8th Semi-Annual Report on the Environment and the Øresund Fixed Link's Coast to Coast Installation

FIRST HALF OF 1999

Danish Ministry of the Environment and Energy

Danish Ministry of Transport

Swedish Control and Steering Group for the Öresund Fixed Link

Danish Ministry of the Environment and Energy, Danish Ministry of Transport,
Swedish Control and Steering Group for the Öresund Fixed Link

8th SEMI-ANNUAL REPORT ON THE ENVIRONMENT AND THE ÖRESUND FIXED LINK'S COAST TO COAST INSTALLATION

January-June 1999

Colophon

Publisher:
Control and Steering Group for the Öresund Fixed Link, County Administrative Board of Skåne, S-205 15 Malmö, Sweden,
Danish Ministry of the Environment and Energy, Højbro Plads 4, 1200 København K,
Danish Ministry of Transport, Frederiksholms Kanal 27, 1220 København K,

Year of Publication: 1999

Title:
8th Semi-Annual Report on the Environment and the Öresund Fixed Link's Coast-to-Coast Installation. January-June 1999.

Editorial Board:
The Danish Environmental Protection Agency, the Danish National Forest and Nature Agency, and the Swedish Control and Steering Group for the Öresund Link.

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Translation:
Swedish-English: John Beal, Malmö.

Resumé:
Via biannual reports, the Danish and Swedish Environmental Authorities inform their respective governments and the general public on the state of operations with the control and monitoring of the construction of the coast-to-coast link over Öresund.

Search criteria:
monitoring; inspection; control; bridges; tunnels; construction; dredging; sediment spillage; extraction of raw materials; Öresund.

Press date: Oktober 1999

Number of pages: 24

Format: A4

ISBN: 87-7909-447-3

Edition: 400 copies

Further information:
This 8th semi-annual report is also available in Danish and Swedish.

Cover Layout: Lars Møller Nielsen.

Cover photograph:
VITESSE measuring sedimentspillage in Öresund, July 1996. Photo: Monika Puch.

Printers: Richard Larsen A/S, København.

Price (incl. VAT): 50 DKK.

Obtainable from: Miljøbutikken, Læderstræde 1-3, DK-1201 København K, Denmark, tlf.: +45 3337 9292, telefax: +45 3392 7690.

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0. Foreword

The explanatory notes to the Danish Construction Bill to build a fixed link over the Öresund states that every six months the Danish Government shall submit a progress report to the Danish Parliamentary Environment and Planning Committee on the environmental consequences of the construction work on the coast-to-coast section. On the Swedish side, the National Environment Protection Agency and the County Administrative Board of Skåne (Scania) are to keep the Swedish Government informed on the implementation of the project and the control and monitoring of the construction work, through the Control and Steering Group for the Öresund Fixed Link (KSÖ).

The seven previous semi-annual reports present the environmental management frameworks and the individual parts of the control and monitoring programme, together with a description of the results upto the end of 1998. This eighth six-monthly report describes the monitoring and control activities during the six first months of 1999.

This report, which has been prepared by the relevant Danish and Swedish environmental authorities, assisted by the Danish Ministry of Transport, is in turn based on reports produced by Öresundskonsortiet and consultants affiliated to various aspects of the authorities' control and monitoring programme.

This biannual report is published in both Danish and Swedish, with a separate version in English.

1. Summary

The authorities continue to be of the opinion that the construction work is being carried out within the framework of the established environmental criteria. Adherence to specific criteria such as the zero solution and the temporary environmental impacts can only be finally evaluated when the construction work has been completed. Consequently, the monitoring of the environmental impact of the construction work will continue throughout the current year and the year 2000.

During the first half of 1999, only small amounts of dredging or restoration of the seabed were carried out. A total of 4 400 m^3 was dredged. At the end of this period, there remained the dredging work in connection with the construction of scour protection for the bridge pillars, as well as backfilling around the bridge pillars nearest Flintrännan, and around the pylons, as a protection against collision from vessels.

From the commencement of dredging work in October 1995 up to the end of the first six months of 1999, a total of 7.4 million m^3 (ca 14.3 million tonnes) had been dredged, representing ca 99 % of total planned dredging work. During the same period, spillage amounted to ca 589 000 tonnes, corresponding to an average spillage percentage of 4.2. Spillage from dredging work up to the end of the first six months of 1999 amounted to ca 109 000 tonnes less than expected.

With the completion of dredging work in the threshold area of Flintrännan, independent measurements have been carried out in this area on the instructions of the County Administrative the depth of Board of Skåne, partly to evaluate the accuracy of measurement, and partly to determine whether the sill had been exceeded, thus affecting the "Zero solution". These independent measurements have shown that the sill was not exceeded and that the measurements have been carried out with great accuracy.

The monitoring of eelgrass has shown that Öresundskonsortiet's own operational criteria, which are more stringent than those of the authorities, have been exceeded on one or two separate occasions. Taken as a whole, the calculation models show that, during the first half of 1999, the operational criteria were exceeded in respect of leaf biomass of eelgrass in a sub-area south of Pepparholm. This excess was not, however, so large as to exceed the authorities' criteria with a temporary reduction of 25 %. The monitoring of common mussels has shown no indication of a reduction in mussel distribution.

The monitoring of eider has shown that they are beginning to become accustomed to the proximity of the artificial island. The eider now forage considerably closer to the artificial island than in 1996 and 1997. The numbers of greylag geese moulting on Saltholm and in Skåne have fallen, after having increased for several years. It is believed that this reduction can be attributed to large-scale heavy metal pollution following the extensive environmental catastrophe in southwestern Spain in 1998, where the major proportion of the European greylag population winters.

The International Advisory Expert Panel held its eighth and final meeting in May 1999. The panel drew the conclusion that the two calculation models for the zero solution today represent the state-of-the-art. The calculation of the zero solution could thus begin and was expected to be finished by the second half of 1999. Finally, the panel recommended that a full programme covering the majority of the monitoring activities be undertaken in the year 2000.

In a separate chapter, an account is given of the calculation of sediment spillage and the uncertainty of the measurements which, during the whole of the construction period, have been the subject of meticulous scrutiny. Results from some minor dredging operations have yet to come in, but these cannot affect the main results of the calculations. The conclusion of the analysis is that the criterion of a maximum 5 % spillage and the spillage percentage error will be met by a very good margin.

2. Introduction

The major part of dredging operations was completed in 1998 and the authorities have therefore adapted their control and monitoring to the scope of the construction work. This semi-annual report has the same structure as before, but has been adapted to the importance of the various sections.

Following the advice of the International Advisory Expert Panel, the authorities have reduced the monitoring of the biological parameters. This means that the authorities during 1999 have used the results from the feedback programme for eelgrass and common mussels instead of their own programme. In contrast to the two previous years, no special investigation of water quality was undertaken during this third year of monitoring. SEMAC JV who performs the authorities' control programme have during the first half of 1999 completed the reporting of the samples collected in 1998.

The report provides an account of construction work status. An enlarged account of current spillage calculations from the dredging operations, which to a greater degree were completed in the second half of 1998, are included in a separate chapter.

3. Construction work in Öresund

3.1 Status of construction work

On 6th January, the Öresund Tunnel Contractors fitted the final tunnel element, and the last two tunnel elements were cast together in March 1999 /ref. 1/. The tunnel pipes were made ready for the fitting of technical equipment, rails and ventilation ducts in March 1999. On the artificial island south of Saltholm and on the artificial peninsula, the alignment constructions of both the railway and the motorway are almost complete /ref. 1/. The removal of the western work harbour on the artificial island is under way, with the material being reused on the island.

During the autumn of 1998, dredging operations were completed in Drogden and Flintrännan. During the spring of 1999, local "high spots" on the seabed continued to be removed. In addition, for safety reasons, material is being deposited in the form of protective islands around the pylons and bridge pillars nearest the fairway, and as protection against erosion around all of the pillars. /ref. 1/. In Flintrännan, the precision of the dredging work in the sill area was inspected (see chapter 3.5).

On 25 March 1999, the last of the high bridge sections was lowered into position by the pontoon crane SVANEN. Thus, the high bridge is complete, with a free span of 490 m. The 203.5 m high pylons were completed in the middle of May, 1999. By the end of June 1999, only a few elements in the western approach bridge were required for Själland and Skåne to become land-linked. The laying of the motorway and railway are in progress on the eastern approach bridge. /ref. 1/.

The new, 14 km long Flintrännan fairway, which runs under the high bridge itself, was inaugurated and formally handed over to the Swedish Administration for Shipping and Navigation on 21 June 1999.

On Lernacken, work has continued on the terminal area and on the toll station, which had virtually been completed by the end of June, 1999 /ref. 1/.

3.2 Approved dredging instructions, spillage budget and completion reports

The dredging work has been divided up into sub-operations, as described in the dredging instructions. These lay down the detailed guidelines as to how each dredging operation is to be carried out in

practice. The areas covered by the dredging instructions and the proportion of dredging work completed to the end of the first six months of 1999 are shown in figure 1.

During the first six months of 1999, no new dredging instructions were submitted for approval. To date, 14 of the original 15 planned dredging instructions have been approved by the authorities. The final dredging instruction is for any compensation dredging which may be needed to attain the "Zero solution".

The most recently approved spillage budget from dredging instruction 14 (rev. 2) is shown in table 2. This budget has been updated with the "accounts" for dredged volumes up to 1 July 1999, and the estimated sediment spillage. Dredgings amounting to 4,400 m^3 for the first half of 1999, are not shown in the dredging volumes in table 1. This is because, at the end of 1998, a report had been made of the estimated dredged volumes to the depth planned (theoretical mean level) as laid down by the Swedish Water Rights Court. The actual quantities dredged are usually greater. As from 1 July 1999, the only remaining dredging was that in connection with the construction of scour protection around some of the bridge pillars. All other dredging operations had been completed /ref. 1/.

When a sub-operation has been completed, Öresundskonsortiet issues a completion report describing the progress of the dredging operations, the final volumes dredged and the spillage percentage for the sub-operation in question. During the first half of 1999, the authorities have received completion reports for dredging instructions 2, 3, 5 and 12. Together with previously submitted completion reports for dredging instructions 4, 6 and 9, a total of 7 has thus been handed in.

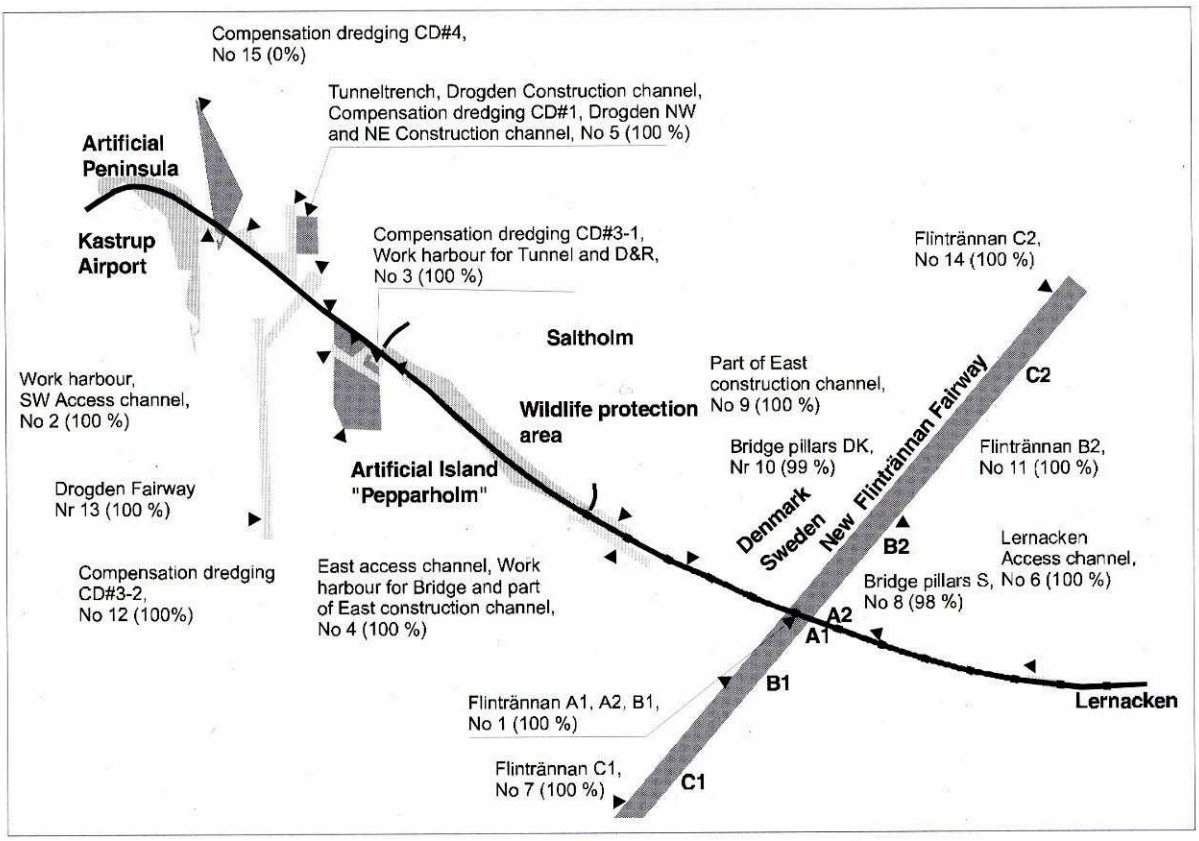

Figure 1. *Status of completed, ongoing and planned dredging work by the turn of the first half-year 1999. Percentages show work completed. Source Öresundskonsortiet, 1999 /ref. 1/.*

3.3 Status of dredging instructions and spillage accounts

The major part of the dredging work was completed in December 1998. Thereafter, the only dredging was the removal of "high spots" from the fairway seabed. In addition, for reasons of safety, material was laid out in the form of protective islands around the pillar-foundations closest to Flintrännan, as well as around the pylons, and as scour protection around all the bridge pillars. This work was carried out in accordance with dredging instructions. 1, 7, 8, 10 and 11 (figure 1) /ref. 1/.

Spillage from the most recent dredging and excavation work has amounted to 2 218 tonnes. Spillage from other sources amounted during the first six months of 1999 to 4 770 tonnes. This spillage stems from activities other than dredging, such as the re-establishing of the bridge abutment on Pepparholm's east side, the removal of the temporary bund on the artificial peninsula and the excavation of cable trenches for the Flintrännan light-houses. The activities during the first six months of 1999 gave rise to a total spillage of 6 988 tonnes.

During the first six months of 1999, a total of 4 440 m^3 was dredged /ref. 1/. From the time these dredgings began and up to the end of the first half of 1999, a total of ca 7.4 million m^3 (14.3 million tonnes) was dredged, corresponding to ca 99 % of the total planned dredging work. During the same period, spillage amounted in total to ca 598 000 tonnes, which corresponds to a spillage percentage of 4.2. By the end of the first half of 1999, spillage was ca 109 000 tonnes less than expected (table 1) /ref. 1/.

The temporal development partly of total production, partly of accumulated spillage expressed as a percentage of total construction work is shown in figure 2. Figure 3 shows the budgeted and the actual spillage. It will be seen that the actual spillage amounts to considerably less than the budgeted.

The extraction of filler sand from Kriegers Flak continued until the end of 1998. Practically speaking, sand extraction is now considered complete. Öresundskonsortiet will therefore be issuing a completion report for the area and will be making a final evaluation of any impacts on the marine environment.

Table 1 summarises the current situation on dredging and reclamation operations for the whole project.

	1999 First six months	Accumulated (Total)	Budget (Total)
Total dredged [tonnes]	0	14 254 234	14 390 710
Dredged - DK [m^3]	0	4 876 500	4 976 500
Dredged - S [m^3]	0	2 517 500	2 517 500
Total dredged [m^3]	0	7 394 000	7 494 000
Spillage [tonnes]	6 988	597.585,9	719 535
Spillage as percentage	-	4,2	5,0
Spillage bank [tonnes]	-2 218	109 413,8	

Table 1. *Presentation of dredging and reclamation work up to and including week 25, 1999, calculated as theoretical mean level. Source: Öresundskonsortiet /ref. 1/.*

No	Area	Period	Calculated quantity						Actual dredged quantity per 1 of July 1999, Based on theoretical mean level				Budget for remaining work		
			Quantity m^3	Quantity tonnes	Spill tonnes	Total Spill %	Dredge Spill %	Recla. Spill %	Quantity m^3	Quantity tonnes	Spillage tonnes	Spillage %	Quantity m^3	Quantity tonnes	Spillage tonnes
1	Flinträннan, central part (A1/A2 and B1)	okt95-aug97	219 000	414 000	16 924	4.1	3.8	0.3	219 000	413 912	13 826	3.3	0	0	3 098
2	Work harbour, peninsula and SW access channel	nov95-maj96	328 000	640 000	23 000	3.6	3.2	0.4	328 000	638 330	22 811	3.6	0	0	189
3	Compensation dredging area CD#3-1, Work harbour forTunnel and Dredging and Reclamation	dec95-sep96	787 000	1 534 000	38 469	2.5	2.0	0.5	787 000	1 534 050	34 989	2.3	0	0	3 480
4	East access & construction channel, Work harbour for Bridge	feb96-apr96	215 000	409 600	18 300	4.5	4.0	0.5	215 000	411 790	17 736	4.3	0	0	564
5	Tunnel trench, Compensation dredging area CD#1 and Construction channel in Drogden	jul96-jun98	2 449 400	4 638 300	251 674	5.4	4.3	1.1	2 449 400	4 648 920	219 638	4.7	0	0	32 036
6	Access channel Lernacken	sep96-apr97	299 000	593 180	17 795	3.0	3.0	0.0	299 000	592 020	24 624	4.2	0	0	-6 829
7	Flinträннan Fairway, area C1	apr97-okt98	495 000	936 000	56 160	6.0	5.9	0.1	495 000	945 450	14 572	1.6	0	0	41 588
8	Bridge piers for Approach Bridge and pylons - S	okt96-mar99	193 500	382 800	19 140	5.0	5.0	0.0	193 500	383 129	24 261	6.3	0	0	-5 121
9	Part of East construction channel	mar97-apr97	136 000	267 000	14 418	5.4	4.6	0.8	136 000	266 560	13 786	5.2	0	0	632
10	Bridge piers for Approach Bridge - DK	mar97-mar99	74 100	146 240	7 312	5.0	5.0	0.0	74 100	145 977	10 603	7.3	0	0	-3 291
11	Flinträннan Fairway, area B2	jun97-feb98	673 000	1 300 090	65 005	5.0	4.8	0.2	673 000	1 298 893	43 382	3.3	0	0	21 623
12	Compensation dredging area CD#3-2	maj97-aug97	657 000	1 292 500	64 625	5.0	4.8	0.2	657 000	1 287 721	62 191	4.8	0	0	2 434
13	Drogden Fairway	jul97-aug98	230 000	437 000	21 850	5.0	4.8	0.2	230 000	437 000	12 874	2.9	0	0	8 976
14	Flinträннan Fairway, area C2	mar98-okt98	638 000	1 212 000	72 720	6.0	5.5	0.5	638 000	1 250 481	64 801	5.2	0	0	7 919
15	Compensation dredging area CD#4	apr00-dec00	100 000	188 000	9 400	5.0	4.8	0.2	0	0	0		100 000	188 000	9 400
	Spillage from other sources – DK				10 873						15 249				-4 376
	Spillage from other sources – S				11 870						2 243				9 627
Total – Danish area		nov95-dec00	4 976 500	9 552 640	459 921	4.8			4 876 500	9 370 348	409 877	4.4	100 000	188 000	50 044
Total– Swedish area		okt95-mar99	2 517 500	4 838 070	259 614	5.4			2 517 500	4 883 885	187 709	3.9	0	0	71 905
Total		okt95-dec00	7 494 000	14 390 710	719 535	5.0			7 394 000	14 254 233	597 586	4.2	100 000	188 000	121 949

Table 2. *Current spillage budget. Table shows actual dredged quantities calculated to theoretical mean level and the remaining planned dredging work, plus measured and budgeted spillage. The budget for estimated quantities is unchanged in relation to the budget shown in the 7th semi-annual report /ref. 2/, but the spillage figures have been updated to 1st July 1999 (see chapter 3.2). Source: Öresundskonsortiet /ref. 1./*

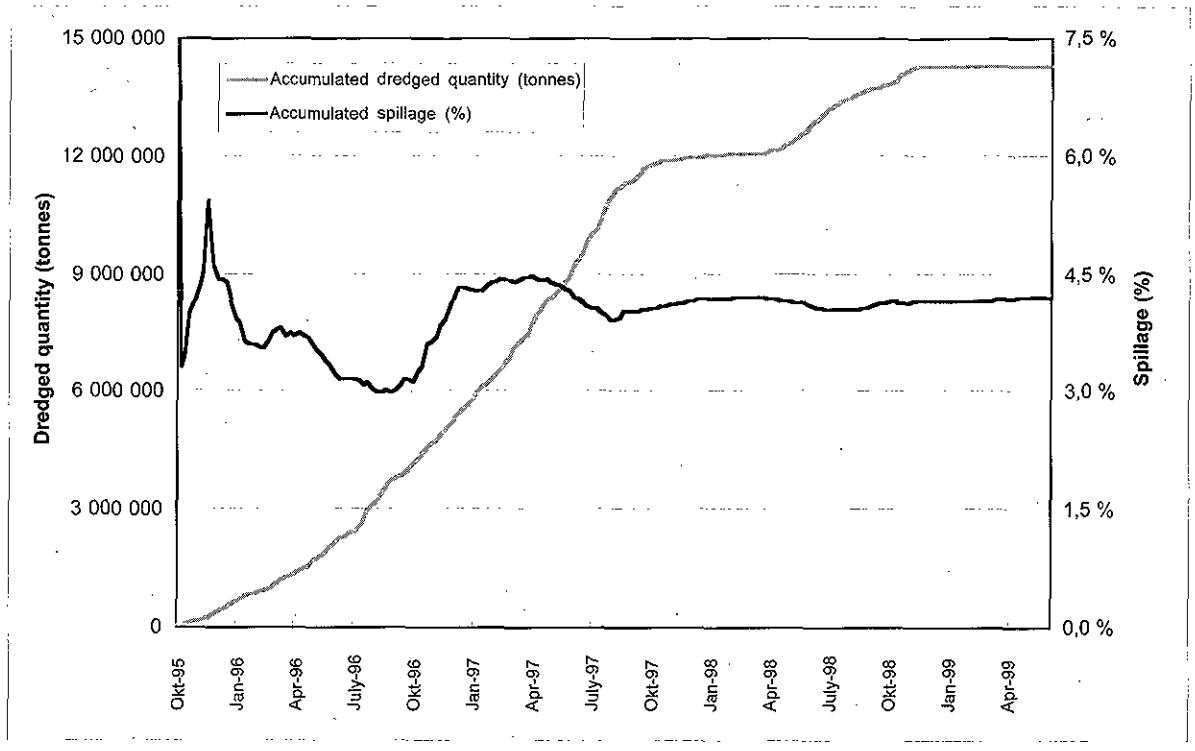

Figure 2. *Temporal development of the accumulated theoretical dredged quantities in tonnes and the accumulated spillage percentage for all dredging work. Source: Öresundskonsortiet /ref. 1/.*

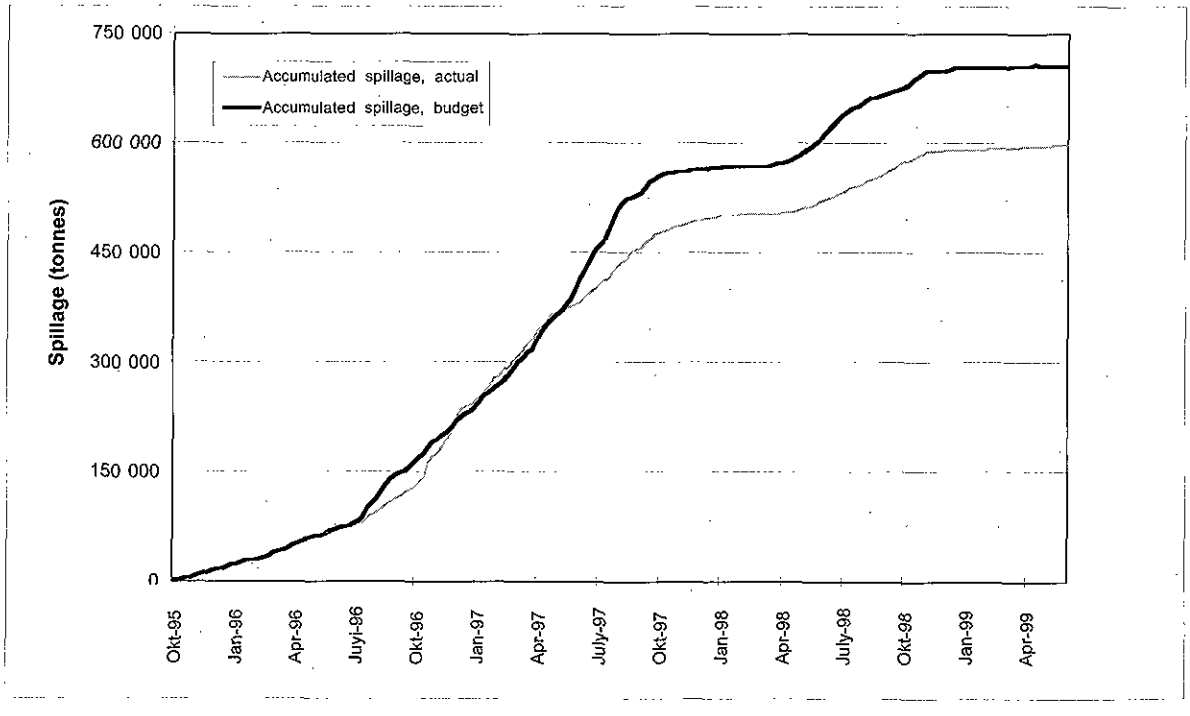

Figure 3. *Temporal development of total spillage from dredging and reclamation work. Graph showing budgeted spillage based on most recent spillage budget. Source: Öresunds-konsortiet /ref. 1/.*

3.4 Spillage measurement and resuspension

The spillage measurement programme registers those particles which are transported suspended in water, whilst measurement of bed load transport registers those particles which are transported along the sea bed.

Spillage from dredging was measured up to November 1998, after which spillage volume has been determined with the help of a model estimate, based on quantities dredged and spillage from other sources. Öresundskonsortiet has demonstrated that this method fulfils the authorities' requirements regarding the margin of error in the spillage calculations /ref. 1/.

The programme for the mapping of possible resuspension from the construction areas has been cancelled since the cessation of dredging operations at the end of 1998.

3.5 Inspection by the authorities

Inspection by the authorities is based on discussions within the technical working groups and on direct access to a series of data collected and processed by Öresundskonsortiet. This data is presented in the environment information system EAGLE, to which the authorities have direct access. The authorities also carry out on-the-spot inspections.

The supervisory authorities and Öresundskonsortiet carry out a continuous examination of the spillage accounts and the technicalities related to the calculation and measurement of sediment spillage. The concluding evaluations of the spillage accounts have reached week 53 1998. Öresundskonsortiet and their consultants carry out further calculations on the margin of error for all the spillage measurements. The preliminary results appear in chapter 7.

The environment information system EAGLE provides the authorities with direct access to the results from the feedback monitoring. This makes it possible to follow the development of the environmental conditions for eelgrass and common mussels. Öresundskonsortiet also presents the results from the feedback monitoring in weekly reports, in which the actual quantities dredged and spillage measured are given

With the completion of dredging work in the sill area of Flintrännan, the County Administrative Board of Skåne called for an independent measurement inspection of the sea bed. The aim of this investigation was to ascertain whether a breakthrough of the sill had been made and to determine the accuracy of measurement. This independent inspection has confirmed that the sill was intact and that the bathymetry has been carried out to a high degree of accuracy.

4. Control and monitoring programme

A comprehensive control and monitoring programme has been drawn up in accordance with the requirements of the Danish authorities /ref. 5/ and the Swedish Water Rights Court rulings /ref. 6/. The primary purpose of the monitoring programme is to register the conditions in the marine environment and provide the basis for necessary countermeasures should any construction operation exceed the expected impact. With the completion of the fixed link, the monitoring programme shall register whether the temporary impacts decline as expected

Öresundskonsortiet uses a feedback programme (section 4.1) in connection with the individual dredging operations, whereby careful monitoring is carried out on selected parameters in the marine environment around the dredging areas. Thus, this programme differs from the more general impact monitoring programme (section 4.2). The aim of the feedback programme is to ensure early intervention if there is a risk that the authorities' environmental requirements are being exceeded.

Responsibility for the implementation of monitoring and control of the construction work is shared between the contractors, Öresundskonsortiet and the Danish and Swedish environmental authorities. Monitoring of the biological impacts has been based during the first six months of 1999 upon the feedback programme, for which quarterly measurement returns are available.

To date, construction work has had only a limited impact on the environment, which is also described in the previously published semi-annual reports on the environment. In 2000, the intention is to perform a comprehensive programme to permit a total evaluation of environmental conditions when the construction work is complete /ref. 3/.

4.1 Feedback monitoring

The feedback programme contains on-going model calculations and sediment surveys of the water columns and of the seabed, as well as of common mussels and of eelgrass. For the purposes of the feedback programme Öresundskonsortiet has established its own operational environment criteria, which are more rigorous and specific than those of the authorities. If Öresundskonsortiet exceeds these operational criteria, the monitoring is intensified..

4.1.1 Sediment monitoring

During the first six months of 1999 the model calculations revealed that in the main no visible sediment plumes had occurred in Öresund. The sediment concentration in the water was less than 2 g/m^3 for more than 99 % of the time. This tallies with the fact that the measurements of suspended sediment have remained around the natural baseline level. On the basis of the model calculations, the sediment-related operational criteria have thus not been exceeded /ref. 1/.

Because of the currents, the sediment spillage from the construction work has been deposited partly in an area north of Middelgrundsfortet and up towards Ven, and partly in the outer reaches of Köge Bukt. The distribution of sediment spillage agrees with the description shown in figure 4 in the fifth semi-annual report /ref. 4/. In Öresund a total of ca 421 500 tonnes had been deposited up to 30 June 1999. For the same period, spillage corresponding to ca 27 % of the total was transported out of Öresund /ref. 1/.

Measurements immediately north of the isle of Middelgrund confirm that the largest deposits from the construction work are ca 5 mm thick, which corresponds to ca 5 000 g/m^2. Furthermore, off the southeastern corner of Pepparholm, a deposit of spillage sediment has been confirmed in an area where the currents divide between Drogden and Flintrännan.

The spilled sediment from the construction work has been deposited generally in those areas which were also natural accumulation areas for fine-grained sediment in Öresund. In 1993, before the construction work had begun, the natural average sediment accumulation on the seabed was measured. These measurements, which were carried out with radioactive isotope of lead 210, gauge the natural long-term accumulation. This provides the basis for a sediment comparison in respect of the construction work. Measurements using sediment traps from the first six months of 1999 are characterised by a large variation caused by weather conditions and the dynamics of the waters of Öresund. The measurements, however, suggest that there has been no impact from the construction work. /ref. 1/.

During the first half of 1999, Öresundskonsortiet's checking of sedimentary conditions has not registered or calculated any values which prompted any feedback action /ref. 1/.

4.1.2 Eelgrass

During the first half of 1999, eelgrass samples were taken in January and in April. On both occasions, 62 stations were checked situated along 21 collection lines (transects) (figure 4). The values for eelgrass shoot density, leaf and root biomass, together with carbohydrate content were tested against Öresundskonsortiet's own operational criteria. Öresundskonsortiet compare the index values for the sampled parameters with the index values from the baseline survey. The index denotes that the result 100 is equal to the result from the baseline surveys. An index value greater than 100 indicates that the value for the parameter is higher than the baseline level. A value smaller than 100 indicates a reduction in relation to the baseline level.

With few exceptions, the criteria have not been registered as having been exceeded for shoot density, leaf biomass, root biomass or carbohydrate content at the stations sampled during the first six months of 1999. In January 1999, the operational criteria (limit values) for shoot density were registered as having been exceeded at a station near Kastrup, and for root biomass at a station near Ribersborg. These excesses meant that further samples were taken in March. In March, the operational criterion at Kastrup in respect of shoot density was still being exceeded, but not during the regular surveys in April. During the regular surveys in April, criteria excesses were registered for root biomass at Ribersborg and at two other stations near Saltholm /ref. 1/.

Generally speaking, the average level for carbohydrates and leaf biomass lies above the baseline survey levels. The average level for shoot density and root biomass generally lies near the baseline survey level. At some stations, and in the reference area however, a considerable decrease in root biomass has occurred compared with the April 1995 survey. New samples will be taken in the second half of 1999 /ref. 1/.

Öresundskonsortiet's model calculations have been used to check the authorities' criteria for leaf biomass and eelgrass distribution. The model calculations compare eelgrass parameters in six areas around the alignment, with a baseline level for the same parameters as in the field surveys. The model calculations were carried out at the beginning of January, April and July 1999. They show that the operational criteria were exceeded in respect of leaf biomass in a locality south of the artificial island (within area 3). Table 3 shows the model results for eelgrass distribution and leaf biomass, compared with the baseline level /ref. 1/.

Date	Area	Leaf-biomass	Distribution
Jan -99	1	94,0	98,0
Jan -99	2	92,8	99,0
Jan -99	3	87,9	94,5
Jan -99	4	92,4	94,8
Jan -99	5	96,5	97,9
Jan -99	6	95,7	100
April -99	1	93,9	98,0
April -99	2	92,8	99,0
April -99	3	87,7	94,4
April -99	4	92,1	94,8
April -99	5	96,4	97,9
April -99	6	95,6	100
July -99	1	94,1	97,8
July -99	2	93,0	99,0
July -99	3	88,1	94,4
July -99	4	92,3	94,8
July99	5	96,5	97,9
July -99	6	95,8	100

Table 3. *Calculated index values of eelgrass leaf biomass and distribution in relation to baseline values for each of the 6 areas in the outer impact zone during January, April and July 1999. Source: Öresundskonsortiet /ref. 1/ (See figure 4 for area divisions).*

As mentioned in the seventh semi-annual report, in the autumn of 1998, problems arose due to exceedance of the operational criteria for eelgrass on Sjollen. These problems were the result of sediment spillage. Since then, the area has been monitored through special feedback action, during the autumn of 1998 and the winter of 1999. In January 1999, the operational criterion for carbohydrates in the root fibers at 6 out of 12 stations on Sjollen was exceeded, and the operational criterion for root biomass was exceeded at 3 stations. Following the most recent survey in May, the carbohydrate level was low and still below the baseline level at all stations, yet the eelgras distribution showed no sign of having been reduced as a result of this carbohydrate level. Carbohydrates are not normally used as monitoring variables in the spring, as the carbohydrate content is extremely variable during this season. In July 1999, the carbohydrate level is checked again to see whether the levels are back to baseline level. The other operational criteria were not exceeded at the Sjollen survey (May 1999) /ref. 1/, which suggests that the effects were of a transitionary nature.

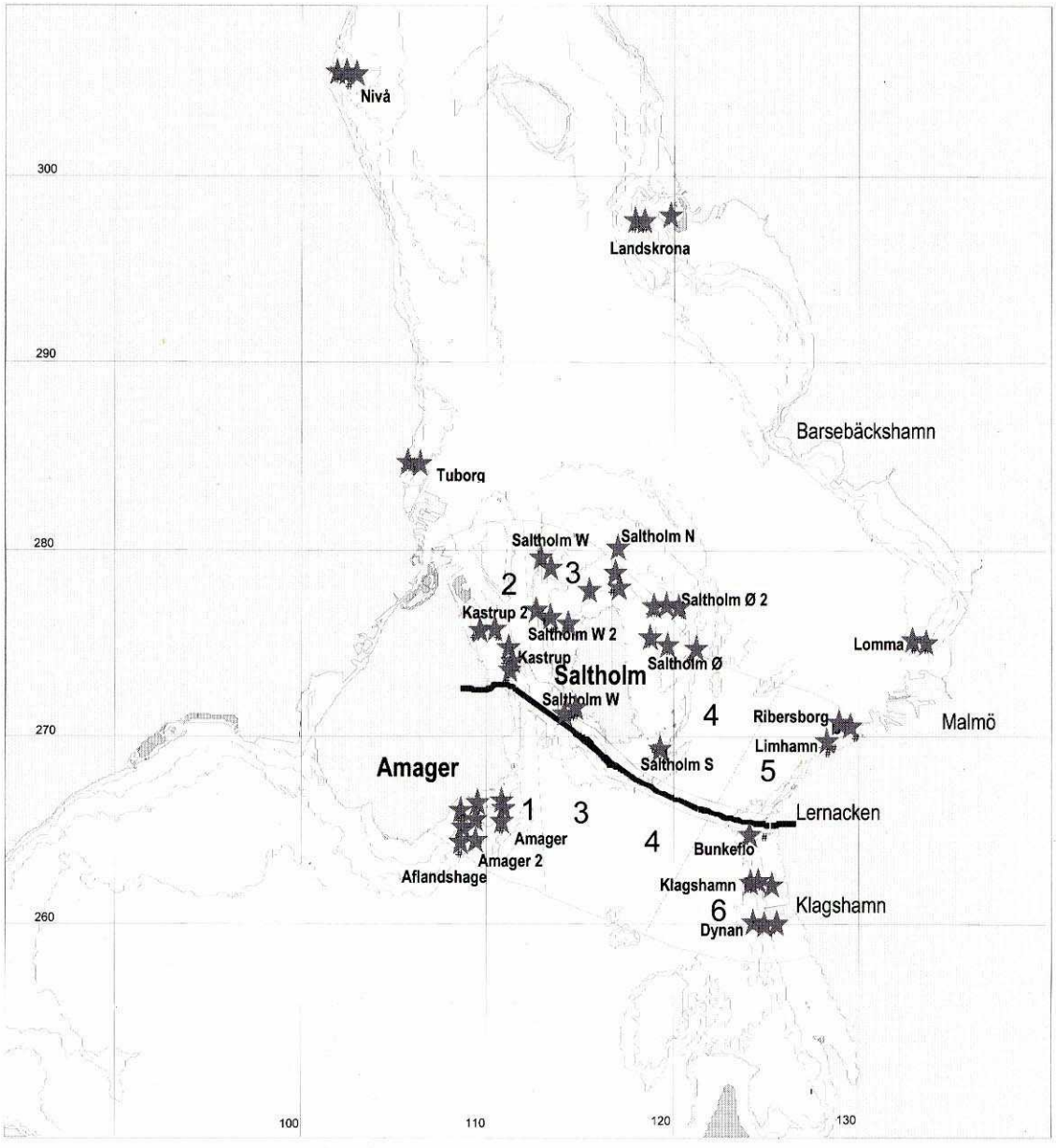

Figure 4. *Location of the six sub-areas and eelgrass stations in the feedback programme. Source: Öresundskonsortiet /ref. 1/.*

4.1.3 Common mussels

During the first six months of 1999, the monitoring programme was carried out with photographic surveys in March and June, registering mussel distribution at over 370 stations (figure 5). Mussels were not collected to determine biomass, and the monitoring of the mussel banks did not give cause for feedback action /ref. 1/. The area surveyed is along the alignment and along the straightened fair ways. The June survey also included the reference area north of Saltholm.

At the majority of stations surveyed, the degree of common mussel coverage was over 40 %. Contiguous areas with a degree of coverage of over 40 % continued to be found primarily in the north and central parts of Flintrännan as well as in Drogden as far as 10-12 km south of the alignment. In the southern part of Flintrännan, the degree of coverage was more varied. No appreciable sign of sedimentation was found on the mussel banks

At a number of stations in the dredged fairways the degree of coverage was greater than 40 %. At many of these stations, however, the mussels formed a thin but even layer. The same applied to the reference area north of Saltholm. Here, the degree of coverage was also high, but in many places the frequency was thinner and more dispersed than what is typical nearer the alignment. Agreement between the observations in March and June was significant.

Results show that the mussel predominent distribution pattern does not differ from the original, and the surveys have not shown any sign of a reduction in mussel distribution or of impact from the dredging work overall, when excluding the directly dredged areas. Rather, the observations suggest that the mussel distribution is controlled naturally by depth and sediment /ref. 1/.

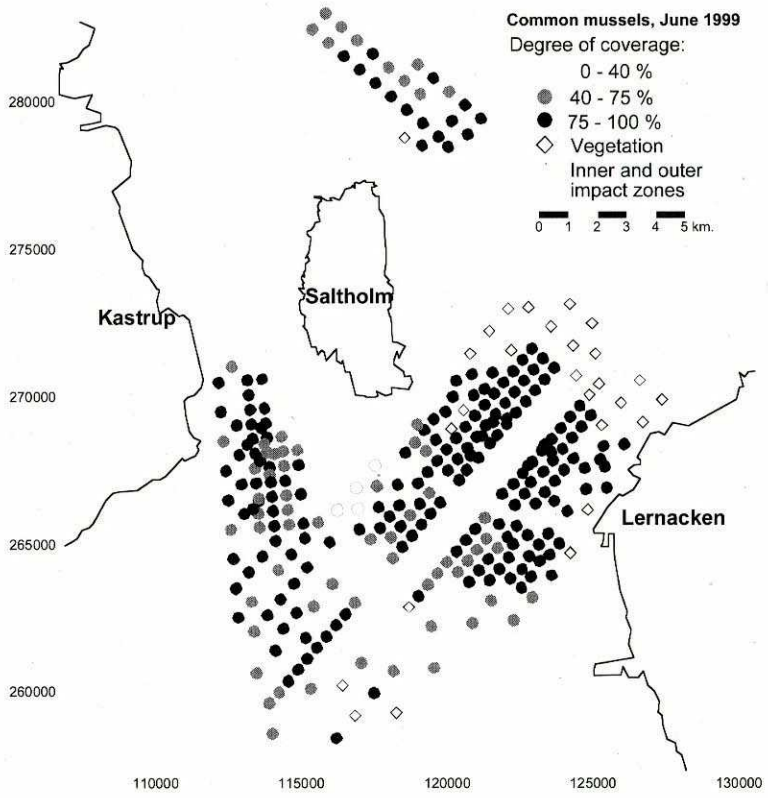

Figure 5. *Degree of common mussel coverage. Result of photographic survey, June 1999. At stations marked with vegetation indicators it was not possible to assess the degree of mussel coverage. Source: Öresundskonsortiet /ref. 1/.*

4.2 Effect monitoring

As a stage in the supervision of construction work, the environmental authorities have undertaken a master monitoring programme to assess whether the observered impacts of the dredging work lie within the framework of the expected impacts. The programme embraces monitoring of the following features of the Öresund environment: water quality, benthic vegetation, benthic fauna, fish, birds, beaches and coasts.

During the first half of 1999, the official programme has included the monitoring of birds on Saltholm and along the Swedish coast, as well as fish on the Swedish side. Surveys have also been carried out on the coastal morphology around Saltholm, with particular emphasis on the area between Pepparholm och Saltholm. The aim is to undertake a full scale official programme on benthic fauna, common mussels, eelgrass and coastal conditions in the year 2000.

4.2.1 Water quality

The construction work and operation of the Öresund Fixed Link must not bring about the release and redistribution of heavy metals, hazardous substances, nutrients or oxygen consumption in such quantities as to create negative ecological impacts, or bring about significantly increased concentrations of heavy metals or hazardous substances in animals and plants. In critical situations with oxygen deficiency in Öresund, there must be a guarantee that dredging operations do not bring about increased harmful effects to the biological conditions.

In the previous semi-annual report /ref. 2/, only preliminary information was presented regarding the water quality for 1998, because quality-assured data for the second half of 1998 was not available when the report was published. The preliminary data suggested that the construction work had not caused an increase in harmful effects to the biological conditions in Öresund during the periods of oxygen shortage. The status report on water quality for 1998 confirms this assumption /ref. 7/.

During 1998, phosphorus concentrations were generally lower than the long term mean value, 11 to 26 years depending on the station. These lower phosphorus contents are probably due to the fact that phosphorus input from point sources have been reduced since 1989. Nitrates and nitrate contents were either lower or equal to the long term mean value up to September. Later in the autumn, the contents were higher than the mean value. Oxygen deficiency was registered at Ven on 13 occasions (see figure 6), but not at the other two stations.

Since most (99 %) of the dredging work had been completed by the end of 1998, monitoring of water quality is not currently included as part of the authorities' control and monitoring programme. Water quality data for Öresund is available through the Danish and Swedish national and regional monitoring programmes.

Judging from the data available for the first half of 1999, and because only small spillage-generating operations have been carried out during this period, it is unlikely that the criteria for water quality have been exceeded.

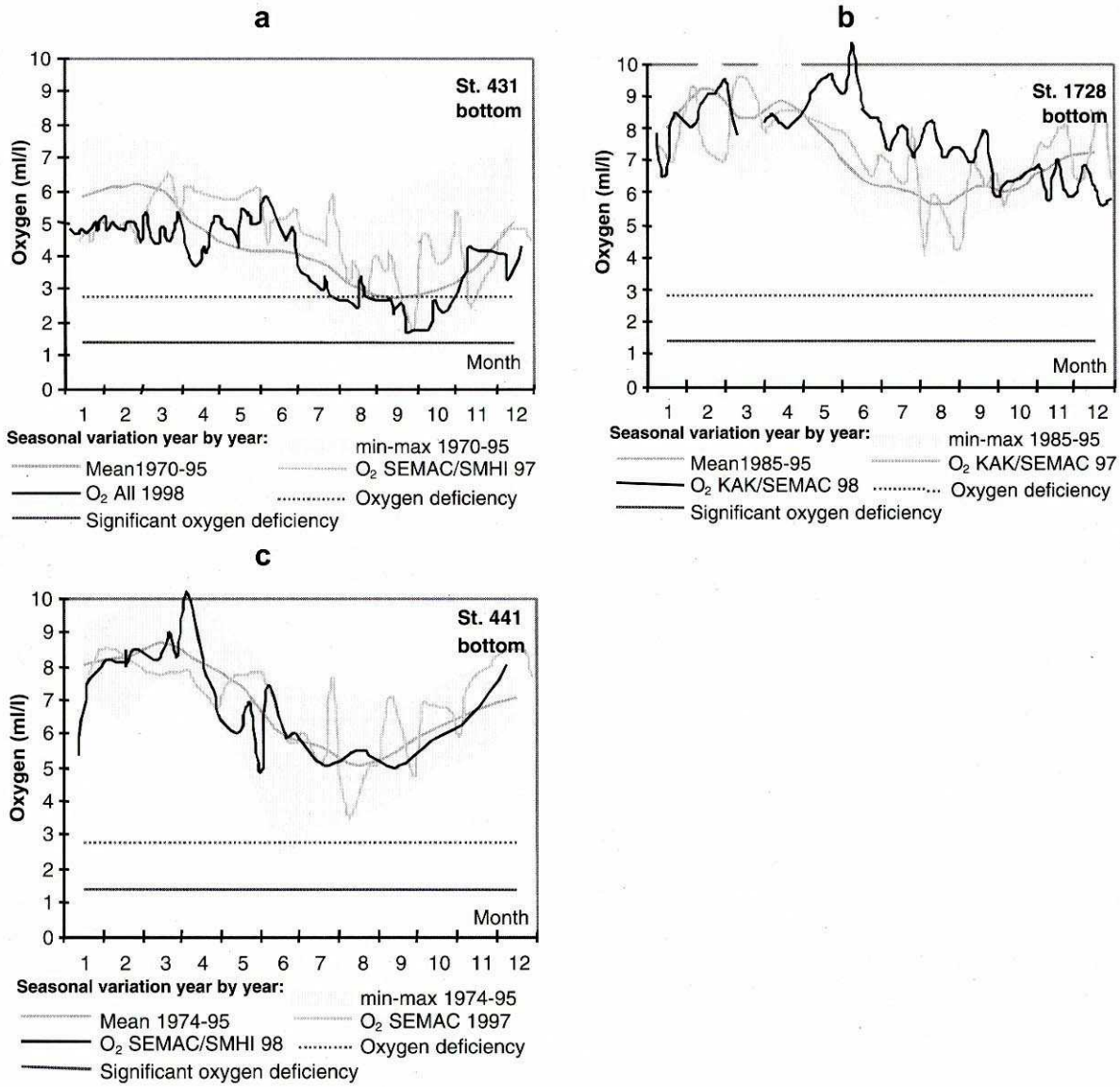

Figure 6. *Seasonal variation at* ***a****: Ven (station 431),* ***b:*** *Drogden (station 1728) and* ***c****: Stevns (station 441) in seabed oxygen concentration during 1997 and 1998, together with monthly mean values, and min-/max values, as shown in figure texts. Source: DMU /ref. 7/.*

4.2.2 Benthic fauna and benthic vegetation

Permanent impacts on plant and animal life in the inner impact zone are acceptable, whilst transitional impacts are acceptable in the outer impact zone, on species composition, distribution and biomass. Generally speaking, a temporary reduction is acceptable in plant and animal life of up to 25 % in the outer impact zone.

In 1999, the authorities did not need to carry out an independent monitoring programme of benthic fauna and benthic vegetation. Instead, the results from the feedback programme's surveys of common mussels and eelgrass have been used. The monitoring in the autumn of 1998 included comparative surveys of the methodology used on common mussels in the feedback programme and the authorities' monitoring programme. These two surveys showed total agreement. Corresponding surveys have also been carried out on eelgrass.

The results from 1999, as set out in sections 4.1.2 and 4.1.3, show that the authorities' criteria for the construction work's acceptable impacts on benthic fauna and benthic vegetation had not been exceeded.

4.2.3 Fish

Situations must not be allowed to arise in which sediment plumes simultaneously block the migration of herring through Drogden and Flintrännan. This criterion, together with those for other natural and environmental conditions, also benefits the migration of eel, garfish, mackerel and lumpsucker through Öresund.

The programme for the monitoting of herring migration was discontinued in 1998 as the major part of the dredging work which could have caused blocking sediment plumes was completed in the autumn of 1998. The surveys from previous years had shown that the construction work had not affected the herring migration. The final report on herring migration was published in the spring 1999 by the Danish Institute for Fisheries Reaserch /ref. 8/.

On the Swedish side during the summer, a separate programme carried out to study the occurrence of eel and flatfish fry, as well as of the stationary fish population. The results of the Swedish Board of Fisheries surveys were not available at the time of publication.

4.2.4 Birds

Only preliminary results are available for 1999 from the surveys of eider, greylag geese and mute swan.

Saltholm's Birds

A reduction in the eider population on Saltholm of up to 15 % is acceptable to the authorities. However, five years at the latest after dredging operations have been completed, the number of nests shall have returned to 90 % of the level observed before construction work began.

In 1999, the total number of **eider** nests was estimated at 5 011. The number of breeding eider was thus ca 1 000 pairs lower than were registered during the period 1993-1997, but comparable with the number registered in 1998. A corresponding reduction in the number of foraging eiders around Saltholm was recorded during the period prior to egg laying /ref. 9/.

More foraging eiders were in the vicinity of the artificial island in 1999 than were registered in 1996 and 1997 (figure 7). The eiders' behaviour did not deviate, however, in respect of date of arrival or intensity in foraging, compared with the period before construction work on the fixed link began. This suggests that the construction work has not brought about a reduction in the eider population /ref. 9/.

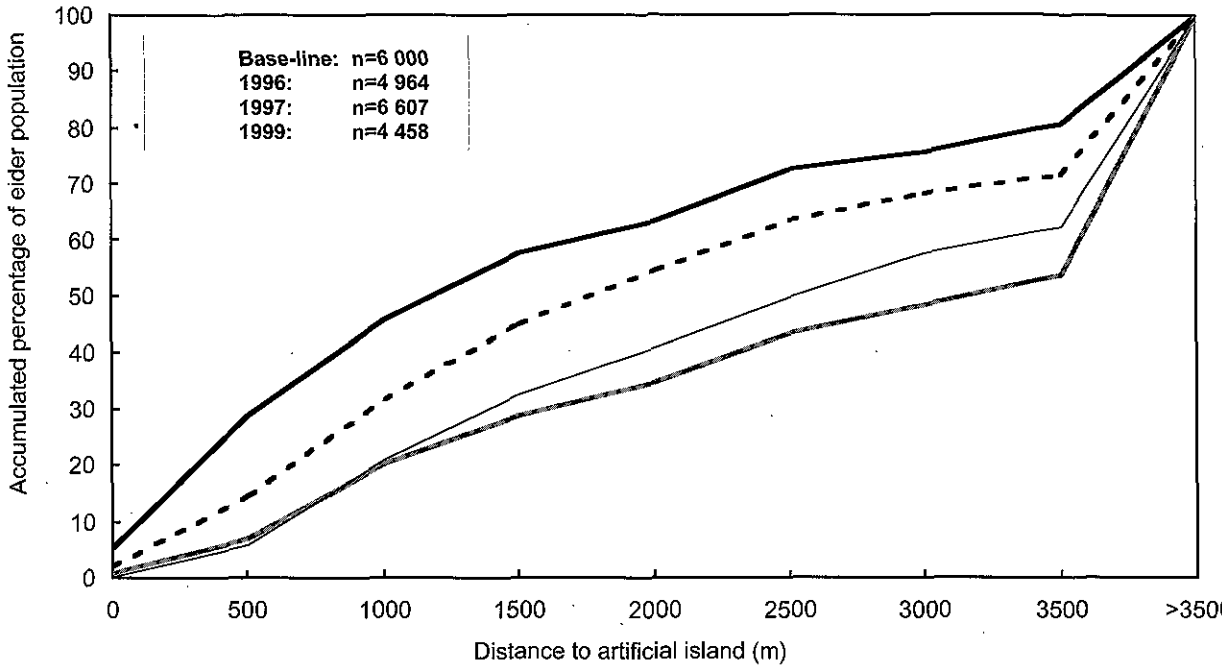

Figure 7. *Accumulated percentage of eider population foraging around Saltholm in relation to the distance to the artificial island. Source: DMU, 1999 /ref. 9/.*

A permanent reduction in numbers is deemed acceptable for moulting greylag geese and mute swans.

The monitoring of **greylag geese** on Saltholm should be viewed in the context of surveys in Skåne, as Saltholm is an important moulting locality for geese from Skåne.

In 1999, ca 11 500 moulting greylags were counted on Saltholm. This is a decrease of ca 3 000 compared with 1998 (see below regarding the pollution of the greylags' Spanish wintering quarters) /ref. 10/.

Disturbance was observed from the construction activities, as a situation arose when the pontoon crane "Svanen" en route to the fixed link, caused increased alertness among the moulting geese, which at that particular time were on their staging grounds at Svaneklapperne. Disturbance from the construction work in 1999 remained at the same low level as in previous construction years when the population increased. It is therefore not particularly likely that the construction work was the cause of the observed decrease in 1999 /ref. 10/.

Current analyses suggest that the number of moulting **mute swans** at Saltholm will show an increase for the second year in succession. For 1999, the population is expected to be over 2 000 /ref. 11/.

A temporary reduction in the number of staging migrants caused by the construction work has been deemed acceptable.

Seen overall, no significant decrease has been perceived in total number of bird days for seabirds, including staging migrants found on Saltholm during the autumn throughout the duration of construction work (1996-1998) compared with the period 1993-1995. Cormorant, eider, brent goose, shoveler, coot, golden plover, spotted redshank and greenshank have, however, used the area around the artificial island to a lesser extent during the time the construction work has been in progress /ref. 12/.

Birds in the Swedish zone

The monitoring of **greylag geese** in the southwest lake-district of Skåne, which is an important recruitment area for Saltholm's moulting geese, continued during the spring of 1999. Breeding pairs in the survey area numbered 665, as against 740 pairs the previous year, which represents a reduction of 10 %. This breaks the markedly rising trend noted over the years /ref. 13/. Preliminary results suggest a markedly increased mortality in that part of the greylag population which winters in southwestern Spain, and can probably be attributed to the extensive release of heavy metals resulting from a collapsed mining dam (Boliden) in the vicinity of the greylags' most important wintering quarters in Spain. /ref. 14/. Blood samples from ringed Skåne greylags which have wintered in southwestern Spain have shown increased lead contents /ref. 15/. The major part of the European greylag goose population winters in southwestern Spain /ref. 14/.

Breeding success was good, and 57 % of 121 returning, ringed greylags which had previously bred in the area, produced broods of thriving young. The broods were of normal size.

Approximately 15 % of ringed birds in the Skåne survey area were found moulting on Saltholm. The percentage of ringed potential moulters identified on Saltholm in the summer of 1999 was lower than previously. These results will be supplemented during the autumn of 1999 with observations from amateurs and bird observatories from other areas. Only then will it be possible to establish to what degree geese from southwestern Skåne have chosen moulting grounds other than on Saltholm.

4.2.5 Beaches and coastline

Monitoring of bathing water

The beach- and bathing water quality along the coasts of Öresund outside the inner impact zone may not be changed in such a way that the criteria on bathing water quality can not be fulfilled.

Since the autumn of 1998, no large-scale dredging operations have been carried out in Öresund, and therefore no supplementary bathing water surveys have been carried out on Amager's beaches during the first half of 1999.

In the Swedish zone, Malmö municipality has monitored the visibility of the bathing water. The results have shown that bathing water quality was unchanged in the Swedish zone during the first half of 1999.

Coastal monitoring

Outside the inner impact zone, no significant changes may be made to the coastline, which, upon completion of the link, must be stable. Sand-silting and significant changes to the character of the seabed between the artificial island and Saltholm must not lead to the formation of a land-bridge between them. Along the other coasts, only insignificant sand-silting along the seabed and coastlines is permissible.

The scope of the control and monitoring programme for 1999 was reduced compared with previous years. Monitoring in 1999 concentrated on the transects around the whole of Saltholm, and primarily on the area between the artificial island of Pepparholm and Saltholm, where smaller amounts of sedimentation have been found. In total, this monitoring comprised 25 transects, from 16 of which 56 sediment samples were taken. Aerial photography was also carried out to the same extent as previously.

The 1999 control and monitoring programme was carried out during May and June, and the results will be given in the next semi-annual report.

During 1999, sand transportation within the area was investigated by a study model with the aim of predicting the impacts caused by the fixed link. Among other things, this study model has used data from the authorities' coastal morphology programme.

5. The International Advisory Expert Panel

The International Advisory Expert Panel for the Öresund fixed link's coast to coast part held its eighth and final meeting from 10 – 12 May 1999 /ref. 16/.

At this meeting, the panel of experts came to the conclusion that the two models used for the calculation of the zero solution represent what is currently state-of-the-art. This conclusion represents an important milestone in the work. The result has been achieved via the development over several years of the two comprehensive three-dimensional models for the calculation of the zero solution, both for the water flow through Öresund and the salt flux and oxygen supply to the Baltic Sea.

At the same time, the experts accepted the view that a simulated zero solution at the Drogden sill would also be synonymous with a zero solution for the Baltic itself, on condition that it is possible to document that the volumes of water, salt and oxygen remain unchanged south of the sill. The panel therefore recommended that this line of thinking should be elucidated further in respect of the stretch of water between Stevns Klint and Skanör.

Öresundskonsortiet expects to be able to deliver the final model descriptions and analyses together with the zero solution calculations during the second half of 1999. Their calculations will be sent to the experts for written comment, after which the material will be sent to the authorities for approval.

The biological conditions were high-lighted thoroughly at a seminar for the expert panel's biologists in June 1998. At this seminar, the results were presented from the monitoring of the biological conditions. The recent results from 1998/99 have not altered the panel's view that the construction work has been carried out without negative impact on the environment.

In order to be able to carry out the final evaluation of whether the criteria regarding the impact of the construction work on the environment have been fulfilled, the panel recommended the implementation of a complete programme for common mussels, benthic vegetation and parts of the bird surveys for the year 2000.

The panel further recommended, in rounding off their work and in concluding the monitoring of the construction work, that the Danish and Swedish authorities arrange a conference for environment researchers and authorities from the countries around the Baltic with the aim of presenting the results from the different monitoring programmes.

6. Forthcoming activities

Activities in the next period are increasingly directed towards the conclusion of ths construction work and the time thereafter.

The seven remaining completion reports for the construction work are expected to be submitted in the late summer of 1999, afterwhich the final report for the complete dredging operations can be discussed and formulated.

The authorities and Öresundskonsortiet continue with their discussions on the control and monitoring programme for the year 2000, as well as for the follow-up period to the year 2003. In this context, a seminar will be held on the future programme for coastal morphology. At this seminar, the results hitherto obtained will be evaluated and future monitoring requirements will be assessed.

Finally, Öresundskonsortiet will present the results from the calculation of the link's blocking impact, in other words whether the zero solution has been achieved.

7. Theme chapter: Calculation of sediment spillage and measurement uncertainty

The agreement between the governments of Denmark and Sweden, through the offices of the authorities, sets out a series of criteria, including those on sediment spillage and measurement error margin uncertainty. The criteria complement each other and form a totality. One of the most important criteria regarding the Öresund dredging operations is that sediment spillage must not exceed 5 % of the total amount dredged /ref. 6, 17, 18/. This criterion has been drawn up in order to safeguard that unacceptable impacts will not arise in the environment. At the same time, criteria have been set up regarding measurement uncertainty in the calculation of the total spillage percentage /ref. 6, 18/. Standard deviation for the spillage percentage must not exceed one percentage unit, representing a variation coefficient of 20 % of the maximum spillage percentage of 5 %.

When carrying out measurements of sediment spillage, there will always be a certain margin of error surrounding the results, and this may be great or small. This uncertainty arises because errors can occur when carrying out the measurements. Traditionally, these errors are divided up into systematic errors and random errors.

Systematic errors, for example, arising from misleading measuring instruments, can be revealed through checks and can be corrected accordingly. This work has proceeded continuously during the dredging operations via Öresundskonsortiet's quality assurance and the authorities' control. Thus, systematic errors are regarded as being minimal.

Random errors are caused by unpredictable variations which can mean that measurements of the same spillage, for example, can produce different results. Such errors are reduced, however, the more times measurements are made.

The error margin for spillage percentage is a measure of the quality of the result, and says something about how much the actual result can deviate from the calculated. When the total spillage percentage is permitted to be 5 % with an error margin (variation coefficient) of 20 %, this means, in popular terms, that the real result with 90 % probability lies within an interval between ca 3.35 % and 6.65 %.

Sea-vessel based measurement of sediment spillage from all sources was carried out **in situ** right over the sediment plumes and in vertical profiles in the sediment plumes. Up to 1997, measurements were carried out round the clock. By means of the profile measurements in the sediment plumes, it was possible to document the actual distribution of sediment in the water column.

During the autumn of 1996, a special method of estimating was developed to determine the spillage from the dredging operations carried out by the dipper dredger. This estimating method calculates the spillage percentage via a combination of direct measurement of the spillage around each individual dredger, and a model calculation of the spillage, with the actual amount dredged as the reference point, as well as for each individual dredger, with previous experience as the reference point.

In connection with the construction work in Öresund, a series of comprehensive statistical analyses (known as probabilistic analyses) were undertaken of all the different dredging activities. As the uncertainty varies depending on whether it is direct spillage measurement at sea, estimating spillage based on results from periodic measurements, or measurement of spillage from pumping of water from sedimentation basins, the individual operations have each been treated separately (figure 8).

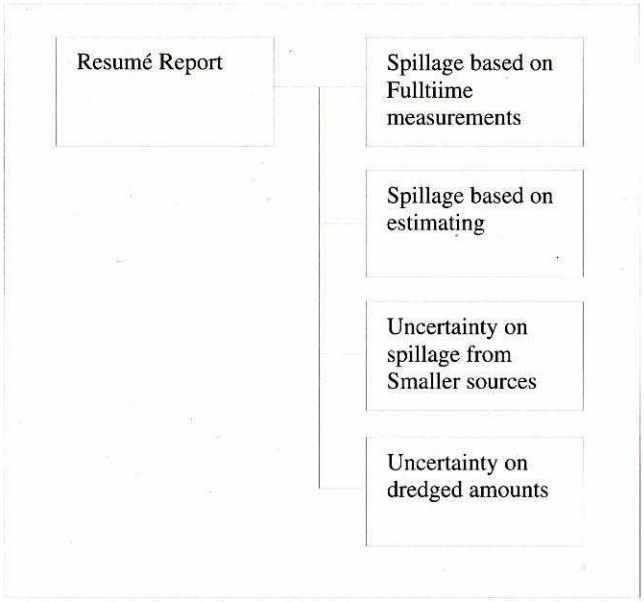

Figure 8. *Overview of the various subjects for the comprehensive statistical analyses for calculating sediment spillage. Source: Öresundskonsortiet /ref. 19/.*

When all the sub-results from the separate analyses have been processed, they will be included in Öresundskonsortiet's comprehensive summary showing whether the construction work has been carried out in accordance with the authorities' criteria. In figure 9, the preliminary results of the calculations are depicted in relation to the authorities' criteria. The results from the calculation of actual spillage, according to both the Danish and the Swedish definitions, deviate marginally from one another. In Sweden, the calculation of spillage is based on the theoretical dredged amount, whereas in Denmark it is based on the actual dredged amount.

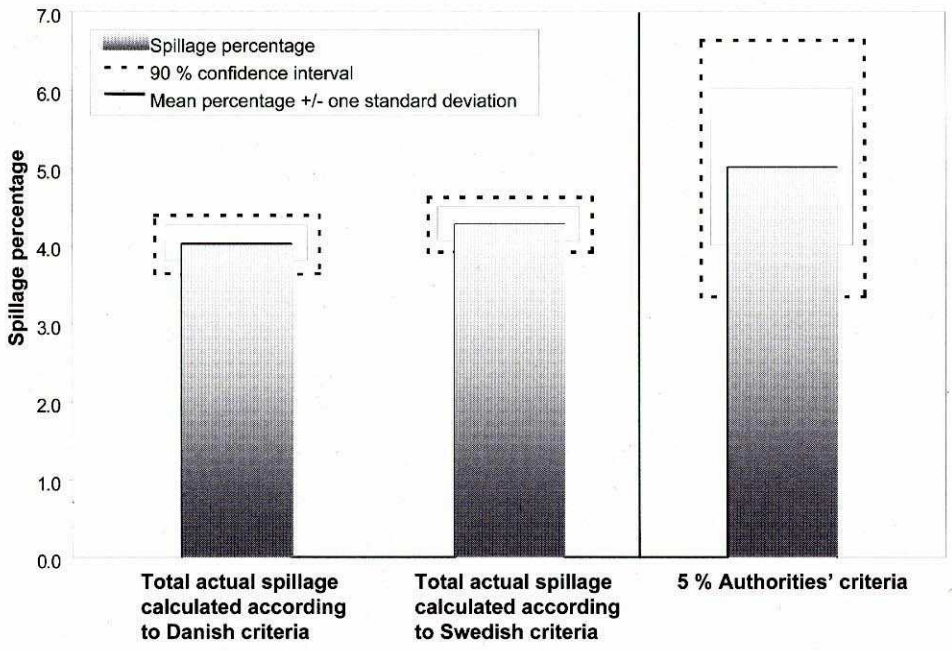

Figure 9. *Calculations of the preliminary actual spillage percentages (the two left-hand columns) seen in relation to the collective criteria of the Danish and Swedish authorities (right-hand column) /ref. 19/.*

The conclusion of the analysis, where only the results from individual small dredging operations are missing, shows that the criterion for the size of the spillage percentage has been fulfilled, and that the uncertainty of spillage percentage will be fulfilled by a very good margin, in accordance with both the Danish and Swedish authorities' criteria /ref. 19/.

8. References

/1/ Öresundskonsortiet, 1999. Biannual Environmental Report for January-July 1999. 34 pp. (In Danish)

/2/ Danish Ministry of the Environment and Energy, Ministry of Transport, The Control and Steering Group for the Öresund Fixed Link, 1999. 7th Semi-Annual Report on the Environment and the Öresund Fixed Link. 24 pp.

/3/ Danish Ministry of the Environment and Energy, Ministry of Transport, The Control and Steering Group for the Öresund Fixed Link, 1998. 6th Semi-Annual Report on the Environment and the Öresund Fixed Link. 20 pp.

/4/ Danish Ministry of the Environment and Energy, Ministry of Transport, The Control and Steering Group for the Öresund Fixed Link, 1998. 5th Semi-Annual Report on the Environment and the Öresund Fixed Link. 22 pp.

/5/ Danish Ministry of Transport, Ministry of Environment and Energy, 1995. Objectives and Criteria, and the environmental authorities' requirements for the overall control and monitoring programme for the Øresund coast-to-coast construction. 20 pp. (In Danish)

/6/ Växjö District Court, Water Rights Court, 1995. Permission to build the Swedish section of the Öresund Fixed Link. Judgement DVA 37/95. Pronouncement Växjö 1995-07-13. (In Swedish)

/7/ SEMAC JV, 1999. Authorities' control and monitoring progamme for the Øresund link coast-to-coast installation. Water quality. Status report 1998. 50 pp plus appendices.

/8/ Danish Institute for Fisheries Reasearch, 1999. Acoustic monitoring of herring in the Sound. Final Report 1993-98. 26 pp plus appendices.

/9/ NERI, 1999. "Monitoring of breeding Eiders at Saltholm, 1999". Pers. com.

/10/ NERI, 1999. "Monitoring of Moulting Greylag Geese on Saltholm, 1999". Pers. com

/11/ NERI, 1999. "Monitoring of Moulting Mute Swans around Saltholm, 1993-1998". Pers. com.

/12/ NERI, 1999. Monitoring of migrating Waterfowl on Saltholm, 1999. 16 pp plus appendices. (Draft)

/13/ Leif Nilsson, 1999. Pers. com.

/14/ Miljöaktuellt, Nr. 5, 23. June 1999. (In Swedish)

/15/ MiljöRapporten Direkt, Monday 7 June 1999. (In Swedish)

/16/ The International Advisory Expert Panel for the Fixed Link Across Øresund. Report of the 8th Meeting, Sophienberg Slot, Rungsted, Denmark 10–12 June, 1999. 8 pp.

/17/ Swedish Ministry of the Environment and Nature Resourses, 16 June 1994. Government descision 38, M93/4027/4. Application from Öresundskonsortiet about permission according to the Law of Water Right (1983:291) to build the Swedish part of an Öresund Link. 29 pp. (In Swedish)

/18/ Danish Ministry of Environment and Energy, 12. October 1995. Regarding permission for Öresundkonsortiet to extract raw material in the construction area for the Fixed Link across Øresund. 12 pp. (In Danish)

/19/ Öresundskonsortiet, October 1999. Sedimentspillage. Uncertainties from the dredging works in connection with the Öresund Fixed Link. Summary Report. 21 pp. (In Danish)