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The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts

J.H. Fosså, P.B. Mortensen & D.M. Furevik
Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway. (E-mail: jhf@imr.no)

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Abstract

The paper presents documentation on the distribution of, and damages to, deep-water reefs of the coral *Lophelia pertusa* in Norwegian waters. The reef areas have traditionally been rich fishing grounds for long-line and gillnet fisheries, and the coral habitat is known to support a high diversity of benthic species. Anecdotal reports claim that trawlers often use the gear, wires, chains and trawl doors to crush the corals and clear the area before fishing starts. To get an overview of the situation, information about the distribution and damage were collected from the literature, fishermen, and our own investigations. The results show that the corals are abundant particularly on the mid Norwegian continental shelf between 200 and 400 m depth. In general it seems that the largest densities are distributed along the continental break and at ridges of morainic origin. The reports from fishermen suggested severe damage to the corals and in situ observations using ROV confirmed the presence of mechanically damaged corals located on trawling grounds. A first estimate of the fishery impact indicates that between 30 and 50% of the reef areas are damaged or impacted. Fishermen claim that catches are significantly lowered in areas where the reefs are damaged. Potential ecological consequences of the destruction are discussed.

Introduction

Lophelia pertusa (L., 1758) is a stony coral (Scleractinia) belonging to the family Caryophylliidae. It is distributed throughout the world oceans except in the polar regions (Zibrowius, 1980; Cairns, 1994). The preferred temperature range seems to be 6–8 °C (Frederiksen et al., 1992; Freiwald, 1998) and the main depth distribution between 200 and 1000 m (Zibrowius, 1980; Freiwald, 1998). The shallowest record of a living *Lophelia* reef is at 39 m in Trondheimsfjorden, Norway (Rapp & Sneli, 1999), while the deepest records extend down to 3000 m in the Atlantic (Squires, 1959).

Seven species of scleractinians occur in Norwegian waters, of which *Lophelia pertusa* and *Madrepora oculata* L., 1758 form colonies. *Madrepora*, however, is less abundant than *Lophelia* and has never been reported to build reefs (Dons, 1944; Frederiksen et al., 1992). *Lophelia* has been known for centuries to scientists and fishermen, especially those using passive gear such as gillnets and long-lines in deep water. The first systematic study on the distribution of *Lophelia* and the associated fauna in Norway was performed by Dons (1944).

The reefs are considered as good fishing places for net and long-line. Fishermen set their gear as close as possible to the reefs, but not directly over them, in order to avoid potential damage or loss of equipment. A quite parallel practice is described by Breeze et al. (1997) from Nova Scotia. Although these fishing techniques may cause breakage of corals it is assumed that the damage is of limited extent. Moderate damage probably occurred when the first small bottom trawls started, but the degree of impact probably changed dramatically with the development of larger vessels with powerful trawls, e.g. rockhopper gear, adapted to operate on rough stony bottoms and coral areas.

Bottom trawling on the banks of the Barents Sea started in the 1930s. The activity scaled up in the 1960s by the introduction of factory and wetfish trawlers. In the mid 1980s trawling occurred along the continental break and extended further to the banks on the shelf as a result of lower quotas for the Norwegian Arctic cod. It was at the end of the 1980s that rockhopper gear was developed allowing larger vessels to trawl in earlier inaccessible areas due to the roughness of the bottom, e.g., by presence of coral reefs. The fishery on the continental break targeted Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum, 1792), redfish (mostly *Sebastes marinus* (L., 1758)) and saithe (*Pollachius virens* L., 1758)). By the end of the 1990s, the practice increasingly involved double-trawls, which sweep larger areas per unit time (personal communication with O.A. Misund, Institute of Marine Research).

It was in the early 1990s that long-line and gillnet fishermen contacted the Institute of Marine Research (IMR) to express their concerns about the effects of trawling on coral reefs. They claimed that corals had disappeared from trawling grounds, and that their catches in these areas were lowered. Their worries also concerned the potential function of the reefs as nursery areas for fish.

Currently, there has been an increased interest and concern around the effects of fisheries on benthic invertebrates and bottom communities (e.g., Jennings & Kaiser, 1998; Lindeboom & deGroot, 1998; Watling & Norse, 1998; Hall, 1999). Tropical coral reefs represent high diversity communities endangered by a range of human activities (Reaka-Kudla, 1997). The *Lophelia* reefs represent a highly complex habitat on the continental shelf, slope and seamount environments with a highly diverse associated fauna (Fosså & Mortensen, 1998; Rogers, 1999). The ecological effects of degraded or completely destroyed reefs may thus be substantial.

Since there were no estimates of the total area occupied by deep-water coral reefs in Norway, it was thus not possible to estimate the extent of the damage caused by fisheries. Therefore, the purpose of the present study was two-fold. Firstly, to gather information on the occurrence of *Lophelia pertusa* as given by fishermen and the literature in order to provide estimates of the extent of corals in Norwegian waters. And secondly, to inspect selected sites in order to confirm the damage reported by the fishermen so as to provide documentation of impacts of bottom trawling on the reefs.

Methods

Published and non-published information

Dons (1944) compiled the oldest published records of *Lophelia* in Norwegian waters. Since he plotted the findings on maps of different scales, we read the geographical co-ordinates as accurately as possible. Additional published material derives from Strømgren (1971), Fernandez Pulpeiro et al. (1998), Freiwald (1998) and Mortensen et al. (2001). These authors note the sites on maps as well and, occasionally, as geographical co-ordinates. Information from annual reports of lost gillnets in areas with heavy net fisheries, including coral reefs, performed by the Norwegian Directorate of Fisheries (NDF) retrievals (Anon, 1991–99), was also used. NDF record the presence of corals as stretches between geographical co-ordinates. The Norwegian State Oil Company (Statoil) has registered accurate positions for 70 reefs in the Haltenbanken area using a Remotely Operated Vehicle (ROV) (Hovland et al., 1997; Mortensen et al., 2001). Lastly, the records of coral sites encountered during trawl surveys carried out by IMR, which are reported as co-ordinates in station lists.

Information from fishermen

We provided the fishermen with bathymetrical charts to plot the occurrence and status of coral reefs. If necessary, details were discussed on the telephone. Fishermen records were gathered during 1997 and 1998. Their observations are based on what the fishermen usually call ‘glass coral’ (*Lophelia*) caught in trawls, nets or on long-lines. Observations of prominent gorgonians, also called ‘red forest’ or ‘bushes’ were excluded. We declined the use of questionnaires since our experience is that very few answer and we used our network of known fishermen along the coast instead.

ROV-inspections

Five locations were visited to verify the information provided by the fishermen. In 1999 we used the University of Bergen’s ROV ‘Aglantha’ with video camera operated on board RV ‘Johan Hjort’ (IMR). In 1998 we used the ROV ‘Solo’ (equipped with side scan sonar) on board SV ‘Seaway Surveyor’ and 1999 a Triton-ROV on board SV ‘Geograf’. These two vessels, which are equipped with multibeam echosounders were used to check information from fishermen on damages to coral reefs. With these two vessels we could work differently than with the simpler ‘Aglantha’-system. We chose first an arbitrary section in a reported area. We then used data from the multibeam echosounder to produce a topographical map with a vertical resolution of 0.5 m. Finally,

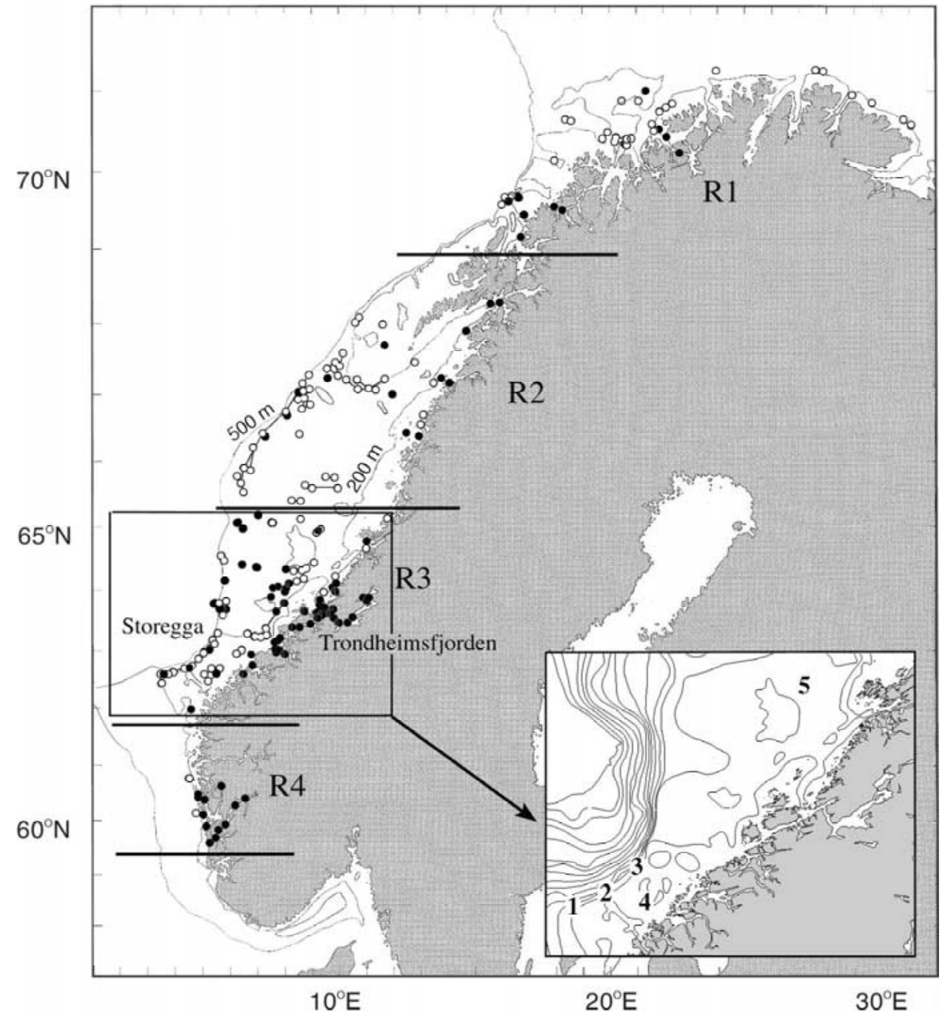

Figure 1. The distribution of *Lophelia* corals in Norwegian waters. The black circles represents records from the literature or verified records of *Lophelia*. Grey circles represent non-verified information from fishermen. Four regions R1–R4 are defined and used for estimates of areas (see Table 3). Framed areas to the left and right show ROV-inspected localities: (1) Aktivneset, (2) Korallneset, (3) Sørmannsneset, (4) Maurdjupet and (5) Iverryggen.

the area was visually inspected with the ROV-cameras. The side scan sonar was used to document trawl tracks. Dead coral fragments lying on the slopes of reefs are commonly seen as they are part of the natural process of decay in coral reefs (Wilson, 1979; Mortensen, 2000). Therefore, in order to distinguish natural decay from impacts by human activities, such as bottom trawling, we looked for broken living colonies tilted, turned upside down and/or in unexpected/awkward positions on levelled sea bottom. The remains of fishing gear such as gillnets, anchors, and trawl nets among corals added to the evidence while furrows or scars in the sea bottom are unmistakable evidence of trawling activity (see e.g. Lindeboom & de Groot, 1998).

Size estimation of coral areas

Estimation of the size of coral areas was done on charts with a scale of 1:500 000. Single point records were assumed to represent a normal sized reef of about 200 m in diameter (Mortensen et al., 1995). Area indicated by lines or stretches between two co-ordinates were calculated using two alternative widths: 200 and 500 m, which represent an estimation of the extent of the bottom surface affected by a trawl. The choice of the widths are based on the following assumptions: the trawls used in these areas are around 100 m between the trawl doors and have 30–40 m wide gear (Dag M. Furevik, unpublished information). In a frequently trawled area, however, the surface area affected will

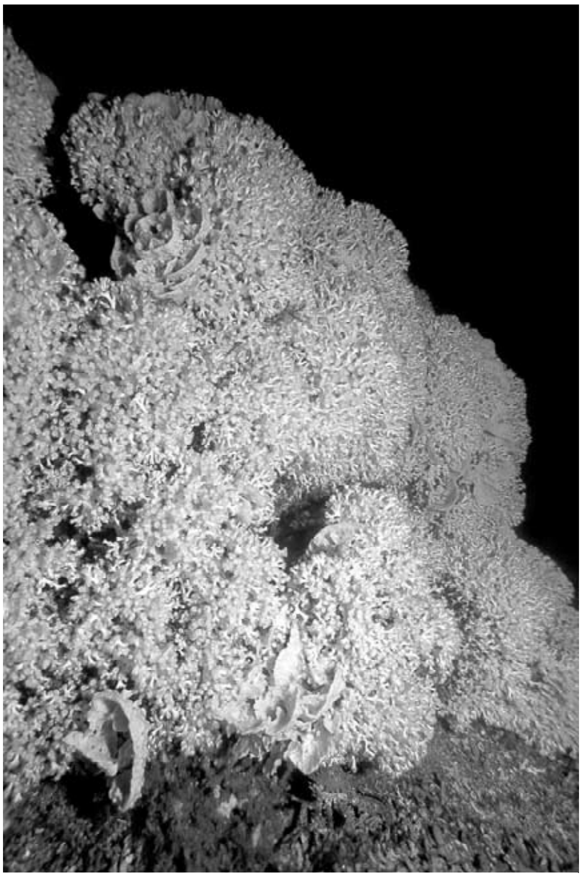

Figure 2. Lophelia pertusa colonies at 40 m depth on the Tautra ridge in Trondheimsfjorden, Norway. This reef is protected by the 8 June 2000 statute with status as a marine nature reserve on an interim basis. Photo by Erling Svensen.

probably be much larger than the chosen 200 and 500 m, and in some cases exceed 500 m. We believe that our size estimates are thus conservative. Lastly, a coral area is a section of the bottom defined by several co-ordinates. However, an area is rarely entirely covered by corals or reefs, but they are scattered on elevations, ridges and iceberg plough marks.

Results

Occurrence of corals

In total we present 407 records of corals determined by 583 geographical points of colonial scleractinians. Records of *Lophelia pertusa* from the literature (n = 95), Statoil (n = 70), NDF (n = 29) and IMR (n = 55) are considered as verified information, while records from fishermen (n = 158) at sites not checked by us as non-verified (Table 1, Fig. 1).

The presence of corals mentioned in the literature are restricted to the fjords and near coastal waters because earlier research had limited access to sea going vessels. Dons (1944) had only two records from the shelf break in mid-Norway (between 63° and 68° N) and four from Northern Norway on the basis of information from fishermen. The records from the continental break derived mainly from fishery-related activities, NDF and IMR. Statoil provided information for the shelf Southwest of Haltenbanken (Hovland et al., 1997; Mortensen et al., 2001.) IMR provided information from trawling activities scattered on the shelf and continental break.

Corals are most abundant on the continental shelf in mid-Norway at 200-400 m depth (Fig. 1). The largest densities occur along the continental break and on edges of shelf-crossing trenches. A photo of a well-developed reef from Trondheimsfjorden is given in Figure 2.

Inspected localities

Many reports on coral occurrences as well as damage originate from Storegga, a steep part of the continental break between 62° 30′ N and 63° 50′ N (Fig. 1). Three localities on Storegga were inspected between 1998 and 1999: Aktivneset, Korallneset and Sørmannsneset. During 1999 two localities were inspected on the shelf: Maurdjupet and Iverryggen (Table 2, Fig. 1). All these localities and surrounding areas are subject to extensive bottom trawling.

Sørmannsneset

Fishermen reported areas with severely damaged corals, especially at the shallowest depth (200 m) (Fig. 3). There are also claims of increased bottom depth in a number of areas, (detected in the echograms) as a consequence of reefs being ‘trawled away’. Some refer to specific locations with abundant coral reefs that have disappeared by now, others state that corals were present until 1992–93. Sørmannsneset had been considered a good fishing place for tusk and ling with passive gear 10–12 years ago. Thus, the general impression is that coral reefs have decreased significantly in this area. We performed two inspections with ROV in 1998 at Sørmannsneset covering a vertical range from 370 to 225 m and distances between 2.5 and 2.9 km (Fig. 3, Table 2). The observations confirmed that the most severe damage occurred at shallowest depths (200 m) as crushed remains of *Lophelia* skeleton were spread over the area while living corals were

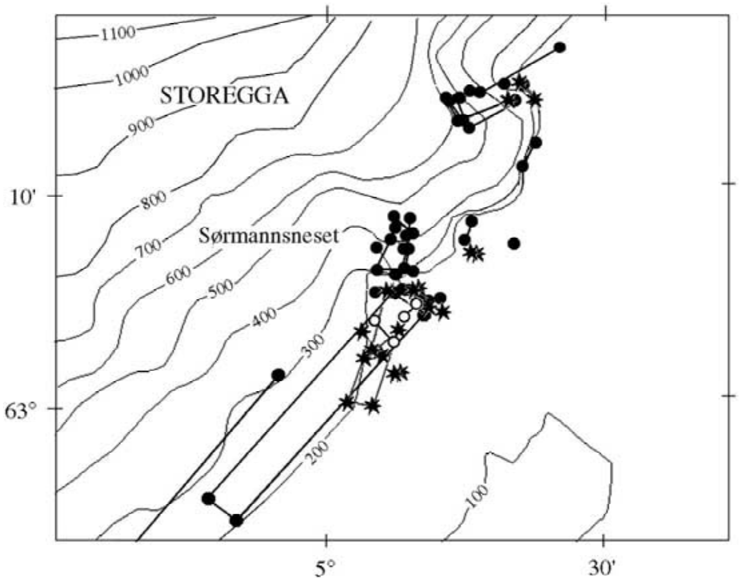

Figure 3. Sørmannsneset on Storegga shelf break. Filled circles; presence of corals; stars; damaged corals reported by fishermen; open circles; ROV inspections.

rarely found (Fig. 4). We encountered many signs of human activity: lost gillnets, an anchor, wires, a buoy, and remains of a trawl net entangled with corals. In addition, sonargrams from the side scan sonar detected furrows penetrating into areas of damaged corals (Fig. 5). We interpret these furrows as caused by trawl doors or other parts of a trawl gear cutting through the surface of the bottom. On the other hand, well-developed, seemingly intact, coral reefs were observed in the deepest parts although they were not abundant.

Korallneset

Korallneset used to be a good coral locality, but heavy trawling has reduced the corals considerably, the fishermen claim. However, they also report a number of areas with undamaged corals. At Korallneset nearly 2.6 km of the sea bottom was inspected between 305 and 205 m depth. Almost all corals observed were crushed or dead.

Aktivneset

Aktivneset is subject to heavy trawling and fishermen report damaged reefs in the shallow parts although many corals are still undisturbed. One fisherman claims he has detected large coral reefs on the echosounder.

The ROV inspection showed this location to be very rich in corals all along the 7 km ROV transect between 350 and 270 m depth. The reefs were neither large nor high, but smaller colonies covered significant areas. However, damage was evident as well as signs of human activity such as a rubber boot, ghostfishing gillnets and furrows in the bottom sediments.

Maurdjupet

Similar report as from Korallneset: an area previously considered a good fishing ground, but that has been 'cleaned for corals' due to heavy trawling activity. Damage is severe, especially on the slopes of a smaller basin or depression in the shelf. The video inspection on mounds in the basin showed intact coral reefs in considerable quantities. The trawled area on the slope and on the flats around the basin was not inspected because the ROV broke down, so fisherman reports could not be checked.

Iverryggen

We repeatedly received alarming information from fishermen claiming that extensive areas with prominent coral reefs had disappeared after heavy trawling activity. They affirmed that these reefs were notably well developed on a slope rising from a plain at approximately 300 m depth to 134 m. Five inspections revealed severe damage to colonies of *Lophelia* and other corals such as gorgonians (Figs. 6–8). Every inspection verified damage to corals that exhibited all stages of degradation, e.g., from almost intact living coral colonies to completely crushed reefs. The packed dead coral fragments forming the base of nat-

Table 1. Overview of the contribution from the different sources of information

Source	Status of reefs	R1	R2	R3	R4	Sum
Total number of fishermen*		8	12	19	1	31
Fishermen	Damaged areas	4	10	51	–	65
"	Intact corals	6	7	27	1	41
"	Status unknown	6	11	32	–	49
Charts	Unknown	3	–	–	–	3
Directorate of Fisheries (dredge)	Unknown	–	–	29	–	29
IMR (trawl)	Unknown	–	11	11	–	22
Statoil (ROV and multibeam)	Intact	–	–	70	–	70
Scientific literature (see Methods)	Different	14	7	59	15	95
IMR (ROV inspections)	Damaged areas	–	2	9	–	11
IMR (ROV inspections)	Intact corals	–	–	18	4	22

*Some fishermen informed about damaged areas as well as intact reefs in different regions and are counted in several columns.The correct number of fishermen is 31. IMR: Institute of Marine Research). R1–R4 refer to the regions defined in Figure 1.

Table 2. ROV inspections on the Norwegian continental shelf and break in 1998–99 (see also Figure 1)

Locality	Date	Depth (m)	Dist (km)	Start N	Start E	Stop N	Stop E
Sørmannsneset	16 May 98	345–260	2.5	63° 04.90′,	05° 11.00′	63° 03.70′,	05° 09.60′
"	"	370–225	2.9	63° 04.50′,	05° 05.50′	63° 03.20′,	05° 07.50′
Aktivneset	26 April 99	350–270	7.0	62° 37.80′,	03° 31.25′	62° 34.25′,	03° 34.00′
Korallneset	27 April 99	305–205	2.2	62° 41.45′,	04° 03.80′	62° 40.25′,	04° 03.75′
Maurdjupet	"	280	–	62° 36.17′,	05° 10.02′		
Iverryggen	17 May 99	199–170	0.6	64° 56.65′,	09° 06.75′	64° 56.98′,	09° 06.73′
"	"	180–170	0.2	64° 57.10′,	09° 07.88′	64° 57.22′,	09° 07.95′
"	"	200–191	0.3	64° 57.63′,	09° 08.64′	64° 57.62′,	09° 09.00′
"	"	203–195	0.1	64° 58.25′,	09° 10.57′	64° 58.20′,	09° 10.71′
"	"	259–231	2.0	65° 04.34′,	09° 15.78′	65° 05.17′,	09° 17.37′

The depth range covered, and the positions at start and stop. In the locality Iverryggen the distance between start and stop might be longer than given because the ROV did not follow a straigth course.

ural *Lophelia* reefs also seemed to be crushed and spread around (Fig. 6).

At Iverryggen damage due to passive gear was confirmed as well, as indicated by the presence of lost gillnets (Fig. 8). The nets and the anchor-ropes may sometimes severely disturb the corals by breaking down and tilting parts of the colonies. This impact is not uncommon in other coral grounds as well.

Table 3. Estimates of total area of corals and estimated damaged areas (km^2)

Region	Total area	Damaged area	Damaged area as %
R1	222–237	30–40	15–17
R2	590–702	176–242	30–35
R3	715–875	356–456	50–52
R4	0.5–1	<0.3	5

R1–R4 refer to the regions defined in Figure 1.

Estimation of coral areas and damaged areas

Table 3 shows estimates of areas with corals in Norwegian waters. The range of estimates derived from the use of minimum and maximum widths (200 and 500 m, respectively) in the calculation of stretch areas between two points.

The four regions defined, R1-R4, have different sizes, the two northern regions (R1 and R2) being the largest and the two southern (R3 and R4) the smaller ones. The northern- and southernmost have fewest coral areas. Of R2 and R3 it is R3 that has the largest area of corals and because R3 is smaller than R2 it also has the highest density of corals. The percentage of

Figure 4. Video photograph from Sørmannsneset at the Norwegian continental break, 220 m depth (16 May 1998), showing a barren landscape with crushed remains of *Lophelia* skeleton spread over the area. This is a region subject to considerable bottom trawling. A track can be seen stretching from bottom-left to up-right of the photograph, indicating the path of a trawl.

damaged coral reef areas varies between 5% (R4) and 52% (R3) (Table 3). There is a connection between the size of the coral areas, the number of reporting fishermen in all regions and the extent of the damage, i.e., the more reports from fishermen, the more corals in the region and higher the percentage of damaged corals (Tables 1 and 3).

Discussion

Methods

We have relied heavily on fishermen reports, as they were the only source of information on the largest coral areas. It is thus crucial that the fishermen distinguish between *Lophelia*, which they call 'glass corals' or 'white corals' and other corals such as gorgonians, which they report as 'red forest' and 'bushes'. The chances of confusion between *Lophelia*, *Madrepora* and stylasterid hydrozoans was considered minimal as *Madrepora* and stylasterids don't build reefs and are by far not as abundant as *Lophelia* (Dons, 1944; Frederiksen et al., 1992; Mortensen et al., 1995). All ROV-inspections confirmed that the localities pointed out contained *Lophelia* corals, intact or damaged. We therefore conclude that fisherman's reports are a reliable source of information and also have been of great value for the estimation of coral areas.

The estimation of the size of intact and damaged areas are based on points, lines (stretches) and areas as reported by fishermen. The estimation of areas from lines between co-ordinates were based on an assumed range of width of the trawl ground, and introduced thus, an uncertainty. However, as the number of reported stretches comprised a small fraction compared to the number of points and areas, the total estimates exhibited a moderate range (Table 3) and do not affect the main conclusions. Since the methodology used for the estimation of total coral area and damaged area is the same, the estimates are comparable, i.e., the bias is systematic.

Distribution of corals

In general the corals occur on substrate of morainic origin (Hovland & Mortensen, 1999; Mortensen, 2000) and the largest densities are found along the continental break and edges of trenches crossing the shelf. Very few records are from levelled parts of the shelf.

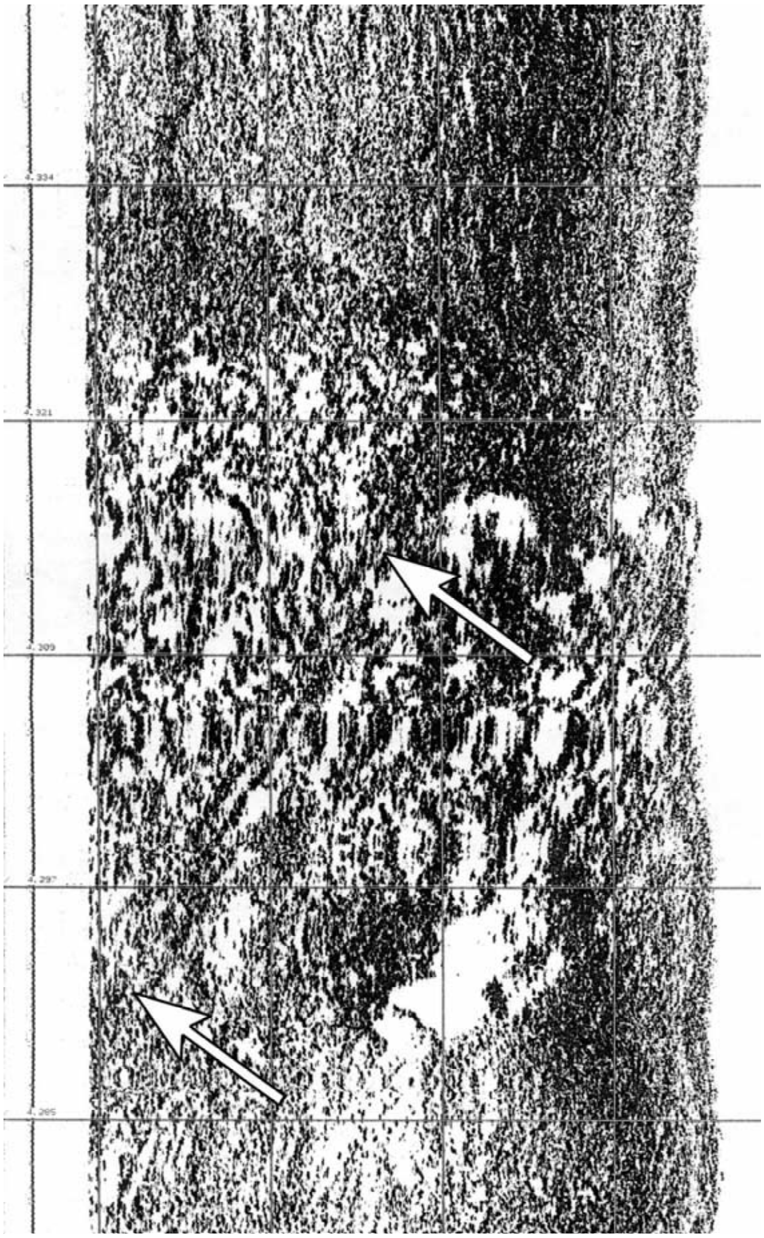

Figure 5. Sonargram from a side scan sonar mounted on the ROV 'Solo'. The arrows indicate a trawl track penetrating a coral area (confirmed by video-inspection). Sørmannsneset 16 May 1998.

The largest density of colonies was found in R3. The reason for this is not obvious, but there might be a connection with the distribution of North Atlantic Water (NAW). This water mass meets the Norwegian continental break at Storegga (Hansen & Østerhus, 2000). Here, the current splits in two on its way northwards: one core borders the continental break while the other flows closer to land. The two main concentrations of corals, along the edge and on the banks south of Haltenbanken, are located in the midst of the NAW branches. However, the circulation pattern on the shelf in mid Norway is complex with several eddies and areas of retention basically governed by the bottom topography (see Sætre, 1999). As long as not all records reported by the fishermen are confirmed it is premature to further elaborate on this.

R1 and R4 exhibited the lowest occurrences of corals. This can indicate that *Lophelia* might be closer

Figure 6. Fragments and larger pieces of dead *Lophelia pertusa* from a trawling ground near Iverryggen on the Norwegian continental shelf at 190 m depth, 17 May 1999. The bottom substrate is apparently severely disturbed.

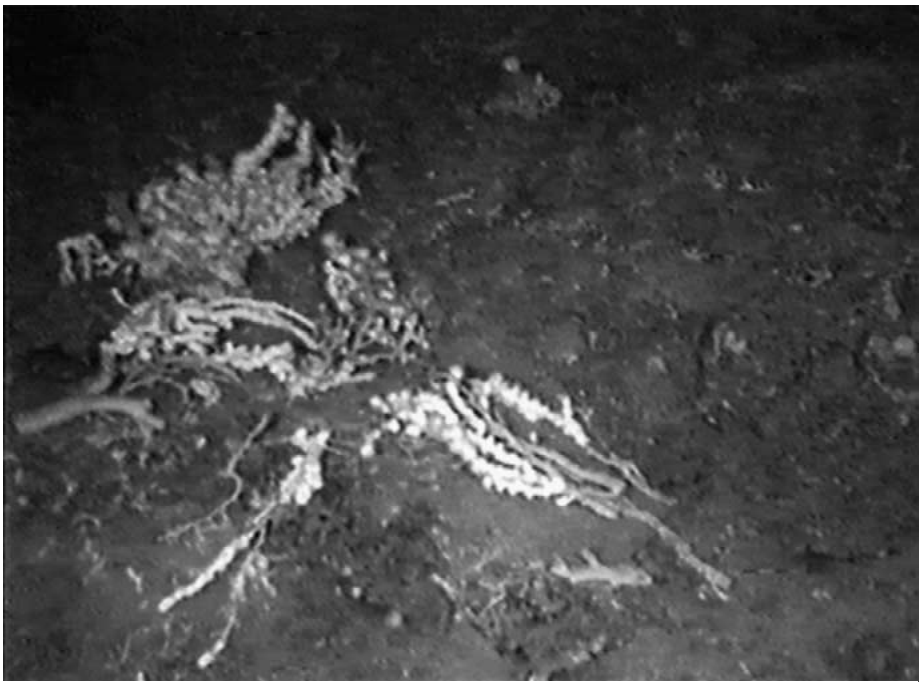

Figure 7. Gorgonians torn apart in an area with damaged *Lophelia pertusa* near Iverryggen at 200 m depth, 17 May 1999. The damage is probably recent since some of the branches are still living.

Figure 8. Two ropes belonging to a gillnet are seen in the lower part of the picture. *Lophelia pertusa* reefs are also damaged and torn apart by passive fishing gear such as anchored longlines and gillnets. Iverryggen 17 May 1999 at 200 m depth.

to its northern limit in R1 while the continental shelf is narrow and therefore provides less area of suitable substrate in R4. The link between the number of reports of coral areas by fishermen and the distribution of coral reefs and good fishing grounds is clear.

Damaged areas

Damaged corals were present in all inspected localities except for Maurdjupet. It has been impossible to perform direct quantitative observations of how much of a reef or reef area has been impacted or destroyed. For instance, on the shallowest part of Sørmannsneset where only fragments of dead *Lophelia* spread around without evidence of living colonies in the surroundings were observed (Fig. 4), one can safely conclude that the colonies have been wiped out. Otherwise, the extent of the damage given here is the best possible estimate allowed by the methodology. The few reports on damage in R4 probably reflects the low number of reefs, most of them localised in the fjords where trawling is forbidden. Because of the inherent limitations of the methodology, the present estimates of total coral areas are to be considered as preliminary and should be confirmed by future surveys. Still, this paper presents the first indication of the scale of the problem. It has been important to express the extent of impact from trawling to the fishermen and authorities in an understandable way. Based on the results in Table 3 we therefore conclude that the damage of coral reefs in Norway amounts to between 30 and 50% of the total area.

Impact on coral populations

Increased mortality is the most obvious effect from mechanical impact by for instance bottom trawling. The corals are crushed or buried, and wounds in the tissue and possible microbial infection may also reduce the health of the corals. It is not possible to evaluate the impact that destroyed reefs on the shelf have on coral populations. On a scale from intact to extinct there may be a point below which corals will not be able to maintain populations. The effect will also depend on the reproduction potential, but at present very little is known about the sexual reproduction of the species (Rogers, 1999). It is reasonable to assume that they have a planktonic larva similar to their tropical counterparts (Fadlallah, 1983). Evidence of this is found in the North Sea, where corals have colonised submerged components of oil rigs, far away from known locations of colonies (Bell & Smith, 1999). A long-lived planktonic larva may facilitate recolonisation of damaged coral areas.

Bottom trawling also increases resuspension of bottom sediment and release of nutrients near the bottom (Piskaln et al., 1998; Watling & Norse, 1998). On a world-wide scale siltation is one of the largest sources of degradation of coral reefs (Norse, 1993) and may suppress growth rates of adult colonies (Cortés & Risk, 1985). Siltation or sand deposition due to bottom trawling may have a negative effect on *Lophelia* corals. Roberts & Anderson (2000), studying *Lophelia* in an aquarium, have indications that sand deposition can reduce the level of polyp extension. However, Riegl (1995) shows that scleractinian corals actively clean sand from the surface and conclude that the corals are capable of coping with considerable amounts of sand deposition and that declining reef health in sedimented areas may also be due to additional environmental stress.

Ecological consequences

Species diversity is about three times higher on *Lophelia* reefs compared to the surrounding soft-bottoms (UK Biodiversity Group, 2000), thus confirming the general positive relation between habitat complexity and species diversity in the marine environment (Huston, 1994). This implies that the reefs on the shelf and fishing banks represent patches of high diversity in an environment of low diversity. Anthropogenic degradation of a significant part of the *Lophelia* reefs may thus dramatically change the distribution of species diversity along the whole shelf and slope.

It is hypothesised that reefs may function as centres of spreading for associated fauna. Although the fauna associated with the reefs is rich we have no examples of species that are obligate reef dwellers. The reef habitat may nevertheless play an important role for species such as *Munidopsis serricornis* (Lovén, 1852), *Ophiacantha* spp. and *Eunice* spp. which all exhibit high abundances on the reefs, but are seldom found in other Norwegian habitats (Fosså & Mortensen, 2000). If the reefs containing core populations of such species disappear the species may have difficulties in either spreading or sustaining their own populations.

Video inspections showed dense aggregations of redfish (*Sebastes* spp.) on the reefs, which in May–June, were dominated by gravid females with distended bellies (unpublished information). Furevik et al. (1999) reports that long-line catches of *Sebastes* spp. may be six times higher, and for ling and tusk two to three times higher, on the reefs compared to non-reefs areas. This give support to fishermen's reports that the reefs are attractive fishing places and that their disappearance influences the fish distribution in the area. However, these assertions are still to be confirmed, e.g., we know very little about how important *Lophelia* is for the fish.

The *Lophelia* corallites grow 5–10 mm per year (Mortensen & Rapp, 1998) and the growth rate of a *Lophelia* reef is estimated to be 1.3 mm per year (Mortensen, 2000). Consequently, it will take hundreds of years for a colony to reach a diameter of 1.5–2 m while it will take thousands of years to build a reef structure 10–30 m thick. Thus, it will take a long time for the reefs to recover and for the restitution of their ecological function, if at all.

Conclusions

- According to verified records *Lophelia pertusa* is distributed along the Norwegian coast between 59° 34.4′ N, 05° 11.6′ E and 71° 02.0′, 21° 20.0′ E, mostly between 200 and 400 m depth.
- *Lophelia* is particularly abundant on the continental shelf between 62° 30′ N and 65° 30′ N and on the shelf break between 62° 30′ N and 63° 50′ N (locality: Storegga)
- Damages to *Lophelia* reefs in the continental shelf and break caused by bottom trawling have been documented for the first time. It is estimated that between 30 and 50% of *Lophelia* reefs are either impacted or destroyed by trawling
- Passive gear like long-lines and gillnets anchored on the bottom also impact the coral reefs, but to a considerably lower extent than trawling

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References

Anon, 1991–1999. Retrieval of lost gillnets. Ann. Rep. norw. Dir. Fish. (in Norwegian).

Bell, N. & J. Smith, 1999. Coral growing on North Sea oil rigs. Nature 402: 601.

Breeze, H., D. S. Davis, M. Butler & V. Kostylev, 1997. Distribution and status of deep-sea corals off Nova Scotia. Mar. Iss. Comm. Spec. Publ. No 1. Ecology Action Centre. Halifax, Canada.

Cairns, S. D., 1994. Scleractinia of the Temperate North Pacific. Smiths. Contrib. Zool. 557. 150 pp.

Cortes, J. & M. R. Risk, 1985. A reef under siltation stress: Cahuita, Costa Rica. Bull mar. Sci. 36: 339–356.

Dons, C., 1944. Norges korallrev. K. Nor. Vidensk. Selsk. Forh. 16: 37–82.

Fadlallah, Y. H., 1983. Sexual reproduction, development and larval biology in scleractinian corals. Coral Reefs 2: 129–150.

Fernandez Pulpeiro, E., C. Besteiro & F. Ramil, 1988. Sublittoral bryozoans of the Norwegian Sea. Thalassas 6: 23–27.

Fosså, J. H. & P. B. Mortensen, 1998. Artsmangfoldet på *Lophelia*-korallrev og metoder for kartlegging og overvåkning (Diversity of species associated with *Lophelia* coral reefs and methods for mapping and monitoring) (in Norwegian with abstract and legends to tables and figures in English). Fisken og Havet No 17. 95 pp.

Fosså, J. H., P. B. Mortensen & D. M. Furevik, 2000. *Lophelia*-korallrev langs norskekysten. Forekomst og tilstand (*Lophelia* coral reefs in Norway. Distribution and effects of fishing) (in Norwegian with abstract and legends to tables and figures in English). Fisken og Havet No 2. 94 pp.

Frederiksen, R., A. Jensen & H. Westerberg, 1992. The distribution of the scleractinian coral *Lophelia pertusa* around the Faroe islands and the relation to internal mixing. Sarsia 77: 157–171.

Freiwald, A., 1998. Geobiology of *Lophelia pertusa* (Scleractinia) reefs in the north Atlantic. Habilitation thesis, Univ. Bremen, 116 pp.

Furevik, D. M., L. Nøttestad, J. H. Fosså, Å. Husebø & S. B. Jørgensen, 1999. Fiskefordeling i og utenfor korallområder på Storegga (Fish distribution on and off coral reefs at Storegga) (in Norwegian with abstract and legends to tables and figures in English). Fisken og Havet No 15. 33 pp.

Hall, S. J., 1999. The effects of fishing on marine ecosystems and communities. Fish Biol. Aqua. Res. Ser. 1. 274 pp.

Hansen, B., & S. Østerhus, 2000. North Atlantic-Nordic Seas exchanges. Prog. Oceanog. 45: 109–208

Hovland, M., & P. B. Mortensen, 1999. Norske korallrev og prosesser i havbunnen. John Grieg forlag, Bergen. 155 pp.

Hovland, M., P. B. Mortensen, E. Thomsen & T. Brattegard, 1997. Substratum-related ahermatypic corals on the Norwegian continental shelf. Proc. 8th. Int. Coral Reef Symp. Vol. 2, Panama 1996, 1203–1206.

Huston, M. A., 1994. Biological Diversity. The Coexisistence of Species on Changing Landscapes. Cambridge University Press, Cambridge, 681 pp.

Jennings, S., & M. J. Kaiser, 1998. The effects of fishing on marine ecosystems. Adv. Mar. Biol. 34: 201–352.

Lindeboom, H. J. & S. J. de Groot (eds), 1998. IMPACT-II. The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. Neth. Inst. Sea Res., rep. 1998–1.

Mortensen, P. B., 2000. *Lophelia pertusa* (Scleractinia) in Norwegian waters. Distribution, growth, and associated fauna. Dr. scient. thesis, Univ. Bergen.

Mortensen, P. B. & H. T. Rapp, 1998. Oxygen- and carbon isotope ratios related to growth line patterns in skeletons of *Lophelia pertusa* (L) (Anthozoa: Scleractinia): Implications for determination of linear extension rates. Sarsia 83: 433–446.

Mortensen, P. B., M. Hovland, T. Brattegard & R. Farestveit, 1995. Deep water bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64° N on the Norwegian shelf: structure and associated megafauna. Sarsia 80: 145–158.

Mortensen, P. B., M. Hovland, J. H. Fosså & D.M. Furevik, 2001. Distribution, abundance and size of *Lophelia pertusa* coral reefs in mid-Norway in relation to seabed characteristics. J. mar. biol. Ass. U.K. 81: 581–597.

Norse, E. A., 1993. Global marine biological diversity. A strategy for building conservation into decision making. Island Press, Washington DC, 383 pp.

Piskaln, C. H., J. H. Churchill & L. M. Mayer, 1998. Resuspension of sediment by bottom trawling in the Gulf of Maine and potential geochemical consequences. Cons. Biol. 12: 1223–1229.

Rapp, H. T. & J. A. Sneli, 1999. *Lophelia pertusa* – myths and reality (abstract only). 2nd Nord. Mar. Sci. Meet., Hirtshals, Denmark, 2–4 March 1999.

Reaka-Kudla, M.L., 1997. The global biodiversity of coral reefs: a comparison with rain forest. In Reaka-Kudla, M. L., D. E. Wilson & E. O. Wilson (eds). Biodiversity II. Understanding and Protecting Biological Resources: 83–108.

Riegl, B., 1995. Effects of sand deposition on scleractinian and alcyonacean corals. Mar. Biol. 121: 517–526.

Roberts, J. M. & R. Anderson, 2000. Laboratory studies of *Lophelia pertusa* — preliminary studies of polyp behaviour. Poster 9th Deep Sea Biology Symposium. Galway, Ireland, 25–30 June 2000.

Rogers, A. D., 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Int. Rev. Hydrobiol. 84: 315–406.

Squires, D. F., 1959. Deep sea corals collected by the Lamont Geological Observatory. 1. Atlantic corals. Am. Mus. Nov. 1965: 1–42.

Strømgren, T., 1971. Vertical and horizonthal distribution of *Lophelia pertusa* (Linne) in Trondheimsfjorden on the west coast of Norway. K. Nor. Vidensk. Selsk. Skr. 6: 1–9.

Sætre, R., 1999. Features of the central Norwegian shelf circulation. Cont. Shelf Res. 19: 1809–1831.

UK Biodiversity Group, 2000. Tranche 2 Action Plans. Volume V – Maritime Species and Habitats. Peterborough, English Nature.

Watling, L. & E. A. Norse, 1998. Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting. Cons. Biol. 12: 1180–1197.

Wilson, J. B., 1979. 'Patch' development of the deep-water coral *Lophelia pertusa* (L.) on Rockall bank. J. mar. biol. Ass. U.K. 59: 165–177.

Zibrowius, H., 1980. Les Scléractiniaires de la Méditerranée et de l'Atlantique nord-oriental. Mem. Inst. Oceanog. No 11, 226 pp.