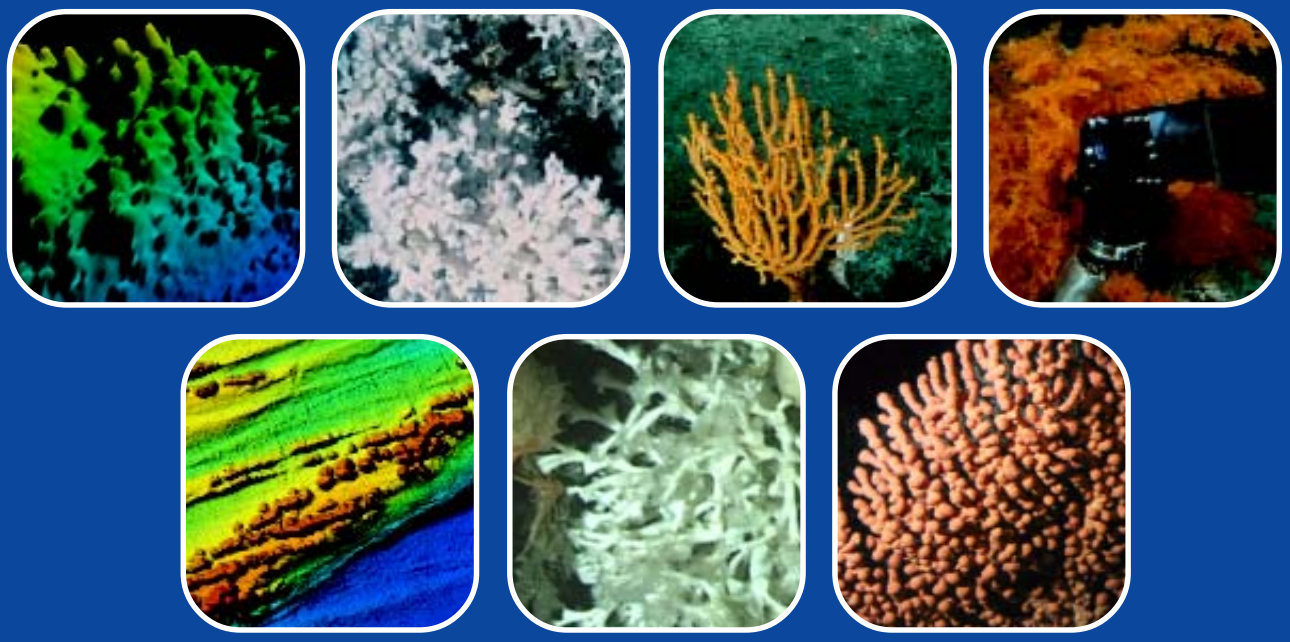
The Royal Society of Edinburgh

# Europe's Hidden Coral Worlds



Report of a Conference
organised jointly by
The Royal Society of Edinburgh
&
The Scottish Association for Marine Science
(SAMS)

Wednesday 23 February 2005

# Europe's Hidden Coral Worlds

## CONTENTS

# Programme

9.00 **Registration & Coffee**

9.30 **RSE Welcome**
*Professor Alasdair McIntyre CBE FRSE*
*Emeritus Professor of Fisheries and Oceanography,*
*University of Aberdeen*

**Chairman's Welcome**
*Professor Jack Matthews FRSE*
*Scottish Association for Marine Science (SAMS)*

9.35 **Giant Carbonate Mounds as a Niche for Europe's Deep-Water Coral Worlds**
*Dr Jean Pierre Henriet*
*Department of Geology and Soil Science,*
*Ghent University, Belgium*

10.05 **Q & A**

10.15 **Deep-Water Coral Growth and Deep-Water Coral Reefs: Oceanographic Control**
*Professor Christian Dullo*
*Director, Department of Paleoceanology,*
*GEOMAR, Germany*

10.45 **Q & A**

10.55 **Tea & Coffee**

11.25 **A Portrait of Deep-Water Coral Ecosystems in the World Oceans**
*Professor André Freiwald*
*Institute of Paleontology,*
*Erlangen University, Germany*

11.55 **Q & A**

12.05 **Lunch**

13.15 **Historical Discovery and Recent Mapping and Management of *Lophelia* Coral Reefs in Norway**
*Dr Jan Helge Fosså*
*Head of Research Group Benthic Habitats,*
*Institute of Marine Research, Bergen, Norway*

13.45 **Q & A**

13.55 **Conserving Europe's Coral Reefs**
*Dr Mark Tasker*
*UK Joint Nature Conservation Committee,*
*Scottish Natural Heritage*

14.25 **Q & A**

14.35 **Tea & Coffee**

15.05 **Coral Reefs at Haltenpipe and the Kristin Field, Offshore Mid-Norway**
*Dr Martin Hovland*
*Marine Geology Specialist, Statoil*

15.35 **Q & A**

15.45 **Panel Discussion**
*Comprising all the day's speakers*

16.15 **Summary**
*Dr Murray Roberts*
*Marine Biologist*
*Scottish Association for Marine Science (SAMS)*

16.35 **Vote of Thanks**

16.45 **Close**

## Introduction and Background

The term 'coral reef' is normally associated with shallow-water tropical seas, but recent developments in the technology used to survey the deeper waters of the continental shelf and slope have revealed dramatic and diverse coral ecosystems. These are formed by relatively few coral species, often referred to generically as deep-water or cold-water corals. These ecosystems represent an exciting habitat in the depths of the oceans but their true extent is only now being fully realised. This one-day conference, which attracted some of the leading international figures in this field, focused on key areas of geology and biology, as well as conservation and management.

Cold-water corals are found along the European continental margin where they can develop reef structures, colonise seabed mounds and are intimately associated with large carbonate mounds. The two main species are the framework-forming *Lophelia pertusa* and the frequently associated species *Madrepora oculata*. A large number of carbonate mounds have been discovered in the Porcupine Seabight, to the west of Ireland. Cold-water corals are also found to colonise smaller seabed mounds. Examples are found in the Rockall Trough, to the northwest of the UK, and include the Darwin Mounds, described as 'sand volcanoes' capped with coral colonies. The majority of reefs described so far in the north-east Atlantic are found along the Norwegian continental shelf.

All speakers began by demonstrating that knowledge of cold-water corals in the north-east Atlantic stretched back 150 years, with some of the earliest work published by the Royal Society of Edinburgh. **Professor Henriet** discussed the formation of carbonate mounds. He asked if cold-water corals play a role in this process and suggested that mound formation occurs at the interface between external and internal processes. **Professor Dullo** spoke of the importance of oceanographic conditions on the distribution of cold-water corals. **Professor Freiwald** provided an overview of the key cold-water coral species around the world and highlighted important aspects of these communities. **Dr Fosså** gave an overview of research in Norwegian waters and the impact of the fishing industry. He went on to show how some areas have been protected and what he believes needs to be done to safeguard cold-water corals. **Dr Tasker** gave a national conservation agency's perspective on how to protect cold-water corals. He detailed the problems that are faced and suggested some solutions to overcome them.
**Dr Hovland** spoke of his experiences in the oil industry in terms of surveying areas of cold-water corals in Norway. He presented evidence that the occurrence of corals may be related to methane seepage from the sea floor.

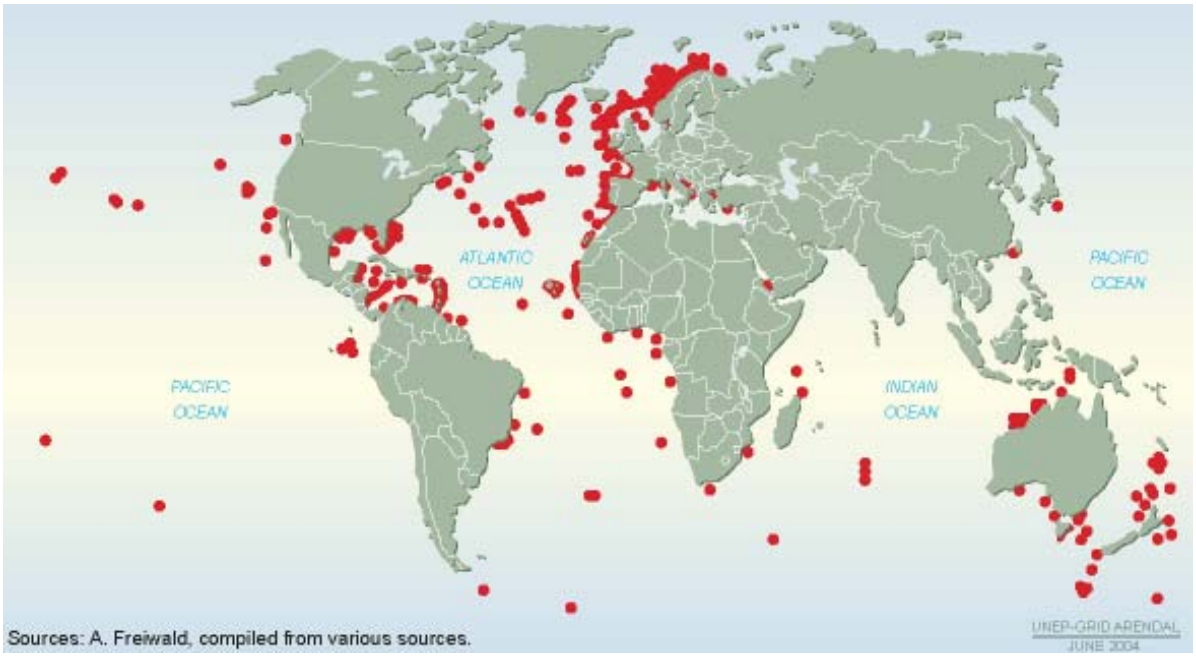



**Figure 1** *Global distribution of cold-water coral reefs: points on the map indicate observed reefs of varying size and stages of development but not the actual area covered. The high density of reefs shown in the North Atlantic probably reflects the intensity of research in this region. Further discoveries can be expected worldwide, particularly in the deeper waters of subtropical and tropical regions.*

**Professor Jean-Pierre Henriet**
Department of Geology and Soil Science,
University of Ghent, Belgium

### *Giant Carbonate Mounds as a Niche for Europe's Deep-water Coral Worlds*

Professor Henriet began by showing maps of cold-water coral distribution produced in the 1800s. He pointed out the correlation with modern day maps produced by researchers who are re-discovering these areas along the European continental margin. They host prolific cold-water coral worlds and Professor Henriet asked whether these ecosystems play a role in the development of carbonate mounds or whether cold-water corals are purely opportunists? He suggested that the mound structures in the Porcupine Seabight and other areas might be better understood by looking to the past. Past examples of carbonate structures include the red marble sites found in Belgium that were created by Devonian carbonates. Professor Henriet suggested that these ancient sites indicate that mounds are complex and stratified structures that reflect a succession of different facies and ecosystems. The presence of ancient mound structures seems to argue that mound-building has been a recurrent strategy of life in the oceans. Therefore, the best way to understand the succession of mounds is by

looking back through history. This can be achieved by coring through a mound and analysing the changes with depth. Debate still abounds on the formation of mounds, whether they are related to methane seepage from the underlying geosphere or are formed by the interplay of oceanic and biological forces.

In 1994 and 1997 the carbonate mounds in the Porcupine Seabight were re-discovered. This research revealed mounds of up to 200 metres in height and spurred European research through the 5th Framework programme with projects such as ACES, ECOMOUND and GEOMOUND. Professor Henriet showed sidescan sonar images of Thérèse Mound that indicated sand waves formed by strong currents. This appears to be an important external control on mound formation, but he asked whether there could also be an internal control through methane seepage. GEOMOUND investigations suggested that seepage of hydrocarbons might occur near mound structures. Surveys carried out by Statoil show many pockmarks and mud volcanoes over the area. Fluid migration may cause different types of surface features in different situations. The next stage is to investigate the whole geological sequence contained within a carbonate mound by drilling through the Challenger Mound from the top to the base (170 metres). Survey work has shown that the Challenger Mound appears 'extinct' and no longer supports live cold-water coral reefs. This exciting work will be carried out in May 2005 through the Integrated Ocean Drilling Programme on drilling vessel *JOIDES Resolution*.

Simultaneously, work has been ongoing investigating analogous areas from the Porcupine Seabight to the Gulf of Cadiz. Results from investigation of the mud volcanoes on the Pen Duick Escarpment on the Moroccan margin in 2002 may be applied to the Porcupine Seabight as they produce similar seismic profiles. Cores taken in the Pen Duick Escaparpment on the RV *Sonne* cruise in 2003 and the RV *Marion-Dufresne* cruise in 2004 showed a change from abundant coral fragments with a clear chemical signal below a dissolved carbonate layer indicating high levels of methane. Therefore, Professor Henriet suggested that mounds might be formed by pressure gradients and currents as well as the internal migration of fluids.

Professor Henriet would like to move towards an Atlantic Mound Laboratory where a number of different sites could be compared, including the Belgica Mound Province in the Porcupine Seabight, the Pen Duick Escarpment of Morocco and the terrestrial Kess-Kess mounds in Morocco. He believes that an understanding of both the external and internal controls on mound formation is needed as "geology feeds life, while life builds geology".

**Discussion**

Professor Henriet explained that the work he mentioned in his talk was first presented in Marakesh two weeks previous. When asked about the present state of knowledge of

terrestrial mounds he explained that the Kess-Kess mounds have been investigated and showed Devonian carbonates on igneous rocks with a methane signature on top as well as indications of microbial activity.

**Professor Christian Dullo**
Head of the Department of Paleoceanology, GEOMAR, Germany.

***Deep-water Coral Growth and Deep-water Coral Reefs: Oceanographic Control***

Professor Dullo began by drawing analogies between Moroccan land mounds and the carbonate mounds found in the Porcupine Seabight and the Rockall Trough. The first research carried out in the Porcupine Seabight raised the questions: how and when were these mounds formed? One suggestion has been that mound formation re-started when the Mediterranean outflow water (MOW) began again following deglaciation.

Further research has revealed that many small mounds in the Belgica Mound Province are well-covered by deep-water corals. Professor Dullo described this as a dynamic environment with complex oceanography. The boundary between MOW and the North Atlantic Current (NAC) through the north-east Atlantic allows for a concentration of nutrients and this also tends to be where deep-water corals are found. The main water masses are the surface water, which follows a north-east direction and the intermediate water (MOW), which follows the contours of the continental margin. The MOW has higher salinity and therefore a higher density. It is this density gradient that concentrates organic carbon from the sea surface and provides nutrients for the corals.

Water mass studies were carried out on various cruises in the Porcupine Seabight and Rockall Trough. The Belgica Mound Province showed warm surface water with a sharp density change at the boundary with the MOW. Similar conditions were observed at the Hovland Mound Province in the Porcupine Seabight, but these were different to those observed in the Rockall area where there is lower input of MOW. There also appears to be strong seasonality in terms of the nutrient input, with video footage showing phytodetrital mats being present in springtime. This is supported by a higher concentration of polyunsaturated fatty acids (PUFAs) on top of the mound and peaks in the amount of sediment in sediment traps. Work by Professor Freiwald in 2002 also suggests seasonality in oxygen and carbon isotopes from *L. pertusa* skeletons, which may relate to nutrient cycles.

Data compiled from benthic landers (*in situ* monitoring equipment) also show how dynamic this environment is. The *RV Meteor* cruise in 2004 to the Porcupine Seabight and the Rockall Trough deployed a lander that remained on the seafloor for four months. A small variation in salinity was observed as well as daily and monthly variations in current speed.

Professor Dullo went on to explain some of

the research carried out on the Propeller Mound in the Hovland Mound Province. ROV surveys and surface sediment analysis revealed different facies, including drop-stones on sand, mud and coral framework. Foraminiferal assemblages were investigated in off-mound cores and suggested differences between interglacial and glacial periods in terms of nutrients and currents. This would suggest prolific deep-water coral growth during the Holocene (inter-glacial) period. Glacial oceanography suggests that there would have been no density gradient during glaciation and, therefore, insufficient nutrients to support deep-water coral ecosystems. Therefore, Professor Dullo postulated that carbonate mound development and growth is controlled by environmental changes.

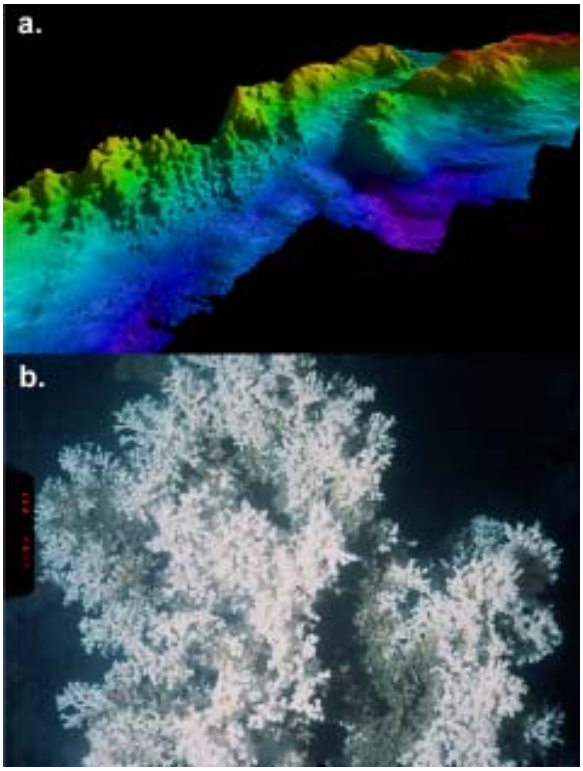



***Figure 2*** *Cold-water coral reefs can form characteristic mounds on the seabed like these reef mounds in Scottish waters near the island of Mingulay in the Sea of the Hebrides. (a) 3-D visualisation from a multibeam echosounder survey showing the characteristic seabed mounds formed by a* Lophelia *reef (MINCH project, SAMS). (b) Live colonies of* Lophelia pertusa *form these mounds (JM Roberts, SAMS).*

## Discussion

Professor Dullo explained that a mound is termed as 'dead' when there is low coral coverage, for example the Propeller Mound has only 10% cover. The Propeller Mound is unlikely to be a new mound as it is around 200 metres high. However, Professor Freiwald commented that it is dangerous to term mounds as 'dead' as this can mean a very different thing to a biologist than to a geologist. Professor Dullo explained that mounds do not grow larger as there is likely to be interplay between glacial and interglacial periods i.e. causing removal of the mound during glaciation. Professor Dullo explained that the knowledge of where corals are found may not necessarily be used to predict where deep-water corals could be found in the Indian and Pacific Oceans as the same trends may not hold worldwide.

**Professor André Freiwald**
Institute of Paleontology,
University of Erlangen, Germany.

***A Portrait of Deep-water Coral Ecosystems in the World's Oceans.***

Professor Freiwald began by showing where deep-water coral ecosystems are found. He showed maps detailing the worldwide separation between tropical coral ecosystems and temperate kelp forest ecosystems and explained that deep-water corals are not influenced by the same factors. The distribution of deep-water corals instead seems to be more restricted by the presence of intermediate water masses that tend to be deeper in the tropics, but far shallower towards the poles. Of the 1335 species of scleractinians, only ten are azooxanthellate, colonial, framework-building organisms. An interesting exception to the rule is the solitary coral *Desmophyllum cristagalli*, which can grow at very high densities forming a basic framework often on overhangs and with polyps orientated downwards. These occurrences are seen in both 900 metres water depth in the Porcupine Seabight and in 20 metres in Chilean fjords. These sites experience high currents as well as bioerosion of the solitary coral frameworks.

Some of the places around the world where deep-water corals are found include the octocoral gardens of the Aleutian Islands, shallow *L. pertusa* reefs in Scandinavian fjords, and bathyal carbonate mounds to the west of Ireland and to the west of Mauritania. The octocoral gardens of the Gulf of Alaska are studied through fisheries observers on trawlers. Octocorals, such as the bamboo coral, can live for 300 years and show clear banding which is useful for paleoclimatic studies. Professor Freiwald noted the disturbing evidence that the estimated bycatch of octocorals was around two million tonnes between 1986 and 2002.

The coral ecosystems of the north-east Atlantic show a depth distribution for *L. pertusa* from just 35 to 2000 metres, with the majority occurring between 200 and 1000 metres. *Madrepora-oculata* is found at similar depths but is less prevalent. Both species are found in fjords, deep shelves, continental slopes, oceanic banks and seamounts, as well as on the mid-Atlantic ridge. In the Tisler-Havler study area of the Skagerrak in Norway, multibeam surveys have shown that *L. pertusa* reefs are found at the point where the fjords funnel, creating suitable oceanographic conditions. These reefs are 100 metres long and 10 metres thick and are found on 'drumlins' or sub-glacial bedforms. These areas have been protected by the Norwegian government since 2003.

The Porcupine Seabight has around 80 exposed mounds ranging from 120 to 250 metres high. There is a deeper band at 800 - 1000 metres with a high degree of coral colonisation. A mound will develop by growing until it collapses, due to current conditions and bioerosion of the framework, where it then forms a carpet creating new substrata for subsequent colonisation. The

shallower band between 600 and 800 metres on the bank reveals semi-buried or buried mounds with mostly dead coral cover. Trawling intensity in this area is high.

Dense coral rubble covers the slopes of inactive mud volcanoes off Morocco. *Dendrophyllia alternata* was the most dominant species and was dated at 44-39 thousand years old, whereas *L. pertusa* was younger at 32-22 thousand years old. This suggests that there have been pulses of colonisation, extension and migration through time. The carbonate mounds off the coast of Mauritania were recently surveyed by an Australian oil company. This revealed a large proportion of coral rubble with very little living coral. The mounds appear similar to those in the Porcupine Seabight in terms of their geological formation.

There are many gaps in the worldwide distribution of deep-water coral reefs but this probably represents a lack of investigation rather than an absence of reef structures. For example, there have been no deep-water coral reef discoveries in the Pacific or Indian Oceans. However, deep-water corals are likely to be a global phenomenon.

A matter of conflict arises with the fishing industry. The use of bottom trawls, gill nets and longlines appears to have a negative effect on deep-water coral habitats and this has been well documented on carbonate mounds off Ireland. A future challenge may be to link to fisheries-based observations and develop a better understanding of the role of deep-water coral ecosystems for specific fish species. Professor Freiwald believes that this situation is not only a case of overexploitation but also of habitat fragmentation and believes that technology should be developed to investigate this.

**Discussion**

Professor Freiwald was asked about the black rings on the bamboo octocoral. He explained that they are organic internodes, lacking in calcite, which allow the coral to flex with water currents. He also explained that there is not much literature on whether corals are found on the mid-Altantic Ridge. There appears to be a good coverage but the information is from trawler data, not direct observations. Seamounts in this area are now subject to further investigation.

When asked what represented the greatest threat to cold-water coral habitats, Professor Freiwald replied that this was deep-water trawling. There has been a great deal of damage in the Porcupine Seabight, although the boats tend to avoid the larger mounds, so this is probably more of a problem in the Rockall area as the mounds are smaller and therefore easier to trawl over. Professor Freiwald believes that first we need to improve knowledge of their distribution through mapping and then ground-truth and quantify the level of impact from fishing activity. He pointed out that there have only been five years of ROV study in the north-east Atlantic.

Professor Freiwald believes it is not clear where deep-sea corals originate from. He

referred to genetic work carried out by Le Goff-Vitry and Rogers, but pointed out that this was in the north-east Atlantic only. They did not address where the corals came from, instead they found corals from the Darwin mounds to have the highest degree of inbreeding, those from the Belgica Mound Province the highest degree of recolonisation whilst those from the Norwegian fjords showed clear evidence of genetic isolation. However, this study was carried out using a relatively low number of samples, so the authors are necessarily cautious in their interpretation.

**Dr Jan Helge Fosså**
Head of Research Group Benthic Habitats, Institute of Marine Research, Bergen, Norway.

### *Historical Discovery and Recent Mapping and Management of* Lophelia *Coral Reefs in Norway*

Dr Fosså began by explaining how it was in the 1980s and 1990s that we saw a new era begin in cold-water coral research. This was partly due to technologies made available through the oil industry alongside the increasing evidence for trawl damage to deep-water coral reefs. It became clear that further mapping, research and management of these habitats were needed. This was taken on board by the Institute of Marine Research (IMR) in Bergen who started a programme to investigate the position of reefs and the extent of any damage. This information could then be passed on to managers and the public.

The first IMR coral cruise in Norwegian waters was in 1997 and surveyed using sidescan sonar and sampled using a grab and dredge. The dredge proved to be very destructive and has not been used again during IMR surveys. Since then more advanced equipment has been used to map coral habitats. The areas were ground-truthed using both video and biological sampling. These surveys clearly showed the negative impact of fishing between trawled and non-trawled areas and led Dr Fosså and his colleagues to predict that 30 – 50 % of the deep-water coral habitats in Norway have been impacted or damaged.

Multibeam sonar appears to be an effective tool for mapping coral habitats. Dr Fosså showed how mounds can be identified from these 3-D maps and can also be used to predict where we are likely to find coral reefs. Maps from Træna on the Norwegian shelf showed iceberg plough marks as well as seabed features he interpreted as likely *L. pertusa* reefs. However, this technique does require verification with video surveys. The backscatter data from multibeam echosounders may be another acoustic resource that will be useful for detecting the presence of *L. pertusa*.

With the discovery of *L. pertusa* reefs and the realisation that they were being damaged, regulations for the protection of coral reefs in Norwegian waters were first issued in 1999. These were based on the following principles:

- Intentional destruction of coral reefs is prohibited
- Precaution is required when fishing close to known reefs

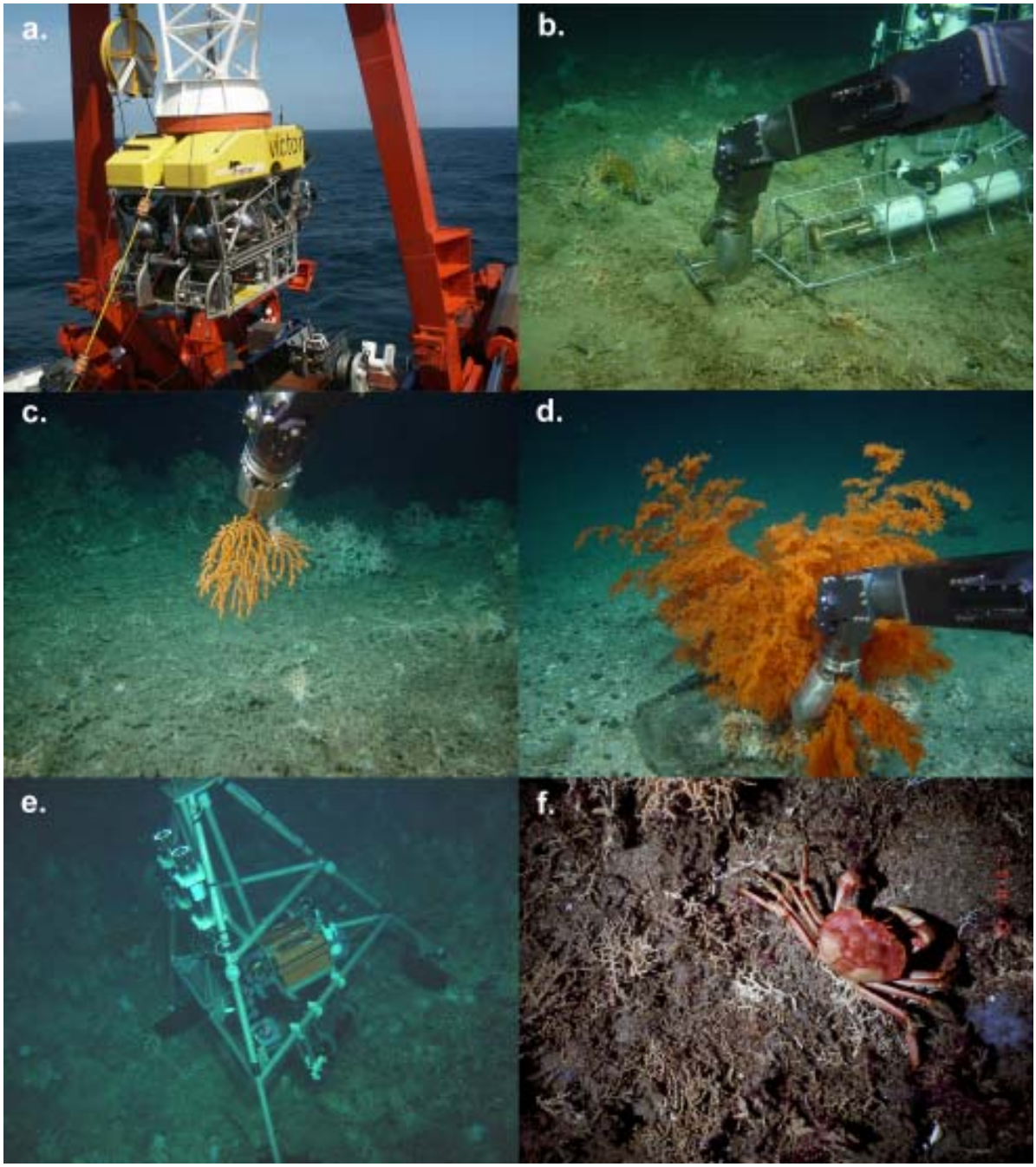



**Figure 3** *Submersibles and benthic landers provide the technology to study cold-water coral ecosystems at great water depths. Here work around a giant carbonate mound at 800 m water depth is shown. (a) The* VICTOR *6000 ROV (JM Roberts, SAMS). (b) An ROV manipulator arm used to move a current meter and put it into position (*VICTOR *team, Ifremer & AWI). (c,d) An ROV manipulator arm used to gather precise samples of gorgonian and antipatharian corals (*VICTOR *team, Ifremer & AWI). (e) The SAMS photolander deployed on the Galway carbonate mound to record environmental variability and take time-lapse photographs (VICTOR team, Ifremer & AWI). (f) A lander photograph showing a benthic crab (probably* Geryon *(*Chaceon*)* affinis*) on the coral-covered surface of the carbonate mound (JM Roberts, SAMS).*

- Certain areas were closed to all bottom-fishing to protect coral reef habitats

Dr Fosså suggested that relying on the term 'known reefs' could leave currently unknown reefs vulnerable to damage and this can only be resolved by further mapping. Dr Fosså showed a map of Norway with known *Lophelia* areas and also detailed places that were protected from bottom trawling, and all human activities that involved disturbing the seabed.

Dr Fosså went on to show maps and video footage from the Røst reef from a survey carried out in 2002. The multibeam map showed a ridge structure 45 km long dropping off steeply on one side. In close-up there appear to be many mounds as well as iceberg ploughmarks. Along the edge of this ridge are dense areas of *L. pertusa*. This area has the largest concentration of deep-water corals known in the world at present.

Dr Fosså then asked why we should try to conserve these areas. He believes that since these habitats are relatively widespread, they may be a far more important ecosystem than previously thought. They are also important as biodiversity hotspots and may represent an essential, or at least preferred, fish habitat. Dr Fosså concluded that mapping of coral habitats must continue and techniques to improve this should be further developed. He also believes that it is crucial to learn more about the ecological importance of deep-water corals in order to make properly informed management decisions. Finally he feels that as long as the true ecological importance of cold-water coral reefs is not known, the precautionary principle should be employed in their management.

**Discussion**

Dr Fosså was asked how he would survey if he had unlimited time and resources. He discussed how he would base a wide-area mapping exercise on a multibeam echosounder survey supported by adequate visual ground-truthing.

**Dr Mark Tasker**

UK Joint Nature Conservation Committee, Scottish Natural Heritage

***Conserving Europe's Coral Reefs***

Dr Tasker stated that although deep-water corals have been known for about 150 years, only recently has their conservation become an issue. He believes conservation requires knowledge of the location, the level of impact from human activity, a desire to conserve and mechanisms to change human behaviour. All this needs to be supported with enforcement and monitoring. He explained how fishermen have known about areas of deep-water corals for a long time and showed a chart of the Faroes seabed that was surveyed in the 1940s in order to develop the fishing industry. This chart shows the areas of deep-water corals in the 1940s and allowed the subsequent loss of coral due to fishing practices to be clearly seen when the older charts were compared to modern day maps.

Compared to the fishing industry, Dr Tasker believes that the oil industry has a good record

in terms of deep-water coral awareness. He used the example of the formation of the Atlantic Frontier Environmental Network (AFEN). This was a UK consortium of oil companies and government regulators including the Department of Trade and I ndustry, Aberdeen Marine Laboratory and the Joint Nature Conservation Committee. AFEN started mapping licensed areas off the conti-nental shelf of Britain using wide-area sidescan sonar surveys (TOBI), which led to the discovery of Darwin Mounds.

Dr Tasker then went on to ask what activities could affect corals. He suggested that these could include physical damage from trawlers, pipelines and anchors, smothering by drill cuttings or sediment, chemical effects from drill fluids, and also ocean acidification due to global warming. Negative effects of fishing have been uncovered through visual surveys of the deep-water coral areas; however, he believes that the impact of the oil industry may be minimal, although little research has been carried out. He noted that deep-water corals have been found to colonise North Sea oil platforms and shipwrecks close to deep-water oil fields.  In terms of a desire to conserve, Dr Tasker believes that this needs to be put down in law or a political statement. In the European Union (EU) this normally occurs through two forms of legislation: the Habitats Directive, a direct method, and environmental impact assessment (EIA) or strategic environmental assessment (SEA), a more indirect method. The Habitats Directive requires designation of special areas of conservation (SAC) and maintenance of conservation status for areas within 350 nautical miles offshore. The UK has started the process to designate the Darwin Mounds in the Rockall Trough as an SAC.

Fishing is regulated at an EU level under the common fisheries policy (CFP) and the European Commission can take emergency action if a marine ecosystem is under threat. This type of emergency action was used initially for the Darwin Mounds and has now become permanent. In comparison to European countries that are not members of the EU such as Norway, this process is long-winded and very area–specific. However, as Norway is not subject to the CFP and long-line fishermen were concerned over the habitat damage inflicted by trawlers which they believed to be affecting long-term fish stock viability, they acted very quickly to create closed areas.

Dr Tasker asks if there is a better way to legislate over these areas and believes that using the SEA process for the fishing industry may be advantageous. SEA is open to public decision-making and participation. It is essential to involve fishers in the process, although this will be hard to insert into the complicated EU fisheries governance mechanisms. Enforcement is also an important issue and could be achieved by satellite monitoring of vessels, direct monitoring by 'police boats' or by piggybacking on other ships. To conclude, Dr Tasker believes that we have still some way to go as Europe's coral reefs are not yet safe and we need to improve assessment and management

procedures. But perhaps most of all, we need improved political will.

**Discussion**

Dr Tasker was asked whether the priority for Europe should be be just about European deep-water corals or also about protecting those outside Europe e.g. heavily trawled areas such as those off West Africa. Dr Tasker explained that JNCC has recently signed up to a programme of reducing the UK's global environmental footprint. He mentioned how some of the British overseas islands have a richer biodiversity than the whole of the UK. However, he believes the UK should still look after its own 'back yard'.

It was suggested that a ban on deep-sea trawling may protect deep-water corals. Dr Tasker said that this would be a simple solution but pointed out that there is an entire economic community of fishermen and that people still like eating fish. However, high seas fishing has low productivity and low numbers of fishing boats, yet causes the most damage, so banning this may be an option in the future. In terms of changing European fishing practices, Dr Tasker pointed out that, due to cultural differences, the wish to conserve varies from country to country. Therefore, the best option is to try to change cultural views. The alternative would be to leave the EU, although Dr Tasker does not believe this is the ideal solution.

Dr Tasker thinks that the system needs to be simplified to speed up the process of conserving areas, but believes that maps and images are vitally important. A good example is the situation in Rockall, where the level of evidence of fishing damage was not strong enough to convince everyone, demonstrating the need for clear-cut visual evidence. A good baseline survey would also help and JNCC will be collaborating with Fisheries Research Services Aberdeen to map areas of the Rockall Bank this summer.

The issue of climate change and the possible acidification of the oceans was raised. Dr Tasker pointed out that although acidification is more likely in surface waters, there may be a point where it affects deeper waters. This could mean that present areas of corals may become unsuitable while other areas become suitable for deep-water corals. The effect of acidification is well known for tropical corals, causing a decrease in the rate of calcification. It may possibly become technically feasible to dispose of carbon dioxide into the seabed or by injecting it into intermediate waters. Dr Tasker pointed out the usefulness of SEA to assess such procedures.

For the SEA approach to be used in the fishing industry it must apply to one particular process. Dr Tasker suggested that such 'processes' including annual total allowable catch (TAC) rounds, individual sea areas, or one particular fishing method, e.g. beam trawling. He also pointed out that the governance of the EU is changing to become more regional, which may make SEA more feasible. The UK government is planning to examine the SEA approach to fisheries management by testing its use for one fishery in a defined area. The issues for SEA are challenging, but not insolvable.

water so tend to migrate out of the substratum. He then showed acoustic images of pockmarks and rare footage of methane bubbles escaping from a pockmark. Images of the seafloor showed bacterial mats that he believes are related to the closure of methane seeps. The next stage of sealing may be the formation of carbonate structures such as deep-water coral mounds or reefs.

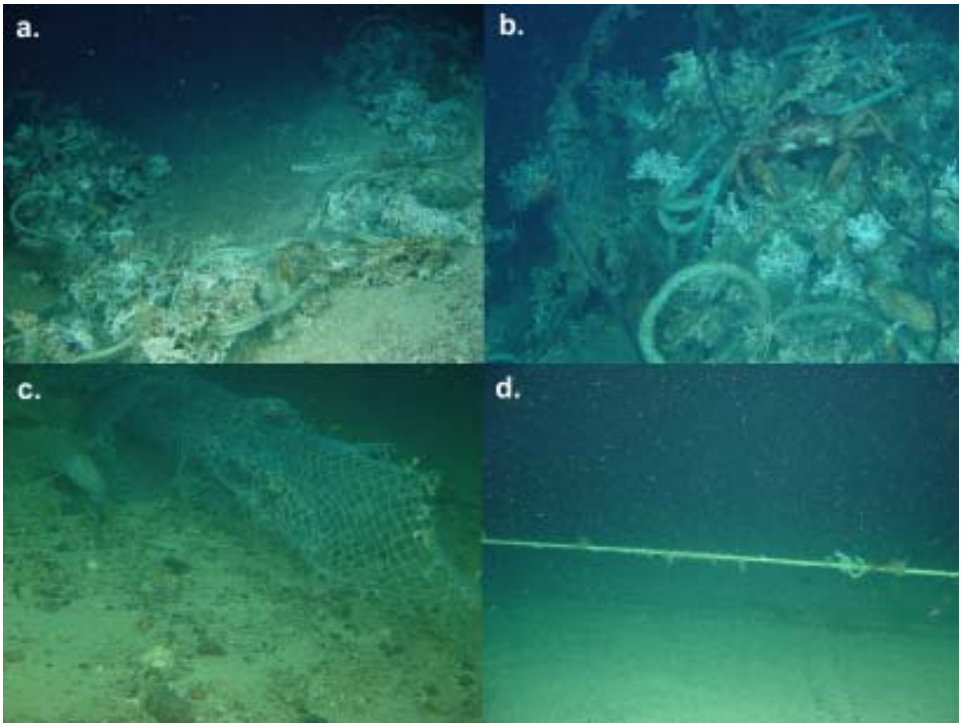



**Figure 4** *Fishing impact recorded on carbonate mounds in the Porcupine Seabight. (a,b) Coral debris caught in a lost trawl net. (c,d) Lost fishing net and lines. (*VICTOR *team, Ifremer & AWI).*

**Dr Martin Hovland**
Marine Geology Specialist, Statoil, Norway

### *Coral reefs at Haltenpipe and the Kristin Field, offshore Norway*

Dr Hovland initially showed a map of Britain and Norway with the pipelines belonging to Statoil. He believes that deep-water coral occurrences are linked to fluid seepage from the seafloor, so explained how evidence for seepage is detected in geophysical surveys. He showed diagrams of a transect of the northern part of the North Sea showing the seepage and leakage of hydrocarbons from reservoir rocks. Hydrocarbons are lighter than

It was in 1982 during seafloor mapping for a pipeline that Statoil came across a 50 metre diameter reef covered in the cold-water coral *L. pertusa*, the Fugløy Reef. The ROV *Solo* used to survey the seafloor revealed trawl marks, methane bubbles and bacterial mats close to deep-water coral areas.

The Haltenpipe project began in the 1990s and revealed 57 large reefs, including those of the Sula ridge. An ROV survey was carried out that confirmed these as deep-water coral

reefs. A cluster of nine reefs, the Haltenpipe Reef Cluster (HRC), was selected for investigation and monitoring prior to the pipeline construction. This work dated *L. pertusa* samples at 8,600 years old and also showed the variation in regional density of reefs on the Norwegian continental margin. When the seabed was examined, certain types of subsurface features appear to be related to where the reefs are found. Seismic and geochemical data from these reef areas suggested that Palaeocene dipping sedimentary rocks and neighbouring Cretaceous rocks are conducive to the migration of light hydrocarbons.

A new area of development for oil and gas on the Norwegian continental margin is the Kristin field. In this area coral reefs are found inside pockmarks on the seabed. There are also occurrences of the bivalve mollusc *Acesta excavata,* which Dr Hovland described as often associated with methane seepage. Dr Hovland hypothesised that the co-occurrence of corals and pockmarks suggests that gas and pore water may stimulate coral growth by increasing the nutrient supply, believed to be in the form of bacteria and microorganisms. This is known as the hydraulic theory.

**Discussion**

Dr Hovland explained that there has not been enough research on pockmarks. Dr Hovland is intending to study them further, in particular to study the diurnal and bimonthly pumping of pore waters. Benthic Foraminifera have been found in pockmarks; he asked whether this is by chance or an effect of the pockmark. He emphasised the importance of bacterial mats to indicate methane seepage, but has not seen deep-water corals colonising the bacterial mats around drill cutting piles.

**Panel Discussion**

***Global warming***

The discussion revolved around what the panel believed the effect of global warming on deep-water corals would be. Professor Freiwald reminded people that previous climatic changes have already removed deep-water corals from the Mediterranean and, therefore, thinks that deep-water corals could become extinct in some areas and move into others, e.g. the very northern North Sea.

Dr Hovland stated that coring from carbonate reefs in Norwegian waters has dated *L. pertusa* at 8,600 years old, which is some time after the last deglaciation. This may suggest that deep-water corals would take time to recover from an event such as any major change in the North Atlantic Oscillation. The implications of such major change would include temperature changes and iceberg damage.

***Deep-water fishing***

The discussion then focused on how to involve the fishing industry in deep-water coral conservation and how regulatory measures similar to those applied to the oil industry could be adopted. Dr Tasker suggested that there are significant differences between the oil and fishing industries; a few large wealthy multinational companies form the oil industry, while the fishing industry varies from nation to

nation and is often formed by many small individual operators. He believes that engagement needs to be tackled at a generic level.

Dr Johnston from Greenpeace pointed out that the absence of data on the negative impact of industries is often used to stall action; this has happened in other industries and is happening now with deep-water coral conservation. He recommended employing the precautionary principle.

Dr Hain from the United Nations Environment Programme (UNEP) suggested that there are historical reasons for the lack of co-ordination between the fishing industry and the environmental sector. This is partly due to the fishing industry being well established while the environmental sector is percieved as being a modern phenomenon. The United Nations is aiming to co-ordinate the two sectors, but as the fishing industry is covered by Food and Agriculture Organisations and the environment by UNEP this may still be hard to achieve. He believes that there needs to be more understanding between the sectors. He also believes that the relationship between deep-water corals and neighbouring ecosystems should be investigated, as it is between tropical coral reefs and mangroves. There would then be the need to protect all associated environments. In terms of cold-water coral reefs, Dr Fosså did not know of any such closely associated ecosystems, but believes that sponge aggregates are also very important for their associated biodiversity. Trawling in these areas gives a high yield of fish, suggesting that the ecosystem may be important for biodiversity.

***Public Perception***

Public interest in tropical corals has increased as the diving industry has grown, therefore, the panel were asked to consider how the public perception of deep-water corals could be changed or enhanced. Dr Fosså believes that it is necessary for scientists to spend a lot of time with the press, but this is very time-consuming. An audience member pointed out that in the USA 10 % of funds have to be spent on public awareness, which is not the case in the UK. Dr Ross supported this and pointed out that in the USA scientists often take a professional educator and teacher on board research cruises.

The panel accepted that an 'observatory' on the seabed would be a good way to engage the public. Dr Tasker suggested that the shallow fjordic deep-water coral reefs in Norway are an ideal place. Professor Henriet pointed out that the project 'ESONET' is planning to start just such a European deep-water research observatory. Dr Hain (UNEP) explained that work is in progress as part of the International Coral Reef Initiative (ICRI) that will improve public awareness of cold-water coral reefs. This has worked well for tropical corals. There is a television documentary being prepared on deep-water corals that will be broadcast on the BBC World Service that should reach an audience of between 70 and 80 million people.

***Future Research***

Professor Freiwald suggested that we need to learn more about the basic biology of

deep-water corals e.g. their reproduction and spawning. This is often limited by weather conditions that constrain the times when research at sea can take place, making fjordic studies useful. There is a need to link biology and geology as well as continuing with mapping and monitoring.

Professor Dullo suggested that we should investigate how dynamic processes are recorded in deep-water corals to see how the world was thousands of years ago. This is useful for predicting what we can expect from a global warming event.

Professor Henriet believes that there should be further investment in exploration as well as conservation. He also suggests further interaction with industries such as the oil industry, which has useful resources both in terms of existing data and technical expertise. He also believes we should continue ground-truthing. There have been around 35 cruises to the Porcupine Seabight and this effort needs to be sustained. There also needs to be more interaction with fisheries.

**Dr Murray Roberts**
Marine Biologist,
Scottish Association for Marine Science,
Oban, UK.

### ***Summary – Historical background and Scotland's Inshore* Lophelia *Reefs***

Dr Roberts began with an historical perspective and by describing the initial records of cold-water corals in Scottish waters. Dr Roberts has since investigated these historical areas and described a *Lophelia* reef formation to the south-east of Barra in the Sea of the Hebrides. He showed detailed 3-D acoustic mapping and photographs from this area revealing aggregations of living *Lophelia*.

In summarising the day's talks, Dr Roberts mentioned the need for our biological knowledge of cold-water coral reefs to develop to a similar level to our geological understanding. He emphasised the exciting potential of the project to drill the Challenger mound to understand the genesis of carbonate mounds and how close interdisciplinary collaborations were essential to gain full benefits from any deep-water research efforts. Another important point that Dr Roberts noted was the use of palaeo-records to understand past variability and predict the results of future environmental change. He also felt that statistical modelling techniques using the growing database of cold-water coral occurrence and associated habitat requirements should be developed to allow predictive mapping of deep-water coral areas to be developed. There was also a clear need to increase the involvement of all marine

stakeholders from the fishing and oil industries to the general public.

To conclude, Dr Roberts highlighted the need to understand and integrate larger-scale processes to appreciate fully the ecological significance of cold-water coral reefs.  However, the lack of unified methodologies remains a barrier, which can only be overcome by an international and interdisciplinary approach. He suggested there is also a need to unify methodology and definitions. He also suggested we learn from the shallow-water coral community as well as striving to continue the efforts in basic ocean exploration and mapping. All of these elements are vital to design appropriate conservation measures. A final point that he felt came across from the conference was that the expertise, technology and areas of the ocean described were almost exclusively from the developed world. There is now a clear and urgent need to transfer this knowledge and expertise to the developing world.

# Acknowledgements

*The Royal Society of Edinburgh wishes to acknowledge the support of*

**Shell U.K. Ltd**

**

**The Scottish Association for Marine Science (SAMS)**

**

**Statoil ASA, Norway**

*and thank the Organising Committee*

**Professor Jack Matthews FRSE**
The Scottish Association for Marine Science (SAMS)

**Dr Murray Roberts**
The Scottish Association for Marine Sceince (SAMS)

**Mr Duncan Welsh**
Events Officer, The Royal Society of Edinburgh

---

**Figure 1**

Courtesy of Professor André Freiwald
Institute of Paleontology, University of Erlangen, Nuremberg, Germany

**Figures 2 - 4**

The Alfred-Wegener-Institut für Polar-und Meereforschung (AWI) and the Institut Français de Recherche pour L'Exploitation de la Mer (Ifremer) are gratefully acknowledged for permission to reproduce the *VICTOR* 6000 images from expedition ARKXIX/3a.

# Participant List

**Mr Allan Bain**
Scottish Agricultural College, Ayr
**Mr Robert Baldi**
Department of Environment, Food and Rural Affairs (DEFRA), London
**Ms Lina Barrios**
Heriot-Watt University, Edinburgh
**Dr Doug Beare**
Fisheries Research Services, Aberdeen
**Dr Shona Blake**
Scottish Agricultural College, Ayr
**Mr Norry Bleakley**
Scottish Agricultural College, Ayr
**Dr Colin Braithwaite**
Division of Earth Sciences, University of Glasgow
**Mr David Bryden**
Scottish Agricultural College, Ayr
**Ms Inez Campbell**
School of Life Sciences, Heriot-Watt University, Edinburgh
**Ms Susan Chambers**
National Museums of Scotland
**Professor Euan Clarkson FRSE**
Grant Institute of Earth Sciences, University of Edinburgh
**Mr Thomas Claverie**
University Marine Biological Station Millport
**Dr Tam Dalyell MP FRSE**
House of Commons, London
**Miss Lyndsey Dodds**
Scottish Association for Marine Science (SAMS)
**Dr Gerard Duineveld**
Royal Netherlands Institute for Sea Research
**Professor Christian Dullo**
Department of Paleoceanology, GEOMAR, Germany
**Mr Tom Edwards**
Information Centre, Scottish Parliament
**Professor André Freiwald**
Institute of Paleontology, Erlangen University, Germany
**Ms Nohora Galvis**
School of Life Sciences, Heriot-Watt University, Edinburgh
**Miss Susan Gass**
Scottish Association for Marine Science (SAMS)
**Miss Charlotte Gilfillan**
Scottish Agricultural College, Ayr
**Miss Lucy Gillis**
School of Life Sciences, Heriot-Watt University, Edinburgh
**Miss Karen Greaney**
School of Life Sciences, Heriot-Watt University, Edinburgh
**Ms Janine Guinan**
Department of Earth and Ocean Sciences, National University of Ireland
**Dr Stefan Hain**
Division of Environmental Policy Implementation, UNEP World Conservation Monitoring Centre, Cambridge
**Miss Amadine Heger**
Oceanlab, University of Aberdeen
**Dr Jan Helge Fosså**
Institute of Marine Research, Bergen, Norway
**Professor Jean Pierre Henriet**
Department of Geology and Social Science, Ghent University, Belgium
**Dr Lea-Anne Henry**
Scottish Association for Marine Science (SAMS)
**Mr Kohei Hibino**
Japan Wildlife Research Centre, Tokyo
**Miss Anne Holford**
Oceanlab, University of Aberdeen
**Dr Martin Hovland**
Statoil
**Mr Veit Hühnerbach**
National Oceanography Centre
**Miss Michaela Hunter**
Scottish Agricultural College, Ayr
**Ms Johanna Järnegren**
Norweigan University of Science and Technology

**Dr Paul Johnston**
Greenpeace Research Laboratories,
University of Exeter
**Dr Kostas Kiriakoulakis**
Department of Earth and Ocean
Sciences, University of Liverpool
**Dr Marc Lavalaye**
Royal Netherlands Institute
for Sea Research
**Miss Catriona Lazenby**
Scottish Agricultural College, Ayr
**Mr George Lees**
Scottish Natural Heritage
**Mr David Long**
British Geological Survey
**Miss Paula Low**
University Marine Biological
Station Millport
**Mr Martin Ludvigsen**
Department of Marine Technology,
Norweigan University of Science
and Technology
**Professor Alasdair McIntyre CBE FRSE**
Department of Zoology,
University of Aberdeen
**Dr Conny Maier**
Royal Netherlands Institute
for Sea Research
**Dr James Mair**
School of Life Sciences,
Heriot-Watt University, Edinburgh
**Dr Fransesca Marubini**
School of Biological Sciences,
University of Aberdeen
**Mr James Massey**
ERT (Scotland) Ltd,
Heriot-Watt University, Edinburgh
**Professor Jack Matthews FRSE**
Scottish Association for
Marine Science (SAMS)
**Miss Rosanna Milligan**
Scottish Association for
Marine Science (SAMS)
**Ms Ann Montgomery**
Shell U.K. Ltd
**Mr Sandy Morrison**
Scottish Agricultural College, Ayr
**Miss Marion Perutz**
FRS Marine Laboratory, Aberdeen
**Mr Paolo Pizzolla**
Department of Life Sciences,
Heriot-Watt University, Edinburgh
**Professor Imants G Priede FRSE**
Ocean Lab,
University of Aberdeen
**Dr Murray Roberts**
Scottish Association for
Marine Science (SAMS)
**Dr Steve Ross**
University of North Carolina
at Wilmington, USA
**Dr Stephen Simpson**
Institute of Evolutionary Biology,
University of Edinburgh
**Mr Chris Smith**
Deep Sea World,
North Queensferry
**Mr Alan Stevenson**
British Geological Survey
**Miss Heather Stewart**
British Geological Survey
**Dr Mark Tasker**
Scottish Natural Heritage
**Miss Jessica Trebileo**
Linacre College,
Oxford University
**Dr Martin White**
Department of Earth and
Ocean Science, National University
of Ireland
**Dr Pat Wightman**
Scottish Agricultural College, Ayr
**Mrs Margaret Wilson**
Department of Earth and
Ocean Science, National University
of Ireland
**Professor George Wolff**
Department of Earth and
Ocean Sciences, University of
Liverpool
**Ms Annette Woodham**
ERT (Scotland) Ltd,
Heriot-Watt University, Edinburgh

## The Scottish Association for Marine Science (SAMS)

Since its foundation in 1884, SAMS has been committed to promoting, delivering and supporting high-quality independent research and education in marine science, particularly on issues relevant to Scotland. As a Learned Society SAMS has about 600 members and employs 120 staff. Its research portfolio includes aspects of marine biology, chemistry, physics, geology and engineering. SAMS is a Collaborative Centre of the Natural Environment Research Council and an Academic Partner in UHI Millennium Institute under whose auspices SAMS delivers the BSc (Hons) Marine Science, and trains around 25 postgraduate research students.


## The Royal Society of Edinburgh (RSE)

The Royal Society of Edinburgh is Scotland's National Academy of Science and Letters. An independent body with charitable status, its multidisciplinary fellowship of 1,400 men and women of international standing represents a knowledge resource for the people of Scotland. Committed to its Royal Charter of 1783 for the "advancement of learning and useful knowledge" the Society recognises the important role it can play in today's Scotland. Working as part of the UK and within a global context, the RSE seeks to contribute to Scotland's social, economic and cultural wellbeing by:

- organising conferences and lectures for the specialist and for the general public on topics of national and international importance
- providing independent, expert advice to key decision-makers in Scotland
- awarding over £1.5million annually to Scotland's top young academics to promote research in Scotland
- enabling leading Scottish-based researchers to collaborate with the best of their international counterparts
- inspiring school children in classrooms from the Borders to the Northern Isles and promoting their interest in science, society and culture.

If you would like further information
about the work of the RSE

Please contact

The Royal Society of Edinburgh
22-26 George Street
Edinburgh
EH2 2PQ

Telephone/Textphone: +44 (0) 131 240 5000
Fax: +44 (0) 131 240 5024
Email: rse@royalsoced.org.uk

**www.royalsoced.org.uk**

Scottish Charity No: SC000470

Europe's Hidden Coral Worlds: 23 February 2005



ISBN 0 902198 54 8

www.royalsoced.org.uk