5th Semi-Annual Report on the Environment and the Øresund Fixed Link's Coast to Coast Installation

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Swedish Control and Steering Group for the Öresund Link

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

5th SEMI-ANNUAL REPORT ON THE ENVIRONMENT AND THE ÖRESUND FIXED LINK'S COAST-TO-COAST INSTALLATION

July-December 1997

Colophon

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0. Foreword

The comments to the Danish Constuction Bill to build a fixed link over the Öresund state that every six months the Danish Government will 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 Environmental Protection Agency and the County Administration of Scania (Skåne) are to keep the Swedish Government informed on the implementation and control and monitoring of the construction work through the Control and Steering Group for the Öresund Link (KSÖ).

The four previous six-monthly reports, published in February and September 1996, and May and October 1997, presented the environmental management framework and the individual elements of the control and monitoring programme, together with a progress report upto mid-1997.

This fifth report describes the control and monitoring activities for the latter half of 1997. It has been prepared by the Danish and Swedish environmental authorities, assisted by the Danish Ministry of Transport, based on reports presented by Öresundskonsortiet, and consultants affiliated to various sections of the authorities' control and monitoring programme.

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

1. Summary

It continues to be the authorities' overall opinion that the construction work is being carried out within the framework of the applicable criteria. Some of the criteria, however, such as the zero solution and the temporary environmental effects within the outer impact zone, can only be finally evaluated at a later stage. Consequently, the monitoring of the effects of the construction work will continue as planned.

During the second half of 1997, no new dredging instructions were approved. In November 1997, the Swedish Water Rights Court gave permission for an increase in dredging volume on the Swedish side of 0.8 million m^3, to 2.8 million m^3, in order to secure the minimum depth in the realigned Flintrännan Navigation Channel. Thus, in total, since dredging began in October 1995, there has been a net increase in the estimated dredging volume of approx. 670 000 m^3.

Since construction work began, and until the end of 1997, approx. 4/5ths of the total planned volume has been dredged. Spillage from these approx. 6.2 million m^3 amounts to approx. 4.1 %, corresponding to approx. 485 000 tonnes. This amount is approx. 80 000 tonnes less than expected, when compared to budgeted spillage, and represents a good safety margin to the stipulated 5 %-spillage limit for the remaining dredging work.

According to Öresundskonsortiet's own feedback monitoring programme, in round figures 3/4 of sediment spillage stays in Öresund. In Öresundskonsortiet's opinion, this has not caused problems for eelgrass, mussels, foraging areas for birds, fish migration through Öresund or water transparency along bathing beaches. The authorities' effect monitoring and control programme for water quality, benthic vegetation, benthic fauna, as well as for fish gives the same indications.

The authorities' monitoring of greylag geese, eider and swans indicates displacements in their distribution away from the area where construction work is being carried out. The extent of these displacements is dependent on the degree of availability of alternative food supplies. Despite the displacement in these species' distribution around Saltholm, there is nothing to suggest that any changes have taken place in foraging, physical condition or reproduction which can be attributed to the construction work.

Authorities' coastal monitoring programme shows that changes are taking place in the seabed conditions of Öresund between the artificial island and Saltholm. Here, there has been an increase in the quantity of fine particle material and limestone in the sediment. These changes were foreseen, but in terms of volume are not of such a magnitude as to cause the formation of a land-link between the two islands. No deterioration has occurred in water tranparency along the bathing beaches, either on the Danish or on the Swedish side.

The International Advisory Expert Panel held its 7th meeting in Malmö from 10-12 November 1997.

2. Introduction

During the second half of 1997, the cutter-suction dredger CASTOR left the area after having dredged virtually the whole tunnel trench, and completed an essential part of the compensation dredging in the area south of Saltholm. The critical dredging works have been the new navigation channel in Flintrännan and the tunnel trench in Drogden, together with the straightening of the Drogden Navigation channel.

Environmentally speaking, the first half of this period was characterised by the hot summer, resulting in very high water temperatures. The high rate of sunlight at the same time resulted in high production of eelgrass and tasselweed, and thus the signs of a reduction in biomass noted in 1996 were turned into powerful growth in 1997.

The SEMAC Joint Venture, which implements the authorities' control programme for water quality, benthic fauna, benthic vegetation and coastal conditions has, during the latter half of 1997, begun its second year of monitoring. The International Advisory Panel of Experts, at their 7th meeting in November 1997, considered the preliminary results of the control and monitoring programme.

Cooperation between the authorities in Denmark and Sweden as well as with Öresundskonsortiet has worked satisfactorily within established frameworks. Cooperation with the consultants has also worked satisfactorily.

There follows below a status report on the implementation of the construction work, the progress of the dredging work and the environmental conditions in Öresund in connection with the construction work. In conclusion, there is an overview of forthcoming activities.

3. Construction work in Öresund

3.1 Construction work status

In August 1997, Öresund Tunnel Contractors fitted the first tunnel segment into place near the artificial island at Kastrup. By the end of the year, 6 of the total 20 tunnel segments were in place. These six segments have a total length of more than 1 kilometer /ref 1/. On the artificial island south of Saltholm and on the artificial peninsula, two tunnel portals to the immersed tunnel are being built. Also on the artificial island, the railway alignment is almost finished and the road ramp is expected to be completed by February 1998 /ref 1/.

On the high bridge's western pylon, a series of technical problems has meant that what is known as the sub-foundation at the base of the caisson has had to be rebuilt. It also transpired that part of the concrete in the west pylon's north leg had to be removed and recast. These delays were of no importance to the overall time schedule. The eastern approach bridge is beginning to take shape. Its caissons and piers are positioned along the bridge-alignment by the pontoon crane SVANEN. The first two sections at the Lernacken bridgehead were lifted into place before the end of the year /ref. 1/.

At the turn of the year, approx. 83 % of the dredging and reclamation work had been carried out, and the greater part of the remaining dredging work is expected to be completed during 1998 /ref 1/. During the winter months, little dredging work has been done. Consequently, there has only been need to use one dredger in the fairways and access channels in Drogden and Flintrännan.

All contracted works are thus underway, and the project's total delay, amounting to less than 6 weeks compared with the master plan, was partly caused by problems with production of the tunnel segments in the start-up phase /ref. 1/.

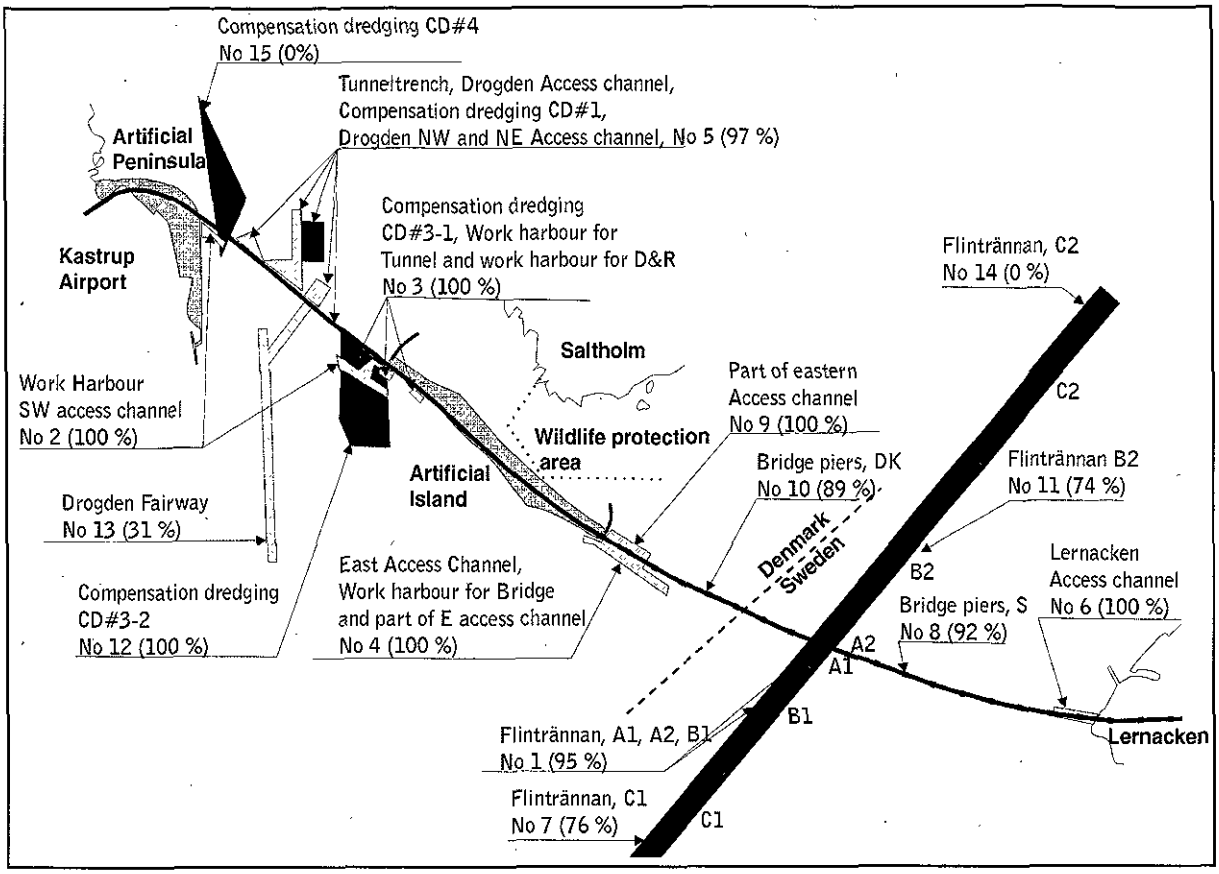

Figure 1. *Status of completed, ongoing and planned dredging work at the end of 1997. The various dredging instructions are numbered. Percentages show work completed. Source: Öresundskonsortiet.*

3.2 Approval of dredging instructions and spillage budget

The dredging instructions lay down the detailed guidelines as to how each dredging operation is to be carried out, and, in accordance with these, Öresundskonsortiet must account for expected spillage. The location of dredging work within the approved dredging instructions, together with the proportion of dredging work actually completed, is shown in figure 1.

No new dredging instructions were approved during the second half of 1997. Dredging instruction 14 has, however, been forwarded to the authorities for consideration. Thus, the situation remains the same in that the Danish and Swedish authorities, at the end of 1997, had approved 13 out of 15 planned operations.

The latest revised spillage budget, applicable as at 31 December 1997, is shown in table 1. The spillage budget is updated in step with the establishment of the contractor's detailed formulation of the individual dredging operations. The spillage budget contains "accounts" for the hitherto dredged quantities, together with the estimated sediment spillage for the planned dredging operations. From the spillage budget, it can be seen that individual part-operations can have a spillage higher than 5 %, which is acceptable so long as the overall mean for the construction work as a whole does not exceed 5 %.

In November 1997, the Swedish Water Rights Court considered Öresundskonsortiet's application for an increase in the dredging volume on the Swedish side /ref. 2/. The Water Rights Court granted permission for an increase in volume on the Swedish side of 0.8 million m^3 upto approx. 2.8 million m^3 in order to ensure the minimum required depth in the realigned Flintrännan Navigation Channel.

Compared with the first half of 1997, the spillage budget has been updated from the standpoint of the Water Rights Court's decision to allow an increase in dredging volume for dredging instructions 1, 7 and 14, which all refer to Flintrännan. The expanded quantities are partly matched by a diminished requirement in the concluding compensation dredging in dredging instruction 15. Finally, the quantities in the approach channel to Lernacken have been increased slightly in operatioal plan 6. In total, the dredging volume budget has, since the construction work began in the late summer of 1995, been increased by approx. 670 000 m^3 /ref. 3/ to a total of 7.5 million m^3.

3.3 Status of dredging instructions and spillage accounts

At the end of August, the dredging vessel CASTOR left the area, having in the main completed the dredging work in the tunnel trench and in compensation extraction area CD#3-2 (fig. 1). A further six mechanical dredgers have carried out dredging work. The most extensive operations occurred in Flintrännan (areas C1 and B2), in Drogden Fairway and in compensation extraction area CD#3-2 beside the artificial island. The work has been carried out in accordance with dredging instructions 5 - 8 and 11 - 13 /ref. 1/. The excavated material has been reused in constructing the artificial peninsula and island.

The supervisory authorities and Öresundskonsortiet carry out a continual review of the spillage accounts and the technical situation in relation to the calculation and measurement of the sediment spillage. The concluding evaluation upto week 35 1997 is currently being prepared /ref. 4/.

Spillage from dredging work in extraction areas 6, 8 and 13 has been greater than expected, namely the installation channel at Lernacken, excavating for the bridge piers in the Swedish and Danish sectors, and in Drogden Fairway. On the other hand, spillage from dredging work in the remaining extraction areas has been less than expected /ref. 1/.

During the latter half of 1997, a total of just under 1.3 million m^3 was dredged, of which the greater part was in compensation extraction area CD#3-2 and in area B2 in Flintrännan /ref. 1/. The overall mean spillage for all dredging operations during the latter half of 1997 amounted to 3.8 %, which is a fraction lower than for the previous half year.

From the commencement of construction work upto the end of 1997, a total of approx. 6.2 million m^3 has been dredged (ca 11.9 million tonnes), representing approx. 83 % of the total planned dredging work. For the same period, there was a spillage totalling approx. 485 000 tonnes, representing a mean spillage of approx. 4.1 %. Spillage during the whole of 1997 has been less than budgeted, with the total at the end of the year being approx. 80 000 tonnes less than expected. Thus, there is a good safety margin for the remainder of the dredging work, which makes it unlikely that the authorities' 5 %-limit will be exceeded.

No	Area	Period	Calculated quantity						Quantity actually dredged as at 31 Dec 1997, calculated to theoretical mean level				Budget for remaining work		
			Quantity m3	Quantity tonnes	Spillage tonnes	Spill-age %	Dredge spillage %	Fill spillage %	Quantity m3	Quantity tonnes	Spillage tonnes	Spill-age %	Quantity m3	Quantity tonnes	Spillage tonnes
1	Flintrännan, central section (A1/A2 och B1)	Oct95-Aug97	219.000	414.000	16.924	4,1	3,8	0,3	207.802	392.746	12.149	3,1	11.198	21.254	4.775
2	Work harbour, peninsula and SW access channel	Nov95-May96	328.000	640.000	23.000	3,6	3,2	0,4	328.000	640.000	22.811	3,6	0	0	189
3	Comp. extraction area CD#3-1, work harb. for Tunnel plus work harb, for D&R	Dec95-Sep96	787.000	1.534.000	38.469	2,5	2,0	0,5	787.000	1.534.000	34.989	2,3	0	0	3.480
4	East acc chann. work harb. Bridge plus part of east installation chan	Feb96-Apr96	215.000	409.600	18.300	4,5	4,0	0,5	215.000	409.600	17.736	4,3	0	0	564
5	Tunnel trench, CD#1 plus Drogden installation channel	Jul96-Jun98	2.449.400	4.638.300	251.674	5,4	4,3	1,1	2.384.600	4.525.805	216.787	4,8	64.800	112.495	34.887
6	Installation channel Lernacken	Sep96-Apr97	299.000	593.180	17.795	3,0	3,0	0,0	299.000	593.180	24.624	4,2	0	0	-6.829
7	Flintrännan, area C1	Apr97-Oct98	495.000	936.000	56.160	6,0	5,9	0,1	376.200	718.542	9.551	1,3	118.800	217.458	46.609
8	Bridge piers for Approach Bridge plus pylons/S	Oct96-Mar99	193.500	382.800	19.140	5,0	5,0	0,0	178.259	353.953	22.767	6,4	15.241	28.847	-3.627
9	Part of east installation channel	Mar97-Apr97	136.000	267.000	14.418	5,4	4,6	0,8	136.000	267.000	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	65.949	129.920	9.067	7,0	8.151	16.320	-1.755
11	Flintrännan, area B2	Jun97-Feb98	673.000	1.300.090	65.005	5,0	4,8	0,2	499.907	964.820	38.710	4,0	173.093	335.270	26.295
12	CD#3-2	May97-Aug97	657.000	1.292.500	64.625	5,0	4,8	0,2	657.000	1.292.500	48.191	3,7	0	0	16.434
13	Drogden Fairway	Jul97-Aug98	230.000	437.000	21.850	5,0	4,8	0,2	71.776	136.375	7.374	5,4	158.224	300.625	14.476
14	Flintrännan, area C2	Mar98-Oct98	638.000	1.212.000	72.720	6,0	5,5	0,5	0	0	0		638.000	1.212.000	72.720
15	Compensation extraction 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						6.401				4.472
	Spillage from other sources - S				11.870						94				11.776
Total – Danish area		Nov95-Dec00	4.976.500	9.552.640	459.921	4,8			4.645.325	8.935.200	377.142	4,2	331.175	617.440	82.779
Total - Swedish area		Oct95-Mar99	2.517.500	4.838.070	259.614	5,4			1.561.168	3.023.241	107.895	3,6	956.332	1.814.829	151.719
Total		Oct95-Dec00	7.494.000	14.390.710	719.535	5,0			6.206.493	11.958.441	485.037	4,1	1.287.507	2.432.269	234.498

Table 1. *Current spillage budget 31 December 1997. Table shows actual dredged quantities calculated to the so-called theoretical mean level and the remaining planned dredging work, plus measured and budgeted spillage. The table has been revised to accord with the budget presented in the 4th biannual report (see section 3.2). Source: Öresundskonsortiet.*

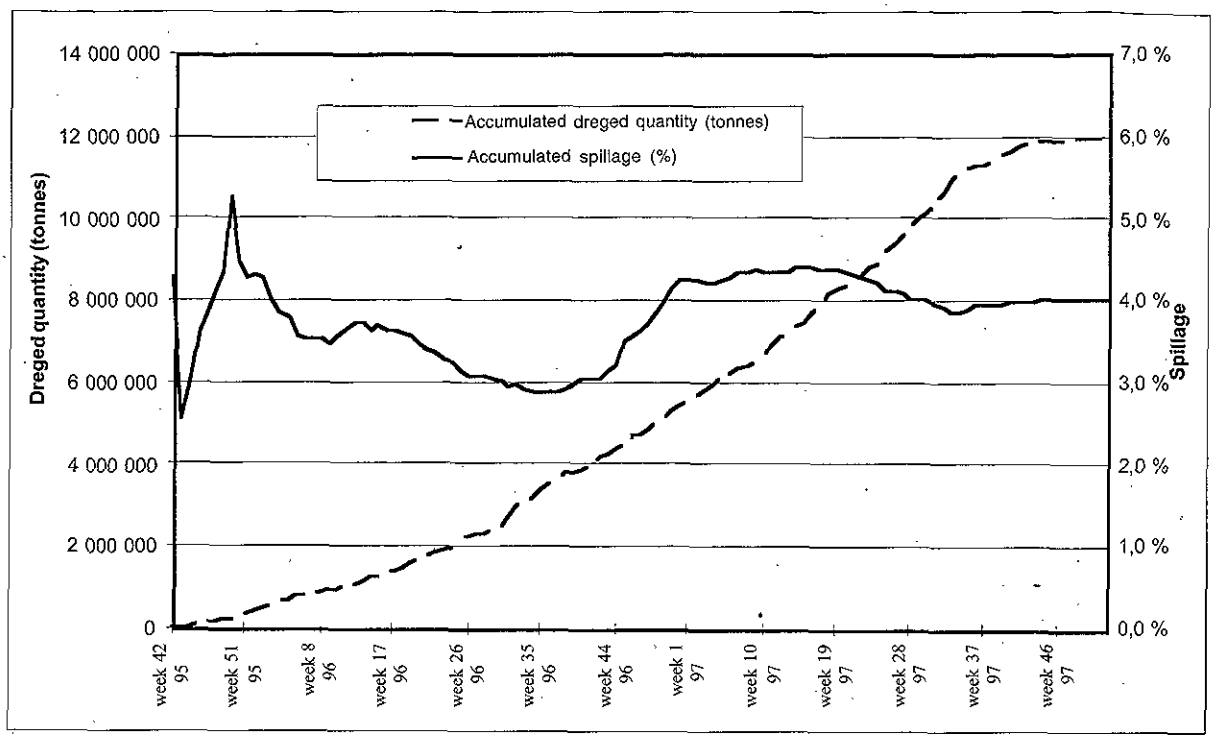

Figure 2. *Development in time of the total quantity produced in tonnes and the accumulated spillage expressed as a percentage of the dredging work as a whole. Source: Öresundskonsortiet.*

Development in time of the total quantity produced in tonnes, and the accumulated spillage expressed as a percentage of the total dredging work, is shown in figure 2. Figure 3 compares budgeted and actual spillage, and it will be seen that the actual spillage, especially during the latter half of 1997, has lain markedly below budgeted spillage.

During the second half of 1997, approx. 290 000 m^3 of sand filler has been extracted from Kriegers Flak in the Baltic Sea with an average spillage of approx. 3.8 %. Since 1 January 1996, a total of approx. 900 000 m^3 has been extracted, with an average spillage of 2.7 %. Spillage from this extraction thus lies considerably under the permitted 5 %.

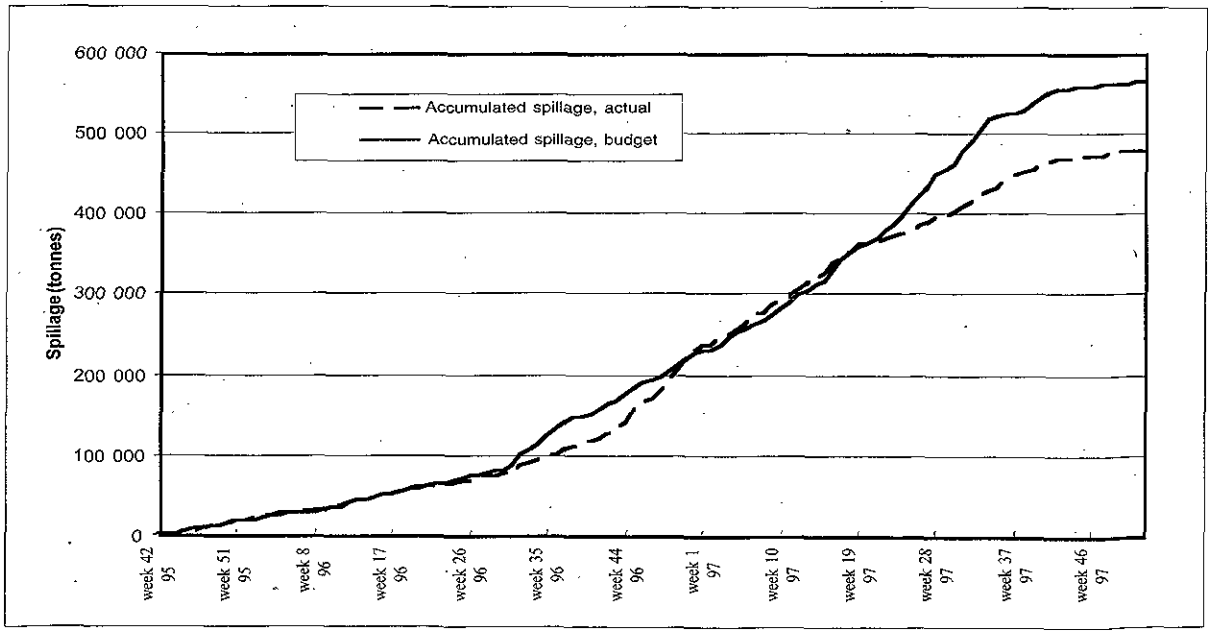

Figure 3. *Development in time of measured spillage in relation to budgeted spillage. Source: Öresundskonsortiet.*

3.4 Spillage measurement, resuspension and bed load transport

The spillage measurement programme registers 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 CASTOR comprises the predominant individual source of spillage and has therefore been measured around the clock upto August. Spillage amounts from the smaller dredgers are determined by a combination of direct measurements around each individual dredger, and a model estimate spillage based on the actual amount dredged, once again for each individual dredger /ref. 1/.

The contractor programme for the mapping of any resuspension from the extraction areas has been regularly carried out throughout the period. The seabed is sampled once a month to determine the amount of deposited sediment within each extraction area.

During the second half of 1997, a side-scan sonar was used to monitor bed load transport from areas (CD#1 and CD#3-2) which had been dredged using the cutter-suction dredger CASTOR.

Upon the completion of the dredging work in area CD#3-2 and the follow-up monitoring of bed load transport, Öresundskonsortiet has stated that there remained 14 000 tonnes of fine sediment within the extraction area after the cessation of the standard spillage monitoring programme. The greater part of this sediment is expected to be resuspended during the winter of 1997/98. This will be investigated during 1998. Even if all this sediment were to be transported out of the area, the amount of spillage from this dredging operation will still be below budget.

In addition, the other extraction areas have been monitored with the help of under-water video. This check has shown that, within the 200 m limit, the sea bed has not been covered with spilled sediment during the second half of 1997.

The conclusion of the monitoring programme is that part of bed load transport not measured by the standard spillage monitoring programme amounts to 0.5 % of measured spillage, and it has therefore been decided that 2 425 tonnes be added to the spillage, as a result of bed load transport.

3.5 Inspection by the authorities

Inspection by the authorities supervision is based on discussions in the technical working groups, and on direct access to various data, collated and processed by Öresundskonsortiet. These data are presented in the environmental information system EAGLE. The authorities also carry out on-the-spot inspections.

Through the environmental information system EAGLE, the authorities can gain swift access to data which enables them to follow the development of environmental conditions, partly with regard to sediment spillage and the assessment of the effects on eelgrass and common mussels through results from feedback monitoring. During the second half of 1997, a series of infringements /ref. 1/ of Öresundskonsortiet's own operational criteria were registered in EAGLE (see section 4.1.1-3). The character of these infringements, and the resultant action taken by Öresundskonsortiet, did not give the authorities cause to comment.

During the latter half of 1997, the Swedish and Danish authorities carried out on-the-spot inspections at Öresundskonsortiet in connection with the collection of eelgrass and common mussels, and the use of side-scan sonar. The authorities have also obtained technical information on Öresundskonsortiet's model for estimating sediment spillage and on calculating the degree of uncertainty in the spillage estimates. In addition, the authorities have also carried out inspections of the bridge construction yard in Malmö's north harbour, of construction work in Öresund, and of the tunnel factory in Copenhagen's north harbour.

4. Control and monitoring programme

A collective control and monitoring programme has been drawn up in accordance with the Danish authorities' requirements /ref. 5/, and with the Swedish Water Rights Court's ruling /ref. 6/. The prime purpose of this programme is to register the conditions in the marine environment and provide the basis for taking countermeasures should any construction operation have a greater effect than expected. When the fixed link is complete, the monitoring programme will register whether the temporary effects on the marine environment decrease as expected.

Responsibility for the implementation of monitoring and control of the construction work is shared between the contractors, Öresundskonsortiet and the Danish and Swedish environment authorities.

4.1 Feedback monitoring

For the individual dredging operations, Öresundskonsortiet uses a feedback programme involving frequent monitoring of selected parameters in the marine environment surrounding the dredging areas. In this respect, the programme differs from the more general, effect monitoring programme (section 4.2). The feedback programme is intended to ensure that early action is taken in respect of the implementation of construction work where there appears to be a risk that the authorities' environmental demands may be infringed. The feedback programme includes continued model work and the analysis of sediment in the water columns and on the sea bed, and of common mussels and eelgrass. In connection with the control and monitoring programmes, Öresundskonsortiet has set up what are known as its own operational environmental criteria, which are more rigorous and specific than those of the authorities. If Öresundskonsortiet exceeds these operational criteria, intensified surveillance is usually initiated.

4.1.1 Sediments

During the latter half of 1997, sediment plumes have been visible in Drogden and Flintrännan, and in a broad belt down towards Stevns. According to the model calculations, these plumes have only been visible for 1 % of the time in the northern sector of Öresund because south-flowing currents have dominated during this period. The coast south of Limhamn has been affected by sediment plumes 1 % of the time during the autumn as a result of the completion work of the Lernacken installation channel.

During the period when mussel larvae settle on the sea bed (June to September), sedimentation rates have not been found to exceed the critical value for longer periods of time.

Plumes with a higher concentration than 15 mg/l have only been found locally around the sources themselves. This limit applies to water for bathing, and to birds around Saltholm. The shallows around Saltholm, as well as the bathing beaches along the Danish and Swedish coasts, have not been affected /ref. 1/.

Sediment spilt from the extraction work builds up because of the current conditions in Öresund, especially in the area north of Middelgrundsfortet, and in the outer reaches of Køge Bay. Immediately north of Middelgrunden are found the largest deposits of upto 5 000 g/m^2, which corresponds to a measurable thickness layer of 5 mm (fig. 4). The model calculations, upto and including 24 December 1997, have shown that 76 % of the presently accumulated spillage, representing a total of approx. 375 000 tonnes, stays in Öresund, whilst the remainder is carried out of Öresund by the current /ref. 1/.

During the second half of 1997, because of Öresundskonsortiet's survey of the sediment conditions, no values leading to feedback action have been measured or calculated /ref. 1/.

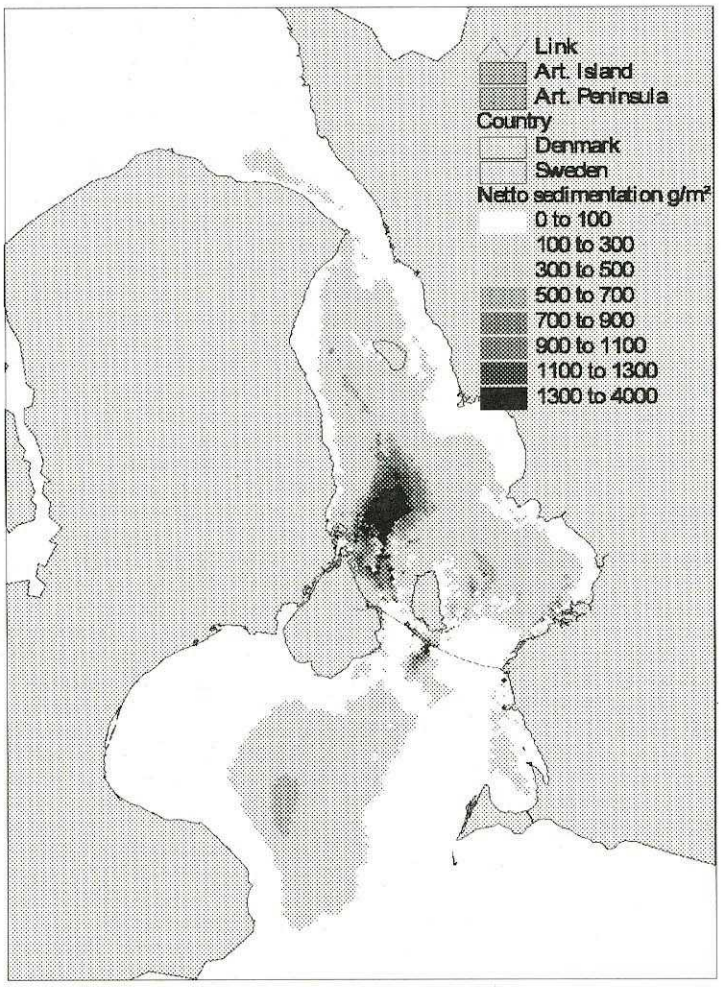

Figure 4. *Calculated net sedimentation in g/m² as at 24 December 1997 (Hindcast-calculation). Source: Öresundskonsortiet.*

4.1.2 Eelgrass

During the second half of 1997, eelgrass has been collected twice a month at 10 - 13 stations within the outer impact zone. The number of stations has been increased so as to be able to follow the effects of dredging in CD#3-2 /ref. 1/. The values of eelgrass-shoot density, leaf and root biomass and carbohydrate content have been tested against Öresundskonsortiet´s own operational criteria. Added to which the model calculations and an annual monitoring are used to evaluate the effect on eelgrass in those areas in which field surveys are otherwise not carried out.

During August 1997, six continuous eelgrass beds were monitored during Öresundskonsortiet´s examination of the authorities´ criteria for eelgrass. The survey revealed a general increase in most of the variables in comparison to the baseline investigation from 1995, with the exception of the area just northwest of Saltholm, where leaf biomass at a depth of 5-6 meters had been affected. Locally, carbohydrates have temporarily exceeded the operational criteria at a station south of Saltholm, which Öresundskonsortiet has evaluated as a natural variation, probably unrelated to the construction work /ref. 1/.

Thus, with one temporary exception, the eelgrass programme for the second half of 1997 has revealed no infringements of Öresundskonsortiet´s own operational criteria /ref. 1/.

4.1.3 Common mussels

During the second half of 1997, monitoring have been carried out twice a month. On each occasion, distribution has been registered with the help of photography, whilst sampling of mussels for the analysis of biomass has been carried out only once a month. In general, the

photodocumentation showed no real covering of the mussel banks in the surveyed areas of Drogden and Flintrännan. However, during September and November, a thin, "dirty" deposit appeared on the common mussel beds in the southeast sector of Drogden, probably stemming from the dredging activities in the large compensation extraction area CD#3-2. Thus, the photodocumentation tallies with the model, which shows that, during the same period, considerable resuspension occurred. It was concluded that these deposits had made no appreciable difference to the common mussels' survival since they were soon washed clean again by the currents and waves /ref. 1/.

The biomass of the common mussel has, in general, shown a tendency to rise, but this increase has not been uniform, with biomass decreasing in other areas. In July 1997, in Flintrännan, there was a decrease in biomass, resulting in a temporary infringement of Öresundskonsortiet's operational criteria for biomass. The photodocumentation has revealed that the reduction is probably not connected with construction work, as virtually no covering of the mussel banks has occurred with material from the dredging operations.

4.2 Effect monitoring

As a feature of the supervision of the construction work, the environmental authorities carry out a monitoring programme to determine whether the observed effects of the construction work lie within the framework of the expected effects /ref. 7/. This programme covers monitoring in the following aspects of the Öresund's environment: water quality, benthic vegetation, benthic fauna, fish, birds, beaches and coasts.

Effect monitoring is long term and is primarily aimed at establishing the effect of the construction work, and the environmental changes from year to year. It is directed towards a broader sector of the ecosystem, unlike the feedback monitoring, which focuses on fewer variables and on the outer impact zone around the dredging operations.

4.2.1 Water quality

The construction work and the operation of the Öresund link must not lead to release and redistribution of heavy metals, hazardous substances, nutrients, or cause oxygen consumption, in such quantities as to create negative ecological effects or bring about significantly increased concentrations of heavy metals or hazardous substances in animals or plants. In critical situations with oxygen deficiency in Öresund, it must be ensured that the dredging work does not cause increased harmful effects to the biological conditions.

The scope of the programme in 1997 regarding stations, sampling frequency and parameters monitored was set out in the 4th biannual report /ref. 2/.

During 1997, oxygen deficiency was only registered at the station south of Ven, six times during August, September and November, when it lasted two weeks at the most. The transparency (Secchi depht) in Öresund fluctuated around the average for the period 1985-1995. With the exception of total-nitrogen content, the nutrient concentration for 1997 in the total water column was lower than the average for the periods previously surveyed off Ven (1970-1995), Stevns (1974-1995) and Drogden (1985-1995). The total nitrogen concentration showed average values /ref. 8/.

The registered conditions lie within the natural variations in Öresund and the construction work has thus not affected the water quality in Öresund, either in respect of nutrients or oxygen concentrations.

4.2.2 Benthic fauna and benthic vegetation

Permanent impact on plant and animal life in the inner impact zone is acceptable, whereas transitional impact on species composition, distribution and biomass is acceptable in the outer impact zone. A temporary decrease in plant and animal life of upto 25% is acceptable in the outer impact zone.

The purpose of this monitoring is to follow the development of the benthic fauna and vegetation in Öresund, in order to document whether any changes lie within the framework of the criteria laid down by the environmental authorities.

Benthic fauna

The status report on common mussels /ref. 9/ presents monitoring results from 48 stations. This demonstrates that the biomass in the outer impact zone has increased during 1997 compared with the baseline survey. In areas with a degree of coverage of more than 40 %, no significant reduction in biomass has been registered, in relation to the baseline survey. Authorities' requirements regarding degree of coverage and biomass must therefore be regarded as having been fulfilled.

Concentrations of the metals copper and zinc in mussels have increased significantly during 1997 compared with the baseline survey, but since the increase is general for the whole survey area, the blame cannot be attributed to the construction work.

The status report for 1997 regarding fauna, except common mussels, presents monitoring results from 47 stations with a depth interval in Öresund of 4 – 47 meters /ref. 10/. In the main, no general changes can be demonstrated between the years 1995 to 1997, either in the area as a whole, or within the two most important communities (Macoma and Abra communities) in Öresund.

The International Advisory Expert Panel have earlier expressed reservations regarding the benthic fauna programme, and most recently, at the 7th meeting in Malmö 1997 /ref. 11/ at which the status reports for the previous year /ref. 12, 13/ were presented, the panel stated that, statististically speaking, the programme was too weak to reveal changes. With the aim of strengthening the programme, the authorities and Öresundskonsortiet, as an innovation for the second year of monitoring, have introduced a correlation analysis between the changes over time in the benthic fauna and the so-called hindcast-data regarding the actual sediment spillage at the individual stations. The results of this analysis show that it is possible, with reasonable certainty, to draw the conclusion that the sediment spillage resulting from the first two years of the building of the bridge has not had any negative effect, either through reduction in biomass or increased variation in species composition.

Benthic vegetation

The control and monitoring programme for benthic vegetation embraces communities of eelgrass (*Zostera marina*) tasselweed (*Ruppia spp.*) and sugar kelp (*Laminaria saccharina*). A more detailed description of the scope of the programme, and the positioning of the stations, is to be found in the authorities' 2nd biannual report /ref. 14/ and in SEMAC JV's annual report for benthic vegetation 1997 /ref. 15/.

As with the 1996 results, the analyses of the data from the baseline and the 1997 monitoring here again fail to show that vegetation has been affected by the construction work.

Working from these surveys, it can be concluded that the build-up in the coverage (eelgrass, tasselweed and sugar kelp), biomass (eelgrass, tasselweed) and shoot density (eelgrass) within the outer impact zone does not differ appreciably from the build-up in the control area, when comparing the 1997 surveys with the baseline surveys (fig. 5). It should, however, be noted that there is very little data available for sugar kelp, and in the present situation, it is not possible to determine if the authorities' criteria regarding sugar kelp have been fulfilled.

The 4th biannual report /ref. 2/ stated that there was too little data on tasselweed biomass to be able to draw any conclusions regarding biomass development after the first year monitoring. The reason for the faultiness of data was that the baseline surveys and the authorities' control programmes respectively had used different sampling methods. Prior to the 1997 tests, therefore, an intercalibration of these methods was carried out, which however showed that the different methods gave comparable results.

Regression analysis of sediment spread and eelgrass-shoot density and biomass revealed no connection between eelgrass development during the years 1993 to 1997 and the quantity of accumulated spillage from construction work.

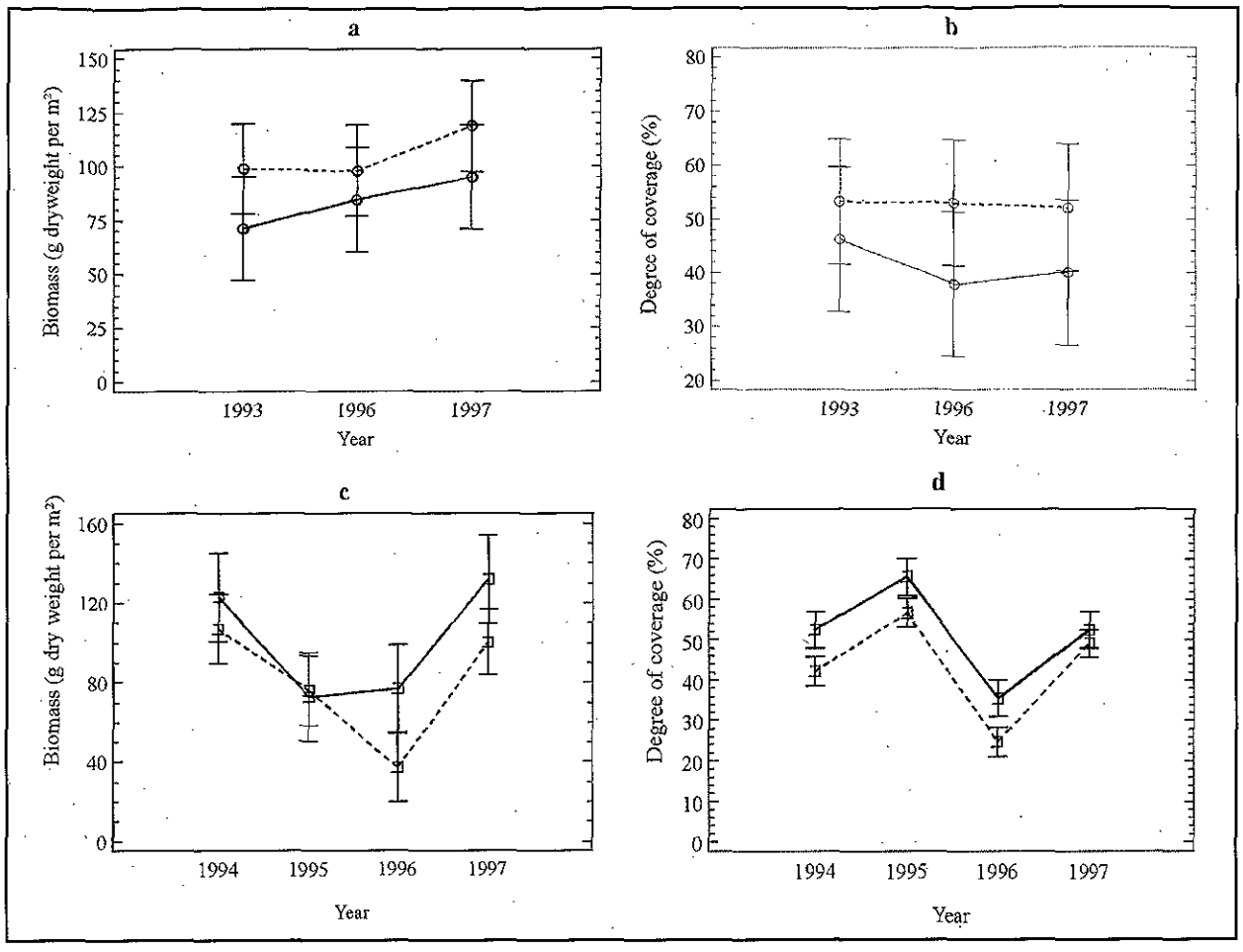

Figure 5. *Eelgrass biomass (a) and coverage (b) in the control and outer impact zone during 1993, 1996 and 1997, as well as tasselweed biomass (c) and coverage (d) in control and outer impact zone 1994-1997, expressed as average mean at 95 % confidence interval. Control area is shown by whole lines and outer impact zone by broken lines. Source: SEMAC JV, 1998.*

Shallows vegetation around Saltholm.

In connection with the bird monitoring programme around Saltholm, vegetation surveys of the shallows to a depth of 3 m have also been carried out. The results from shallows of less than 1 m, and deeper than 1 m, have each been analysed separately. The shallowest areas consist of mixed tasselweed communities and the deeper water is dominated by eelgrass.

In the 4:th biannual report /ref. 2/, the authorities reported a significant reduction in tasselweed's coverage around Saltholm between 1995 and 1996, and which was greatest nearest the construction work. The authorities' view was that the reduction had been caused by a combination of ice and sediment spillage.

When comparing results from 1995 and 1997, it can be seen that the coverage of both tasselweed and eelgrass has increased markedly on Saltholm's east side, whilst the coverage on its west side has remained at the same level in 1995 and 1997. This suggests that the vegetation in the shallows around Saltholm in 1997 has not been affected by the construction work.

4.2.3 Fish

Situations must not be allowed to arise where sediment plumes simultaneously block the migration of herring through Drogden and Flintrännan. By establishing this criterion, together with the criteria for the other natural and environmental conditions, allowance has also been made for eel, garfish, mackerel and lumpsucker, which also migrate through Öresund.

Apart from the monitoring of herring migration, special programmes for monitoring the abundance of eel fry, the recruitment of flatfish, and so on, have also been introduced, as laid down by the Swedish Water Rights Court.

The monitoring of the migration of herring through Öresund takes the form of acoustic measurements of population size at various times during the course of migration. Herring abundance is measured via echo soundings along a plotted route network throughout the whole of the Öresund. These echo measurements are complemented by simultaneous gill net fishing in order to establish size and species composition of the fish observed by echo sounding.

Monitoring cruises from October 1996 onwards, have revealed an increase in herring biomass in Öresund compared with previous years. Detailed studies of the length ratio of herring observed from October 1996 to October 1997 have shown that, during this period, a considerably greater proportion of smaller herring have been observed than in previous years. This greater proportion comprised, during the Autumn of 1997, of a large quantity of 4-year old herring.

These observations are supported by further observations of an increased concentration of herring larvae in the spawning grounds during 1994, together with an increased abundance of 3-year herring caught at the spawning grounds during 1996.

The registered observations of biomass from the 1997 survey show that the herring have followed their normal migration pattern and that the construction work in 1997 has thus not affected the herring migration through Öresund.

4.2.4 Birds

A reduction of 15 % in the eider population on Saltholm has been accepted during the construction phase. The number of breeding eider pairs shall, however, within 5 years at the latest after the completion of the work on the sea bed, be at least 90 % of the number of breeding eider pairs registered during the baseline surveys. For the other waterfowl breeding on Saltholm, the numbers must not be substantially reduced.

A temporary decrease in the number of feeding and resting migratory birds has been accepted on Saltholm as a consequence of the construction work. However, the number of feeding and resting migratory birds is expected to be restored, at the latest, two years after construction work has ended. For greylag geese and mute swans, the possibility of a lasting decline in the number of moulting birds has been accepted.

Saltholm´s birds

The preliminary results of the 1997 bird survey were presented in the 4th biannual report /ref 2/. The final processing of this material confirms the preliminary findings /refs 16, 17, 18/.

Eiders revealed a changed distribution away from the area around the artificial island. Instead, a greater number of birds was observed in the areas north and southeast of Saltholm. These changes meant that half the eiders had a distance of 2 500 meters or less to the artificial island during 1997, as opposed to ca 1 100 meters during 1995 (fig. 6). A possible effect of the eiders´ changed distribution is increased feeding competition in the more intensively exploited areas, which may result in reduced opportunities for building up fat reserves. This development, as mentioned in the 4th biannual report /ref. 2/, is being evaluated in the 1998 surveys.

A reduction in brood size in 1997 was also registered in other Danish eider colonies, suggesting that smaller broods are due to poor foraging conditions in general, and thus low fat reserve build-up, in the communal over-wintering areas outside Öresund.

So far as the *greylag goose* is concerned, the final processing of the 1997 surveys shows that both in 1996 and in 1997, on average, fewer greylags were counted at roosts and feeding grounds nearest to construction operations. This can be compared with the fact that the total number of greylags increased during the same period. The greylags´ distribution areas have not expanded, but parts of Saltholm´s east coast have been exploited more heavily for roosting and feeding

The number of moulting *mute swans* around Saltholm in 1997 amounted to 1 882. Compared with 1994, this is a decrease of 35 %. In one reference area in the Swedish sector of Öresund, the decrease during the same period was 10 %. Locally on Saltholm in 1997, there were relatively fewer swans, compared with 1994, in a zone of 1 500 m around the artificial island. Here, the east coast was used as a foraging area to a greater degree than previously.

Thus, for all three species upon which intensive monitoring are being carried out in Denmark, displacements have occurred in their distributions, away from the area where construction work is being carried out. The extent of these displacements depends on the availability of alternative food supplies. For all three species, decreased utilisation of the area in the vicinity of the artificial island may be a reaction to the increase in the general level of human activity in the area. Despite the displacement in bird distribution around Saltholm, it has not been possible to demonstrate changes in foraging, physical condition, or reproduction.

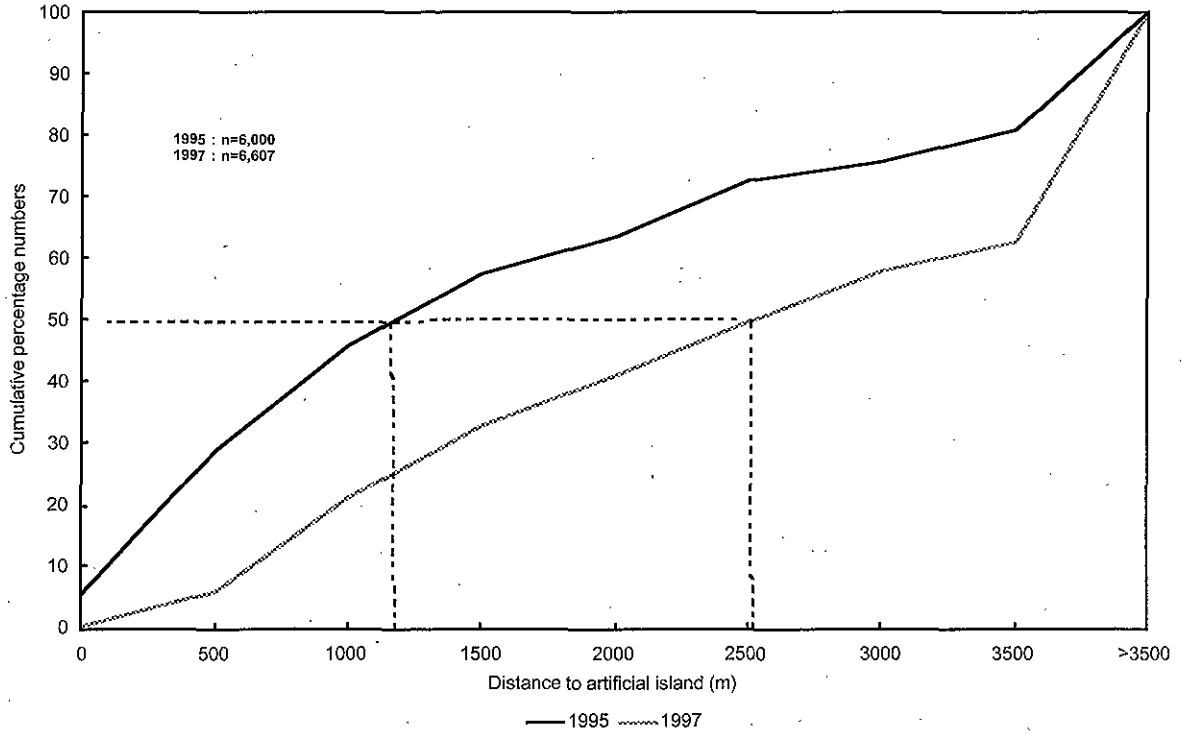

Figure 6. *Distribution comparison between foraging eiders 14 April 1997 (n=6 607) and 13 March 1995 (n=6 000) expressed in distances from artificial island. Source: NERI, Kalø, Denmark.*

Waterfowl along the Swedish Öresund coast

In the autumn of 1997, weekly monitoring were carried out along the coast between Lernacken and Foteviken, and in the reference area of Lommabukten In addition, in the late autumn, supplementary monitoring of tufted duck was carried out in Malmö harbour and in Falsterbo canal.

In order to standardise the comparisons, the number of bird-days has been used (number of birds multiplied by the number of days between the respective countings). This provides a measure of the area's utilisation by birds without being affected by temporary peaks. A comparison between autumn 1997 and the previous autumns, especially 1995, reveals marked differences in bird frequency. Two kinds of difference can be discerned, partly a generally lower occurrence of wigeon in all areas during 1997, and partly more local differences concentrated in the area south of Lernacken, primarily between Lernacken and Klagshamn.

During the period August - November 1997, 260 000 bird-days were recorded between Lernacken and Klagshamn, compared with 466 000 during 1995, corresponding to 55 % of the value for 1995, whilst the corresponding percentage share for the reference area in Lommabukten was 104 % (of 720 000) and for Foteviken 75 % (of 1.7 million). In the latter case, the decline was

primarily noted for wigeon. In the inner impact zone Lernacken - Klagshamn, in addition to wigeon, fewer bird-days were noted for eider, tufted duck, coot and mute swan during 1997, compared with 1995.

Before the commencement of construction work, during the autumn of 1995, 165 000 bird-days were noted for tufted duck between August and November, whilst the utilisation of the area south of Lernacken during 1996 and 1997 was 66 resp. 50 % of the 1995 level. In Lommabukten, the same level was noted for tufted duck during all three monitoring years. The low number of tufted duck in the Lernacken - Klagshamn area is also apparent when compared with the long-term values from earlier studies.

The mussel banks off Lernacken are also an important foraging area for the tufted duck flock of up to 5 000+ individuals which rest in Klagshamn and which search for food on the sea at night. Up to the start of dredging activities in October 1996, the tufted duck exploited the area to a normal degree. The monitoring carried out indicate that the construction work causes disturbance in the tufted ducks' most important feeding grounds off Lernacken, with a resultant reduction in their numbers.

4.2.5 Beaches and coasts

Monitoring of bathing water

The quality of beaches and bathing water along the coasts of Öresund outside the inner impact zone must not be altered to such an extent that the quality requirements for bathing water cannot be met.

A supplementary bathing water programme is being implemented at Amager beach and at Dragør's north and south beaches by agreement with Copenhagen and Dragør municipalities.

During the second half of 1997, no abnormal conditions have been observed along the coasts in Dragør and Copenhagen municipalities.

On the Swedish side, monitoring of the bathing water quality have been made along the beaches in the city of Malmö. The requirement of at least 1 m transparency in adjacent bathing waters has not been infringed during 1997 /ref. 19/.

Coastal monitoring

Outside the inner impact zone, no essential changes may be made to the coastline, which, moreover after the fixed link's construction, must be stable. Sanding-up and major changes to the seabed's character between the artificial island and Saltholm must not be permitted to lead to the formation of a land-bridge between the two islands. Along the other coastlines, only insignificant changes in the seabed and coastal morphology in the direction of a more vegetated coast will be accepted.

In connection with the monitoring of the coasts during 1997 /ref. 20/, comparisons have been made with earlier years, as well as with the 1996 survey, and the baseline study based on aerial photography covering the period from the mid 1950's until 1993.

The monitoring from 1997 shows, first and foremost, that the coastal formation in the natural, dynamically active coastal sections, has undergone changes which constitute a natural development, and which has been going on since the middle of the 1950's. These coastal stretches include Amager's south shore, Aflandshage, the southwest part of Saltholm, Svaneklapperne at the southeast end of Saltholm, and the coast south of Lernacken.

Secondly, in several places, depht changes have been registered from the coastline and out to the 6 meter depth curve. The most significant change in the coastal profile has occurred off the artificial peninsula outside Copenhagen airport, and in the dynamically active areas on south Amager (fig. 7).

Thirdly, the sediment analyses show that changes have been registered in the sedimentary composition on the seabed at several places throughout the area during the period 1996 to 1997. The most significant changes have occurred in the sea lane between the artificial island and Saltholm. Here, the concentration of fine-particle material has increased at the same time as the limestone content in the sediment has increased. This sediment accumulation is attributed as an effect of construction work on the fixed link.

At its meeting in November 1997, the International Advisory Expert Panel considered that there has been produced a viable baseline. It is the panel's opinion that the natural variability of the area makes it very difficult to distinguish changes caused by construction work from changes which occur naturally. The panel recommends, however, that future monitoring should concentrate on the area between Saltholm and the artificial island, whilst the other parts of the coast be monitored from the air in combination with surveys of a few of the representative transects extending from the coastline.

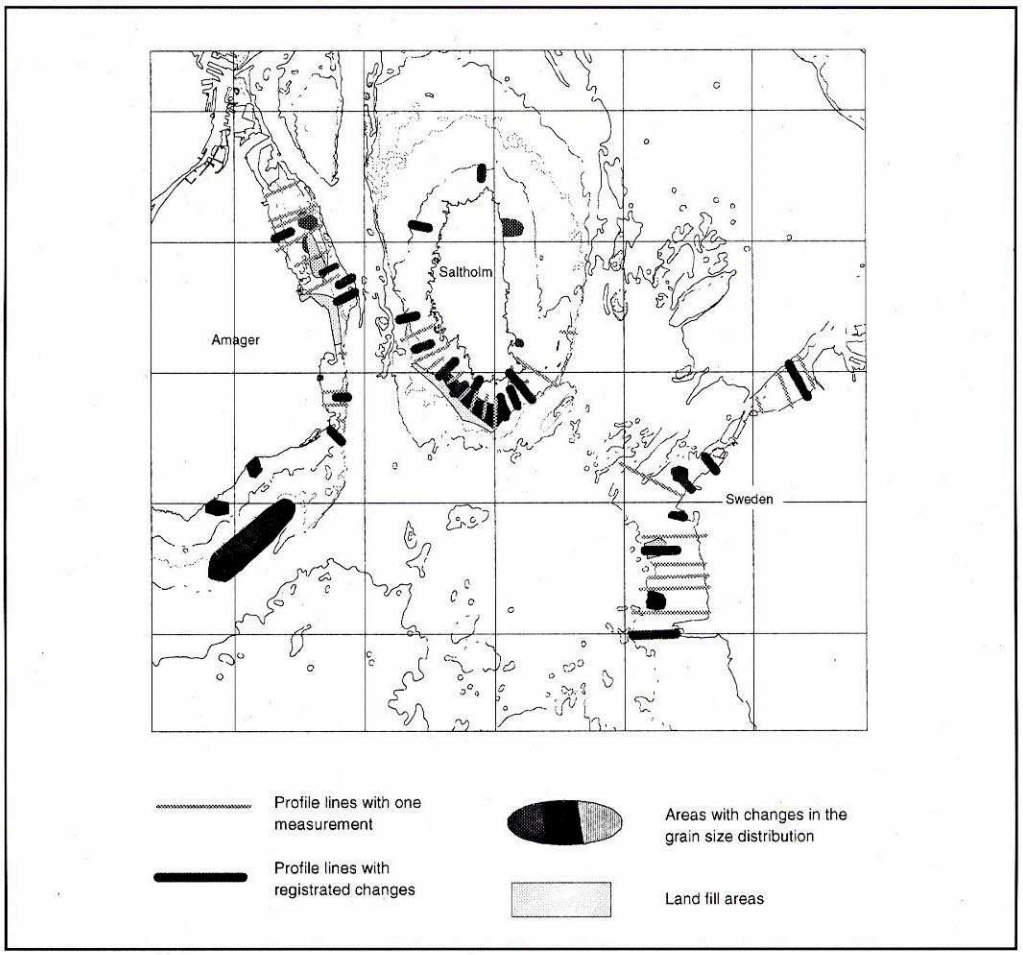

Figure 7. *Results of the coastal morphological monitoring for the period 1996-1997. Source: SEMAC JV, 1998.*

5. The International Advisory Expert Panel

On 10-12 November 1997, the International Advisory Panel of Experts held their 7th meeting, in Malmö, during which they examined the further development of the hydrographic models used in the calculation of the "zero-solution" for the throughflow of water in Öresund. The panel of experts also examined the various control and monitoring programmes set up to ensure that the effects of the construction work in Öresund fall within the established requirements and criteria.

Against a background of presentations and discussions, the panel of experts made a number of recommendations regarding the various parts of the control and monitoring programme /ref. 11/.

The experts also recommended that a special seminar should be arranged, from 4-5 May 1998, at which the panel's biologists will discuss the adjustments of the control and monitoring programme to be introduced upon the completion of the dredging operations for the Öresund fixed link.

The Danish and Swedish authorities will take the panel of experts' recommendations into account in future adjustments with the control and monitoring programme, as well as in other authorities' work.

6. Forthcoming activities

During the first half of 1998, the authorities are to monitor the development of sediment spillage from the remaining dredging operations for the alignment of the sea lane in Drogden, for the remaining dredging of the tunnel trench for the artificial island, and the dredging work in Flintrännan. The greater part of these operations is expected to be completed during 1998. In addition, the authorities are awaiting the first final reports, whereby the work according to the dredging instructions, will be completed. The first final reports will probably cover dredging instructions 2, 3, 4 and 9.

The content of the authorities' control and monitoring programme is amended one year at a time, to allow any necessary adaptations to be carried out in respect of the progress of the construction work and the environmental effects. These adaptations to the programme for the third year will be carried out during the course of the first half of 1998, in an across-the-board form of cooperation between all the authorities, consultants and Öresundskonsortiet involved.

In May 1998, the biologists on the International Advisory Panel of Experts will hold a seminar, during which forthcoming biological monitoring programme will be discussed.

On the Swedish side, an information meeting for other Swedish authorities and interested organisations will be held in May 1998, at which the results of the environmental monitoring and the progress of the construction work will be presented.

The next biannual report is expected to be available in October 1998.

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