

**Zeitschrift:** IABSE reports = Rapports AIPC = IVBH Berichte  
**Band:** 63 (1991)

**Artikel:** Design and results of a biological feedback monitoring programme  
**Autor:** Randløv, Anders  
**DOI:** <https://doi.org/10.5169/seals-48495>

#### **Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

#### **Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

#### **Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

**Download PDF:** 16.01.2026

**ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>**

## Design and Results of a Biological Feedback Monitoring Programme

Concept et résultat d'enregistrement de données biologiques

Entwurf und Ergebnisse eines biologischen Rückkopplungsüberwachungsprogramme

**Anders RANDLØV**

Marine Biologist

COWIconsult

Copenhagen, Denmark



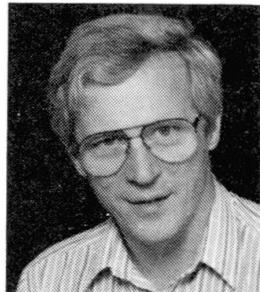
Anders Randløv, born 1949, cand.scient from the Univ. of Copenhagen, Research Biologist at the Marine Pollution Lab. of the National Agency of Environmental Protection and the Institute of Marine and Fisheries Research. Since 1982 with COWIconsult, from 1987 as Head of Department of ecology and environmental chemistry.

**Kurt JENSEN**

Marine Biologist

Water Quality Institute

Copenhagen, Denmark



Kurt Jensen, born 1944, cand.scient. from Univ. of Copenhagen 1970. Lecturer at Univ. of Copenhagen, Roskilde and Odense, Consulting Biologist, Research Biologist at the Marine Pollution Laboratory of the National Agency of Environmental Protection, since 1989 Head of Department of aquatic ecology at The Water Quality Institute.

### SUMMARY

An Environmental Impact Assessment of the construction of the Great Belt Link (Denmark) showed that construction activities might have adverse impact on the marine environment. Therefore, a monitoring programme designed to quantify and control these effects was started in 1989. The programme comprises a new feedback principle implying mitigating actions to be taken by contractors if the biological effects exceed limits stipulated in the Environmental Impact Assessment. The design of the programme was based on the recommendations made by an international panel of environmental experts. The paper presents the results and discusses the relevance of the feedback principle.

Concept et résultat d'enregistrement de données biologiques

### Résumé

L'étude de l'impact sur l'environnement de la liaison du Great Belt a montré que les activités de construction pourraient avoir un effet négatif sur l'environnement marin. Un programme d'enregistrement destiné à quantifier et à contrôler ces effets a débuté en 1989. Le programme comprend un nouveau principe d'enregistrement entraînant des mesures à prendre par les entrepreneurs si les effets biologiques dépassent certaines limites fixées. Le programme a été réalisé sur la base de recommandations d'un groupe d'experts internationaux de l'environnement. Les résultats sont passés en revue et le principe de rétroaction est discuté.

Entwurf und Ergebnisse eines biologischen Rückkopplungsüberwachungsprogramms

### Zusammenfassung

Eine Abschätzung der Umweltfolgen der Konstruktion der Grossen-Belt-Verbindung zeigte, dass Bautätigkeiten einen Einfluss auf die Meeresökologie haben könnten. Deswegen wurde 1989 ein Überwachungsprogramm gestartet, das entworfen wurde, um die Wirkungen zu quantifizieren und zu kontrollieren. Das Programm umfasst ein neues Rückkopplungsprinzip, das Abhilfemaßnahmen seitens der Baufirmen vorsieht, wenn die biologischen Auswirkungen die in der Umweltverträglichkeitsprüfung gesetzten Grenzen überschreiten. Der Programm-entwurf gründete auf den Empfehlungen eines internationalen Fachkreises von Umweltxperten. Der Artikel präsentiert die Ergebnisse und diskutiert die Bedeutung des Rückkopplungsprinzips.



## 1 INTRODUCTION

Specific requirement regarding the marine environment were stipulated by the act on the Great Belt link. To comply with these requirements A/S Storebælt forbindelsen (the company to which has been established to construct and run the link) has established a comprehensive environmental programme [1].

To neutralize a potential impact on the Baltic Sea - as required by the act - the design has been greatly modified and mitigating actions have been taken in accordance with the result of hydrographic modelling [2].

To minimize environmental impact in the near field, ecological mapping, environmental impact assessments, baseline investigations and biological monitoring have been carried out. This paper describes the handling of the near field environment with emphasis on the biological monitoring programme.

## 2 INTERACTIONS BETWEEN ENVIRONMENTAL AND ENGINEERING ACTIVITIES

The construction work and the monitoring of possible associated effects on the marine environment in the near-field of the construction site in Storebælt were initiated in 1989.

The monitoring programme is the last in a series of activities which are necessary for the successful handling of the biological effects in the near-by marine environment. The scheme shown in Fig. 1 emphasize the close interaction between the traditional engineering activities and the environmental activities.

It is the general experience from the Great Belt link project that environmental issues should be addressed early in the planning process. The possibilities for mitigating actions are progressively reduced as the planning and the construction process proceeds.

In particular, it is important to define and include the environmental requirements to the construction work in the tender documents in order to minimize the impact from the construction phase.

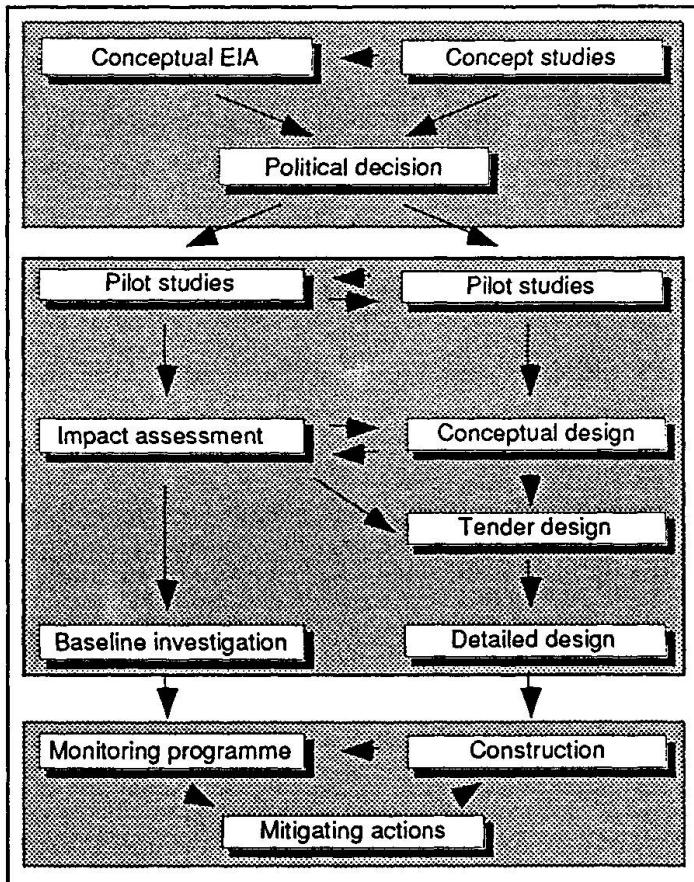


Fig. 1 Interaction between environmental and engineering activities.

### 3 DEFINITION OF MONITORING PROGRAMME

#### 3.1 Objectives

The objectives of the biological monitoring programme are:

- to assess biological effects which can be used to initiate feed back loops whereby the construction process may be altered to mitigate environmental damage;
- to assess the extent and character of other possible adverse environmental effects arisen from the activities;
- to provide adequate environmental information to respond to public interest and settle possible issues.

#### 3.2 Feedback Monitoring

Biological monitoring with feedback possibilities is a totally new concept, which has not previously been demonstrated to function in practise. The basic idea is that unacceptable changes in the environment caused by construction activities can be defined in terms of biological variables, and that the exceeding of the prefixed limit can lead to changes in construction activities which mitigate the adverse effects.

Three biological events have been chosen as important elements for the feedback monitoring:

- wintering eider ducks,
- spring spawning herring, and
- phytoplankton blooms.

These elements have been chosen for the reason that they may be affected by the construction activities at distances beyond the near-field area.

#### 3.3 Key Biological Variables

In addition to the feedback parameters a number of other key biological variables have been selected on the basis that these are significant ecological components of the Great Belt marine ecosystems, and that effects of construction can be quantified reliably. The key biological variables are:

- eelgrass,
- kelp,
- mussels, and
- soft bottom fauna.

The use of key biological variables illustrates two other important principles of the monitoring programme:

- All parameters can be quantified;
- Falsifiable hypotheses have been established; some of these are conditional and will only be investigated when finding a significant effect in the first hypothesis.



## 4 ENVIRONMENTAL EFFECTS OF THE CONSTRUCTION ACTIVITIES

### 4.1 Ecological Mapping

As a basis for the Environmental Impact Assessment (EIA) and the definition of the monitoring programme the marine ecology of the Great Belt has been mapped prior to the start of the construction work (Fig. 2). The mapping was performed using diver operated video equipment, sediment and bottom fauna sampling equipment and fishing gear.

The area accommodates several areas of high ecological interest:

- *Herring spawning*: The area around Sprogø is used as spawning area for spring spawning herring.
- *Eiders/Mussel*: The area around Sprogø holds large flocks of wintering eider ducks gathering from great parts of northern Europe. The number of birds may in some winters reach figures of around 100,000. The eiders feed on the rich mussel beds in the area. The eiders are the main reason for the area being declared an EEC bird protection area.
- *Stone reefs*: Stone reefs are rich biotopes which are important as fish spawning and nursery areas and as feeding grounds for adult fish.

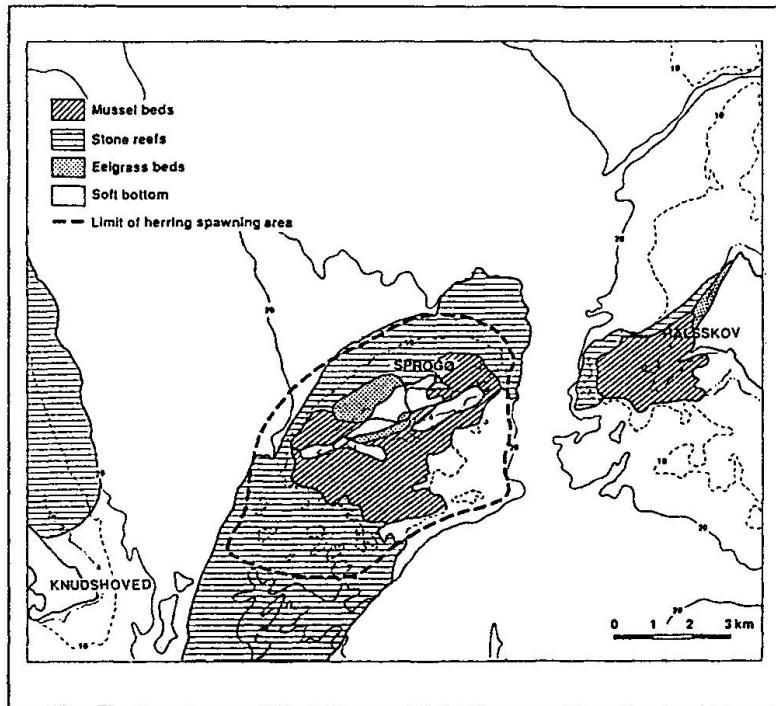


Fig. 2 Marine biotopes in the Great Belt

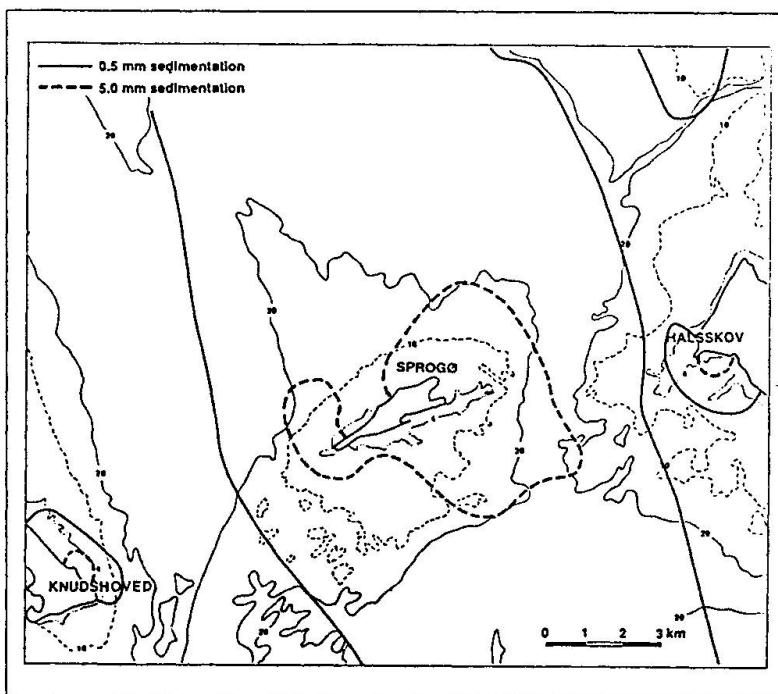
### 4.2 Environmental Impact Assessment

The conceptual EIA performed in 1988 [3] was upgraded in 1990 to a full EIA in 1989 [4]. A revised EIA [5] has since been prepared in order to allow for much higher dredging spill rates than anticipated in the first EIA.

The main environmental effects are related to the reclamation and dredging activities. The major part of the dredging activities concerns the dredging of reefs with the purpose of facilitating the flow of water to and from the Baltic Sea. This illustrates the dilemma between mitigating environmental effects in the far field (the Baltic Sea) and the near field (the Great Belt): The greater the effort to achieve the "zero solution" [2] for the Baltic Sea, the greater the environmental damage in the Great Belt.

In addition to direct destruction of habitats by dredging and reclamation the effects are related to the release and sedimentation of particles during dredging; the calculated sedimentation shown in Fig. 3 gives an indication of the intensity of this impact.

The main environmental effects predicted by the EIA and now partly verified by the monitoring programme (see later) listed below.



#### Short term effects (<10 years):

- Reduction of *mussel biomass* by x% due to reclamation, lee effects and smothering. It is estimated that the carrying capacity of the mussel beds as feed for eider ducks is reduced correspondingly.
- Decrease in macro vegetation on stone reefs by 30-40%.
- Decrease in area used as *herring spawning areas* by 20%.
- Change in composition of local *soft bottom fauna* communities due to smothering and anoxic conditions.

**Fig. 3** Predicted sedimentation from dredging activities.

#### Long term effects (10+ years):

- A possible decrease in population size of wintering eiders and other diving ducks which feed on mussels;
- An increase in the area of eelgrass beds due to lee effects;
- A possible reduction of the area of herring spawning grounds;
- An incomplete recovery of perennial species of algae at stone reefs and eelgrass beds.

## 5 RESULTS OF MONITORING PROGRAMME

### 5.1 Overview

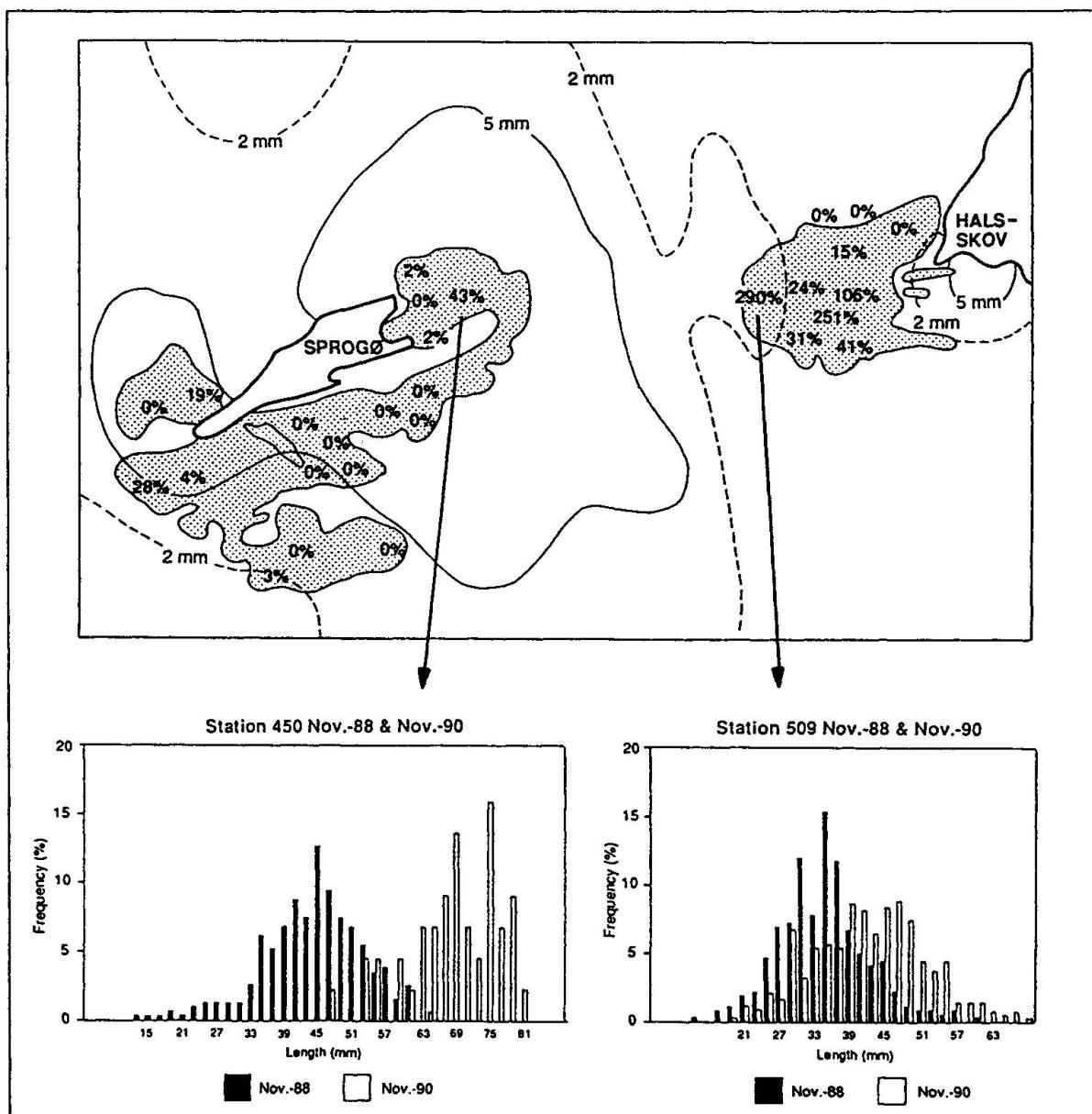
The biological monitoring programme was initiated in 1989 and it is now possible to assert some of the short term effects. Some effects are insignificant in relation to the regional ecology, e.g. the release of nutrients from suspended sediment material and the release of oxygen consuming substances.

Other effects may prove to have serious consequences, e.g. the effects of suspended sediment material on mussel beds and - ultimately - on the eider duck population as described below.



## 5.2 Effects on Mussel Beds and Eider Ducks

The monitoring of the conditions of the mussels beds along the alignment have shown a dramatic decrease in the population density (individuals/m<sup>2</sup>) around Sprogø (i.e. close to the dredging activities); at other stations at greater distance (Halskov rev) a similar decrease could not be observed [6] (Fig. 4). Analysis of the development of the size distribution of the remaining individuals at the affected stations indicate that the decrease is caused by unsuccessful recruitment of young individuals. (Young individuals are recruited from swimming larvae which settle on the bottom; the larvae and newly settled juveniles are more susceptible to damages from smothering).



**Fig. 4** Reduction in mussel population density and recruitment. **Above:** Population density in November 1990 relative to November 1988 in %. **Bottom left:** Typical shift in size distribution at station with decrease in population density. **Bottom right:** Typical size distribution from Halskov rev stations where little or no impact has been assessed.

The monitoring programme has also shown that the predators (mainly eiders and sea stars) during winter consume mussels corresponding to the production of one year [7]. It may therefore be assumed that the carrying capacity of the area for eiders has been reduced and that part of the eider population will be forced to find other wintering areas. Preliminary results from the winter 90/91 strongly suggest that this is the case: the number of eider around Sprogø have been drastic reduced and seemingly the eiders have moved to other locations in the Danish waters where an increase in numbers has been recorded [8].

## 6 CONCLUSION

The results and the experience from the biological monitoring programme so far have indicated that it is possible to assess the environmental impact from such projects, and to some extent limit the effects by mitigating actions.

However, some points are crucial for the possible applicability of the feedback principle:

- The monitoring programme must be based on a comprehensive baseline study and an impact assessment which enable the definition of precise and realistic limits relevant to the environment in question, which can release mitigating actions;
- Environmental considerations which ensure that a precautionary principle is introduced must be involved prior to the planning of the construction and the elaboration of tender material;
- All involved parties must have commitment to following the precautionary principle, be it (client, contractor, authorities, etc.);
- The monitoring programme must include a sufficiently fine grid - in time and space - in order precisely enough to demonstrate the transgression of feedback limits;
- The results of the monitoring programme must appear at intervals much shorter than and the time steps in the planning and progression of the construction work.

The present results of the biological monitoring programme in connection with the construction of the Great Belt Link indicate that a monitoring programme based on such principle may be drawn up, but so far none of the above critical items have been fully achieved.

## ACKNOWLEDGEMENT

The biological monitoring programme is undertaken by a joint venture between COWIconsult and Water Quality Institute in cooperation with Prof. John Gray, University of Oslo. Client: A/S Storebæltsforbindelsen.



## REFERENCES

- 1 POUlsen, KNUD MOSE, *<paper in these proceedings>*
- 2 MØLLER, JACOB STEEN, *<paper in these proceedings>*
- 3 COWIconsult, Environmental Investigations, Status Report no. 2: Biological Mapping, Impact Assessment. Main report, June 1988.
- 4 Danish Hydraulic Institute and LIC Engineering in cooperation with COWI/VKI-Joint Venture, Environmental Impact Caused by Dredging Operations, Compensation Dredging and Dredging for Bridge Piers - Fixed Link across Storebælt, January 1990.
- 5 COWI/VKI-Joint Venture and Danish Hydraulic Institute/LIC Engineering, Storebælt Environmental Programme, Environmental Impacts Caused by Dredging, Reclamation and Disposal Operations, Including Lee Effects around Sprogø, October 1990.
- 6 COWI/VKI-Joint Venture, The conditions of the Mussel Beds in the Central Part of the Great Belt in November/December 1990, January 1990 (1. draft).
- 7 COWI/VKI-Joint Venture, Predation on Mussel Beds by Eiders in the Central Great Belt, November 1989.
- 8 POUlsen, KNUD MOSE, Pers. comm.