The intertidal sediments

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Cost 647 Intertidal sedimentary subgroup: Long termed studies of ecological and physical parameters especially within the Danish Wadden Sea. The following items have been dealt with: 1) baseline studies concerning zoo-biology (1980-85) and some physical factors (1983/85). 2) Studies in the Ho Bugt area as such dealing with the bottom sediments and the suspended matter. Further studies of the landscape elements, the sediments, and the dynamics have been dealt with through remote sensing.

The working group settled the importance of the local physical parametres co-ordinated with the benthic base-line studies. Further the long termed trends in hydrology and climatology were emphazised. The fundamental object of the project is to obtain data on those scales of natural, temporal variability which is attributable to climatic/hydrographic factors.

As to the discussion of the sediments it is in this relation essential to relate the character of the sediments to the dynamics of the environment.

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The aim is analyses of environmental gradients and description of the distributional pattern of benthic macro invertebrates (numbers, biomass and species composition) in tidal sediments of a shallow Danish estuary partly in the northernmost part of the Danish Wadden Sea, the Ho Bugt area and partly in the southernmost part behind the island Rømø. Variations exist significantly along a major estuarine gradient from fine anaerobic sediments rich in organic matter to coarse aerobic sediments. A second environmental gradient exists from depositional areas near the salt marshes to turbulent regions adjacent to deep tidally scoured channels. Further there exist grandients as to salinity and finally – which is extremely important – there exists a difference between the northern Ho Bugt area influenced by some pollution (partly through the rivulet Varde Å, partly through the harbour town of Esbjerg) and the southern pure environment east of Rømø. The sedimentation pattern shows quite another range of differences which also in a lot of cases are decisive. Some areas do have a positive and other areas a negative sediment budget arranged in a changing pattern. This dynamics do change the communities and the ecosystems. The areas of respectively pos. or neg. budget change location with changes in the tidal system according to a special rythm. The pattern can or must be understood to arrange for the model needed to understand the cyclic nature of these changes which again in a

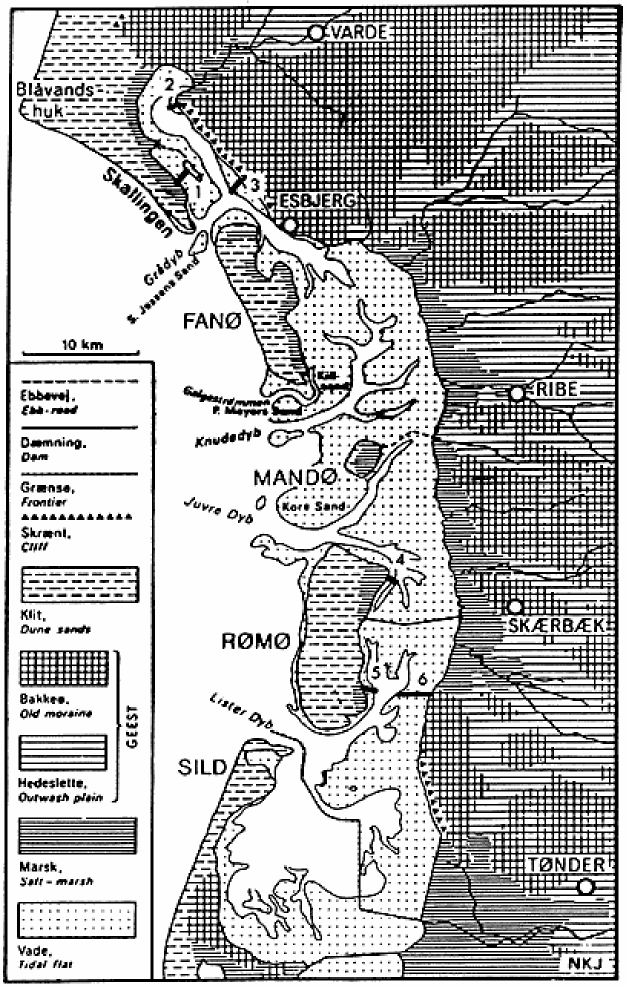

Fig. 1. The location of base-lines Nos. 1-6.

Fig. 1. Placeringen af de 6 basislinier. Nr. 1-3 i Ho Bugt repræsenterer det nordligste tidevandsprisme gennem Grådyb og med forureningskilderne Varde Å og Esbjerg (havn og by). Nr. 4-6 repræsenterer det sydlige vadehav uden større lokale forureningskilder. På grund af Rømø Dæmningen er Rømø Leje Bugt (nr. 5 og 6), udvalgt sammen med nr. 4, placeret nordligst i læ af Rømø. Vurderet under ét er der udvalgt 3 vesteksponerede vader og 3 vader beliggende i læ af barrierekomplekset.

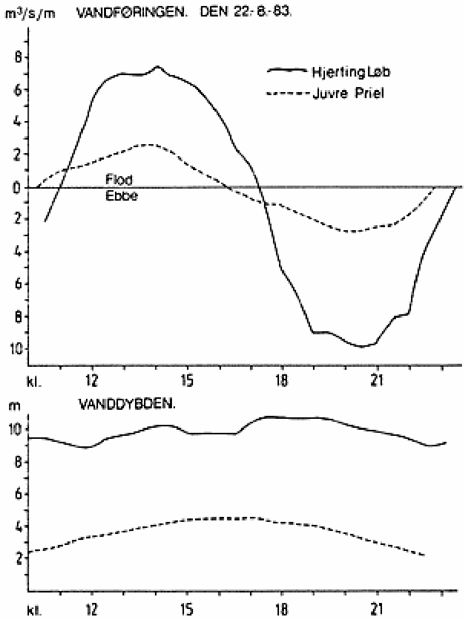

Fig. 2a. Water regime and the water depth, 22.8.83. *Hjerting Løb* inflow: $1{,}062\times10^5$ m^3/m width, outflow: $1{,}438\times10^5$ m^3/m width. Change of current: 10^{50}, 17^{15}, 23^{30} h. *Juvre Priel* inflow: $0{,}377\times10^5$ m^3/m width, outflow: $0{,}450\times10^5$ m^3/m width. Change of current: 10^{18}, 16^{15}, 22^{50} h.

Fig. 2a. Eksempel på vandudvekslingen og vanddybden i Hjerting Løb og Juvre Priel 22.8.83.

complexed way interfere with the action of man in nature. An understading of these dynamics can only be achieved

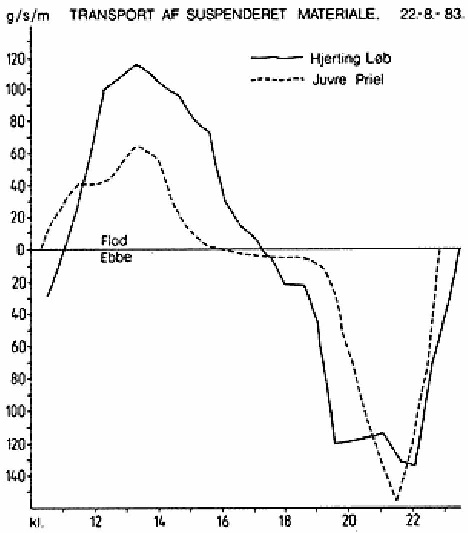

Fig. 2b. Total transport of suspended matter, 22.8.83. *Hjerting Løb*: during flood period: 1,530 kg/m width, during ebb period: 1,650 kg/m width. *Juvre Priel*: during flood period: 821,7 kg/m width, during ebb period: 1,031.3 kg/m width.

Fig. 2b. Transport af suspenderet materiale i Hjerting Løb og Juvre Priel 22.8.83.

through the studies mentioned, and they are decisive for regulations as to pollution problems.

When the model for the area as such is worked out the possibility to register the change in physical factors of a broad scale character must it be climatic or hydrographic in character, will be possible. Further the geographical limits of the species involved is, of course, important. The Waddensea is well suited for such studies as both the variability of physical conditions (sediment, salinity, temperature, etc.) and the likelihood of artificial changes are greatest near to the shore line.

The programme: Baseline studies of the mentioned character is of primary interest as well scientifically as technical. It will suite the purpose of supervising the tidal areas as well as support specific studies.

The base lines are placed within 2 parts of the Danish tidal area and situated free of human activities as far as it is possible. The aim is to describe the natural variations of ecological and physical parameters for comparison with fluctuations in other tidal areas along european costs. Further the limits for variation of these parameters can be established rather close.

Within each of the 2 mentioned areas 3 base lines are established as seen on the map fig. 1. For each tidal prism a base line is situated onthe mainland central flats (no. 3 and 6) exposed E of the tidal inlet. Another line is placed on the leeside of the barrier system (no. 1 and 4) and the last ones in a sheltered place (no. 5) or representing low salinity (no. 2). The base lines are all levelled once a year and each of the three types are levelled each second month within a year, to register the dynamical changes.

Twice a year the benthos is sampled to register the species and to valuate the primary production of the area.

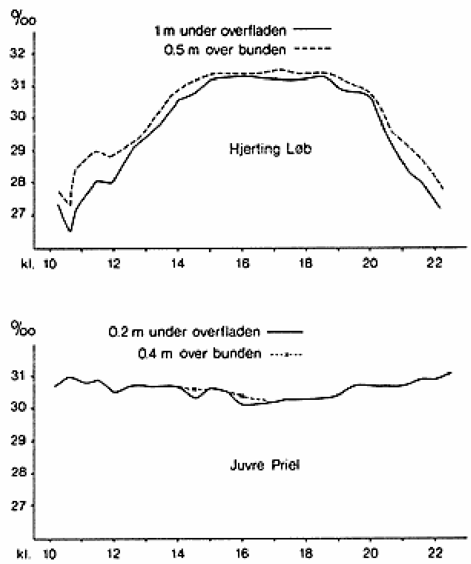

Fig. 2c. Salinity, Hjerting Løb and Juvre Priel, 22.8.83.

Fig. 2c. Salinitetsmålinger i Hjerting Løb og Juvre Priel 22.8.83.

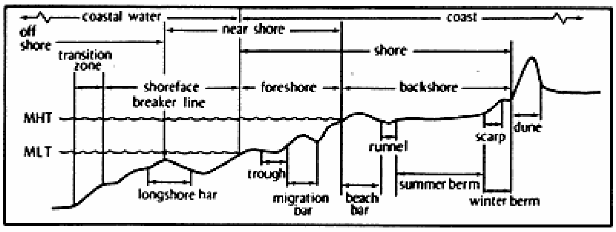

Fig. 3. Scheme illustrating the names of different form elements of the beach.

Fig. 3. Formelementer på en eksponeret tidevandskyst.

Hydrography: Through the years measurements are carried out in some of the creek systems. They help to provide basic knowledge of the hydrography of the whole region. Each campaign cover at least 14 hours measurement to register a full tidal period of 12.25 h. The following parameters are registered: current velocity and direction, salinity, temperature, content of O_2 and transmission of light as well as the depth. Each parameter is registered as profiles in different levels down to the bottom. Water samples are taken through the tide and the creek is echosounded simultaneously (fig. 2, a b c).

Sedimentation and erosion: Certain areas within the region have a more permanent character as sedimentation basins. This is of special interest in relation to the fact, that heavy metals do stick to the fine particles accumulated in the basins.

A reliable mapping of the distribution pattern of sediments is carried out by digitized remote sensing technic based on Landsat imageries.

Estuarian systems do change and respond to natural and manimposed stresses, but the lack of long-range data and the normal year to year variations make it difficult to assess an estuary's present stage or to predict conditions in the future.

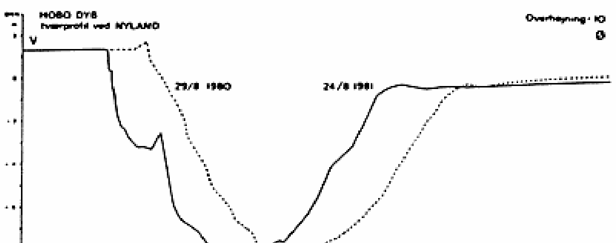

Fig. 4. Cross sections of the channel Hobo Dyb at Nyland as surveyed 29.8.80 and 24.8.81. (J. Bartholdy).

Fig. 4. Tværprofiler af Hobo Dyb ved Nyland opmålt 29.8.80 og 24.8.81 (J. Bartholdy).

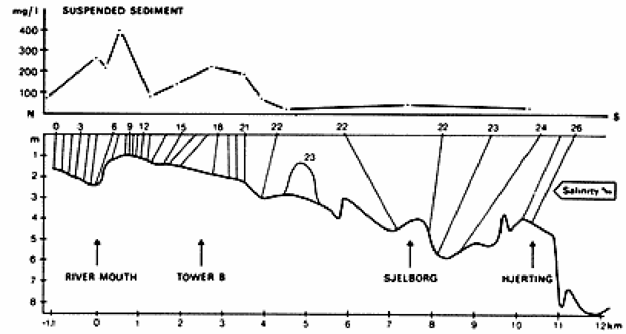

Fig. 5. Profile of the channel Hjerting Løb. Isolines of salinity are shown at low-water. Above the concentration of suspended sediment, the turbidity max. is demonstrated. (M. Pejrup).

Fig. 5. Længdeprofil af Hjerting Løb med indlagte isolinier for saliniteten ved lavvande. Øverst ses de målte koncentrationer af suspenderet materiale, hvoraf turbiditetsmaksimet fremgår (M. Pejrup).

Form elements: The landscapes and form elements of the Wadden Sea regions are predominantly of marine origin, but as they have developed along with a general rise in sealevel and a transgression of the coastal region the landscape details are of a very complex nature. This is due partly to the varied topography of the old land surface and partly to the differences in type of sediments and sediments budgets i.e. in absolute height of the landscape elements combined with the prevailing wave actions and amplitude of tides. Everywhere the effects of marine forces will result in specific surface forms.

The tidal landscape is composed of a number of featu-

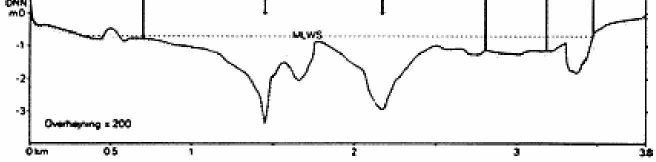

Fig. 6. Lateral distribution of suspended sediment at a cross section of Ho Bugt during flood 15^{00}-19^{00} h. Low-water at 14^{00} h, high-water 19^{00} h. (M. Pejrup).

Fig. 6. Lateralfordeling af suspenderet materiale ved tværsnit af Ho Bugt fra Marbæk (basislinje 2) til Ho (sedimentationsbassin) under flod kl. 15.00–19.00. Lv 14.00, Hv 19.00 (M. Pejrup).

res and form elements, the geographical location of which might reflect the dynamics behind.

To the sea level of today (the zero) a series of landscape elements is given: the near shore, the foreshore and the backshore at the sea side of the barrier island (the outer coast), fig. 3. Through the tidal inlets of different depths follow the channels (and creeks) and the tidal flats, the salt marsh, the moores and the old landscape, fig. 1. Within the tidal flats chosen for the Cost 647 studies there exist quite a lot of characteristic form elements placed at different heights and different exposure to the dynamical forces. This means that it is the wave actions and the normal tides which govern the different types of sediments at the bottom and in suspension, the daily change of water coverage and the transport mechanisms in different salinities etc. During storm and floods it is the wave action which primarily govern the exchange of sediments, periods with a high energy input and transport capacity and with a net surplus of sediments to the Wadden Sea of rather high amounts. It is taken from the outer coast but rather quickly replenished by the longshore drift.

Wave action and rip currents are the dominating hydrodynamical forms in the beach area. The sand transport along the coast is interrupted by the nearly perpendicular directed currents of the tidal inlets. Outside and inside the inlets tidal deltas are formed (van Veen 1950, Børge Jakobsen 1963).

The dynamical processes in the tidal area are strong, they are periodical and aperiodical, and they are due to a variety of forces. Wadden Sea sediments are eroded and resedimented, they are based on a steady supply from the North Sea and reworked steadily. The strongly changing dynamics occur with the rythm of the tides, but not the less aperiodically by strong and week wave action, by drift and gravity currents.

As a result of this several zones of tidal flat forms are given for a certain period (some years). The creeks are often changing place through lateral displacement (meandering), see fig. 4. The tidal flat areas may be subdivided because areas with an average higher and lower dynamics may be distinguished, representing different grain size compositions. Along the low waterline of channels the energy of currents and waves has the strongest influence. As a result only sand is deposited in the long run. When the large waves occur the sand is coarser than normal. At the same time morphological features as beach ridges, swash berms and megaripples occur. The somewhat sheltered tidal flat show small ripple marks on their surface, in rough weather as wave ripples resulting in a characteristic puddle tidal flat. In more sheltered sand flats with a silt content of about 5% the surface is completely flat, no ripples occur. In muddy sand flats the dynamic processes af reworking are less intensive resulting in an alternating bedding of sand and mud (Reineck 1980). Aperiodical weather changes cause beddings richer in sand. Quiet

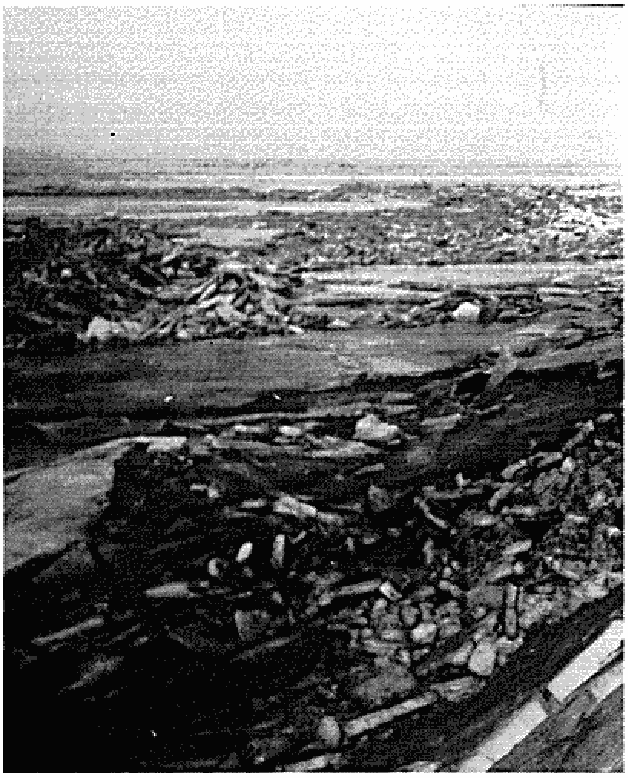

Fig. 7. Ice floes at low-water, note the heaps caused by ice-pack. The height are normally up to 3-4 m caused by the changes in water level of the various tides.

Fig. 7. Isflager og isskruninger, fot. ved lavvande. Skruningerne er ca. 4 m høje og forårsages af tidevandet i relation til storme og større blæst, hvor havvand via dyb og render løfter og presser isflagerne op.

weather conditions – especially after storms when much material has been eroded and brought into suspension – cause beddings rich in mud. The largest accumulation of finer grained materials occur in the sheltered basins with mud flats, i.e. the head of the Ho Bugt, cfr. figs. 5&6. with demonstration of the turbidity maximum, a result of the current conditions and the settling lag and scour lag effects (van Straaten & Kuenen 1958, Postma 1967).

After only one frosty night the higher tidal flats are covered with ice needles and freeze slowly. Strong winters – up to several months of frost – can demonstrate heavy ice floes drifting in the channels, moving up and down on the tidal flats and resulting in large heaps of scoured ice floes. In the bottom of the floes sandy and muddy sediments are freezed in the ice and in this way carried to other places, fig. 7. After such a winter 1/2 meter of sediments can be found in heaps (diameter 100-200 m) spread over the tidal flats. Together with the sediments amounts of f.i. Cardium may freeze onto the ice floes. Of cource the Mytilus banks placed on the levee of the channels are most liable to destruction during an icy winter.

Human interference – apart from the pollution – is demonstrated through construction of harbours, closing of gaps in the dunes to hinder overwash processes, deepening of the entrance to tidal inlets used for shipping traffic, embankments of the Marsh areas and last but not least the dams to the isles hindering the residual water transport within the Wadden Sea.

Water exchange between the Wadden Sea tidal prisms and the North Sea is only fragmentary, a conception which is important for numerous sedimentological as well as biological problems.

Overall sediment distribution has only been extensively described, and we are still working on more knowledge about exact rates of sedimentation for sand as well as for mud and on the transport mechanisms on the tidal flats.

The tide. Foir the areas described the following tidal characteristics are decisive.

	Ho	Rømø Leje Bugt
Mean high water level	+ 0.60 m DNN	+ 0.96 m DNN
Spring tide high water level	+ 0.75 m DNN	+ 1.16 m DNN
Mean low water level	– 0.72 m DNN	– 0.85 m DNN
About 10 high tides a year exceeds + 2.00 m DNN.		
About 3 high tides a year exceeds + 2.50 m DNN.		
About 1 high tides a year exceeds + 3.00 m DNN.		

Terminology and classification of sediments is given in the table 1.

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Tabel I Sedimentklassifikation (efter Wentworth og Krumbein).

Sedimentgruppe		Korndiameter	
dansk	engelsk	i mm	Φ-enheder
sten	boulder	256 og derover	÷8,0 –
	cobble	128 – 256	÷7,0 – ÷8,0
		64 – 128	÷6,0 – ÷7,0
ral	pebble	32 – 64	÷5,0 – ÷6,0
		16 – 32	÷4,0 – ÷5,0
		8 – 16	÷3,0 – ÷4,0
		4 – 8	÷2,0 – ÷3,0
grus	granule	2 – 4	÷1,0 – ÷2,0
sand: meget groft	sand: very coarse	1 – 2	0 – ÷1,0
groft	coarse	0,5 – 1	1,0 – 0
mellem	medium	0,25 – 0,5	2,0 – 1,0
fint	fine	0,125 – 0,25	3,0 – 2,0
meget fint	very fine	0,0635 – 0,125	4,0 – 3,0
silt	silt: coarse	0,0312 – 0,0635	5,0 – 4,0
	medium	0,0156 – 0,0312	6,0 – 5,0
	fine	0,0078 – 0,0156	7,0 – 6,0
	very fine	0,0039 – 0,0078	8,0 – 7,0
ler	clay: coarse	0,0020 – 0,0039	9,0 – 8,0
	medium	0,0010 – 0,0020	10,0 – 9,0

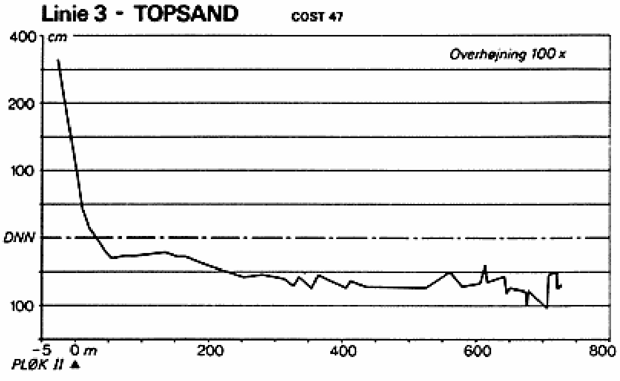

Fig. 8. Profile indicating the different form elements of the tidal flat at Topsand.

Fig. 8. Længdeprofil af vaden ved Topsand (basislinje 3). Tidevandets størrelse er ca. 135 cm med svingninger i sommerhalvåret med laveste vandstand beliggende i kote –1,2 m til –0,6 m DNN.

BASE-LINE NO. 3: TOPSAND/SÆDDING

The base-line is situated at the »stjert« Topsand, central flat, just east of the deep Grådyb, i.e. at the most exposed place on the mainland tidal flats (fig. 1). The »stjert« is built up on the watershed between the tidal channels Hjerting Løb to the north and Havneløbet to the south in front of the harbour of Esbjerg. The mainland coast from Esbjerg to Marbæk forms the east coast of Ho Bugt. It is characterized by a sharp transition from the old moraine to the tidal flats by a cliff 8-10 m high. The exposition towards the west means erosion of the beaches and coastal cliffs at all types of weather with heavy winds, i.e. a source of sandy material – mostly of a rather coarse type – which characterizes the upper part of the beach profile. The beach (summer-berm) is placed at the level +3-+4 m DNN with a rather sharp transition to the tidal flat (+0,7 m DNN) and a change in grain size composition. The profile is given on fig. 8. The line is about 700 m from the normal high water to about 100 m from the border of the deep. This outer part of the tidal flat is a Mytilus bank with soft sediments and channels for the very quick changes of water level close to lowtide. The base-line is marked by 2 iron tubes and pointing at the light Jerg Banke 222° (360°N). The line is levelled once a year, sampled for benthos and biomass twice a year. During 1983/84 two of the base-lines: No 3, Topsand, and No 4, Juvre, have been levelled and sampled each 2nd month to consider the dynamics through the seasons. This will have to be done consequently for the other 4 base-lines.

The landscape

Morphologically the tidal flat can be divided into 5 sections: *A.* An innermost highlying part 0-200 m at level -0,25 m DNN characterized by coarse grained sediments and two small bars with two intermediate priel systems.

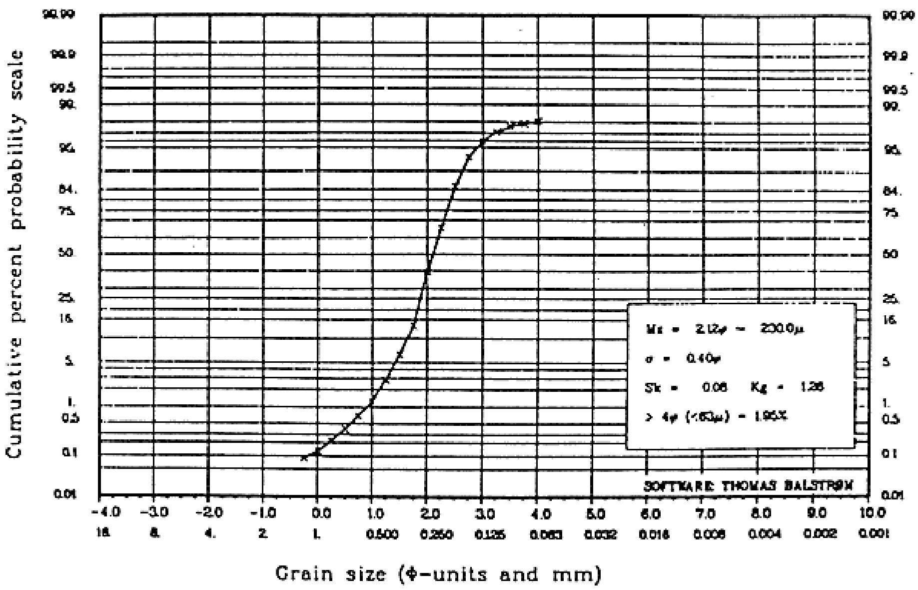

Fig. 9. Topsand 1.5.83. The innermost 200 m, sampled at II.
Mz = mean grain size.
0=sorting of the sediment, i.e. the standard deviation indicates the width of the grain size distribution.
Sk = the symmetri of the grain size distribution round the mean grain size. If the coarser part dominates, it indicates areas under erosion. If the finer part dominates, it indicates areas with sedimentation. Asymmetric size distribution indicates that the sorting processes are not yet finished.
Kg = kurtosis. The presence or not of a distinct top indicates which type of material is found. A well sorted sediment has a pronounced tapering top.

Fig. 9. Topsand 1.5.83. De inderste 200 m, prøvetagning ved pløk II. Kornstørrelsesfordeling efter Folk & Ward.

The beach profile above demonstrates typical breaks at the levels of ± 0,00 m DNN and +0,5 m DNN. The priel systems are low lying (10-15 cm deep) areas alongside the coastline with an outgoing trend towards the north. Inbetween tidal flats with lug-worms are found.
B. A puddle tidal flat formed as a consequence of the interplay between wave erosion and sand bars moving towards the coast. It is standing at the level -0,25 m-0,50 m DNN and is vegetated by Zostera nana and is situated at 200-335 m west of iron tube II, situated at normal high water level. Immediately to the west is found a priel system, a low lying area about -0,70 m DNN directly east of the innermost Mytilus bank.

C. The innermost Mytilus bank is about 100 m in east-west extension and raises to the level -0,30 m DNN. It is situated at 335-435 m W of II.
D. A tidal flat of about 100 m in east-west extension standing at the level about -0,65 m DNN. It is formed by stormy weather erosion in the exposed central part of the Mytilus area. It is situated at 435-535 m W of II.
E. The outermost Mytilus bank of which about 200 m in east-west extension is mapped. It has topmost levels at -0,35 m DNN and a minor creek was levelled -0,95 m DNN. The channel Havneløbet is found at about 800 m W of II.

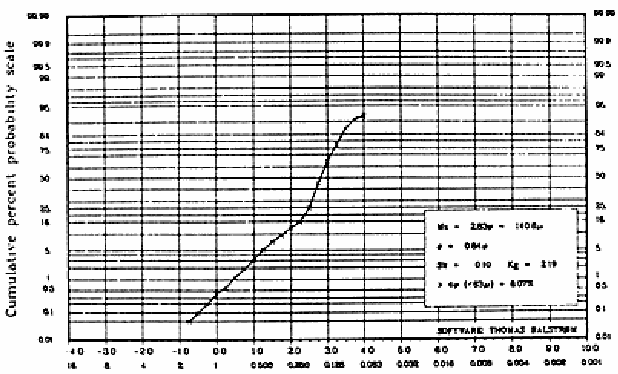

Fig. 10. Topsand 1.5.83. Puddle tidal flat, sampled at 335 m W of II.

Fig. 10. Topsand 1.5.83. Pytvade, prøvetagning 335 m V.f. pløk II.

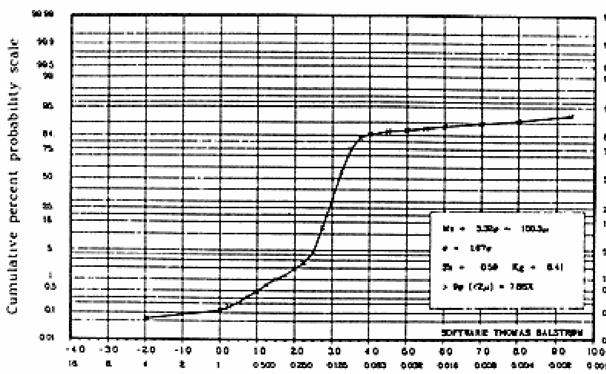

Fig. 11. Topsand 1.5.83. Lug-worm tidal flat in the center of Mytilus bank, sampled at 470 m W of II.

Fig. 11. Topsand 1.5.83. Sandormevade placeret midt i Mytilus-banken. Prøvetagning 470 m V.f. pløk II.

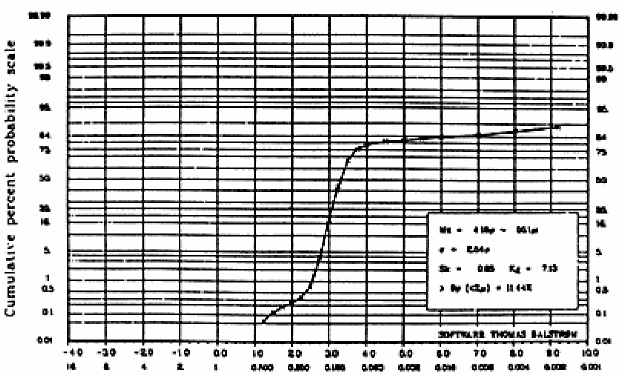

Fig. 12. Topsand 1.5.83. Top of Mytilus bank, sampled at 617 m W of II.

Fig. 12. Topsand 1.5.83. Top af blåmuslingebanke. Prøvetagning 617 m V.f. pløk II.

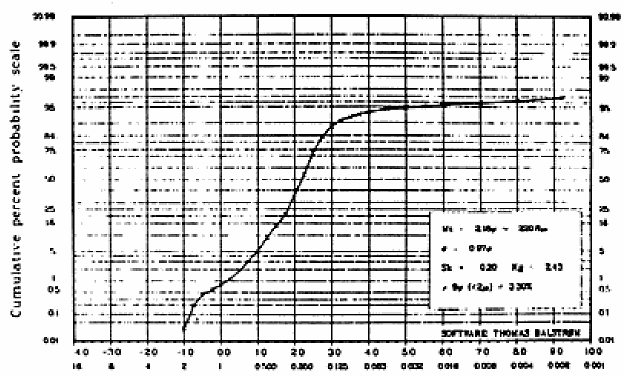

Fig. 14. Topsand 18.6.83. Puddle tidal flat, sampled at 35 m W of II.

Fig. 14. Topsand 18.6.83. Pytvade. Prøvetagning 35 m V.f. pløk II.

The sediments

A. The sands of the beach and the innermost 200 m are characterized by fig. 9. Mean grain size is 230-280 μ with only 2% below 64 μ. The tidal flat with lug-worms inbetween the priels shows a mixture of two types of sand: the beach sand and the tidal flat sand. It has a mean grain size of 180 μ as 70% of the sand is about 125 μ. This two-topped distribution of grain sizes is even more clearly shown in the following type of landscape *B*, the puddle tidal flat (fig. 10).
D. The lug-worm tidal flat in the center of the Mytilus bank. The sorting is pronounced by a mean grain size of 100 μ and about 8%(2 μ (fig. 11).
E. The top of the Mytilus bank, which is similar to analysis of an eroded mud flat in the bank. Mean grain size is 55 μ and 11%(2 μ (fig. 12). The grain size composition of newly deposited mud is given on fig. 13. The mean grain size is 25 μ and 17%(2 μ.

Changes through the year

A. The described form elements and the sedimentological characterization is based on the first sampling of 1/5-83. The following studies of the base-line have been carried out on the 18/6, 14/9, 12/11-83 and 14/3-84. Seen from a meteorological point of view it was a quiet year, and neither in the form elements nor in the sediments any significant variations outside the cycle of the year demonstrate itself. The normal change between winter and summer

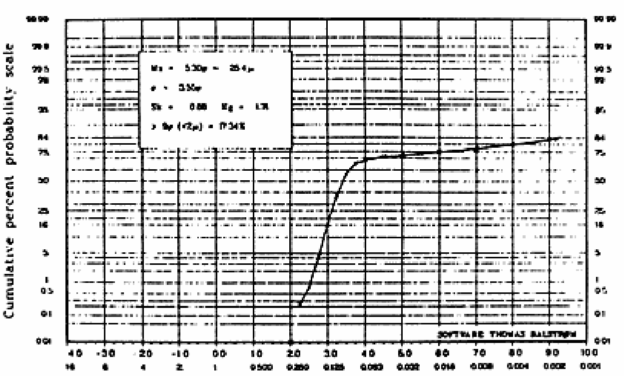

Fig. 13. Topsand 1.5.83. Mytilus bank, newly deposited mud, sampled at 722 m W of II.

Fig. 13. Topsand 1.5.83. Blåmuslingebanke, nyligt aflejret slik. Prøvetagning 722 m V.f. pløk II.

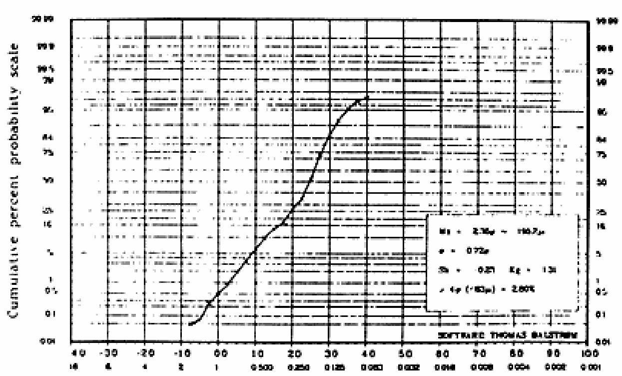

Fig. 15. Topsand 18.6.83. Lug-worm tidal flat, sampled at 151 m W of II.

Fig. 15. Topsand 18.6.83. Sandormevade. Prøvetagning 151 m V.f. pløk II.

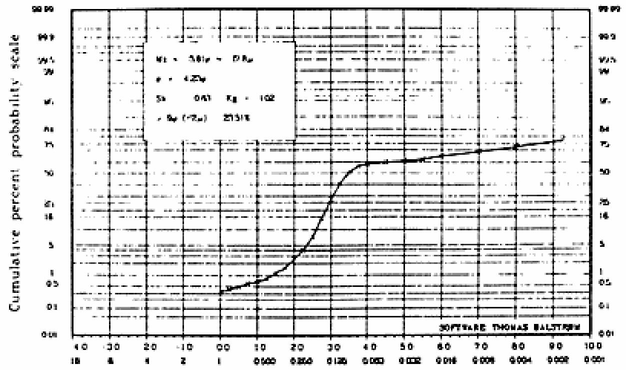

Fig. 16. Topsand 18.6.83. Inner Mytilus bank, newly deposited mud, sampled at 335 m W of II.

Fig. 16. Topsand 18.6.83. Indre muslingebanke, nyligt aflejret slik. Prøvetagning 335 m V.f. pløk II.

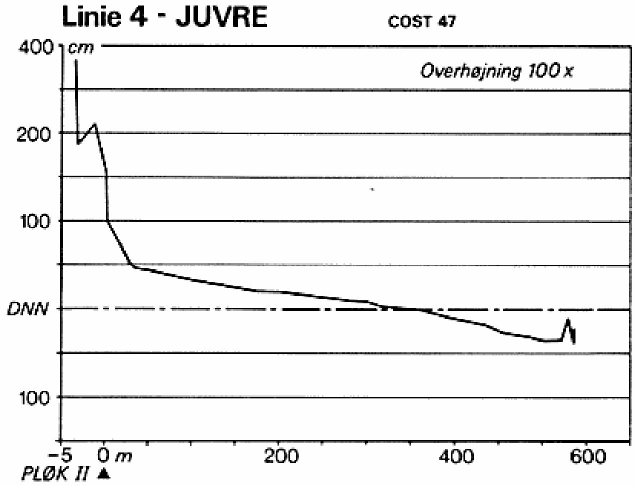

Fig. 17. Profile indicating the different form elements of the tidal flat at Juvre.

Fig. 17. Længdeprofil af vaden ved Juvre (basislinie 4). Tidevandets størrelse er ca. 175 cm.

profile is clearly seen for the beach profile (A) and the sediments are somewhat finer and with a better sorting in summer, compare fig. 9 and 14. which show samples from the same locality. The mean grain size from the summer profile is 220 μ and about 3%(2 μ, in both respects a finer sediment. This coinsides with the description of the tidal flat: a puddle tidal flat with lugworms. The lug-worm tidal flat inbetween the priel systems is without any change for the two situations described. Sedimentologically the summer situation is similar to the grain size distribution given in fig. 10, even if this one is somewhat finer (fig. 15). As mentioned above two types of process and therefore two types of sediments are found in a mixture: About 25% round 500 μ and 70% round 125 μ. The mean grain size is 195 μ and about 3%(63 μ.

B. The puddle tidal flat is mainly the same for the two seasons. The same is valid for a newly deposited mud, cfr. fig. 16. which demonstrates the grain size distribution for the mud from the inner Mytilus bank (*C*). The mean grain size of 18 μ and 24%(2 μ is finer than for the situation 1/5-83, but the distribution, i.e. the form of the diagram correspond with the mud analyzed on 1/5-83.

After the storms of the autumn the inner profiles of the base-line 3 is slightly changed, and coarse grained material deposited on the tidal flats. The mega ripple tidal flat do now have a mean grain size of 290 μ with only 1%(63 μ. The lug-worm tidal flat, the outer tidal flat (B) is not influenced cfr. fig. 15. For sediments of the inner Mytilus bank (C) a rather prominent change is seen as the mean grain size now is 97 μ with only 10%(2 μ (cfr. fig. 16). The same is to be found on the tidal flat within the mussel bank (*D*, fig. 11) where the sediment is quite clearly far more coarse grained and with a disperse sorting. Mean grain size is 173 μ and only 2%(63 μ.

To complete the variations through the year a short description of the samples of 14/3-84 will be given: as to the forms no greater change can be demonstrated compared to the situation on 1/5-83 (fig. 8). Sedimentologically the mega ripple tidal flat is similar to the analysis of 1/12-84. Mean grain size is 282 μ and 2%(63 μ. The same is to be found at the puddle tidal flat (B). Mean grain size is 180 μ and 2%(63 μ as well as for the inner Mytilus bank (C). The eroded tidal flat (D) shows a digram conform to the situation of 1/5-83 (fig. 11) even if it is displayed parallel to a more coarse grained sediment. Mean grain size is 116 μ and 3%(2 μ. For the outermost Mytilus bank (E) the grain size distribution is quite similar to the described material of 1/5-83.

BASE-LINE NO. 4, JUVRE

The base-line is situated at the tidal flat north east of the isle of Rømø on the lee-side but just inside the deep Juvre Dyb, fig. 1. Formerly – before the construction of the Rømø dam – this meant a possibility for deposition of material partly around the northern end of the isle and partly because the base-line site is about similar to the former watershed between Lister Dyb and Juvre Dyb. Today this area is dominated by the Juvre Priel, an ebb-dominated channel which has changed the former sedimentological balance of the area. The channel is heavily eroding the coast further south and it demonstrates a heavy negative water balance, cfr. the ydrography p. 47.

The profile of the base-line is given on fig. 17. It demonstrates a low-lying tidal flat east of the salt-marsh foreland of Rømø and the two mentioned landscape elements are separated by a distinct cliff of erosion 0,75 m in height. In front of the cliff a row of brushwood groynes arranged

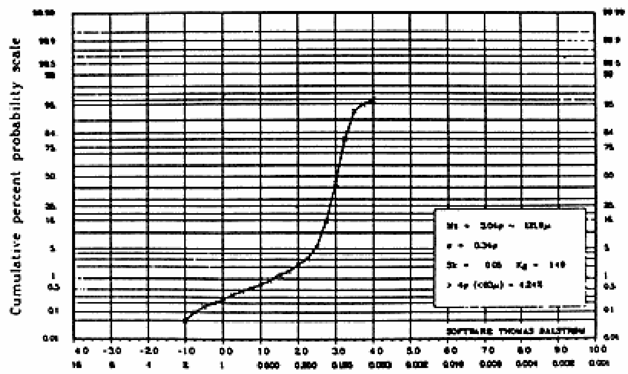

Fig. 18. Juvre 29.4.83. Pytvade med Zostera nana. Prøvetagning 30 m Ø.f. pløk II.

Fig. 18. Juvre 29.4.83. Pytvade med Zostera nana. Prøvetagning 30 m Ø.f. pløk II.

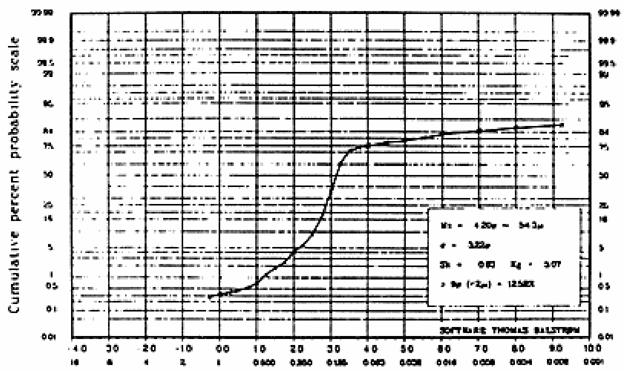

Fig. 20. Juvre 19.6.83. Innermost lug-worm tidal flat close to Spartina mounds, sampled at 50 m E of II.

Fig. 20. Juvre 19.6.83. Indre sandormevade tæt ved Spartina-tue. Prøvetagning 50 m Ø.f. pløk II.

in squares about 20×20 m is constructed to protect the foreland and to act as a simple land reclamation system. The level of the tidal flat within the groynes is +1,00-+0,50 m DNN. East of this a zone approx. 20 m wide is occupied by Spartina at the level of +0,50 m DNN. The base-line is about 600 m with a Mytilus bank bordering the Juvre Priel. The base-line is marked by two iron tubes and pointing at the direction 126° (360° N) perpendicular to the Juvre Priel.

The landscapes

Morphologically the tidal flat can be divided into the following 6 main sections:

A. 0-60 m. Bare tidal flat with lug-worms, level +0,50 m-+0,40 m DNN.

B. 60-160 m. Puddle tidal flat with Zostera nana, level +0,40 m-+0,20 m DNN.

C. 160-260 m. Puddle tidal flat with lug-worms, level +0,20 m-+0,10 m DNN.

D. 260-340 m. Tidal flat with mega ripples, level +0,10 m-± 0,00 m DNN.

E. 340-440 m. Bare tidal flat with lug-worms, level ±0,00 m-0,25 m DNN.

F. 440-600 m. Mytilus bank, level -0,10 m-0,65 m DNN, bordering the Juvre Priel.

The sediments

A. The inner tidal flat demonstrates a two-topped composition of sediments. About 10% round 400 μ and 80% round 125 μ. The mean grain size is 124 μ and 6%(64 μ.

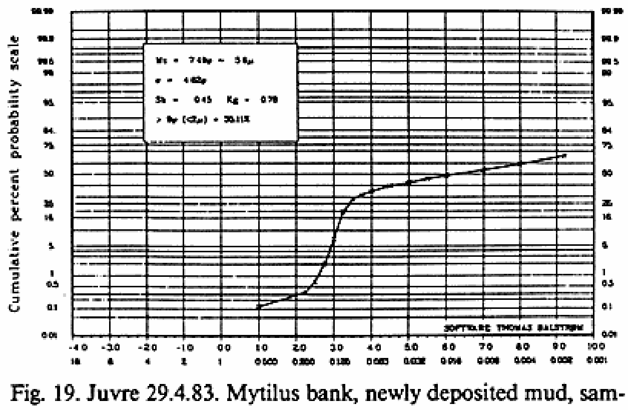

Fig. 19. Juvre 29.4.83. Mytilus bank, newly deposited mud, sampled at 532 m E of II.

Fig. 19. Juvre 29.4.83. Blåmuslingebanke, nyligt aflejret slik. Prøvetagning 532 m Ø.f. pløk II.

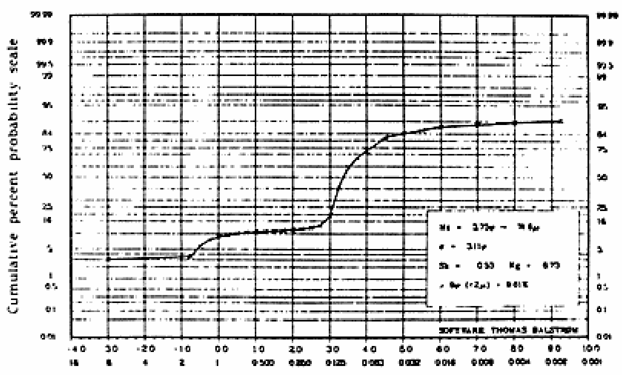

Fig. 21. Juvre 19.6.83. The reclamation area, sampled at 14 m E of II.

Fig. 21. Juvre 19.6.83. Slikgård. Prøvetagning 14 m Ø.f. pløk II.

B. The puddle tidal flat with Zostera nana is very characteristic for the grain size composition of sediments for the whole locality as such. Mean grain size is 122 μ and 4%⟨63 μ (fig. 18).
C. Puddle tidal flat with lug-worms is very similar to B.
D. Tidal flat with mega ripples. The mean grain size is still the same, now 121 μ, but the content of fine grained material is higher (5%⟨2 μ). At the same time some rather coarse material appears, about 5%. A similar occurrence of rather coarse grained material is also found in C.
E. This bare tidal flat with lug-worms corresponds in its sedimentary composition to B (the puddle tidal flat), fig. 18.
F. The Mytilus bank has on its normal level (at -0,30 m DNN west of the top) sediments with a mean grain size of 118 μ and 35%⟨2 μ, fig. 19.

Changes through the year

The described form elements and the sedimentological characteristics are based on the first sampling of 29/4-83. The following studies of the base-line are carried out on 19/6, 12/9-83 and 20/1 and 12/3-84. Each time levelling as well as sedimentological sampling has been performed.

The results of analysis from 19/6-83 are similar to 29/4-83. This time sedimentological sampling was also performed partly at the innermost tidal flat close to the Spartina mounds (fig. 20) and partly of the reclamation areas (fig. 21). The protected part of the tidal flat (fig. 20) has a mean grain size of 54 μ and 13% ⟨2 μ. It consists of 25% very fine grained material and a coarser bulk of about 125 μ. The sediments in the reclamation area (fig. 21) are scarcely as fine grained because of a rather heavy supply of coarse material which is deposited under stormy weather and remains afterwards because of the groynes. In these sediments about 20% are coarser than 125 μ and 5% coarser than 1500 μ. The mean grain size is 75 μ and 10%⟨2 μ. The rest of the base-line corresponds to the former analysis of 29/4-83.

In the situation of 20/1-84 the sediments in the outermost part of the lug-worm tidal flat (80-100 m) +0,35 m-+0,40 m DNN are more fine grained than 29/4-83. The mean grain size is still about the same (120 μ), but a greater content of fine grained material is found 5%⟨2 μ. The rest of the analysis corresponds to the former.

In the situation of 12/3-84 the sediments in the lug-worm tidal flat are more coarse than found 29/4-83 (fig. 20). The mean grain size was now 126 μ and 5%⟨ 2 μ. The rest of the analysis corresponds to the result of 29/4-83.

BASE-LINE NO. 1: Skallingen, Store Lo

The base-line is situated at the tidal flat in the center of the eastcoast of Skallingen on the lee-side of the peninsula, fig. 1. The old coastline of about year 1600 was placed at the westcoast of Langli, as Skallingen at that time (mapped by Johs. Meier 1643) was only a bar system building up 3-4 km W of Langli. The salt marsh of Skallingen is formed on a high-sand within the latest 100 years, and the transition from the salt marsh to the tidal flat is characterized by a minor cliff of erosion 20-30 cm high.

The profile of the base-line is given on fig. 22. It demonstrates a minor highlying and mainly lowlying tidal flat with at least 3 distinct landscape elements. The base-line is marked by 2 iron tubes and pointing at 66° (360° N) perpendicular to the Hobo Dyb.

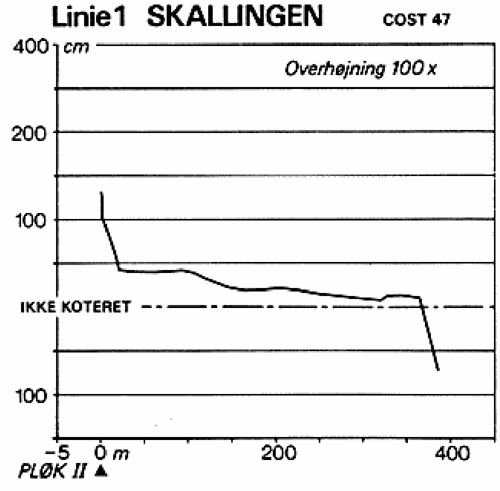

Fig. 22. Profile indicating the different form elements at the tidal flat at Skallingen.

Fig. 22. Længeprofil af vaden på Skallingen (basislinie 1). Tidevandets størrelse er ca. 120 cm.

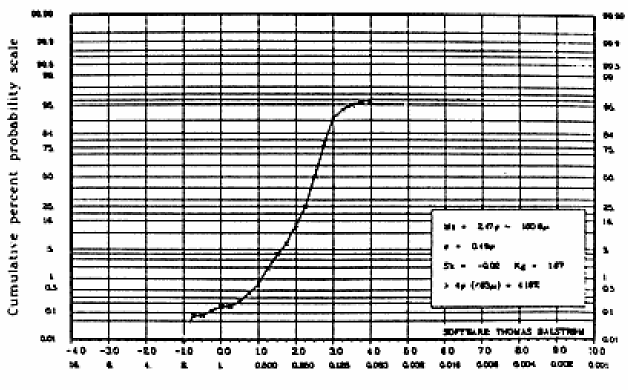

Fig. 23. Skallingen 13.3.84. Lug-worm tidal flat with puddles. Sampled at 41 m E of II at a level of + 0,40 m DNN.

Fig. 23. Skallingen 13.3.84. Sandormevade med pytter. Prøvetagning 41 m Ø.f. pløk II i niveau +0,40 m DNN.

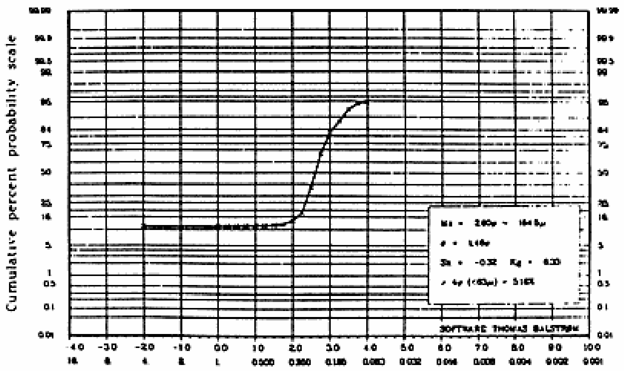

Fig. 24. Skallingen 13.3.84. Cardium tidal flat. Sampled at 270 m E of II at a level of + 0,15 m DNN.

Fig. 24. Skallingen 13.3.84. Hjertemuslingevade. Prøvetagning 270 m Ø.f. pløk II i niveau +0,15 m DNN.

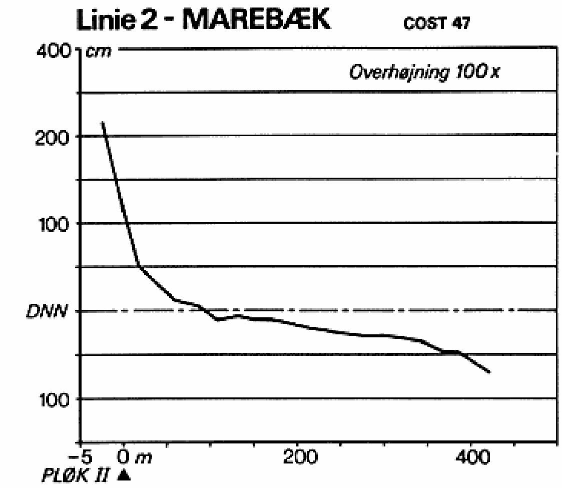

Fig. 25. Profile indicating the different form elements of the tidal flat at Marbæk.

Fig. 25. Længdeprofil af vaden ved Marbæk (basislinie 2). Tidevandets størrelse er ca. 100 cm.

The landscape

Morphologically the tidal flat can be divided into 6 main zones:

A. The highlying part 0-10 m E of II at a level of +0,60-+0,70 m DNN, vegetated by scattered Spartina plants.

B. A land-priel system 10-35 m E of II at a level about +0,40 m DNN.

C. A lug-worm tidal flat with puddles 35-150 m E of II at a level of +0,40-+0,20 m DNN.

D. A tidal flat with few lug-worms, scattered Cardium and dominated by Litorina 150-250 m E of II at a level about +0,20 m DNN.

E. A lowlying tidal flat +0,20-+0,10 m DNN dominated by Cardium, silty sand, and scattered Mytilus.

F. A narrow channel W of the Mytilus bank to the east, placed at about 315 m E of II at a level of +0,05 m DNN.

G. The Mytilus bank 315-380 m E of II, partly dominated by erosion. Top of the bank is found at the level +0,38 m DNN. The channel Hobo Dyb is found within 5 m.

The sediments

A. The sediments within the Spatina zone have a mean grain size of 169 μ and 4,5%(63 μ. A rather coarse sediment.

C. The lug-worm tidal flat with puddles (+0,40 m DNN) is even more coarse grained with a mean grain size of 180 μ and 4%(63 μ (cfr. fig. 23). On the lower part of the same tidal flat in the level of +0,20 m DNN the mean grain sizes are 163 μ and 5%(63 μ.

E. The Cardium tidal flat as such is characterized by about 10% coarse grained material, 85% finer material (about 125 μ) and 5% fine grained material (silt and clay). The mean grain size is 165 μ and 5%(63 μ (cfr. fig. 24). The topmost sediment at the same locality is far more fine grained with a mean grain size of 68 μ and about 12%(2 μ.

F. The Mytilus bank is characterized by erosion and the sediment has a mean grain size of 158 μ and 4%(2 μ. Newly deposited mud was found with a mean grain size of 20 μ and 20%(2 μ.

BASE-LINE NO. 2: MARBÆK

The base-line is situated at the northernmost part of the tidal flat at the mainland coast just south of the estuary of the rivulet Varde Å, fig. 1. It is exposed for all westerly winds as well as for southern winds. The position is just west of the old cliff system of Esbjerg bakkeø, 8-10 m high, representing the coastline of the Atlanticum, and the sandy moraine is quite a source of material during and just after stormy weather.

The profile of the base-line is given on fig. 25. The beach is found in a level of +3 m-+4 m DNN with a steep slope to the tidal flat. The profile as such demonstrates a low-lying tidal flat with a migration bar a half metre below the knickpoint at +0,50 m DNN of the profile, indicating the high water line. Further a minor mega ripple is seen at -0,10 m DNN. The width of the line is about 400 m where the profile is sloping to the channel, Hjerting Løb, which at the suspension maximum meets the outlet of Varde Å, just west of the base-line, i.e. 100-200 m to the north. – Morten Pejrup (1983) had his base-line with 3 towers for measuring sedimentological, climatological and hydrographical parametres from Marbæk to Ho, fig. 6.

The base-line is marked by 2 iron tubes and pointing at 246° (360°N) perpendicular to the channel, Hjerting Løb.

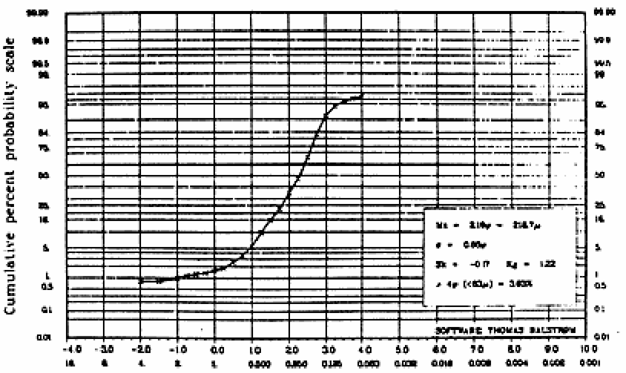

Fig. 26. Marbæk 13.3.84. Steep sloping tidal flat at tower A (M. Pejrup). Sampled at 423 m W of II at a level of -0,75 m DNN.

Fig. 26. Marbæk 13.3.84. Relativt stejlt skrånende vade ved tårn A (M. Pejrup). Prøvetagning 423 m V.f. pløk II i niveau -0,75 m DNN.

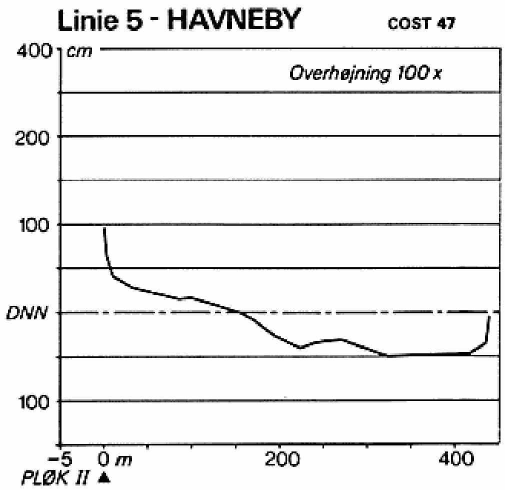

Fig. 27. Profile indicating the different form elements of the tidal flat at Havneby.

Fig. 27. Længdeprofil af vaden ved Havneby (basislinie 5). Tidevandets størrelse er ca. 200 cm.

The landscape

Morphologically the tidal flat is formed as a twoside cuspate foreland and can be divided into 4 main sections:

A. The migration bar just in front of the steep profile of the beach. It is placed 65-100 m W of II at a level of +0,10 m-+0,15 m DNN.

B. An innermost highlying part (-0,10 m DNN) which as mentioned represents a mega ripple system with a minor runnel partly in front of the migration bar to the east and partly in between 2 ripples. The beach profile has typical knickpoints at +0,10 m, +0,20 m and +0,50 m DNN. This rather coarse grained tidal flat occupies about 90 m in width: 100-190 W of II.

C. A rather steep sloping tidal flat 190-350 m W of II.

D. The steeper sloping tidal flat towards the channel, Hjerting Løb, -0,50 m--0,75 m DNN.

The sediments

As for all other sites on the base-line the samples are taken in a metal ring (2×5 cm, vol. 20 ml). Further a sample is taken representing the layering of the sediments (plastic tubes, 5 cm in diameter), and in some sites a sample of the newly deposited mud on the surface.

A. The sediments of the migration bar have a mean grain size of 262 μ and 2,1%(63 μ, a coarse grained and well sorted sediment. Sampled at 86 m W of II.

B. The higher-lying tidal flat representing the mega-ripple system shows about the same type of coarse grained sediment. The mean grain size is 247 μ and 2,3%(63 μ. Sampled at 172 m W of II.

C. The lower-lying tidal flat sloping from -0,10 m--0,35 m DNN still shows the same type of coarse grained sediment. The mean grain size is 232 μ and 2%(63 μ. Sampled at 256 m W of II.

D. The steeper sloping tidal flat at the tower A (M. Pejrup). Mean grain size 219 μ and 3,6%(63 μ. Sampled at 423 m W of II. (Fig. 26).

BASE-LINE NO. 5: Havneby

The base-line is situated on the east coast of the isle of Rømø in the southern part about 500 m N of the harbour, fig. 1. Thus it is normally free of the migrating bar systems round the isle. It represent a tidal flat of an eroded coastline. The salt marsh W of the base-line is the last remnants of a former lagoon with heavy clay deposits of about 1 m thick on a rather coarse grained tidal flat.

The profile of the base-line is given on fig. 27. The beach profile indicates knickpoints at +0,70 m (highwater line) +0,40 m and +0,30 m DNN. A migration bar is seen about 100 m east of II at +0,15 m DNN. The tidal flat as such ends at 125 m east of II, where the low lying tidal flat is seen as a low basin about 200 m-400 m east of II. Towardss the channel Rømø Leje a Mytilus bank is found.

The base-line is marked by 2 iron tubes and pointing 109° (360° N) perpendicular to the Mytilus bank at Rømø Leje.

The landscape

Morphologically the tidal flat can be divided into 8 main sections:

A. The cliff of erosion is covered by Phragmites with a sharp transition to the tidal flat. At 0-20 m east of II a clayey silty tidal flat dominated by Hydrobia found at the level of +0,70 m+0,40 m DNN. It is followed by

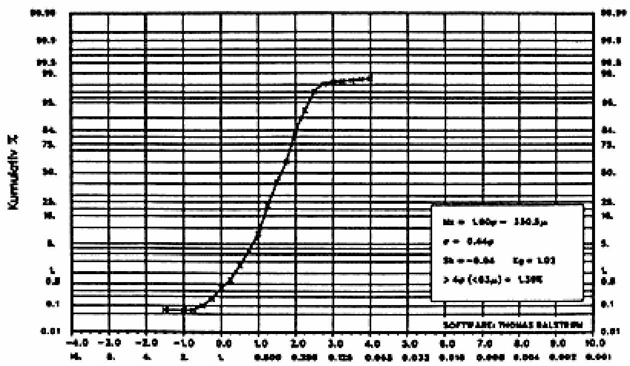

Fig. 28. Havneby 3.8.84. Uppermost part of tidal flat at the margin of the Phragmites. Sampled at 0 m (II), at a level of +1,00 m DNN.

Fig. 28. Havneby 3.8.84. Øvre del af vaden ved foden af tagrørsbevoksningen. Prøvetagning ved pløk II i niveau +1,00 m DNN.

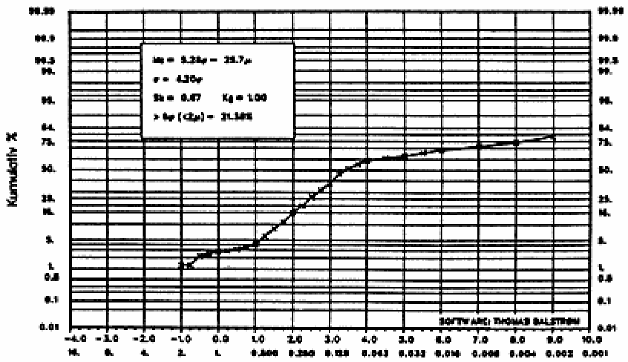

Fig. 30. Havneby 3.8.84. The edge of the Mytilus bank towards Rømø Leje. Sampled at 572 m E of II at a level of –1,00 m DNN.

Fig. 30. Havneby 3.8.84. Kanten af blåmuslingebanke mod Rømø Leje. Prøvetagning 572 m Ø.f. pløk II i niveau –1,00 m DNN.

B. A Zostera-lug worm tidal flat entangled with Enteromorpha. The rather high lying area 20-75 m east of II is sloping from +0,40 m to +0,15 m DNN.
C. A mega ripple within the same environment as B and with Litorina as a supplement. 75-125 m east of II. Top-level +0,15 m DNN.
D. A sloping tidal flat 125-185 m east of II. Still the same environment but Enteromorpha disappear at 160 m. The level is falling from +0,10 m to -0,25 m DNN.
E. A channel 185 m-240 m east of II. It is about 15 cm deep at a level of -0,40 m DNN. Scattered Mytilus but no Zostera anymore.
F. A migration bar 240 m-320 m east of II. Top most level -0,30 m DNN.

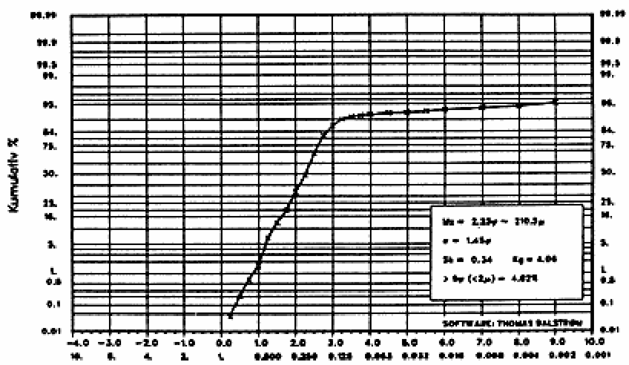

Fig. 29. Havneby 3.8.84. The sloping lug-worm tidal flat sampled at 186 m E of II at a level of –0,10 m DNN.

Fig. 29. Havneby 3.8.84. Skrånende sandormevade. Prøvetagning 186 m Ø.f. pløk II i niveau –0,10 m DNN.

G. A low lying level tidal flat 320 m-415 m east of II at -0,50 m DNN.
H. Mytilus Bank 415 m-550 m east of II. Top most level about ± 0,00 DNN.
J. At 550 m-570 m the edge of Rømø Leje is found at a level of -0,80 m–1,00 m DNN.

The sediments

A. The sediments at the end of the Phragmites are coarse grained and very well sorted. Mean grain size 331 μ and 1,4%⟨63 μ (fig. 28). The tidal flat with Hydrobia, 0-20 m east of II is also characterized by finer sediments even if the mean grain size is 241 μ it contains 7,5%⟨2 μ. The top most sediments sampled superficially are very fine with a mean grain size of 8,7 μ and 29,9%⟨2 μ. Sampled at 8 m east of II. All samples are taken on 3/8-84.
B. The sediments of the lug worm tidal flats with Zostera and Enteromorpha are well sorted with a mean grain size of 208 μ and 4,6%⟨63 μ. The superficially sampled deposits have the same mean grain size but is characterized by a content of clay: 5,5%⟨2 μ. Sampled at 49 m east of II.
D. The sloping tidal flat with lug worms is characterized by a well sorted coarse grained material. Mean grain size 211 μ and 4,8%⟨2 μ (fig. 29). The top most layers are a little finer with a mean grain size of 187 μ and 7,4%⟨2 μ.
E. The environment of the channel is characterized by fine grained sediments. Mean grain size 10 μ and 31,9%⟨2 μ. Sampled at 230 m east of II.
F. The migration bar with scattered Mytilus is characterized by the same fine sediments as E. Mean grain size 12,6 μ and 37,9%⟨2 μ. Sampled at 295 m east of II.
G. The sediments of the low lying tidal flat is characterized by some erosion and sediments of a mean grain size of 48 μ and 16%⟨2 μ. Sampled at 400 m east of II.

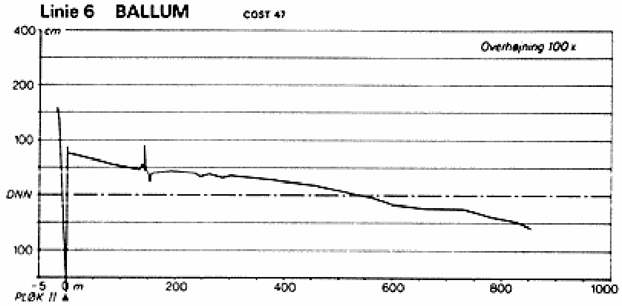

Fig. 31. Profile indicating the different form elements of the tidal flat at Ballum.

Fig. 31. Længdeprofil af vaden ved Ballum (basislinie 6). Tidevandets størrelse er ca. 200 cm.

H. The Mytilus bank is similar to G. A mean grain size of 51 μ and 16%(2 μ. The newly deposited mud is of course finer: mean grain size 9,6 μ and 33,9%(2 μ. Sampled at 437 m east of II.

J. The eastern most edge of the Mytilus bank 572 m east of II at a level of -1,00 m present fine grained sediments with a mean grain size of 26 μ and 21,4%(2 μ (fig. 30). The top most sediments are coarser with a mean grain size of 63 μ and 11,8%(2 μ.

BASE-LINE NO. 6: BALLUM

The base-line is situated on the tidal flat of the main land coast opposite Havneby (No. 5) and representing an exposed site within the Lister Dyb tidal area, fig. 1. It is 850 (1370) m long and starts from the foreland at the northern low-lying part of the Hjerpsted moraine. The tidal area east of Rømø has changed a lot since the construction partly of the dam to Sild (1927) and especially by the construction of the Rømø dam (1949). The Lister Dyb tidal area nowadays is a bay or even can be considered as 2 bays, Rømø Leje Bugt north of Jordsand and Højer Dyb bugten south of Jordsand. The bay south of the Rømø dam, the Rømø Leje Bugt is comparable to the Ho Bugt area. As lying north of Lister Dyb or Grådyb respectively only the free fetch is changed a little but the westerlies have the same influence on both areas. The baseline 4, Juvre, – it is reasonable to mention – has got a position of its own.

As a whole the situation of Rømø Leje Bugt is a silting up of the area south of the Rømø dam. This means even a change to the mentioned tidal flats further south. On the Rømø side erosion is taking place (cfr. base-line No. 5) as the flood from the Lister Dyb is moving towards NE (Ballum, main land approach to the dam) and the tide counterclockwise, i.e. the ebb current is moving alongside the eastcoast of Rømø. This gives the sediment balance quite a rhythmical movement the year around, not to talk about the influence of stormy weather or icewinters.

The base-line is marked by 2 iron tubes pointing 284° (360°N) towards the base-line 5 opposite the channel Rømø Leje. The profile of the base-line is given on fig. 31. It demonstrates a long (850 m) sloping tidal flat placed at +0,75 m in front of the dike (landpriel) to -0,65 m towards the channel Rømø Leje.

The landscape

Morphologically the tidal flat can be divided into 6 main sections:

A. The high-lying, lug-worm tidal flat, arranged as a land reclamatin scheme 0-150 m W of II, the brushwood groynes are indicated on the profile, fig. 31. The tidal flat is sloping from +0,75 m-+0,45 m DNN.

B. A rather high-lying puddle tidal flat with Zostera nana and lug-worms in front of the groynes (and west of a little runnel). It is placed 155-220 m W of II at a level of +0,35 m-+0,40 m DNN. It is followed by

C. A zone of mega-ripples with lug-worms 220-315 m W of II at a level of about +0,35 m DNN.

D. The sloping tidal flat with lug-worms 315-600 m W of II dipping from +0,35 m-0,15 m DNN.

E. The low-lying tidal flat 600-730 m W of II at a level of -0,20 m--0,25 m DNN.

F. The steeper sloping part of the tidal flat with scattered Cardium 730-855 m W of II, ending at a level of -0,65 m towards the channel Rømø Leje.

The sediments

A. The sediments of the newly arranged reclamation scheme are fine-grained, sandy deposits, rather well sorted but without substantial amounts of clay or fine silt. Mean grain size 140 μ and 6%(63 μ (13/9 1983). In the situation

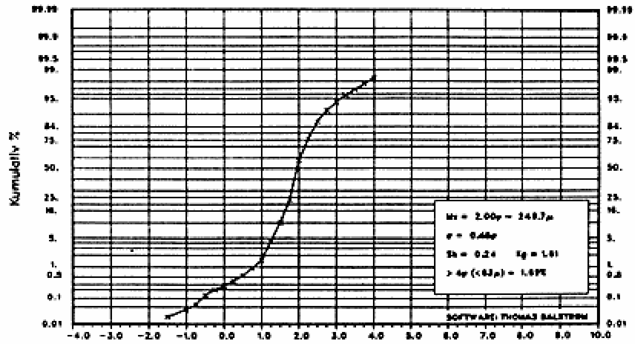

Fig. 32. Ballum 2.8.84. Land reclamation scheme on a lug-worm tidal flat. Sampled at 11 m W of II at a level of +0,70 m DNN.

Fig. 32. Ballum 2.8.84. Slikgård på en sandormevade. Prøvetagning 11 m V.f. pløk II i niveau +0,70 m DNN.

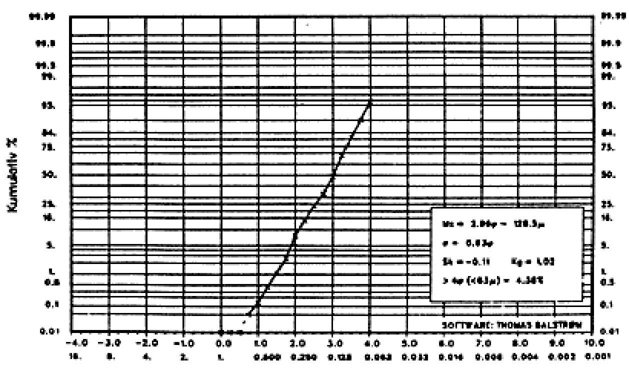

Fig. 33. Ballum 13.9.83. Low lying tidal flat. Sampled at 598 m W of II at a level of -0,25 m DNN.

Fig. 33. Ballum 13.9.83. Lavtliggende vade. Prøvetagning 598 m V.f. pløk II i niveau -0,25 m DNN.

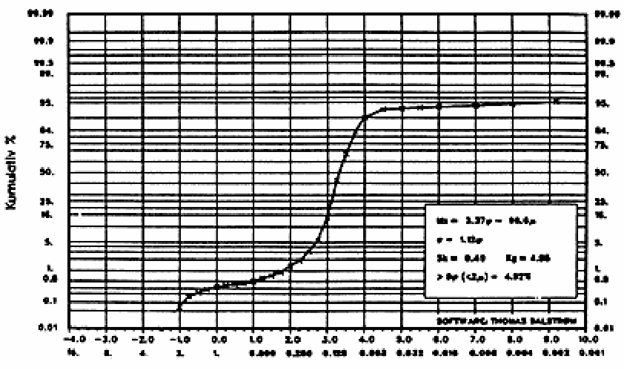

Fig. 34. Ballum 2.8.84. Steeper sloping tidal flat. Sampled at 1370 m W of II at a level of -1,25 m DNN.

Fig. 34. Ballum 2.8.84. Stejlere skrånende vadeflade. Prøvetagning 1370 m V.f. pløk II i niveau -1,25 m DNN.

2/8 1984 a well sorted, but coarse grained sediment was found in the western part of the reclamation scheme. Mean grain size 250 μ and 1,7%(63 μ. Sampled 11 m W of II (fig. 32). At the same time a fine grained and well sorted sediment was found in the middle and eastern part of the scheme: mean grain size 137 μ and 5%(2 μ. Sampled 77 m W of II.

B. The higher lying tidal flat with Zostera and lug worms (+0,35 m DNN) has sediments of the same type as A. Mean grain size 145 μ and 5%(63 μ. Sampled at 194 m W of II. The sample of 2/8-84, sampled at 167 m W of II is similar.

D. The sloping tidal flat with lug worms is finer with a mean grain size of 97 μ and 7%(63 μ. Sampled at 375 m W of II. The sample of 2/8-84 is similar. Sampled at 326 m W of II.

E. The low lying tidal flat at -0,25 m DNN had a mean grain size of 129 μ and 4,4%(63 μ. Sampled at 598 m W of II (fig. 33). The sample of 2/8-84 is similar. Sampled at 693 m W of II.

F. The steeper sloping tidal flat was of a similar type as E. Mean grain size of 122 μ and 5,9%(63 μ. Sampled at 855 m W of II. The samples of 2/8-84 give the following results: mean grain size 130 μ and 3,8%(63 μ sampled at 822 m W of II, mean grain size 102 μ and 6,8%(63 μ sampled at 1036 m W of II, mean grain size 96 μ and 4,8%(2 μ sampled at 1264 m W of II, mean grain size 97 μ and 4,9%(2 μ sampled at 1370 m W of II.

Conclusion

It is in a monitoring programme necessary to classify the areas chosen as to 1) morphology, and 2) sediment budget (sediment balance).

Through long-term studies in Denmark in the areas chosen it is evident that equilibrium forms exist but the situation is not static. It is open systems we deal with, and the dynamics of the tidal areas are great but caused by different agents:

A. The normal active forces:
   a) The tides through the 24 hours and through the year.
   b) The wave action: fluctuations in wind systems according to the varying Grosswetterlagen through short-term periods and through the year.

B. The catastrophes:
   a) Floods, any event which causes a hightening af sea level above +3 m level.
   b) Icy winters: In the Danish area they cover for the last 50 years: 1929 - 1940 - 1941 - 1942 - 1947 - 1959 - 1968 - 1985.

C. The long-term trends.
   a) Rise of sea level. At Esbjerg 1.2 mm/year.
   b) Rise in frequency and force of stormy weather because of changing of jet-stream tracks, i.e. the course of the cyclones. Along Danish coasts floods were formerly registered once in 3 years. During the last 10 years they are registred 2-3 times a year.

D. Human influence.
   a) Damming the Waddensea, thereby changing the pattern of currents and wave influence. Residual currents within the Danish tidal area before 1950 of great effect but afterwards of no greater evidence.
   b) Influence of harbours as to 1) dredging of the entrance, i.e. on the tidal bars, 2) dumping of sediments, 3) pollution.

The changes of the localities chosen should, therefore, be investigated as to sediment balances, temperature-regime, and salinity.

The intertidal areas are exposed to great environmental stresses: changing water coverage, salinity changes, and temperature fluctuations, as these factors show great variability. Only a few species are adapted succesfully to this why each locality has its own key species within the Macoma society. For the six base lines chosen within the Danish tidal area this is exemplified by a division A-E (-J) and sediment analyses given for each. The diagrammes of these analyses indicate the mean grain size (MZ), the sorting of the sediment (o), the symmetry of the grain size distribution around the mean grain size (Sk), and the kurtosis (Kg), the presence or not of a distinct top (a well sorted sediment). Each diagramme tells about the recent dynamics at the locality.

Is it possible to predict long-term trends. As to the physical parametres we need more precise knowledge about 1) bottom topography, 2) sediment patterns in detail, 3) salinity data through the year, 4) residual currents within the Waddensea, 5) the interchange of water with the North Sea, 6) more precise estimates about the accumulation of sand and fine sediments within the Waddensea, 7) hydrographical parametres as currents and tidal prisms for the different unities.

All this is necessary for making a model for the area, i.e. to tell about the development in details.

Sammendrag

COST 647 – økologiske langtidsstudier af Det Danske Vadehav 1979-86.

Fredningen af Skallingen-Langli, diskussion om Lystbådehavn(e) ved Esbjerg, det forstærkede Ribedige eller det fremskudte Højerdige viser tydeligt, hvor dybt de forskellige planer og/eller foranstaltninger griber ind i hele det komplekse natur-, miljø- og eksistensforhold i vadehavsregionen. Andre eksempler af væsentlig art kunne være kviksølvforureningen af Varde Å eller en evt. kommende oliekatastrofe i den sydlige Nordsø med de muligheder for og evt. virkninger af en opsamling af suspenderet materiale, der synes at have store chancer for at finde sted i Det danske Vadehav. Endelig skal der peges på de problemer, den positive materialebalance i relation til dynamikken i området kan afstedkomme med eksempler i den virkning, det får for afvandingsforholdene i å-dalene eller afstrømningsforholdene ved mundingen af diverse sluser, fx ved Kongeåen eller Ballum Sluse.

Bo og virke i et tidevandsområde med bevarelse af det naturlige miljø er en livsnødvendighed, som kræver løbende registrering og indsigt i de dynamiske processer.

De seneste år har man nydt godt af det vadehavsinitiativ, som i 1979 blev taget af Statens naturvidenskabelige Forskningsråd (SNF). Det har betydet, at man for første gang siden 1972 – hvor bevillingerne til De danske Vade- og Marskundersøgelser ophørte – igen har kunnet gå ind i større samlede undersøgelser. Ud over dette initiativ, der dækker morfologiske og sedimentologiske basisstudier af materialeomsætningen i Ho Bugt suppleret af et projekt vedr. målinger af reflektionen fra Flybårne sensorer kalibreret ved hjælp af ground truth målinger, har Danmark 1979 undertegnet COST 47 aftalen: langtidsøkologiske studier i Det danske Vadehav, hvor første 5-års periode afsluttedes den 1/4-84. Den er blevet fortsat som COST 647 – dvs. placeret i en højere kategori – der indebærer økonomisk støtte til afholdelse af møder og workshops foruden den sekretærbistand, man allerede havde nydt godt af.

Med hensyn til materialetransporten i Det danske Vadehav må der skelnes mellem transport af suspenderet materiale og bundtransporten. Sidstnævnte er det vanskeligt at få nøjagtigt hold på, specielt når det drejer sig om materialebudgettet over vaderne. Måling af de forsekllige fysisk-geografiske parametre som vindhastigheder, strømstyrker, vanddækninger, temperatur og salinitet er væsentlige for koncentrationen af suspenderet materiale. Det er vigtigt at kunne stille de rigtige spørgsmål for at få gennemtænkt problemstillingen. Kun langtidsregistreringer foretaget på forskningsmæssigt grundlag – med en stadig opfølgning af viden-niveau, -udnyttelse og -fornyelse i form af detailprojekter – er i stand til at løse de problemer, samfundet til stadighed har og får, og som der er peget på ovenfor. Tager man en evt. forureningssituation og miljøets reaktion herpå, illustrerer det ganske godt det kompleks af videnskabelige og politiske problemer, det indeholder. Tilskud fra floder eller Nordsøen giver kun anledning til en forureningssituation, når man har konstateret en uønsket effekt, men hvem afgør, i øvrigt, hvad der er acceptabelt og for hvem? Det drejer sig om at følge miljøets ændringer, og at identificere de virkende årsager. Det danske Vadehav er et meget komplekst og følsomt økosystem, hvor kendskab til såvel økotyper som de ovenfor nævnte fysiske parametre er fundamentalt nødvendige for i en given »katastrofe«-situation at kunne vurdere grænserne for en rimelig belastning.

Målingerne peger på meget store naturlige og uregelmæssigt forekommende fluktuationer forårsaget af klimatiske og biologiske begivenheder. Disse målinger peger direkte på omflytning af materiale og ændring i livsbetingelserne for flora og fauna i stor skala. Dette betyder, at der må være afgørende ligevægtspunkter og tilstande, man skal kende for at trænge ind til den dybere forståelse af de små regulerende mekanismer, der får dette landskab til at se lige så uforanderligt og »uskyldigt« ud som de terrestriske landskabstyper.

På denne baggrund er det endvidere forståeligt, at det er vanskeligt at spore forureningssituationer, før de langt har overskredet det tilladelige. At kunne følge de ændringer, som diffuse tilskud af flere slags forårsager, kræver langtidsregistreringer med detaljeret kendskab til økosystemers struktur og opførsel.

Det danske Vadehav er karakteriseret af stor biologisk aktivitet baseret på vandudvekslingen (tidevandet) med Nordsøen. Vadehavet er et akkumulationsområde for såvel grov- som finkornede sedimenter. Sekundært tilføres de danske marskarealer gennem sedimentation af suspenderede materialer (inkl. gulstof) en ganske stor del af Nordsøvandets samlede indhold heraf. Disse problemstillinger kendes i princippet, men hverken deres kvantitative størrelser eller deres geografiske placering. Endvidere er tilførslen af diverse tungmetaller og deres balancer ukendte. Tilsvarende er indholdet af såvel kvælstof som fosfor stort set ukendt i Vadehavet. I hvor høj grad er der tale om uheldige (katastrofale) udviklinger af menneskelig aktivitet i området? For at besvare disse spørgsmål er et detailkendskab til topografiske, hydrografiske, sedimentologiske og biologiske forhold i området nødvendig. Ellers kan diverse grænseværdier for opfyldelsen af Miljøstyrelsens målsætninger for kystvande ikke besvares. Der er principiel forskel på et østdansk fjord- eller bugt-

område og på et tidevandsområde. Det er helt andre hydrografiske forhold og balancer, der er tale om.

Vadehavsområdet modtager årligt hundredtusindvis af kubikmeter nye sedimenter og dette samt de dynamiske påvirkninger, som såvel det daglige tidevande som storme udøver, giver anledning til skabelsen af nye sedimentbalancer og nye erosionsområder inden for Vadehavet. Dvs. at samtidig med nye tilførsler af skadestoffer af biologisk og kemisk art er der også tale om resuspension af ældre finkornede aflejringer, hvis typer og geografiske placeringer man ikke kender i detaljer. Vadehavet er generelt et natur- og vildtreservat, dvs. at den generelle målsætning for kystvande er gældende overalt, og ganske store områder af Vadehavet såvel i nord som i syd er omfattet af målsætninger med skærpet kontrol og specifikke krav.

COST 647 vedrører økologiske registreringer af Det Danske Vadehav og omfatter i princippet to delprojekter:

A. Biologiske studier bl.a. med biomassebestemmelser af 10 hoveddyrearter på ialt 50 lokaliteter fordelt med ca. 25 på Grådybs nordlige tidevandsområde (Ho Bugt) i 4 forskellige miljøer samt ca. 25 på Lister Dybs nordlige tidevandsområde (Rømø Leje-bugten) i 4 forskellige miljøer (jfr. fig. 1).

B. Studier af naturmiljøets parametre, dvs. registrering af dynamikken samt reelt en overvågning af kystområdet fra Varde Å til grænsen. Disse studier omfatter dels de under A) beskrevne lokaliteter og dels hydrografiske studier (af hele tidevandsperioder) i samtlige løb i Vadehavet over en 10-årig periode. Endvidere studeres sedimentbalancen og transporten af suspenderet materiale. Dette sker samtidig med en kortlægning af Vadehavets sedimenter (med støtte af satellitdata for senere overvågning ad denne vej). Endelig kortlægges udvalgte sedimentationsmiljøer, hvorfra også tungmetalanalyse m.m. udføres. Herudover er der udvalgt vadeflader i nord og syd (ud for Kongeåen og ud for Brede Å), hvor selvregistrerende instrumenter følger samtlige parametres betydning for diverse balancer og miljøet som helhed (vanddækning, strøm, salinitet, temperatur, sedimentbalance m.m.). Til slut skal nævnes isforholdene i Vadehavet, der studeres specielt i relation til typedyrs udbredelse og springvise fluktuationer (fx sandormen 1968 eller hjertemuslingen 1982). Endelig skal det nævnes, at der på Skallingen planlægges oprettelse af en meteorologisk station for løbende at registrere lokal-klimatiske parametre. Disse målinger vil blive sammenlignet med målingerne fra Hohenwarte forsøgsstation og det nyoprettede Risøprojekt i Esbjerg lufthavn samt naturligvis de traditionelle stationer Blåvand, Sædding Strand og List.

Vor nuværende viden om dynamikken i Det danske Vadehav er i hovedsagen baseret på studier fra perioden 1930-72 (Skalling-Laboratoriet og De danske Vade- og Marskundersøgelser), dvs. før en systematisk anvendelse af selvregistrerende apparatur (startede i 1979) var tilgængelig. Dette betyder, at der stadig eksisterer ubesvarede spørgsmål som sedimentbalancens størrelse og tendens. Hvor kommer såvel det grove sediment som det suspenderede materiale fra? Hvilken vandbalance eksisterer der egentlig i Vadehavet? Bygningen af Rømødæmningen (1949) og låningsvejen til Mandø (1972) har fuldstændigt ændret tidevandets strømningsmønster ved udelukkelse af reststrømme fra Vadehavet, idet to trediedele af Vadehavet er omdannet til bugter. Er Vadehavet et sedimentationsbassin for det suspenderede materiale i Nordsøen, hvortil tungmetaller er adhæderede? Hvorledes foregår egentlig vandudvekslingen mellem Nordsøen og Vadehavet?

Remote sensing teknik kan hjælpe til kortlægning af hele denne dynamik samt til en kortlægning af land-use mønstret i øvrigt. COST 647 er langtidsstudier af økologiske og fysisk-geografiske parametre inden for intertidal sedimentary biotoper langs den europæiske fastlandskyst, dvs. fra Blåvandshuk til Pyrenæerne. Der foregår et nært samarbejde med en række tyske, hollandske og franske kyststationer, der arbejder under diverse universiteter og styrelser.

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