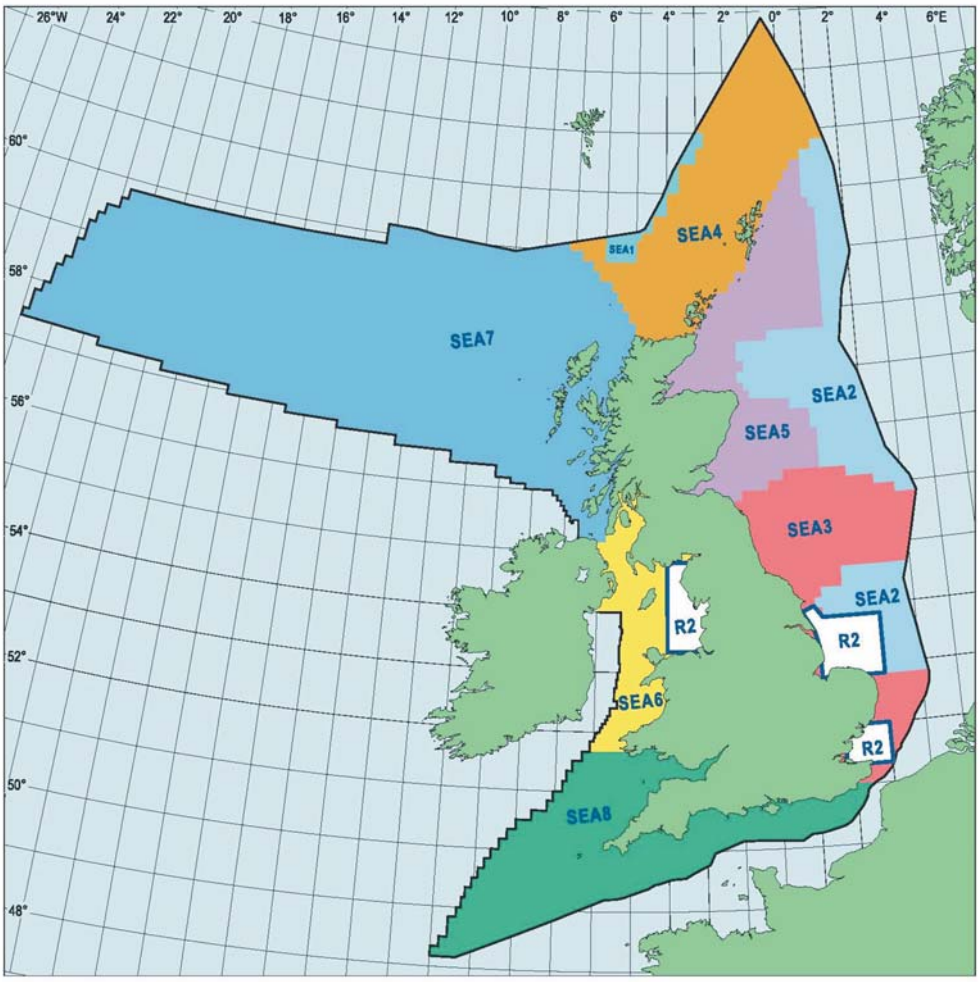
An introduction to the benthic ecology of the Faroe-Shetland Channel (SEA4)

Brian J. Bett



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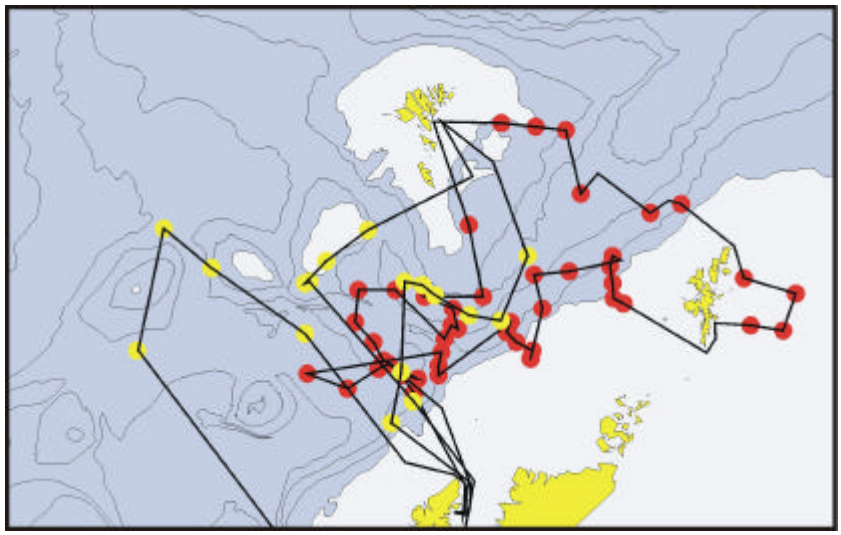
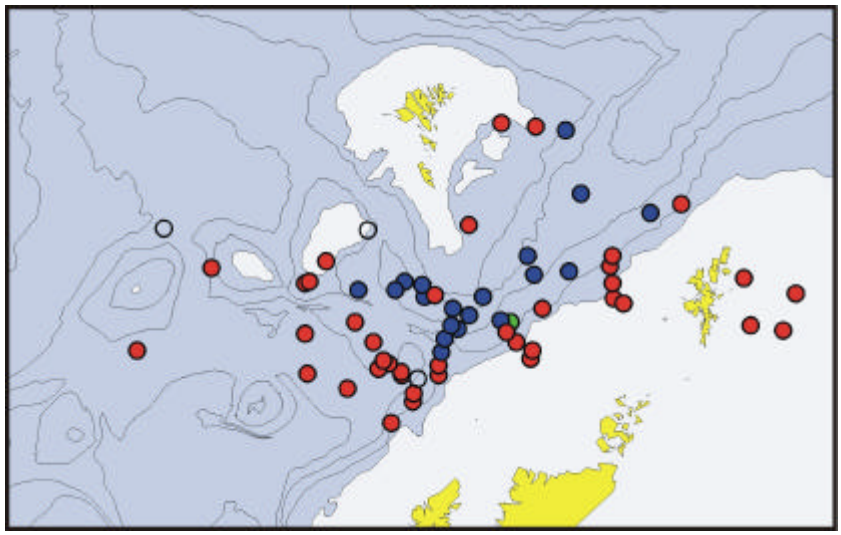
INTRODUCTION

The deep-waters to the north and west of Scotland are the birthplace of deep-sea biology. Under the leadership of Charles Wyville Thomson, the cruises of the HMSS *Lightning* and HMSS *Porcupine* in the late 1860s and early 1870s laid the foundations of this science (Thomson, 1873). These voyages lead directly to the most famous deep-sea expedition of all – the global circumnavigation of HMS *Challenger* (1872-76; Murray & Hjort, 1912).



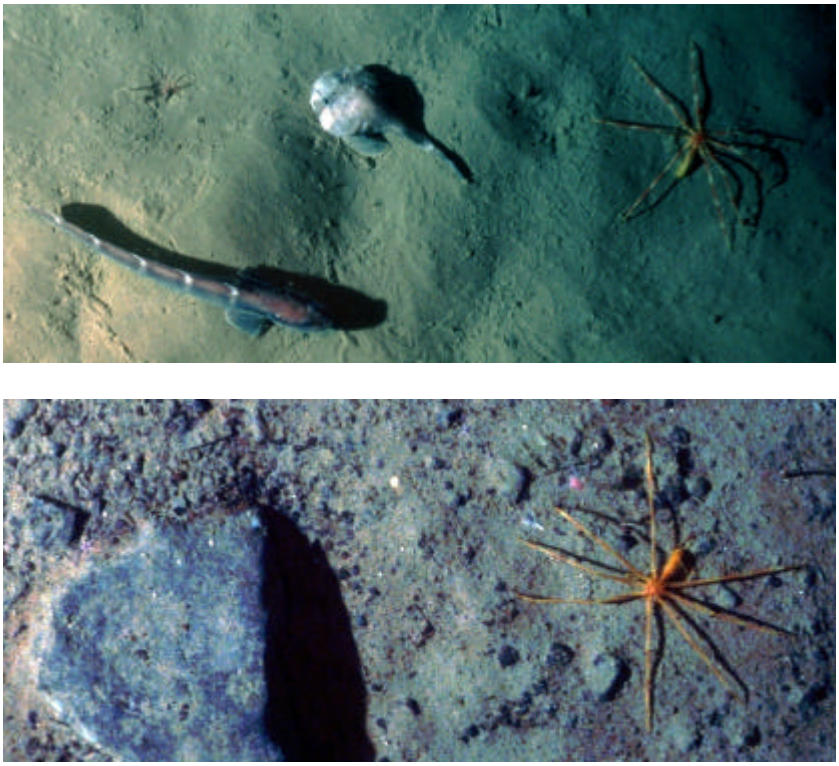
The cruises of the HMSS *Lightning* (yellow) and HMSS *Porcupine* (red) to the north and west of Scotland.

The work carried out from *Lightning* and *Porcupine* was of a truly pioneering nature. Most importantly, it established the existence of extreme temperature ranges in the area and that these are very important in regulating the distribution of animal life.



Bottom water temperature observations from the *Lightning* and *Porcupine* cruises (Red – warm, >4°C; Green – medium; Blue – cold, <2°C).

The results from the *Lightning* and *Porcupine* cruises are still valuable today, and the book recounting these voyages, "The Depths of the Sea" (Thomson, 1873), remains compulsory reading for those interested in the ecology of the region.



Giant sea spiders on the floor of the Faroe-Shetland Channel, one of the characteristic animals of the cold waters identified by the *Lightning* and *Porcupine* cruises.

Despite the significance of the SEA4 area in the early development of deep-sea biology, the area was little studied after these early cruises. It was not until the mid-1990s, and the development of the deep-water oil industry to the West of Shetland that the area was the subject of further major studies.

This report provides an overview of the more recent surveys. The reader is referred to: AFEN (2000), Bett (2000a, b), and Bett (2001) for a more detailed account. The Technical Report on the benthic ecology of the Faroe-Shetland Channel (Hughes, Narayanaswamy and Bett) updates these works, drawing on the data generated by the most recent (1999, 2000 and 2002) DTI surveys.

MODERN SEABED SURVEYS

In 1996 the Atlantic Frontier Environmental Network (AFEN) commissioned a large-scale regional survey of the West of Shetland seabed environment (AFEN, 2000). This survey adopted a new ethos – to make a regional (=strategic) assessment rather than site-by-site specific assessments – and developed a new approach, drawing on the experience of the industry, its regulators, industry contractors and the academic

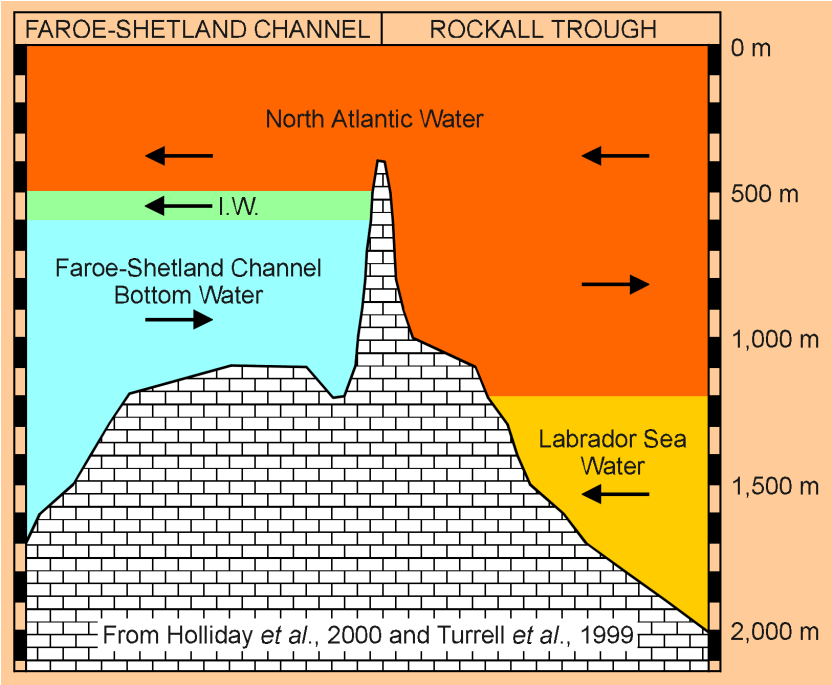
community. The practical conduct of the survey drew on “modern” technology and techniques for seabed survey (e.g. sidescan sonar), sampling (e.g. Megacorer) and visualisation (e.g. WASP, seabed photography). These seabed survey tools were operated in an integrated fashion, the sidescan sonar mapping guiding the seabed sampling and visualisation which in turn fed back ground-truthing data for the improved interpretation of the sidescan sonar data (see e.g. Masson et al., 2000; Bett, 2000a).

Seabed survey tools: top left – Megacorer; top right – TOBI sidescan sonar vehicle; bottom – WASP seabed photography system.

In 1998 AFEN commissioned a further survey, including areas north and west of Shetland and areas in the Rockall Trough. The general concept and approach of the AFEN surveys was then taken forward by the DTI with a survey of the Wyville Thomson Ridge and central axis of the Faroe-Shetland Channel in 1999. The DTI surveys continued with work during 2000 and the completion of SEA4 field work with the 2002 survey to the north of Shetland.

BENTHIC ECOLOGY OF THE SEA4 AREA

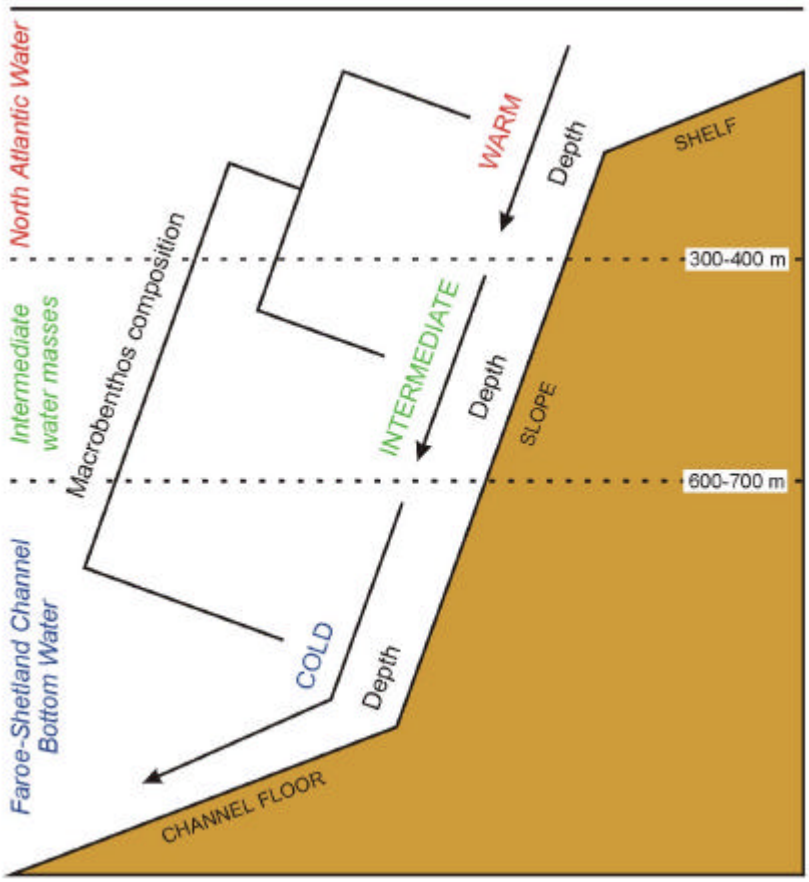
Following the AFEN and DTI surveys, the SEA4 area is undoubtedly the most extensively studied deep-sea area in the world. And perhaps more importantly, all of these studies have been carried out using common approaches and techniques throughout. The resultant dataset of biological and supporting environmental information is a unique resource for the study of deep-sea ecology. And is the more interesting for the complex and varied environmental setting of the SEA4 area.



Hydrography of the SEA4 area (Fareoe-Shetland Channel) and adjacent Rockall Trough.

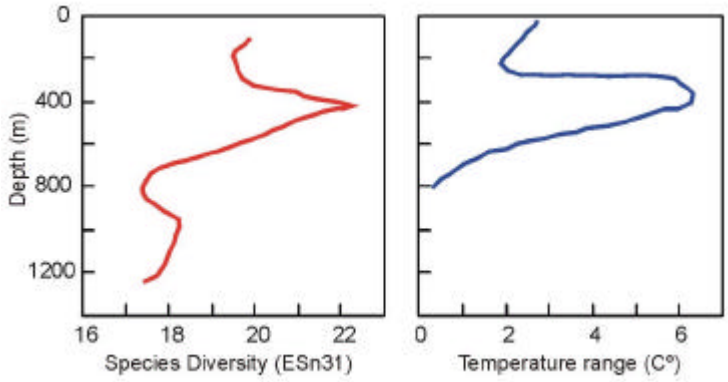
As noted by the early studies from HMSS *Lightning* and HMSS *Porcupine*, the temperature regime in the SEA4 area is critical in determining the benthic ecology of the region. The hydrographic regime in the SEA4 area is rather unique: comparatively warm North Atlantic Water overlies very cold Faroe-Shetland Channel water, producing a region of very rapid temperature change at around 500m water depth. This situation is complicated by waves that travel along the boundary where these warm and cold waters meet. Animals living on the seabed near this boundary may experience large, sudden changes in temperature (up to 8C°) as these waves pass. This is a very unusual condition for deep-sea animals. In most deep-sea areas, temperature changes are minimal (often less then 1C°) and gradual.

Analysis of the distribution of benthic species (macrofauna) in the SEA4 area indicates that the composition of the seabed community tends to vary continuously with depth, as it does in most deep-sea areas, but that there is an enhanced rate of change at depths were major changes in bottom water temperature occur (see Bett, 2001).



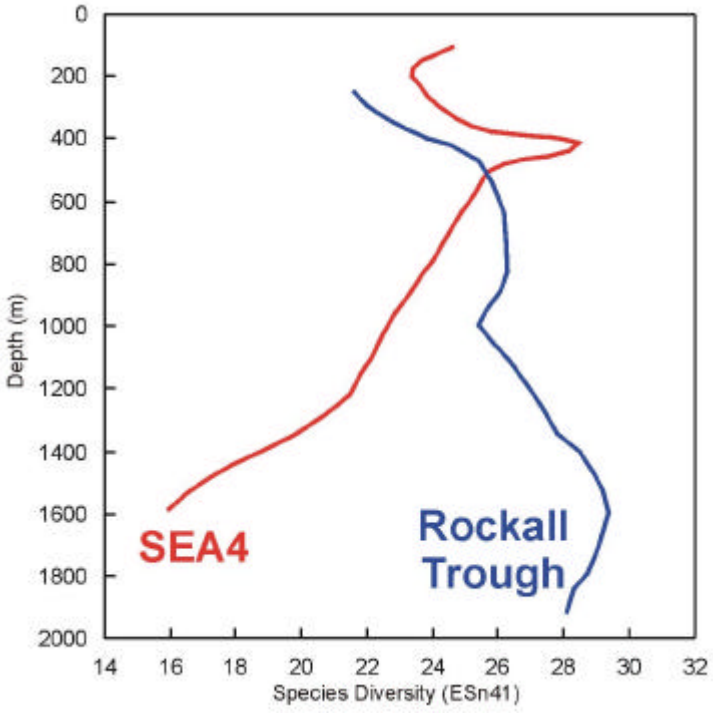
A schematic summary of the benthic ecology of the Faroe-Shetland Channel (Shetland side). Distributions of macrobenthic species appear to be strongly controlled by hydrography (water mass temperature) although there is continuous variation in the composition of the fauna with depth (adapted from Bett, 2001).

The importance of bottom water temperature variations is also apparent in the diversity of the benthos in the SEA4 area, with the diversity of the benthos (macrofauna) appearing to peak in those depths experiencing the greatest of habitat temperature variation (see Bett, 2001).



The apparent relationship between variation in species diversity and habitat temperature range (AFEN 1996 survey data; adapted from Bett, 2001).

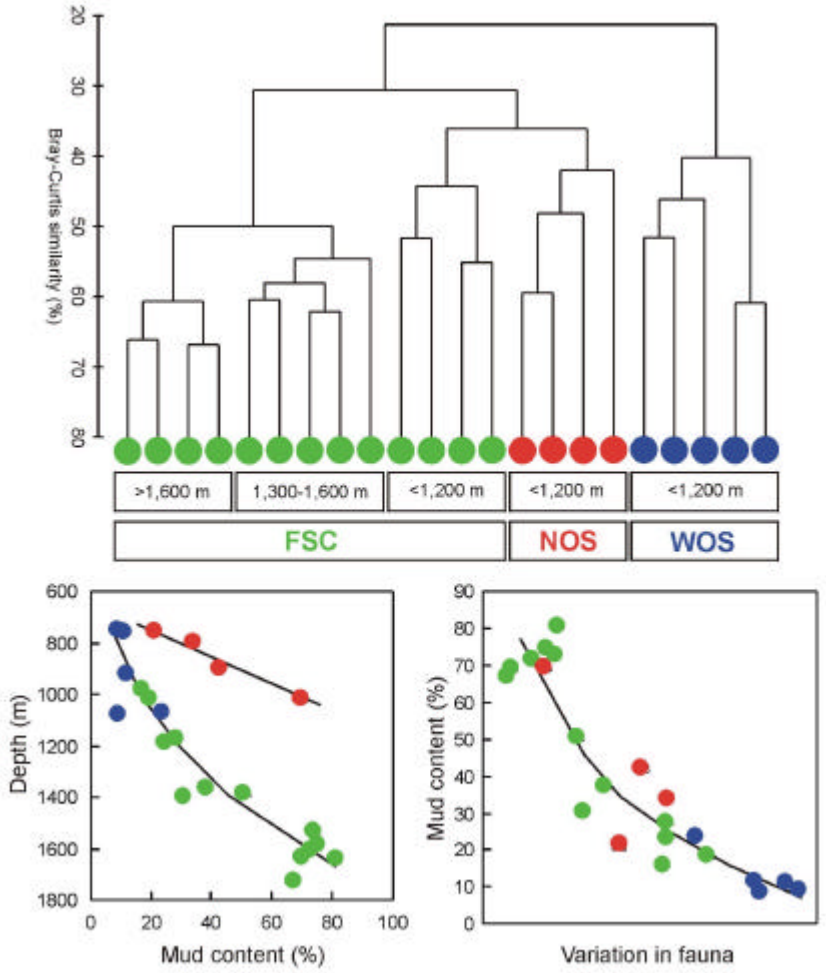
The presence of cold, arctic, waters at depth in the SEA4 area appears to exert a marked influence on the diversity of the deep-sea benthos (macrofauna) of the region most clearly seen when compared with the diversity of the benthos from the adjacent Rockall Trough which does not experience these “arctic” conditions. In the Rockall Trough, in common with many deep-sea areas, diversity tends to increase with depth; however, in the SEA4 area diversity declines with depth. Consequently, at depth, the fauna of the SEA4 area is markedly less diverse than that of the Rockall Trough. This rather dramatic contrast between these adjacent deep-sea areas is thought to result from a mass extinction of the fauna in glacial periods. Being open to the wider Atlantic, the Rockall Trough has been successfully recolonised from areas not subject to impact of glaciation. Whereas the extreme temperature change from the warm Atlantic waters to the “arctic” waters of the deep SEA4 has imposed a physiological barrier to recolonisation (see Bett 2001).



Variation in species diversity with depth in the SEA4 area and the adjacent Rockall Trough (AFEN 1996 and 1998 survey data; adapted from Bett, 2001).

The hydrographic regime of the SEA4 area does exert a dominant control on the large-scale distribution of the fauna in the region, and consequently its diversity. However, other environmental factors, both natural and man-made, do have a significant impact on the benthic ecology of the region.

In the analysis of macrobenthos data, variations in sediment type certainly appear to play a role in influencing the composition of the seabed community, although this effect is often difficult to disassociate from the continuous variation in the community with depth. The effect is best seen when comparing the West of Shetland Slope and the North of Shetland Slope – at a given depth; sediments are muddier North of Shetland.



Variation in macrobenthos community composition with depth and sediment type (as % mud content) in samples from the West Shetland Slope (WOS-blue), the deep Faroe-Shetland Channel (FSC-green) and the North Shetland Slope (NOS-red). Note that although the NOS samples are taken from a comparable depth range to the WOS samples, their fauna has a greater similarity with that of the deeper FSC samples where similarly high sediment mud content is encountered (AFEN 1998 survey data; adapted from Bett, 2000b).

Rather more obvious variations in the benthos in response to seabed type are apparent when the study is based on seabed photographs rather than physical samples (as in the case of the macrobenthos data above). Seabed samplers capable of collecting quantitative samples suitable for the analysis of the macrobenthos, and other environmental parameters, are limited to operation in relatively soft sediments (e.g. muds and fine sands). It is now apparent that the SEA4 region has large areas of coarser sediments (gravel, cobble and boulder) where conventional seabed samplers are either completely ineffective or can only selectively sample local patches of finer sediments. The latter point is important to note when assessing the seabed sample dataset, as it may introduce some bias to the results – for example when operating in the "iceberg ploughmark zone (see below).

The areas of coarser sediment in the SEA4 area have, however, been examined using seabed photography and video techniques that have revealed a wide range of seabed habitats in the region.

DEEP-SEA HABITATS OF THE SEA4 AREA

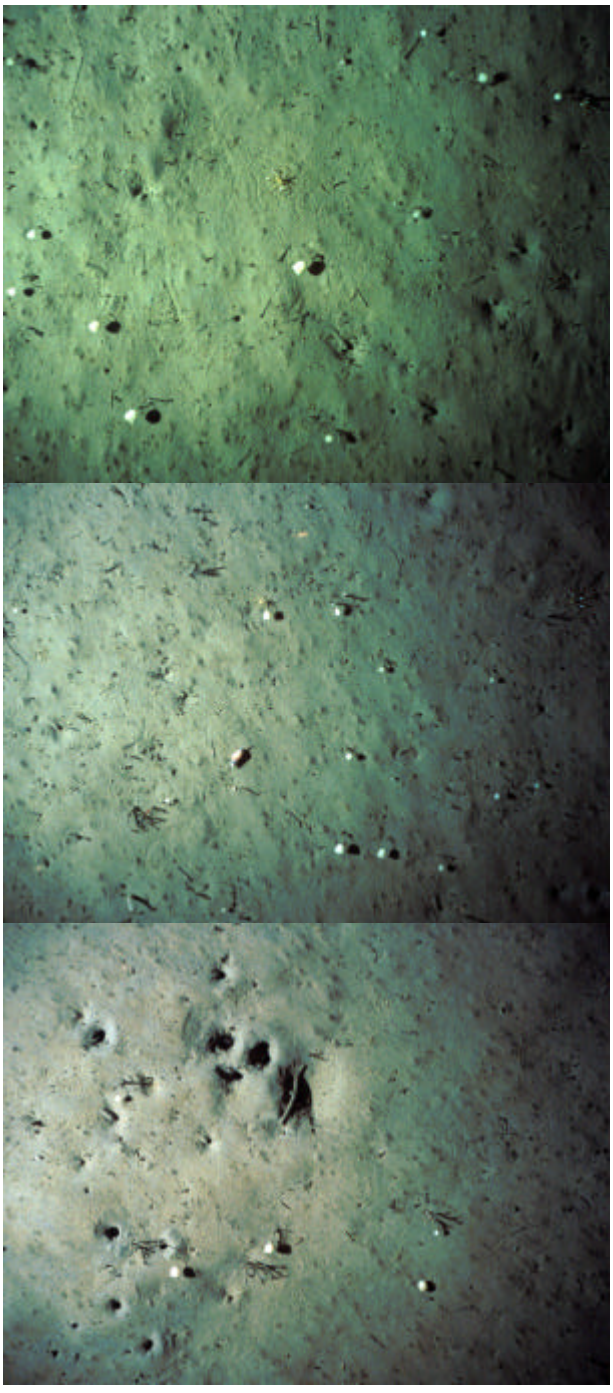
A conventional view of the deep-sea floor is that it is a large expanse of apparently barren flat mud, a habitat unlikely to excite much interest from outside the academic deep-sea biology community (see Gubbay et al., 2002). The SEA4 area, however, encompasses a much broader range of seabed habitat types – a range of variation likely to rival that of any comparable deep-sea area.

Seabed photographs from the mouth of the Faroe-Shetland Channel, showing level-bottom "typical deep-sea" soft sediment habitat. Larger fauna (megabenthos) is relatively sparse, though their burrows, tracks and feeding marks (star shapes) are abundant.

In the mouth of the Faroe-Shetland Channel and the Norwegian Basin beyond there are certainly large areas of level-bottom “typical deep-sea” soft sediment habitat. Although even here the mud diaper province (see geological technical reports) introduces local seabed habitat heterogeneity. The DTI surveys of the diapirs in 1999 and 2000 did not reveal any evidence of “exotic” seabed communities (e.g. such as associated with active mud volcanoes); however, such communities are known to exist in the Norwegian Basin (Milkov et al., 1999) and may occur in the SEA4 area (Bett, pers. obs.).

Seabed photographs from the mud diaper province at the mouth of the Faroe-Shetland Channel, showing the highly sculptured mud blocks and the gravel and cobble seabed found between the block and on the periphery of the diapirs.

The deep-waters (c. 1000-1200m) of the opposite end of the SEA4 area (Faroe Bank Channel and southern reaches of the Faroe-Shetland Channel are rather different in character, having sandier sediments that are home to a more abundant population of megabenthos – white stalked sponges being the visually most striking component of the fauna.



Typical deep-water seabed habitat from the Faroe Bank Channel and southern reaches of the Faroe-Shetland Channel, here the sandy sediments support abundant populations of stalked sponges.

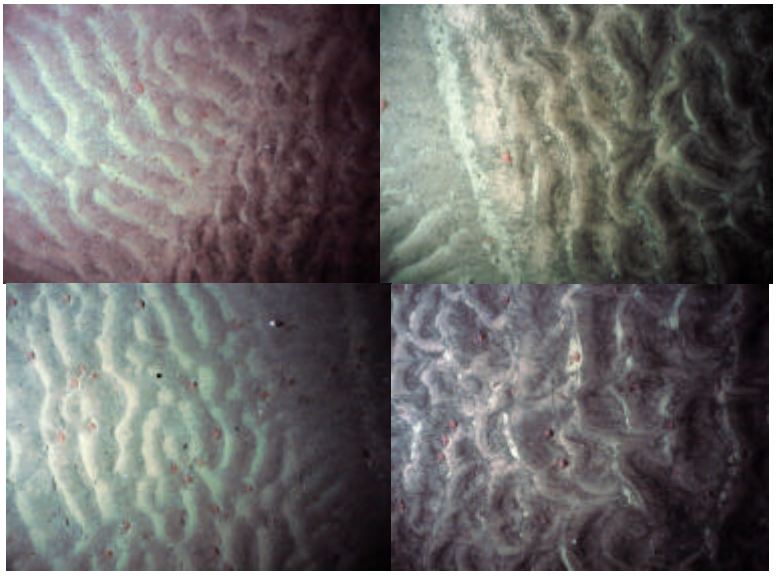
Moving towards the southern edge of the Faroe Plateau coarser sediments are encountered with rather different faunas.

Fine gravel habitat from the foot of the Faroe Plateau / Faroe Bank Channel area, there is near uniform gravel cover at the sediment surface that is carpeted by small brittlestars (too small to resolve in the images reproduced here) with occasional larger megabenthic animals (a feather star and solitary hydroid are shown).

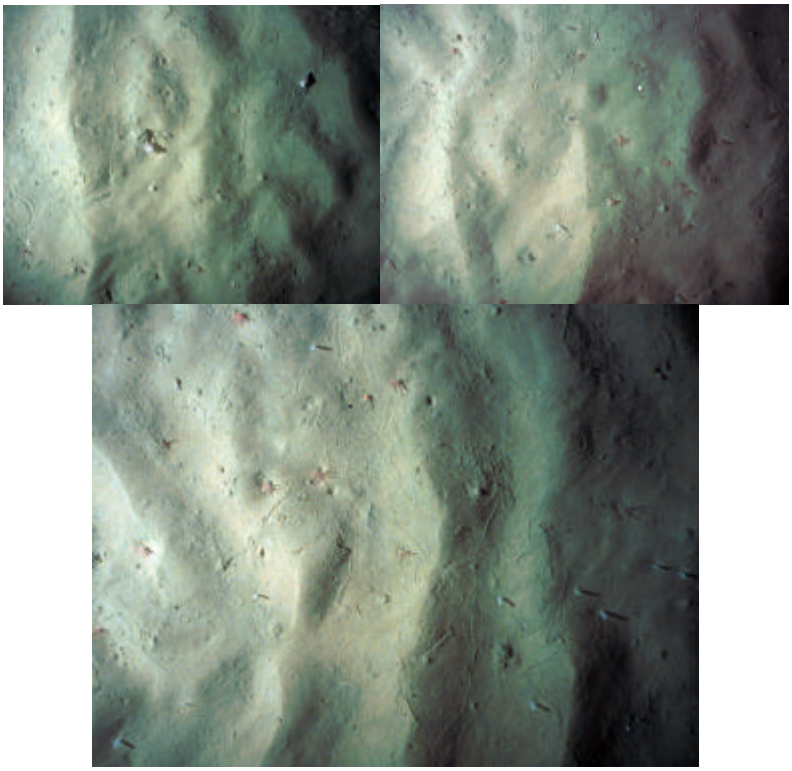
Moving on to the lower slope of the Faroe Plateau, sediments are coarser still, with a further change in the associated fauna. The lack of fine sediments in this area is indicative of significant bottom water currents (see geological technical reports).

Lower slope of the Faroe Plateau, here there is continuous seabed cover by gravel, cobble and boulders, promoting the development of larger sessile megabenthos (sponges and soft corals shown).

Other seabed habitats in the SEA4 area are also indicative of significant bottom water flows that result in the transport of fine sediments: barchan sand dune fields and sandy contourite deposits (see geological technical reports).

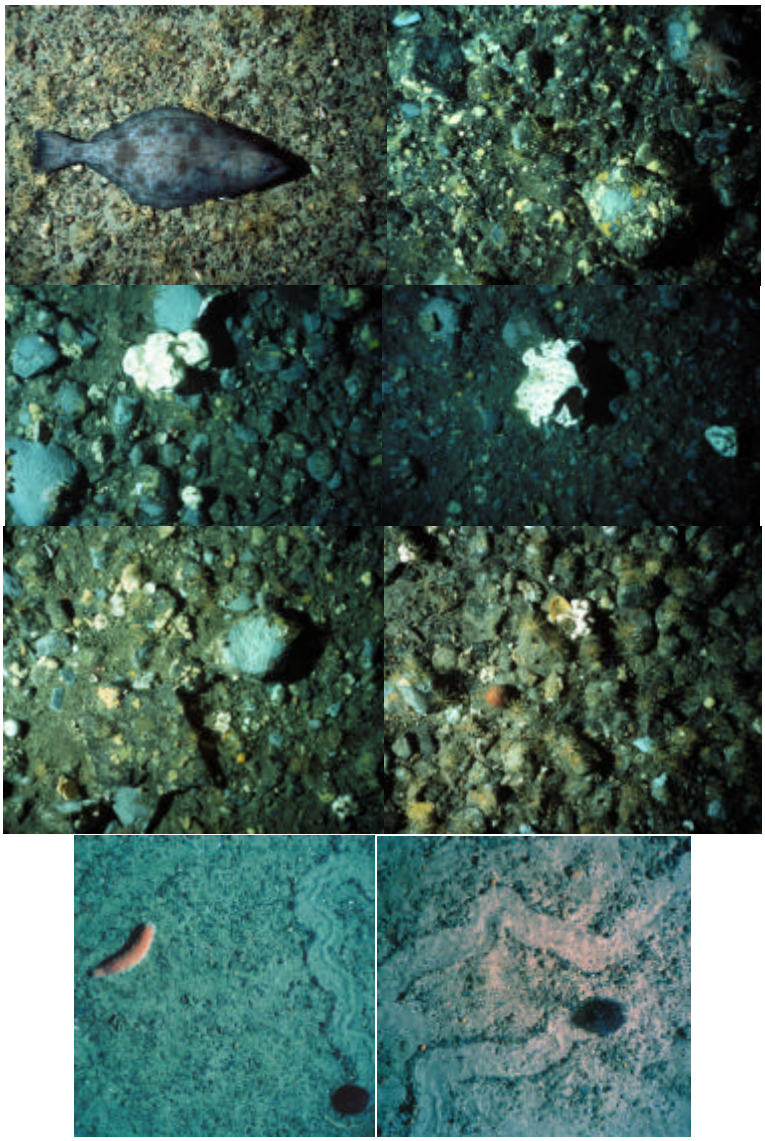


Seabed photographs from the barchan sand dune field in the southern Faroe-Shetland Channel (c. 1200m water depth), small anemones are numerous on these dunes (see Wynn, Masson & Bett, 2002 for further details).



Seabed photographs from the West of Shetland sandy contourite (c. 900m water depth), this habitat supports a unique and novel community of surface dwelling enteropneusts (acorn worms) (see Bett, 2001 for further details).

Coarse sediment habitats are not restricted to the deeper reaches of the SEA4 area, and indeed are particularly widespread on the upper slope (c. 300-500m) in a more-or-less continuous band zone known as the “iceberg ploughmark zone” throughout the region (see geological technical reports). During glacial periods, grounding icebergs gouged furrows in the seabed turning coarser sediments (cobbles and boulders) aside in an action similar to that of a plough harrow (see Belderson, Kenyon & Wilson, 1973). The action of bottom currents has subsequently, at least partially, infilled the furrows with finer sediments. These processes have acted to produce a complex, spatially heterogeneous, mosaic habitat that can repeatedly alternate from “piles of boulders” to open fine sediment areas. The coarse sediment (cobble and boulder) area can support diverse biological communities that exhibit significant local variation in their composition and abundance.



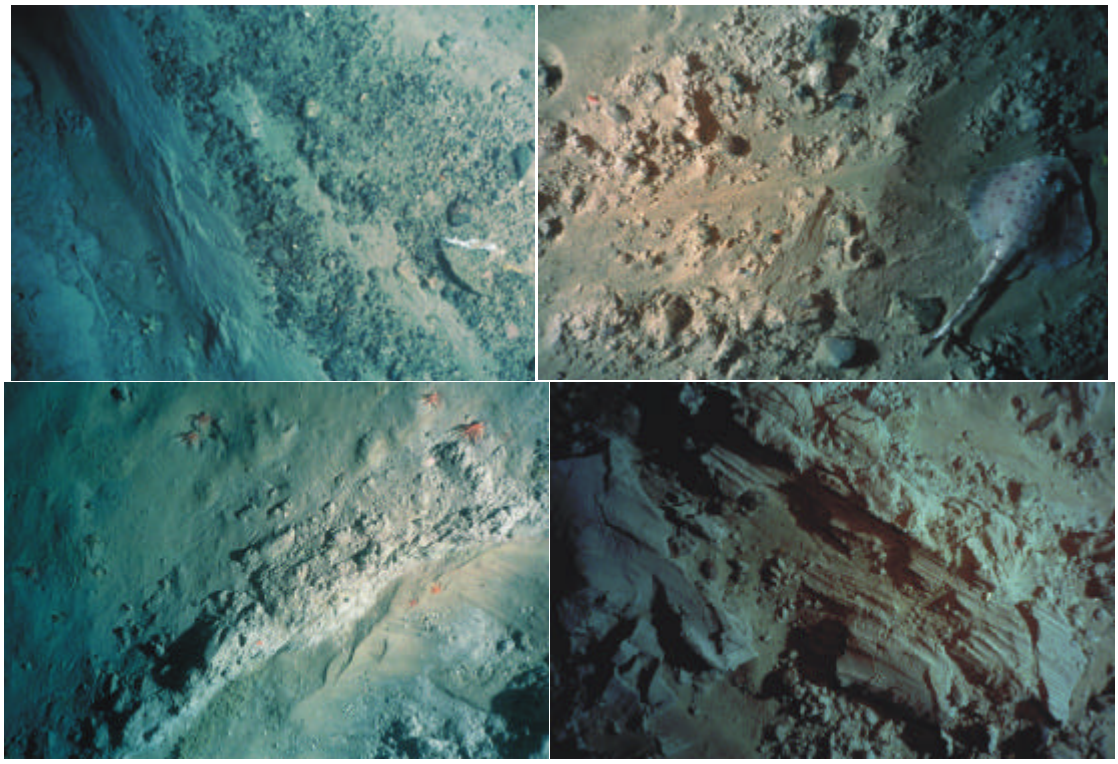
Seabed photographs from the “iceberg ploughmark zone”, this is a mosaic habitat of finer sediments areas (lower two images, showing seacucumber and heart urchins) and coarser sediment gravel / cobble / boulder). The coarse sediment areas often have a well-developed encrusting epifauna and abundant populations of mobile megabenthos and demersal fish.

MAN-MADE IMPACTS ON THE BENTHIC ECOLOGY OF THE SEA4 AREA

Two major industries operate on the deep-sea floor in the SEA4 area – the oil and gas industry and the fishing industry – both of these industries may be expected to exert some adverse impact on the ecology of the deep-sea benthos.

Results from the AFEN 1996 survey (West Shetland Slope) suggested the occurrence of localised contamination of the seabed by heavy metals (Barium) and hydrocarbons as a result of drilling operations (Bett, 2000a). However, the dominant signal in hydrocarbon contamination of deep-water sediments in the SEA4 area was from other sources (shipping and terrestrial; see McDougall, 2000).

The potential impact of the oil industry was specifically investigated during the course of the AFEN 1996 survey; the impact of the fishing industry was not – although it was never the less encountered during most of the large-scale surveys undertaken in the SEA4 area. Bett (2000c) documents the observations of potential fishing impacts recorded during the AFEN 1996 and 1998 and DTI 1999 surveys – in the form of trawl marks and discarded / lost fishing gear observed on the seabed, and a core sample taken in (presumed) trawl disturbed ground. The DTI 2000 survey recorded the presence of trawl marks in the iceberg ploughmark zone to the north of Shetland. The effects of deep-sea trawling on benthic communities is little known, though clearly is likely to be highly destructive to communities of sessile organisms (i.e. sponges) (see Bett, 2000c for further details).



Seabed photographs showing physical disturbance (“trawl marks”) of the seabed presumed to result from the action of demersal trawling in the SEA4 area.

OTHER ISSUES

Deep-water corals

At the outset of the large-scale survey programme in the SEA4 area, deep-water corals were specifically identified as a potential issue in the region. The colonial, bank-forming, stony coral *Lophelia pertusa* was know to occur in the area (see review of Rogers, 1999). Consequently, the first of the surveys (AFEN 1996) specifically investigated areas of suspected coral occurrence. In that survey and subsequent surveys the coral was only infrequently encountered, and then only as isolated colonies. Neither the photographic investigations nor the sidescan sonar surveys (see geological technical reports) provide any evidence for the mass occurrence of *Lophelia* (or other colonial stony corals) in the SEA4 area.

Lophelia pertusa certainly occurs in the SEA4 area, and may be encountered anywhere on the upper slope ("the iceberg ploughmark zone"), though it seems unlikely that it occurs at greater depth, i.e. in areas of permanently cold water. Note that *Lophelia* is often referred to as a cold-water coral to distinguish it from tropical (hermatypic) corals. The lower habitat temperature of *Lophelia* is typically reported as 4°C (e.g. Rogers, 1999), although it can certainly withstand lower temperatures (see Bett, 2000a), there do not appear to be any reliable records of occurrence in "arctic" waters (<2°C).

Taxonomy of the deep-water fauna

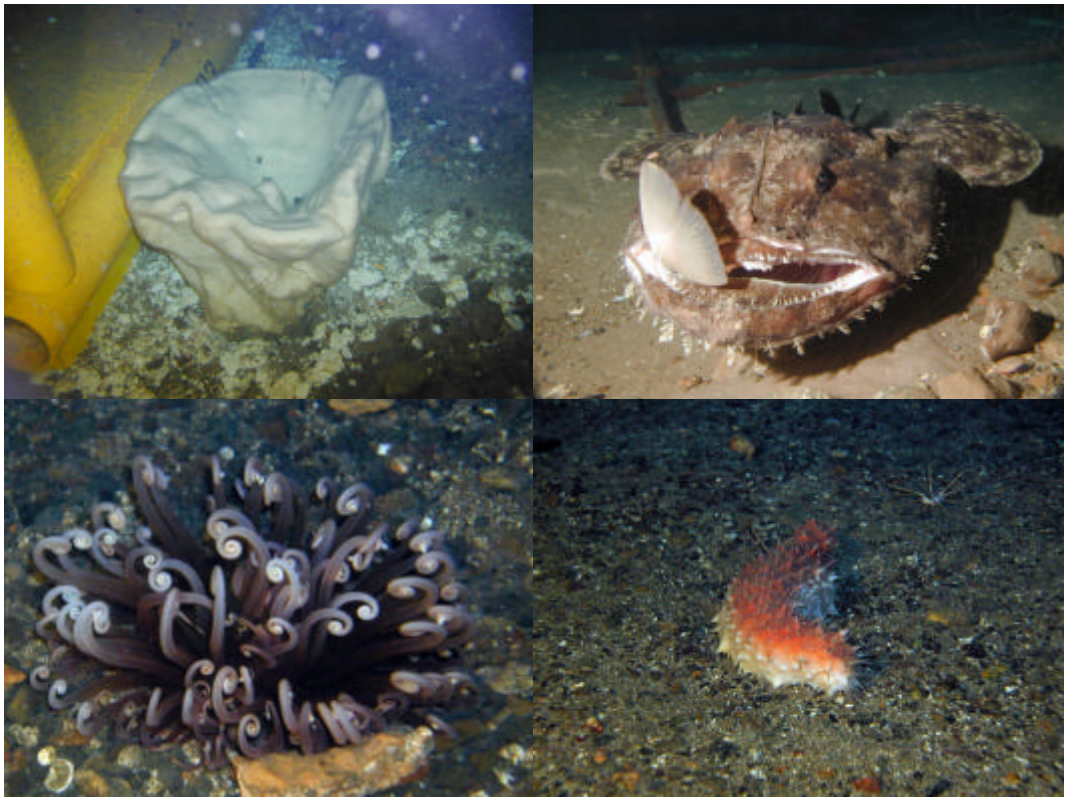
Taxonomy, the science of identification and classification of species, of the deep-water fauna in the SEA4 area is significantly incomplete, as is typically the case in any deep-sea area. In the analysis of the benthos (macrofauna) undertaken following the large-scale survey, approximately one half of all species recovered could not be identified to a known species. Accurate identification of species is fundamental to all biological / ecological knowledge. The time-scales of environmental impact assessments and detailed taxonomic investigations are incompatible. Consequently, additional efforts are required to ensure that taxonomy advances and that the specimens and data derived from the large-scale surveys have a long-term value.

All of the specimen material from the AFEN and DTI surveys has been curated by the National Museums of Scotland (Royal Museum, Chambers Street, Edinburgh), where they are now an internationally significant collection. This action alone will promote the taxonomy of the SEA4 fauna and ensure the long-term value of the material and data. Additionally, AFEN established a taxonomic bursary scheme that has funded specific taxonomic studies of the SEA4 (and SEA7) deep-water fauna (see http://www.ukooa.co.uk/issues/Afen/project5.htm). Other industry funded taxonomic initiatives have also been instituted (e.g. BP Biodiversity Fellowships, see http://www.soc.soton.ac.uk/GDD/BP/).

The photographic investigations undertaken during the large-scale surveys have proved to be extremely valuable in assessing the larger fauna (megabenthos and fish) of the SEA4 area. However, there have been few collections of supporting specimen material with which to confirm the identifications of the fauna made from the photographs. Trawling for specimen material can be practically difficult in rough ground areas and may be rather destructive, both to the seabed environment and the specimens

themselves. However, direct collection of targeted specimens is now a practical possibility.

The exploration and production activities of the industry in the SEA4 area have resulted in the deployment of numerous remotely operated (ROV) vehicles in the region. These vehicles are capable of detailed observation of the fauna and targeted collection of specimen material. There is considerable scope for advancing taxonomy by this means; indeed ROVs offer the possibility to undertake a wide range of detailed biological investigations in the SEA4 area (see e.g. Hudson & Wigham, 2003).



Seabed photographs taken during industry ROV operations West of Shetland (images courtesy of BP and Subsea7).

SUMMARY AND CONCLUSIONS

1. Following the AFEN and DTI large-scale surveys, the deep-water benthos of the SEA4 area are well known; at least as well known as any other deep-water area worldwide.

2. The ecology of the benthos in the SEA4 area is very strongly influenced by the hydrography of the region, particularly the complex temperature regime.

3. Seabed type (i.e. coarser / finer sediment) also exerts a strong influence on the ecology of the region, although it is often difficult to distinguish from the continuous change in the composition of the fauna that occurs with depth.

4. The deep waters of the SEA4 area are rich in seabed habitat types; the distribution of these habitats appears to be well understood / mapped (see geological technical reports).

5. It seems likely that any environmental effects resulting from the activities of the oil and gas industry will be highly localised. However, the environmental impacts of the deep-water trawling industry are already obvious and extensive.

6. As may be expected in any deep-water area, there are significant limitations to the current taxonomic knowledge of the SEA4 fauna. Several initiatives are currently underway to address this problem.

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