	13:40	17:07	207	N 63°36. 46'	N 63°36.48'	150-207	Correa, M.L.
						E 09°22.92'	E 09°22.71'		
15	22/09/11	Nordleksa-Reef	6:40	9:02	142	N 63°36.40 '	N 63°36.48'	149-221	Büscher, J.
						E 09°22.88'	E 09°22.75'		
16	22/09/11	Nordleksa-Reef	12:42	16:41	239	N 63°36. 44'	N 63°36.44'	149-204	Hissmann, K.
						E 09°22.88'	E 09°22.75'		
17	23/09/11	Nordleksa-Reef	7:45	10:36	171	N 63°36.5 6'	N 63°36.45'	162-230	Form, A.
						E 09°22.67'	E 09°22.66'		
					2405 (40h)			**143 - 347**	

4.2 Maintaining the corals on board

Form, Armin & Büscher, Janina

In a first step all coral branches were carefully transferred from the collecting basket of the JAGO submersible into large buckets filled with fresh and clean seawater. After a period of acclimation the living coral fragments and their accompanying fauna were transferred from the buckets into four 500 litres PVC transportation tanks in the wet laboratory of RV POSEIDON (Fig. 3).

Each of the four transportation tanks was equipped with a glass fibre lattice (5 * 5 cm grid size) on the bottom for sample fixation. Small coral fragments were secured with special coral glue on a prepared PVC socket board. Furthermore internal water pumps (equipped with mechanical filters) were installed in each tank. For maintaining a constant water temperature (7,5 ± 1 ℃), a closed recirculation between the PVC tanks and a cooling aggregate (Aqua Medic, Titan 4000) was established.

Figure 2 Transportation tanks in the wet laboratory of RV POSEIDON during cruise POS420 (Photo: S. Hennige).

Due to biological processes the water in the transportation tanks was renewed at regular intervals with fresh seawater which was pumped beforehand with a deap-sea pump from about 40-50 m water depth into up to four 1000 l water containers (placed on deck of RV POSEIDON).

4.3 CTD Measurements and water sampling

López Correa, Matthias

The CTD water column profiles were processed with a pumping system and integrated sensors, which measured conductivity, temperature and density (CTD). Based on these classical parameters a first evaluation of the water column structure is possible. Additionally, a detector for the fluorescence of *Chlorophyll a* (Dr. Haardt) and sensors for dissolved oxygen were mounted to the CTD to derive further measures for the water mass differentiation. The ship-based CTD is an *SBE 9plus* model from *Seabird* connected to a water sampling rosette with twelve 10-litre *Niskin*-bottles, which permitted to collect water samples from defined water masses at different depths. The CTD deployments were conducted using a *Seabird SBE 11plus* deck unit, which was connected to a PC for real-time acquisition. After water mass investigation during the CTD downcasts, the *Niskin*-bottles were closed at characteristic depths. Data of the water mass parameters from the CTD deck unit were converted and extracted with the „Sea-Bird Electronics (SBE) Data Processing, Version 7.18. Due to recurring technical problems with the ship-based CTD-sensors and cable connectivity, we additionally mounted the CTD of the JAGO-submersible to the framework of the CTD Rosette and generated redundant datasets at stations 707-1, 708-1, 709-1, 710-2, 711-1,712-1, 713-1, 714-1, 715-1, 716-1. This sensor unit (SAIV A/S SD204) records depth, temperature, salinity and seawater density. At station II (Selligrunnen) we have data from the ship-based CTD-unit only.

The principal objective of the CTD-measurements during the cruise was to get an overview into the water column structure at the coral reefs in Trondheimfjord on Selligrunnen and at Nordleksa, as well as out on the shelf at the extensive Sula Reef. During all casts the CTD and water sampling units were stopped ~10 m above the actual seafloor, to exclude a potential damage of the reef structures.

Water samples were collected for the subsequent measurement of the geochemical composition related to different depths and water masses. We took samples for stable isotopic compositions of seawater oxygen isotopes ($\delta^{18}O_{sw}$) and of stable carbon isotopes ($\delta^{13}C_{DIC}$) in the dissolved inorganic carbon (DIC). For this purpose 200 ml seawater were fixated with 100 µl $HgCl_2$ and stored in tight-sealed polyethylen bottles. For the trace element compositions we extracted 2 l of seawater from the Niskin-bottles and fixated them with 2.5 ml double-distilled ultra-clean HNO_3. For the Neodymium isotope composition (ε_{Nd}) we extracted ~20 l of seawater from two Niskin-bottles, corresponding to the same depth interval, and fixated them with 10 ml double-distilled ultra-clean HNO_3. The Neodymium isotope seawater samples were stored in 20 l cubitainers. These samples will additionally serve for the measurement of the stable Strontium

isotope composition ($\delta^{88/86}Sr$). To prevent sample contamination gloves were carried at all sampling stages and the water was extracted from the Niskin bottles with pre-cleaned Tygon-tubes. Pipette tips in the ship-based laboratory were pre-cleaned with HNO_3 and MilliQ-water and the tips were changed for each sample. Seawater compositions are currently being measured at GEOMAR and at the GeoZentrum Nordbayern in Germany. This background dataset will serve as reference values for the geochemical compositions of the skeletal parts of the life-collected coral material and will be helpful to establish paleoceanographic proxies from coral aragonite.

The precise position of the CTD casts is given in the Stationlist in the Appendix, and also the extracted subsamples for the geochemical seawater composition are summarized in the Appendix.

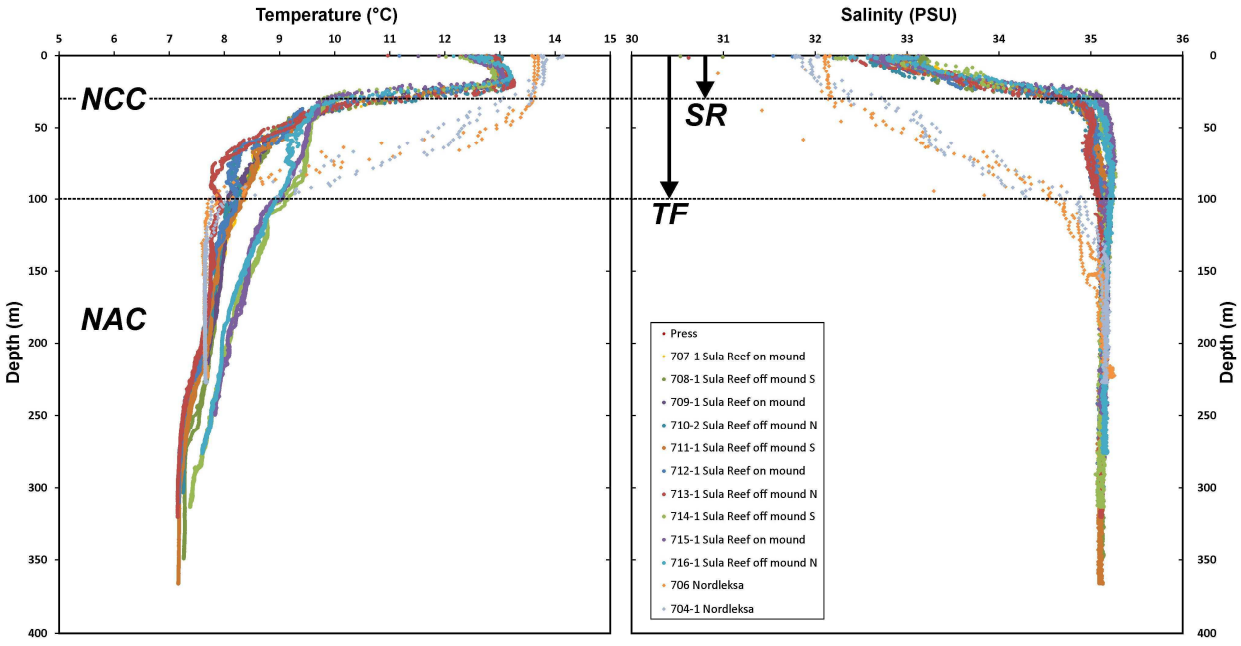

Figure 3 Water column structure with the NCC as surface water mass and the NAC as a bottom water mass, with a mixing zone inbetween. The NCC-volume with this mixing zone reaches down to ~100 m in Trondheimfjord, but only down to ~30 m at Sula Reef.

4.4 On-board experiments

4.4.1 Foodweb dependencies

Müller, Christina

1. Nutrient cycling in a cold-water coral community

In-situ addition of $^{13}C/^{15}N$ enriched glucose/ammonium, DOM and POM followed by a collection of reef derived DOM, POM and zooplankton as well as reef fauna for stable isotope analyses before and after enrichment.

The structure of the food web belongs to the basic information that is needed to understand an ecosystem. The exploration of the structure of the food web of cold water coral communities has been started recently with the aid of the modern technology such as remotely operated vehicles and manned submersibles that are equipped with robot arms. During the cruise the submersible JAGO, operated by Jürgen Schauer and Karen Hissmann, was used to work at hundred meters deep waters of the Norwegian shelf where cold-water corals are living. Equipped with a manipulator arm and a niskin bottle it was possible to sample dominant reef organism as well as reef associated zooplankton and POM with JAGO at two different locations: One sample location was the Sula reef on the Norwegian shelf and the other one at Nordleksa in the Fjord of Trondheim.

Samples of the reef organisms will later be analyzed at the NIOO (Netherlands Institute of Ecology, the Netherlands) for natural isotopic abundance of ^{15}N and ^{13}C in bulk samples as well as specific PLFAs (phospholipid derived FA). Both methods are well known to help the identification of possible food sources (Dodds *et al.* 2009, Boschker & Middelburg 2002, van Oevelen *et al.* 2009).

To gain more detailed information of trophic interactions and food processing *in situ* by a cold-water coral reef system, clod cards (gypsum balls) were prepared that contained as food source either ^{13}C and ^{15}N POM or DOM derived from ^{13}C and ^{15}N enriched algae. The clod cards were brought down to the seafloor next to diverse reef locations at the Sula reef. A ^{15}N ammonium and ^{13}C enriched glucose treatment was brought down at Nordleksa in the Trondheim Fjord. The clod cards dissolve slowly due to current action and release the food sources during dissolution. It was planned to take organism samples close to the cold card position before and after the treatment started to investigate food processing by different members of the cold-water

coral community but due to bad weather conditions the required sampling about 4-7 days after deployment could not be conducted.

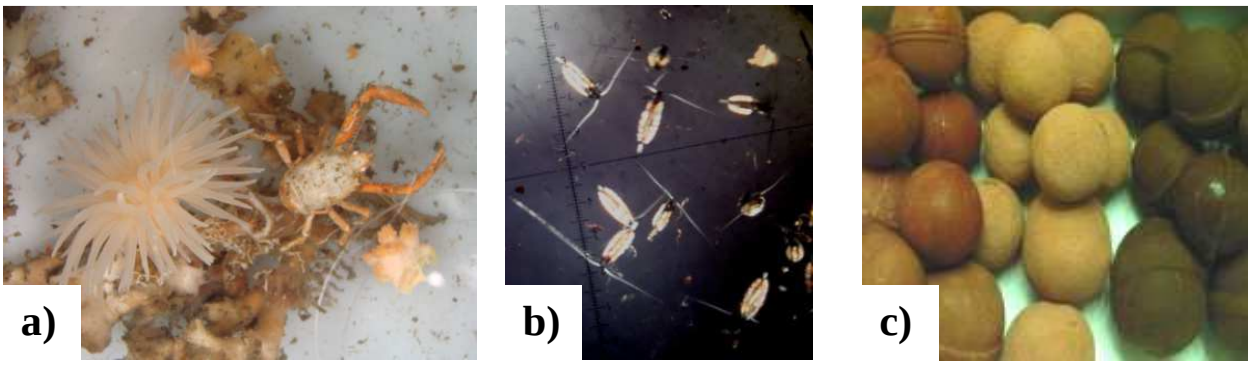

Figure 4 Examples of associated reef fauna (**a**), close ups of zooplankton (**b**), clod cards enriched with $^{13}C/^{15}N$ food sources (each color represents a different food source)(**c**).

2. DOM and POM production and uptake in a cold-water coral reef

2a. Measurements of POM/ DOM production by two common cold water corals: Lophelia pertusa and Madrepora occulata. 2b. Measurements of POC/ DOC uptake by associated fauna in a coral reef: Mycale, Hymedesmia and a random mixture of encrusting death Lophelia branches.

Corals can produce high amounts of DOC and POC. Hereby especially DOC is known to be highly affiliated by bacteria (Wild *et al.* 2008) but also sponges can take up reef-derived DOC (van Duyl *et al.* 2011). To evaluate the importance of these food sources for a cold-water coral reef, the release by two common cold-water corals as well as the uptake by common reef associated organisms like sponges of DOC and POC were measured. For associated organism the common sponges *Mycale* and *Hymedesmia* were chosen, two species that are growing in between and on living coral branches. To take also epiphytic fauna living on death corals into account pieces overgrown by several species were used as well in the incubations. The mucus for the uptake experiment was hereby harvested from white *Lophelia* branches, which were shaken in a small volume of seawater.

For more detailed information on the nutritional value of mucus of the producer species, the mucus will be analyzed for its fatty acid, amino acid and carbohydrate concentration and composition later on at the NIOO.

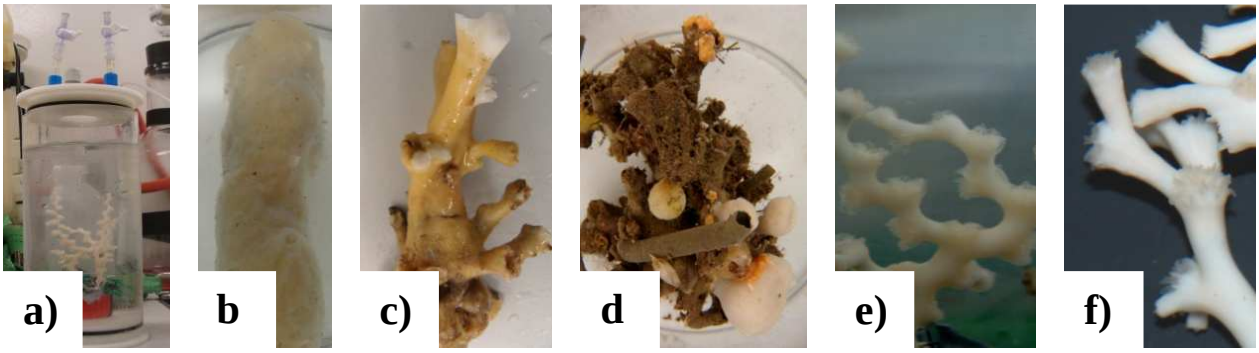

Figure 5 Incubation chamber (**a**), *Mycale* (**b**), *Hymedesmia* (**c**), encrusted death *Lophelia* piece (**d**), *Madrepora* (**e**), *Lophelia* (**f**, picture: M.L. Correa).

3. Nitrification, Denitrification-, Anammox- and Nitrogenfixation-Incubations of two color variants of Lophelia pertusa

Addition of ^{15}N nitrate, ^{15}N ammonium and ^{15}N nitrogen-gas over 24h.

Recent studies on tropical corals highlight the potential of microorganism associated with the coral host to expand the physiological capacities of N uptake (Siboni *et al.* 2008, Shashar *et al.* 1994, Wafar *et al.* 1990). Comparable studies focusing on the microbial community associated with cold water corals also point to a possibility in bacterial mediated supplementary nutrition in these corals (Neulinger *et al.* 2008, Galkiewicz *et al.* 2011). However until now most of the microbial studies on cold water corals are focussed on molecular identification without direct measurements of the processes involved.

During the cruise experiments were conducted on board which targeted important processes of the nitrogen cycle like nitrification, denitrification and anammox. Therefore incubations were prepared with the addition of ^{15}N enriched ammonium (gas-tight (anammox) as well as open incubations (nitrification)), nitrate (denitrification) and nitrogen gas (nitrogen fixation) with two color variants of the common coral *Lophelia pertusa*. The incubations for denitrification and anammox were terminated by adding $HgCl_2$ into the incubation bottle. These samples will be later analyzed for $^{15}N_2$ gas development. For the measurement of nitrification and nitrogen gas fixation corals where removed from the bottles and frozen for further ^{15}N bulk analysis. The water of both treatments was filtered and frozen for further analyses of ^{15}N ammonium and ^{15}N nitrate.

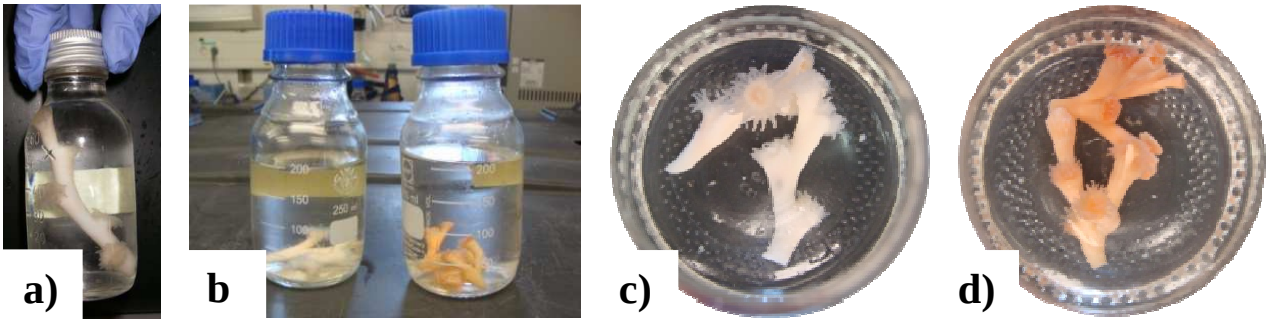

Figure 6 Gas tight incubation bottle, 80ml (**a**, picture: M.L. Correa), incubation bottles, 200ml (**b**), close up of white color variant of *Lophelia* (**c**), close up of red color variant of *Lophelia* (**d**).

4. INO (inorganic nutrient)-Incubation of two color variants of common cold-water corals in the Nord Atlantic: *Lophelia pertusa* and *Madrepora oculata*

Addition of ^{15}N ammonium and ^{13}C bicarbonate for 5 and 10 days.

We also studied the processing and incorporation of C and N derived from inorganic nutrients by the host, coral tissue and coral skeleton was studied over time during the cruise. Hereby corals were incubated in 4l enriched with ^{13}C bicarbonate and ^{15}N ammonium and sampled after 5 and 9 days. For the incubations two color variants of *Lophelia* and *Madrepora* were used to compare the capability of this common two coral species. After the incubations corals were frozen for further analyses of ^{15}N and ^{13}C enrichment in the skeleton and tissue, herby also specific compounds of the tissue like PLFA (phosphor-derived fatty acids) and AAs (amino acids) will be taken into account for evaluating the bacterial part of inorganic carbon and nitrogen fixation and processing.

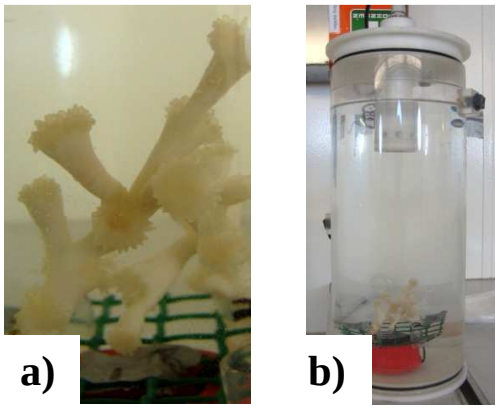

Figure 7 Close up of Lophelia pertusa (**a**), incubation chamber (4l) equipped with stirrer (**b**).

4.4.2 Ecophysiology

Hennige, Sebastian & Roberts, Murray

With the combined threat of global warming and ocean acidification, and increasing numbers of experiments investigating these impacts upon the cold-water coral *Lophelia pertusa*, it is vitally important to understand the baseline variability between corals from different depths and flow regimes. Within the Norwegian fjords, different colour morphs of cold-water corals also exist, but very little is known about their comparative physiology. This investigation thus seeks to examine *Lophelia pertusa* physiology from a variety of different depths and flow regimes to determine their extent of environmental acclimation. This will be repeated with different colour morphs to determine what, if any, differences exist, and also with a previously unstudied species, *Madrepora oculata.*

Aims

1. To collect benthic samples of live coral (*Lophelia pertusa* and *Madrepora oculata*) from various location within Norwegian reefs, spanning a depth and water flow gradient.
2. To conduct onboard experiments to assess baseline growth and metabolism of these coral species along the environmental gradient.
3. To repeat this assessment with different colour morphs of these key coral species.

Main experiment:

The aim of this experiment was to assess baseline metabolism and calcification (growth) rate of *Lophelia pertusa* and *Madrepora oculata.*

Growth: This was assessed in two ways

1) radionuclide labelling,
2) the alkalinity anomaly technique.

1: Replicate corals were removed from aquaria and incubated in 50ml falcon tubes for 3 hours prior to the experiment. At Time zero, tubes were spiked with ^{14}C. Aliquots were taken for total activity assessment. After 6 hours, another aliquot was taken. Preliminary analysis on the water which contained coral fragments has confirmed that ^{14}C was taken up by the coral, further analysis will determine the fraction taken up by tissue and by skeleton (growth rate).

2: The decrease in total alkalinity (TA) during coral incubation can be used to determine the change in calcium carbonate and hence used to determine the growth rate of corals. Samples were taken for TA from the water tanks (see 4.2) at time zero, and from coral chambers isolated from the main container at the end of a 3-hour incubation in purpose-built stirred containers (n = 8). This will be processed back at HWU to determine calcification rate and hence growth.

Metabolism: To assess metabolism, respiration rates were measured on replicate corals. For this, corals were placed in custom-built tubes with stir bars and optode sensors. Respiration was assessed during 3 hours incubation. Results will be normalized back at HWU to coral weight and ash free dry weight. Coral nubbins used in this experiment were frozen for this reason.

5. Preliminary results

17.3.2011, 9-39.9.2011, Jnr 11/4302

CTD Measurements and water properties

López Correa, Matthias

The preliminary results pictured and described below are based on the JAGO-CTD measurements (SAIV A/S SD204) during submersible dives at stations 704-1 and 706-1 at Nordleksa, as well as on the regular CTD-casts at stations 707-1, 708-1, 709-1, 710-2, 711-1,712-1, 713-1, 714-1, 715-1, 716-1 at Sula Reef (again with the CTD-sensor SAIV A/S SD204). At all three investigation sites, in Trondheimfjord and at the Sula Reef, the water column shows a similar structure with a warm and low saline surface water mass, a transition zone underneath, and a sharp boundary against colder waters with a higher salt content below. These water masses can be attributed to the Norwegian Coastal Current (NCC) at the surface, and to the North Atlantic Current (NAC) below, with a mixing zone in between.

At Nordleksa the sea surface temperature is ~13.7 to 14°C and the surface salinities are <32 PSU. The NCC forms a homogenous core until 50 m depth, and is then followed by a mixing zone, which shows a steady increase in salinity to ~34.8 PSU and a steady decrease in temperature to ~7.9°C at 100 m depth. Below a sharp density boundary the NAC shows a relatively stable salinity of >35 PSU and slightly decreasing temperatures with a minimum of ~7.6°C at 230 m depth.

At Sula Reef the NCC is again clearly discernible between 0 and 20 m depth with surface temperatures between ~12 and 13°C, with the NCC-core best defined by a temperature of ~13.3°C. Surface salinities are between <32 and ~33.2 PSU. Below 20 to 30 m the transition zone shows a rapid increase in temperature by 3.5°C to ~9.5°C and a rapid salinity increase to ~35 PSU. Compared to Nordleksa the volume of the NCC is much smaller and the transition zone to the underlying NAC much thinner, despite a similar NCC to NAC salinity gradient. The NAC below ~50 m shows a near stable salinity of ~35 PSU until the sea floor between 270 and 370 m. Bottom temperatures are similar at all sites with ~7°C. However in the water column at ~100 m depth the temperatures differed remarkedly between ~7.7 and ~9.5°C among different sites. There seems to be a systematic pattern along the strike of the Sula Reef and also between off mound sites north and south of the crest.

At Selligrunnen surface waters (NCC) show salinities of <33 PSU with temperatures of ~13℃, which show a steady cooling to ~10.5℃ just above t he watermass boundary at 39 m depth. The NAC-water underneath between 40 and 50 m shows a significantly colder temperature of 8.5℃ and a higher salinity of >35 PSU. Selligrunnen comprises a special scenario, as it poses a sill across the >200 m deep fjord trough, which peaks at less than 45 m below the sea surface. Due to the topographic effect the water column structure just west of the crest of Selligrunnen appears condensed with respect to the relative space oppupied by the NCC and the NAC, compared to Nordleksa. It is remarkable that the surface waters are ~1℃ colder than at Nordleksa and on contrast the bottom water NAC-temperature is ~1℃ warmer than at Nordleksa. The corals at the Selligrunnen (Tautraryggen) comprise one of the world's shallowest sites for *Lophelia pertusa* mounds, which are here fueled by the inflowing NAC, that imposes strong tidal currents across the sill.

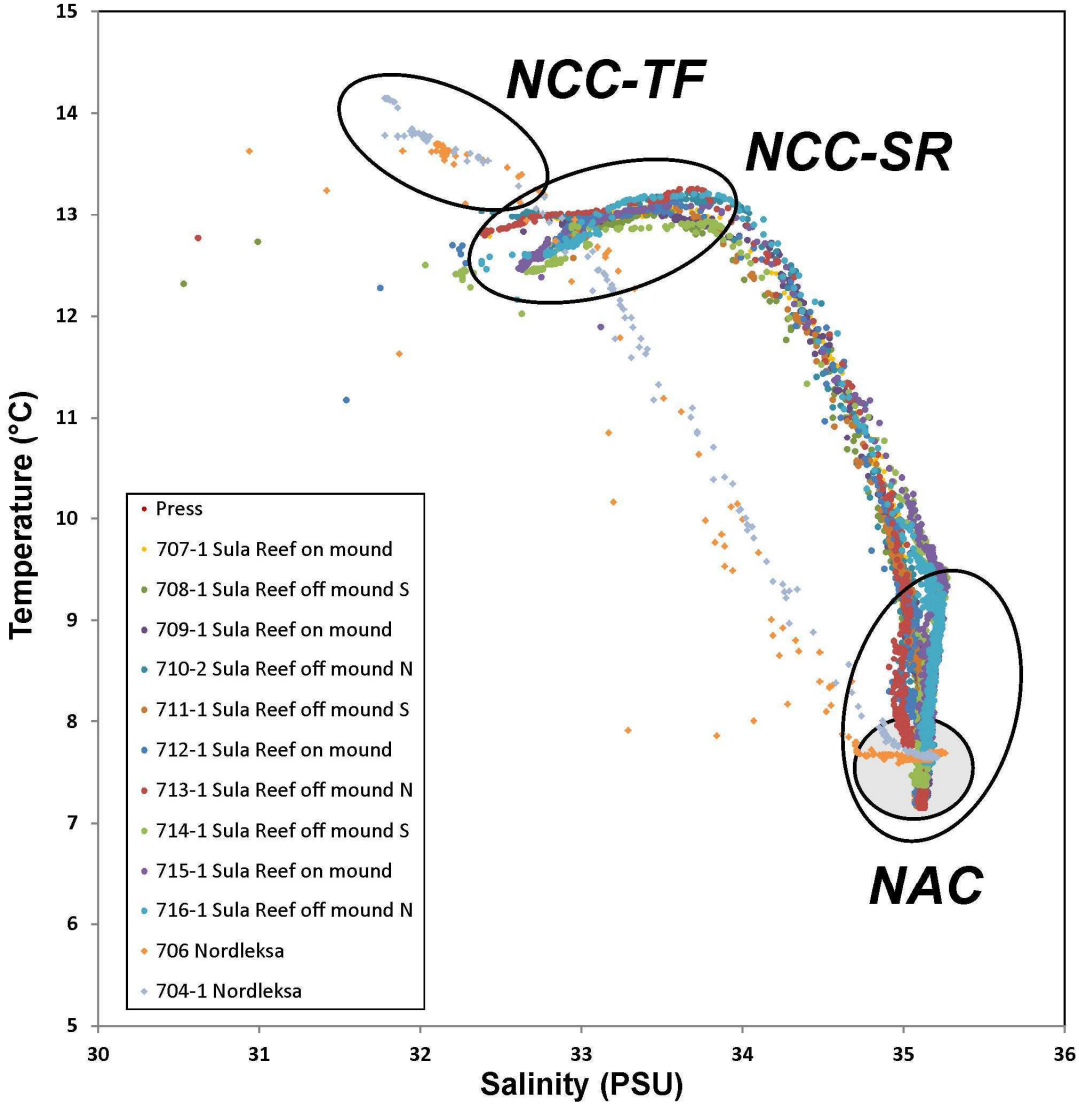

Figure 8 Grey area Reef Site conditions are similar at Sula Reef and at Nordleksa. Abbreviations: Norwegian Coastal Current (NCC), North Atlantic Current (NAC), -Trondheimfjord (-TF), - Sula Reef (-SR).

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We are also very grateful to Jan Helge Fosså (Institute of Marine Research, Norway) for providing reef position data and his support throughout the whole project.

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Appendix

1. Stationlist

Ship-Station (#)	Date	Time (UTC)	Gear	Logbook entry	Latitude (N)	Longitude (E)	Depth (m)
692-1	09/09/11	4:18	CTD/rosette water sampler	to water	63°36.57' N	9°22.80' E	218
		4:34	CTD/rosette water sampler	on deck	63°36.63' N	9°22.83' E	215
693-1		6:48	JAGO submarine	to water	63°36.37' N	9° 21.72' E	269
		7:09	JAGO submarine	on deck	63°36.37' N	9°21.91' E	267
694-1		7:57	JAGO submarine	to water	63°36.10' N	9°21.70' E	183
		10:36	JAGO submarine	on deck	63°36.37' N	9°22.71' E	192
695-1		14:09	JAGO submarine	to water	63°36.46' N	9° 22.87' E	161
696-1		15:04	Plankton net	to water	63°36.53' N	9°23.40' E	219
		15:12	Plankton net	on deck	63°36.56' N	9°23.57' E	228
695-1		16:40	JAGO submarine	on deck	63°36.57' N	9° 24.13' E	226
697-1	10/09/11	15:56	JAGO submarine	to water	63°36.53' N	9°22.99' E	179
		17:59	JAGO submarine	on deck	63°36.95' N	9°24.30' E	228
698-1	11/09/11	6:50	CTD/rosette water sampler	to water	63°36.23' N	9°22.34' E	204
		7:06	CTD/rosette water sampler	on deck	63°36.25' N	9°22.39' E	206
699-1		9:23	JAGO submarine	to water	63°36.35' N	9°23.24' E	220
		11:50	JAGO submarine	on deck	63°36.66' N	9°23.20' E	218
699-1		12:07	JAGO submarine	to water	63°36.70' N	9° 23.27' E	216
		12:33	JAGO submarine	on deck	63°36.82' N	9°23.21' E	222
700-1	12/09/11	12:08	CTD/rosette water sampler	to water	63°35.39' N	10°31.06' E	76
		12:32	CTD/rosette water sampler	on deck	63°35.38' N	10°31.02' E	89
701-1		17:27	CTD/rosette water sampler	to water	63° 35.92' N	9°22.12' E	169
		17:56	CTD/rosette water sampler	on deck	63°35.94' N	9°22.13' E	177
702-1		18:08	Plankton net	to water	63°35.92' N	9°22.13' E	174
		18:21	Plankton net	on deck	63°35.93' N	9°22.13' E	175
703-1		19:58	CTD/rosette water sampler	to water	63° 35.93' N	9°22.13' E	173
		20:12	CTD/rosette water sampler	on deck	63°35.94' N	9°22.11' E	174
703-2		22:56	CTD/rosette water sampler	to water	63°35.93' N	9°22.06' E	173
		23:13	CTD/rosette water sampler	on deck	63°35.91' N	9°22.08' E	170
703-3	13/09/11	1:43	CTD/rosette water sampler	to water	63°35.93' N	9°22.16' E	178
		1:58	CTD/rosette water sampler	on deck	63°35.95' N	9°22.16' E	180
703-4		4:58	CTD/rosette water sampler	to water	63°35.93' N	9°22.15' E	171
		5:16	CTD/rosette water sampler	on deck	63°35.94' N	9°22.16' E	173
703-5		6:57	Plankton net	to water	63°35.94' N	9°22 .13' E	174
		7:10	Plankton net	on deck	63°35.94' N	9°22.21' E	178
703-6		7:59	CTD/rosette water sampler	to water	63°35.94' N	9°22.15' E	175
		8:15	CTD/rosette water sampler	on deck	63°35.93' N	9°22.20' E	177
703-7		11:00	CTD/rosette water sampler	to water	63° 35.91' N	9°22.09' E	173
		11:16	CTD/rosette water sampler	on deck	63°35.94' N	9°22.12' E	177
703-8		13:15	CTD/rosette water sampler	to water	63°35.91' N	9°22.06' E	174
		13:29	CTD/rosette water sampler	on deck	63°35.91' N	9°22.06' E	174

704-1		16:11	JAGO submarine	to water	63°36.50' N	9° 22.40' E	247
		18:21	JAGO submarine	on deck	63°36.32' N	9°23.13' E	217
705-1	15/09/11	7:18	JAGO submarine	to water	63°36.50' N	9°23.01' E	161
		9:37	JAGO submarine	on deck	63°36.66' N	9°24.63' E	244
706-1		12:18	JAGO submarine	to water	63°36.39' N	9° 22.87' E	218
		15:17	JAGO submarine	on deck	63°36.31' N	9°22.93' E	218
707-1	16/09/11	10:10	CTD/rosette water sampler	to water	64°6.28' N	8°6.44' E	293
		10:38	CTD/rosette water sampler	on deck	64°6.35' N	8°6.56' E	293
708-1		11:24	CTD/rosette water sampler	to water	64° 5.58' N	8°7.76' E	355
		11:49	CTD/rosette water sampler	on deck	64°5.54' N	8°7.70' E	352
709-1		12:33	CTD/rosette water sampler	to water	64°5.98' N	8°5.45' E	294
		13:00	CTD/rosette water sampler	on deck	64°6.10' N	8°5.79' E	294
709-2		13:50	Plankton net	to water	64°5.98' N	8°5. 36' E	297
		14:12	Plankton net	on deck	64°6.00' N	8°5.33' E	2 98
709-3		14:13	Plankton net	to water	64°6.00' N	8°5.32' E	297
		14:25	Plankton net	on deck	64°6.00' N	8°5.32' E	297
709-4		14:26	Plankton net	to water	64°6.00' N	8°5. 32' E	297
		14:33	Plankton net	on deck	64°6.00' N	8°5.35' E	2 98
710-1		15:00	Plankton net	to water	64°6.82' N	8°5.36' E	309
		15:09	Plankton net	on deck	64°6.84' N	8°5.31' E	308
710-2		15:31	CTD/rosette water sampler	to water	64° 6.79' N	8°5.32' E	306
		15:41	CTD/rosette water sampler	on deck	64°6.79' N	8°5.28' E	184
711-1		22:07	CTD/rosette water sampler	to water	64°6.68' N	8°10.18' E	372
		22:33	CTD/rosette water sampler	on deck	64°6.65' N	8°10.14' E	373
712-1		23:01	CTD/rosette water sampler	to water	64° 7.84' N	8°10.41' E	320
		23:23	CTD/rosette water sampler	on deck	64°7.84' N	8°10.37' E	316
713-1		23:45	CTD/rosette water sampler	to water	64°8.59' N	8°10.39' E	327
	17/09/11	0:05	CTD/rosette water sampler	on deck	64°8.57' N	8°10.33' E	327
714-1		1:18	CTD/rosette water sampler	to water	64°3 .48' N	8°1.38' E	319
		1:37	CTD/rosette water sampler	on deck	64°3.48' N	8°1.31' E	320
715-1		1:58	CTD/rosette water sampler	to water	64°4.30' N	8°0.16' E	327
		2:15	CTD/rosette water sampler	on deck	64°4.31' N	8°0.07' E	267
716-1		2:43	CTD/rosette water sampler	to water	64°5 .40' N	7°59.15' E	283
		2:58	CTD/rosette water sampler	on deck	64°5.39' N	7°59.09' E	282
718-1		10:05	JAGO submarine	to water	64°6.12' N	8°5.86' E	293
718-2		10:28	Rosette + water pump	to water	64°6.24' N	8°5.89' E	297
		11:59	Rosette + water pump	on deck	64°6.21' N	8°5 .99' E	297
		16:13	JAGO submarine	on deck	64°5.85' N	8°5.55' E	294
719-1	20/09/11	7:40	JAGO submarine	to water	63°36. 46' N	9°22.78' E	150
		10:20	JAGO submarine	on deck	63°36.47' N	9°21.78' E	270
719-2		12:13	JAGO submarine	to water	63°36.46' N	9°22.88' E	168
		14:32	JAGO submarine	on deck	63°36.48' N	9°22.67' E	190
720-1	21/09/11	6:40	JAGO submarine	to water	63°36. 48' N	9°22.83' E	152
		10:25	JAGO submarine	on deck	63°36.39' N	9°22.61' E	157
720-1		12:28	JAGO submarine	to water	63°36.42' N	9°22.80' E	180
		13:05	JAGO submarine	on deck	63°36.52' N	9°22.28' E	258
720-1		13:36	JAGO submarine	to water	63°36.42' N	9° 22.87' E	202

		17:24	JAGO submarine	on deck	63°36.47' N	9°22.36' E	240
721-1	22/09/11	6:35	JAGO submarine	to water	63°36.42' N	9°22.89' E	214
		9:30	JAGO submarine	on deck	63°36.36' N	9°22.94' E	220
722-1		10:31	Rosette + water pump	to water	63°36.52 ' N	9°22.07' E	264
		10:58	Rosette + water pump	on deck	63°36.61' N	9° 22.24' E	251
721-1		12:36	JAGO submarine	to water	63°36.44' N	9°22.80' E	176
		16:55	JAGO submarine	on deck	63°36.48' N	9°23.11' E	154
723-1	23/09/11	7:37	JAGO submarine	to water	63°36. 59' N	9°22.89' E	219
		10:57	JAGO submarine	on deck	63°36.46' N	9°22.73' E	144
724-1	24/09/11	6:59	Rosette + water pump	to water	64°5.89' N	8°5.97' E	315
		7:59	Rosette + water pump	on deck	64°6.08' N	8°5.58' E	294

2. Water sampling

Ship-Station (#)	Depth	Neodymium	Trace elements	Stable Isotopes	Remarks
700-1	50 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
700-1	36 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
700-1	20 m	not taken	not taken	200 ml, 100 µl HgCl2	on-mound
700-1	8 m	not taken	not taken	200 ml, 100 µl HgCl2	on-mound
700-1	1 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	2 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	25 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	60 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	80 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	120 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
701-1	160 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
703-1	170 m	not taken	200 ml, HNO3	not taken	on-mound
703-1	150 m	not taken	200 ml, HNO3	not taken	on-mound
703-1	80 m	not taken	200 ml, HNO3	not taken	on-mound
703-1	65 m	not taken	200 ml, HNO3	not taken	on-mound
707-1	286 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	off-mound
707-1	80 m	not taken	not taken	200 ml, 100 µl HgCl2	off-mound
707-1	2 m	not taken	not taken	200 ml, 100 µl HgCl2	off-mound
708-1	347 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	off-mound
708-1	2 m	not taken	not taken	200 ml, 100 µl HgCl2	off-mound
709-1	2 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
709-1	15 m	not taken	not taken	200 ml, 100 µl HgCl2	on-mound
709-1	45 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
709-1	60 m	not taken	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
709-1	150 m	not taken	not taken	200 ml, 100 µl HgCl2	on-mound
709-1	276 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	on-mound
710-2	295 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	off-mound
710-2	15 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
710-2	2 m	20 l, 10 ml HNO3	2 l, 2.5 ml HNO3	200 ml, 100 µl HgCl2	off-mound
711-1	366 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
711-1	2 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
712-1	310 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	on-mound
712-1	2 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	on-mound
713-1	316 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
714-1	313 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
714-1	2 m	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
715-1	Surface	not taken	not taken	2x 100 ml, 100 µl HgCl2	on-mound
715-1	Bottom	not taken	not taken	2x 100 ml, 100 µl HgCl2	on-mound
716-1	Surface	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound
716-1	Bottom	not taken	not taken	2x 100 ml, 100 µl HgCl2	off-mound

3. Living cold-water coral samples (CITES reg.)

CITES Permit/Certificate: E-03657/11

Permit No: EX-32-2011

Species	Locations/origin	Sampling gear	Sample description	estimated size
Lophelia pertusa	Station I, III	JAGO submersible	small branches and single colonies of both colour variants	37 kg
Madrepora oculata	Station I, III	JAGO submersible	small fragments of both colour variants	0.6 kg
				37.6 kg *

* Note: The actual amount of living coral samples was much less because many of the collected fragments consisted of large parts with dead (“neo fossil”) polyps.