



Development of dysoxia in Norwegian fjords during the 20th century: natural or anthropogenic causes?

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Several fjord basins along the Norwegian Skagerrak coast (NW Europe) are experiencing permanent or periodic dysoxia/anoxia. In order to develop retrospective tools for interpreting changes in bottom-water oxygen conditions beyond instrumental records, eight fjords with established time series of oxygen measurements have been studied. Correlations of instrumental data and fossil records showed that the benthic foraminiferal fauna and the dissolved [O₂] in the bottom-water masses correspond, and proxy records of the oxygen content have been established from before the instrumental measurements began. The fossil records in all investigated fjords show a dominance of calcareous foraminifera. A development towards assemblages dominated by *Stainforthia fusiformis* occurs at different times in different fjords during the 20th century. In two of the investigated fjords (Ærøydypet, Langesundsfjord) no dysoxia occurred during the investigated time interval. The records in three fjords (Kragerøfjord, Sandnesfjord, and Topdalsfjord) show a change from well oxygenated conditions to oxygen depletion. Two other fjords (Håøyfjord, Goosefjord) display less favourable oxygen conditions during the first half of the 20th century, and the conditions are further worsened towards the end of the 20th century. The last fjord (Nordfjord) shows the most depleted oxygen conditions, and from the beginning of the 20th century it appears that this fjord was at least periodically anoxic.

The fjords without any apparent dysoxia, Ærøydypet and Langesundsfjord, do show an increase of *Stainforthia fusiformis* over the last 20 years indicating increased nutrient conditions. The increased supply of organic material has, however, still not affected the bottom-water [O₂]. The timing of the change strongly suggest a cultural eutrophication. In contrast the oxygen depletion observed in Goosefjord at the beginning of the 20th century correlates with historic records of increased of domestic

sewage to the fjord.

The remaining fjords show a change from good or less favourable oxygen conditions to oxygen depletion at different times during the 20th century. Whether or not the onset (pre 1950) deteriorating conditions in these fjords are due to natural or anthropogenic causes is still not clear. However, the marked increase in *Stainforthia fusiformis* during the early 1980's in all fjords (except those where it already dominated) suggest that the causes for deterioration are regionally, rather than locally induced.