

6 SUMMARY

A comprehensive description of hepatic EROD activities in the flatfish species dab (*Limanda limanda* L.) and flounder (*Platichthys flesus* L.) from the North Sea and several estuaries is presented. In 1991 and 1992, liver samples of approximately 5 000 fish were investigated. Dab were caught in the North Sea between 51° N and 58° N and flounder in the estuaries of the rivers Eider, Elbe, Weser, Scheldt (Western Scheldt), Thames, Tyne and the Firth of Forth. EROD activities are expressed as specific activity (ERODM: pmol resorufin · min⁻¹ · mg⁻¹ microsomal protein) and total activity (ERODL: nmol resorufin · min⁻¹ · g⁻¹ liver).

The aim of the study was to find out main pollution sites in the North Sea and gradients of pollution in estuaries by investigation of spatial distribution patterns of EROD activity. For this purpose, EROD activity was measured separately for adult males and females with a body length between 17,0 cm and 25,0 cm and for juvenile dabs (length ≤ 12 cm). On the basis of the results recommendations are given for further scientific investigations.

The investigations were partly carried out during the research project "Fish diseases in the North Sea". In the research project, concentrations of organochlorines in livers of dab and flounder have also been measured (see Landwüst et al. 1996). These results are taken into account in order to find out relationships between EROD activity and organochlorine contents in livers. The investigations carried out by the research project were in line with the recommendations of the North Sea Task Force (NSTF) and Joint Monitoring Group (JMG).

The results are as follows:

- In January (1991, 1992) temperature differences of about 5 °C between sampling sites in the North Sea had no influence on spatial distribution patterns of EROD activities of adult and juvenile dab.
- In August 1991, female dab from British coastal waters showed 2- to 20-fold higher EROD activities than dab caught along the Dutch and German coast. The distribution pattern of EROD activities showed a significant negative correlation with water temperature.
- In the North Sea the distribution patterns of EROD activities did not depend on salinity.
- The state of gonad development was determined macroscopically by histological signs according Maier (cit. in Bückmann 1929)
- In January (1991, 1992) sexually mature dab had developed gonads. In the western North Sea, gonads were not as ripe as in the German Bight. Presumably dab in German coastal waters spawn earlier in the year than those living on the British coast. Furthermore, some differences were detected between 1991 and 1992.
- In August 1991, dab with developed gonads were also caught to the north off the British coast. A prolonged or later spawning season is assumed compared with other areas.
- In estuaries, most of the flounder investigated were in post-spawning condition (resting time) during the period of investigation (March to July).

- In the Tyne estuary, flounder had ripe gonads in March 1992 and July 1991 already outside regular spawning season.
- For female dab and flounder, negative correlations were found between EROD activity and the size of their gonads. For males no correlation could be proved.
- 149 samples (dab and flounder of both sexes) have been checked for correlation between length (17 cm – 25 cm) and EROD activity. Enzyme activity showed a significant positive correlation with length at one site in the Firth of Forth in August 1991 (dab). Further, correlations were found at one station in the river Scheldt for both males and females (flounder). All together the results show that in samples of fish of a body length between 17 cm and 25 cm there is normally no length dependence. Nevertheless a statistical check is recommended.
- In winter and summer male dab showed higher EROD activities than females. In winter the medians were up to 60 fold higher. Therefore males and females should be investigated separately in winter.
- In January EROD activity in immature dab was markedly higher than in mature females.
- EROD activities were similar in immature dab and mature males.
- It is assumed that for juveniles of ≤ 12 cm body length no separation by sex is required.
- In estuaries, EROD activities in male flounder were up to 5 times higher than in females. Only in the river Elbe did most females have higher EROD activities than males.
- Great differences in EROD activities between males and females have been shown for the river Tyne. For females, an inhibition by sexual hormones has to be assumed because they had ripe gonads in March and July, respectively.
- On the basis of results given by other investigators great differences in enzyme activity have been shown for the German Bight. It is assumed that these variations are caused by changing influences of pollutants. It is concluded that the measurements are not comparable because of different methods used.
- Considering the whole North Sea area investigated in this study, remarkable differences between sampling sites have been shown for January and August. For both adult male dab and juveniles, the lowest and highest mean activities differed by an order of magnitude. Adult females showed greater variations.
- Considering all EROD medians of flounder caught in seven estuaries, the ERODM activity was between 50 and 400 $\text{pmol} \cdot \text{min}^{-1} \cdot \text{mg}^{-1}$ and the ERODL between 1 and 10 $\text{nmol} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$.
- Activities were high in males and females for the rivers Elbe and Tyne and low in the rivers Weser and Scheldt in 1991. In 1992 high activities were measured in flounder from the Elbe and Scheldt, low in Weser and Scheldt.
- In estuaries, the spatial distribution patterns of ERODM and ERODL median activities were comparable. The spatial distribution patterns of EROD median activities in males and females showed comparable gradients. The gradients differed between the years of investigation.

- By ranking of median EROD activities and PCB concentrations (see Landwüst et al. 1996) in female flounder the spatial distribution patterns could be compared directly. Corresponding distribution patterns were shown for 6 out of 8 data sets.
- Great differences in EROD activities between sampling sites have been shown along a transect between the mouth of river Eider and the North Friesian mudflats (Wadden Sea). It is assumed that the EROD activities in dab sampled far away from the coast were induced by pollutants transported with the plume of the river Elbe along the North Friesian coast.
- In the North Sea the spatial distribution patterns of EROD activities in adult male and juvenile dab showed significant correlations in both years of investigation. It is assumed that the patterns were caused by variations in pollution or pollution patterns, influencing CYP1A in males and juveniles in a comparable way.
- Further in January (1991, 1992) there were weak correlations between spatial distribution patterns of EROD activities in prespawning adult females, male and juveniles. It is suggested that in females even during spawning CYP1A was induced by pollutants like in males and juveniles, but to a lower extent.
- In January (1991 and 1992) highest enzyme inductions were measured in samples from the Ekofisk oilfield. Because oil rigs are point sources of considerable oil pollution for surrounding waters and sediments it is suggested that EROD activities were induced by oil.
- High enzyme activities have been measured in the eastern North Sea (German Bight and area between Denmark and the Dogger Bank) and on the Dogger Bank.
- A gradient of increasing EROD activities from south to north was typical for the eastern North Sea. In the central North Sea the activities increased from west to east. For explanation of the distribution patterns it is assumed that in these regions the biotransformation enzyme system of dab was induced by the river Elbe plume (eastern North Sea), by riverine inputs in the southern and western North Sea and atmospheric transport and deposition of pollutants far away from the coast.
- The spatial distribution patterns of EROD activities in male dab corresponded to the PCB content in their livers (January 1991, 1992 eight stations in complete).
- The spatial distribution patterns of EROD activities in gravid female dab showed no correspondence with the PCB content in their livers (January 1991, 1992 14 stations in complete).

Spatial distribution patterns of EROD activities have been investigated in the North and estuaries. It was assumed that the patterns were in correspondence with bioavailable pollutants. Considering the actual scientific knowledge about EROD activity in fish, the biomarker should only be investigated in biological monitoring programmes with additional baseline studies. They should contribute to a better understanding of EROD activities in wild fish. First of all modifying factors should be reduced. On the basis of the results, recommendations include:

- For the purpose of biomonitoring, EROD activity should be investigated in male dab and/or juveniles.

- Comparisons in a North Sea area as large as investigated in this study should be made from September to January only. Possible spawning migrations of male dab should be taken into account. For the purpose of investigations in smaller areas, periods out of spawning seasons should be determined individually.
- Future research should be carried out in small manageable areas (for example several transects in the German Bight).
- Further investigations should examine possible seasonal variations of EROD activity in immature dab.
- For the purpose of better understanding of EROD activities in wild fish the basic activities in dab and flounder should be investigated under controlled conditions.
- EROD activity should be investigated only with for example molecular, biochemical and morphological parameters which give information on changes in the liver. In addition CYP1A inducers should be analyzed in the liver, sediment and water.