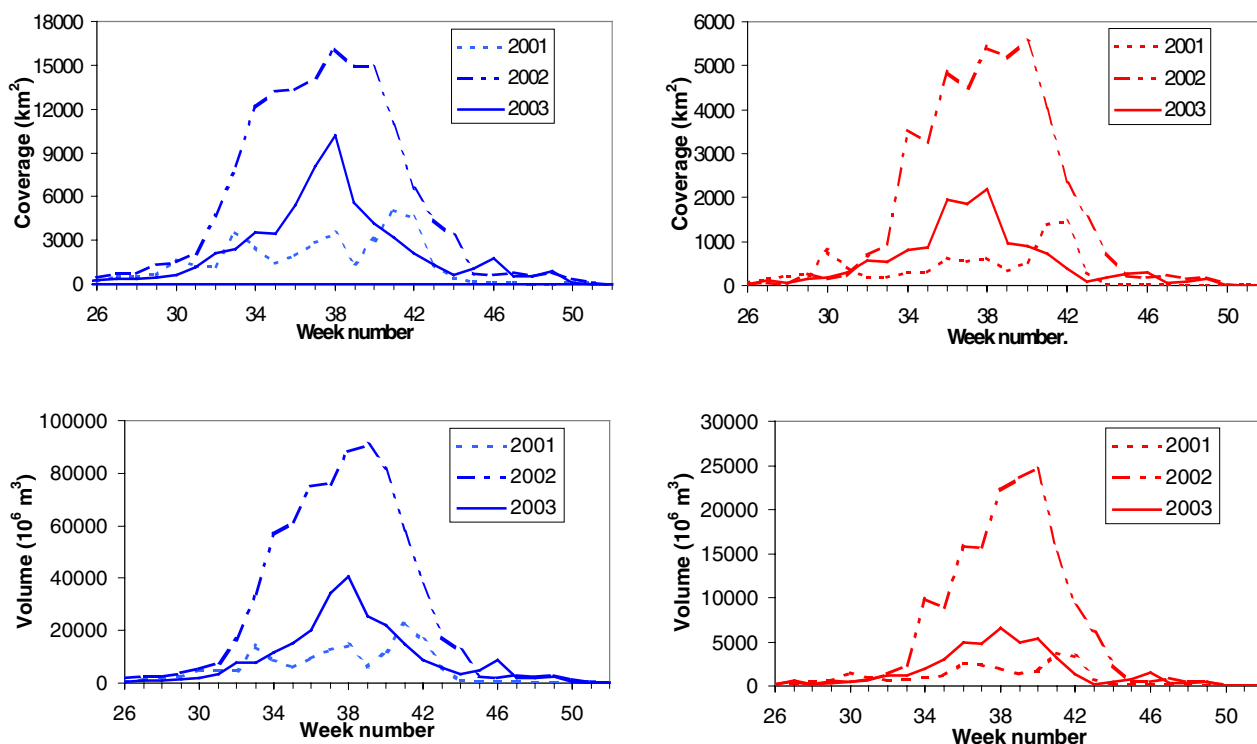


## Oxygen depletion in Danish waters in 2003

The development and decline of areas and water volumes affected by oxygen depletion ( $< 4 \text{ mg l}^{-1}$ ) and severe oxygen depletion ( $< 2 \text{ mg l}^{-1}$ ) was analysed week by week through the last half of 2003, and compared to 2001 and 2002 (Figure 1). The analysis is based on profiles of oxygen concentrations measured by national and regional authorities in Denmark, Germany and Sweden in the Kattegat, the Sound, the Belt Sea and the western Arkona Sea with associated estuaries and bights. The study area appears from Figure 2. The method used for the analysis is described in HELCOM (2003).

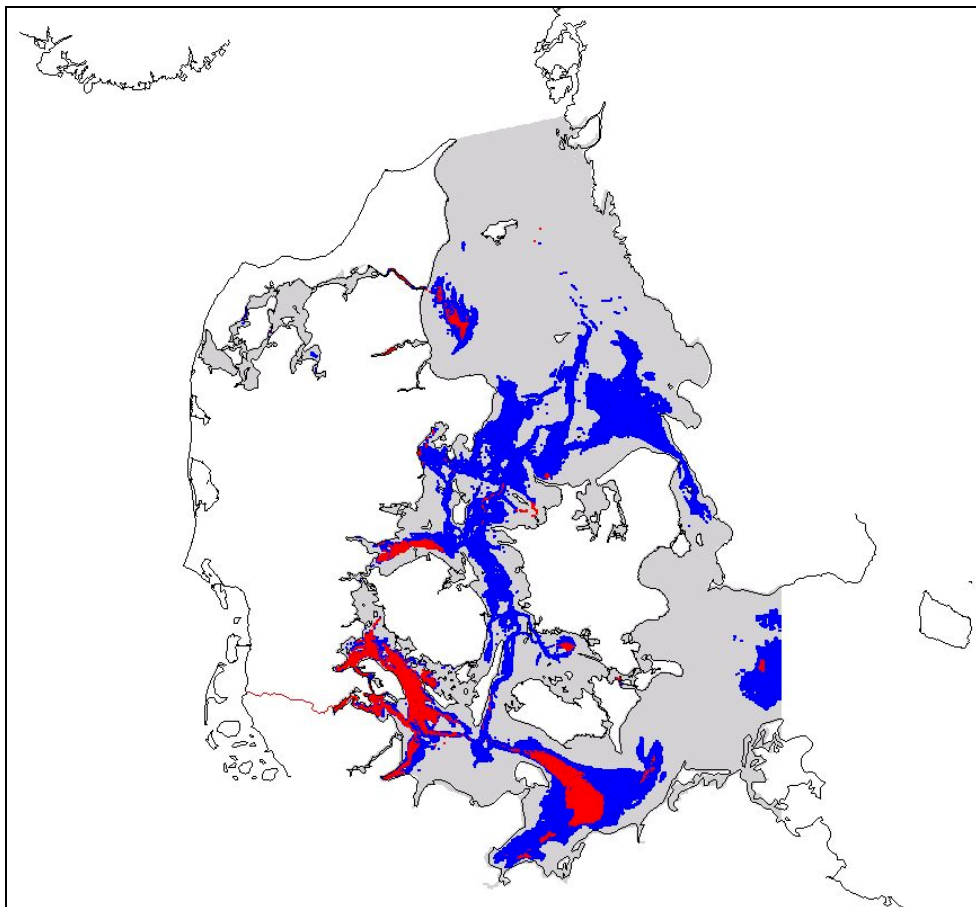


**Figure 1.** Area and volume impacted by oxygen depletion ( $< 4 \text{ mg l}^{-1}$ ) (left panel) and severe oxygen depletion ( $< 2 \text{ mg l}^{-1}$ ) (right panel) in 2001, 2002 and 2003. Includes the entire study area except the Arkona Basin.

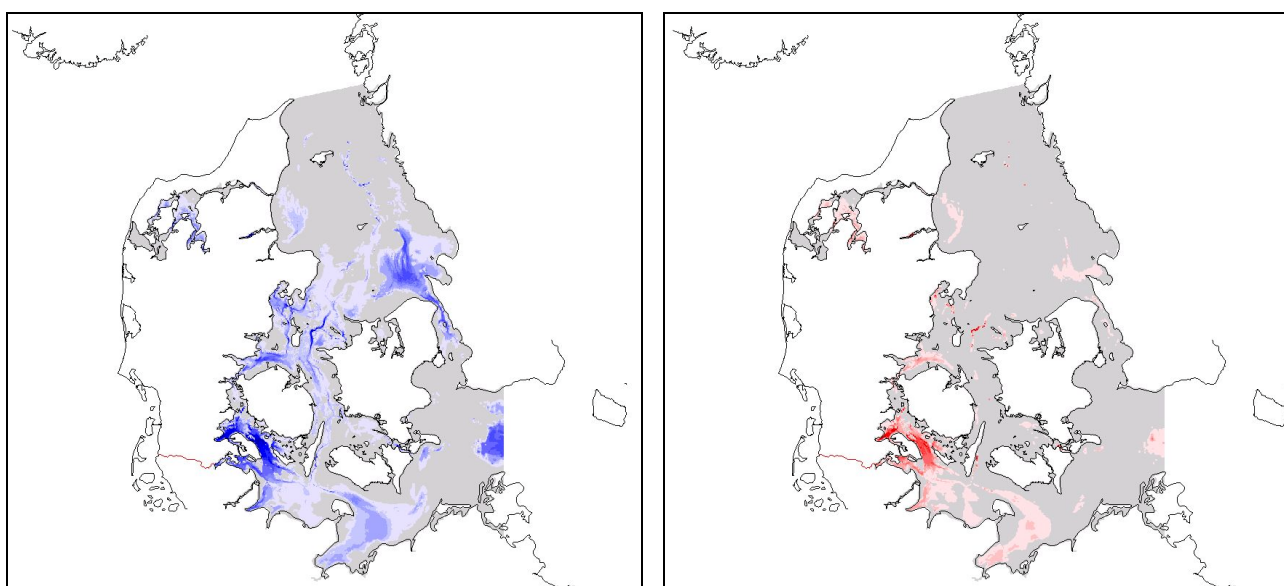
In 2003 oxygen depletion and severe oxygen depletion developed slowly through July (weeks 27-31) and August (weeks 32-35), comparably to the situation in 2001 (Figure 1). In September 2003 the development accelerated to a maximum coverage in week 38 (15-21 September), when oxygen depletion covered an area of ca.  $10,000 \text{ km}^2$ , and severe oxygen depletion ca.  $2,200 \text{ km}^2$  (Figure 2). The corresponding affected water volumes were ca.  $40 \text{ km}^3$  and ca.  $6.6 \text{ km}^3$ , respectively. The following week the area coverage of hypoxia declined rapidly, while the water volume affected by severe oxygen depletion did not decrease until week 41 (6-12 October). At the end of October (weeks 43-44) the hypoxia had been strongly reduced. However, both oxygen depletion and severe oxygen depletion prevailed in the southern Little Belt area until mid December. The persistence of the oxygen depletion and severe oxygen depletion in 2003 in different areas is shown in Figure 3.

The year 2001 can be considered as an average year with respect to hypoxia in the study area. The area coverage of oxygen depletion and severe oxygen depletion was in 2003 nearly 1.5 times the coverage in 2001, and thus more widespread than average (Figure 1, Table 1 and 2). However, it was far less widespread than in 2002, when the areas suffering from oxygen depletion and severe oxygen depletion covered more than 2 and more than 3 times the areas in 2001, respectively.

Besides, in 2002 the hypoxia escalated earlier and persisted at a high level for much longer time than in both 2001 and 2003. The 2002 hypoxia is the most serious recorded in Danish waters.



**Figure 2.** The most widespread hypoxia was in 2003 observed in week 38 (15-21 September). Oxygen depletion ( $< 4 \text{ mg l}^{-1}$ ) covered an area of ca.  $10,000 \text{ km}^2$ , with severe oxygen depletion covering ca.  $2,200 \text{ km}^2$ .



**Figure 3.** The length in weeks of bottom exposure to oxygen depletion ( $< 4 \text{ mg l}^{-1}$ ) (left map) and severe oxygen depletion ( $< 2 \text{ mg l}^{-1}$ ) (right map) in 2003. Intensive colours indicate long exposure to hypoxic conditions.



Regional assessment of areas impacted by hypoxia in 2003 shows that oxygen depletion was more widespread than in 2001 mainly in the southern Belt Sea, the Little Belt, the northern Belt Sea and the southern Kattegat but also in the Great Belt and the central Kattegat (Table 1). Severe oxygen depletion was more widespread mainly in the Little Belt and southern Belt Sea, but also in the Flensborg Fjord, the northern Belt Sea and the southern and central Kattegat (Table 2). In the Sound and the Limfjorden the 2003 hypoxia covered about the same areas as in 2001. In the northern Kattegat hypoxia is only very rarely recorded, but was in 2002.

**Table 1.** Total area and proportion affected by oxygen depletion ( $< 4 \text{ mg l}^{-1}$ ) for each region and the entire area (excluding the Arkona Sea) in 2001, 2002 and 2003.

Region	Total area (km <sup>2</sup> )	Oxygen depletion $< 4 \text{ mg l}^{-1}$		
		2001	2002	2003
Northern Kattegat	4405	2 (0%)	106 (2%)	16 (0%)
Limfjorden	1522	385 (25%)	377 (25%)	416 (27%)
Central Kattegat	8491	66 (1%)	1688 (20%)	674 (8%)
Southern Kattegat	9432	2386 (25%)	7012 (74%)	4123 (44%)
The Sound	1049	248 (24%)	443 (42%)	227 (22%)
Northern Belt Sea	4027	1421 (35%)	2596 (64%)	1827 (45%)
Great Belt	4012	653 (16%)	1740 (43%)	918 (23%)
Little Belt	3019	1103 (37%)	1641 (54%)	1350 (45%)
Flensborg Fjord	293	160 (55%)	162 (55%)	157 (54%)
Southern Belt Sea	7597	2970 (39%)	4820 (63%)	3993 (53%)
Total area	43847	9394 (21%)	20586 (47%)	13700 (31%)

**Table 2.** Total area and proportion affected by severe oxygen depletion ( $< 2 \text{ mg l}^{-1}$ ) for each region and the entire area (excluding the Arkona Sea) in 2001, 2002 and 2003.

Region	Total area (km <sup>2</sup> )	Severe oxygen depletion $< 2 \text{ mg l}^{-1}$		
		2001	2002	2003
Northern Kattegat	4405	0 (0%)	0 (0%)	0 (0%)
Limfjorden	1522	329 (22%)	251 (17%)	344 (23%)
Central Kattegat	8491	8 (0%)	524 (6%)	160 (2%)
Southern Kattegat	9432	93 (1%)	1360 (14%)	331 (4%)
The Sound	1049	3 (0%)	205 (20%)	15 (1%)
Northern Belt Sea	4027	220 (5%)	1208 (30%)	298 (7%)
Great Belt	4012	37 (1%)	965 (24%)	60 (1%)
Little Belt	3019	608 (20%)	1281 (42%)	979 (32%)
Flensborg Fjord	293	121 (41%)	138 (47%)	133 (45%)
Southern Belt Sea	7597	1491 (20%)	3241 (43%)	2024 (27%)
Total area	43847	2909 (7%)	9173 (21%)	4343 (10%)

## Conclusion

The hypoxia in 2003 was nearly 1.5 times more widespread than average (2001), but far less widespread than in 2002. The 2003 hypoxia was more widespread than usual in the Belt Sea and the southern Kattegat, with the southern Little Belt being most seriously affected. In the Sound and the Limfjorden the 2003 hypoxia covered about the same areas as in 2001.

## Reference

HELCOM 2003: The 2002 oxygen depletion event in the Kattegat, Belt Sea and Western Baltic. Balt. Sea Environ. Proc. No. 90, 64 pp.