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VERLAG

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Vlaams Instituut voor de Zee
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Changes in the Algal Vegetation of a part of the Deltaic Area in the Southern Netherlands (Veerse Meer) after its Closure

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With 1 map, 5 tables, 4 plates

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Introduction

Veerse Meer (Lake Veere) is a part of the Oosterschelde — system in the southern Netherlands and is the collective name for the previously euhaline, tidal Veersche Gat and Zandkreek.

Veerse Meer was ultimately shut off in 1961. The eastern dike was closed in May 1960 and the western one in April 1961. After the closure, this area became a brackish water lake with progressive eutrophication. The reduced salinity and cessation of the tidal movements caused pronounced changes in the algal vegetation.

The conditions occurring in the littoral before the closure can partly be seen from the work of DEN HARTOG (1959) and from his unpublished data from the area.

A further reconstruction of the conditions concerning the vegetation of the Veersche Gat and Zandkreek can be made by comparing recent conditions in the lake with those of the neighbouring localities in the Oosterschelde, e. g. Wilhelminapolder, Kattendijke, Katseveer, outside the eastern dike of the Zandkreek and outside the dike of Vrouwenpolder.

The author investigated several localities along the banks of the Veerse Meer in May and October 1964 (see map).

The water in the lake is kept at two different levels: a summer level, corresponding to NAP (i. e. the Dutch standard level), and a 70 cm lower winter level. Thus a comparison between the conditions at the summer and the winter levels was possible on the basis of my samplings.

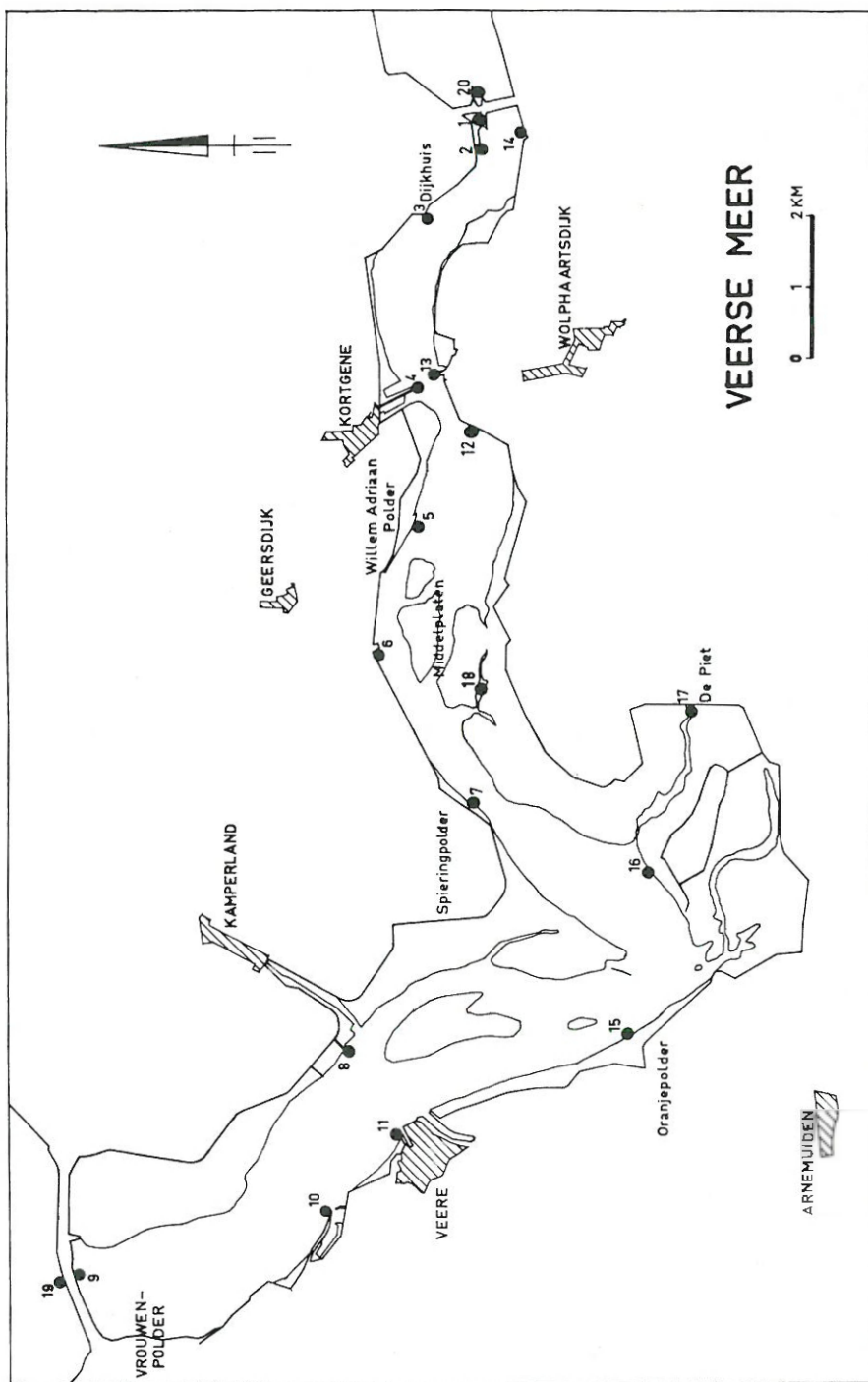
About a seventh of the total water mass of the lake is discharged at the changing of the levels in late autumn.

As a result of the closure, the Veerse Meer is now an almost homogeneous water mass. Only slight differences in salinity were noticed between the localities along its banks. The same is true for the water temperature, while the degree of pollution seemed to be stronger in certain localities.

The present work was done at the Hydrobiological Institute of the Royal Netherlands' Academy of Sciences, at Yerseke.

The main purpose of algological investigations in the Deltaic area is to study the changes in the submarine benthic vegetation, caused by the closure of certain parts of

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this area. According to the Delta plan even more of this area will be closed off in the future.

My work in the Veerse Meer represents but a preliminary approach to the problems in the Deltaic area.

Ecological data

In some of the localities observed in the Veerse Meer chlorinity measurements were made at the time of my samplings (Table 4). In a few places, the phosphorus content was determined as well (Table 5).

Further data on the chlorinity and the measurements of the total phosphorus are given in Tables 1 and 2. The samples were taken in connection with plankton investigations at a certain distance from the coast. These data were kindly put at my disposal by Mr. C. BAKKER, as were the temperature measurements in Table 3.

As seen from the tables, there is no essential difference in the chlorinity of the surface water near the banks (Table 4) and in the middle of the lake (Table 1). Further there are no noteworthy differences in the chlorinity of the surface water between the localities where the algal samples had been gathered. An exception is the area between the Oranjepolder to the Middelplaten, this is even more brackish and presents very peculiar growing conditions (localities 15 to 18).

In comparing the spring and autumn chlorinity data it becomes evident that they were about 10/100 higher after the winter level had been adjusted. The amount of the total phosphorus is considerably higher in the autumn. Especially high values were found in the area between Oranjepolder and the Middelplaten.

The water temperature in May was between 12.2° C and 13.0° C, and between 8.0° C and 9.6° C in October.

Localities

Observations were made by the author of 18 localities in the Veerse Meer (see map).

Locality 1 is situated in the narrow channel which follows the eastern dike. This place is hard to reach, since the algal growth is limited to the vertical wall of the sluices. This wall is overgrown by *Ulothrix flacca*, *U. pseudoflacca*, *Blidingia minima*, *B. marginata*, *Enteromorpha intestinalis*, *E. clathrata* and *Chaetomorpha aerea*.

Locality 2 lies inside the Veerse Meer near the dike at the corner of the sluice at Kats. There is a sandy, muddy substratum with a few small stones. The shallow water is polluted to a rather high degree and thus there is minimum transparency. There was a scarce vegetation of higher algae in spring, represented by *Ulothrix flacca*, *Enteromorpha intestinalis*, *E. clathrata*, *Cladophora alhida* and *Cl. rupestris*. The stones were overgrown by a layer of diatoms of which *Licmophora gracilis* var. *anglica* was dominant. In autumn, after lowering of the water level, the lower "sublittoral" vegetation became accessible. This was dominated by *Polysiphonia nigrescens*, the companion species were *Callithamnion roseum*, *C. scopulorum*, *Petalonia fascia*, *Chaetomorpha aerea*, *Ulva rigida*, *Enteromorpha intestinalis* and the same *Cladophora* species.

Locality 3: Dijkhuis near Kortgene. This locality was somewhat less polluted than the one mentioned previously and its algal vegetation was thus more luxuriant. *Enteromorpha* species (*E. linza*, *E. intestinalis*, *E. ahneriana*, *E. clathrata*, *E. prolifera*,

E. radiata) dominated the spring vegetation here and they were accompanied by *Ulva lactuca*, *Monostroma grevillei*, *Cladophora albida* and *Chondrus crispus* as well as by single specimens of *Petalonia fascia*. In the autumn, *Ulothrix* species (*U. flacca*, *U. pseudoflacca*), *Rhizoclonium riparium*, *Chaetomorpha aerea*, *Blidingia minima*, *Oscillatoria brevis* and *Polysiphonia nigrescens* were additionally observed, while *Enteromorpha radiata*, *E. prolifera* and *Monostroma grevillei* had disappeared from the vegetation.

Locality 4: Kortgene, landing-stage. On this wooden construction an overgrowth of *Ulothrix flacca* and *U. pseudoflacca* was found in spring and autumn. On small stones, lying on the sandy ground, *Enteromorpha* species (*E. linza*, *E. intestinalis*, *E. clathrata*, *E. prolifera*, *E. ramulosa*, *E. multiramosa*, *E. flexuosa*), together with *Urospora penicilliformis* were dominant. Some drifted *Pylaiella littoralis* was found. The autumn vegetation was on the other hand dominated by *Polysiphonia nigrescens* and *Bryopsis plumosa*, accompanied by *Enteromorpha ahlnneriana*, *Chaetomorpha aerea*, *Cladophora rupestris*, *Ceramium rubrum*, *Callithamnion roseum*, *Scytosiphon lomentaria*, and *Ulva lactuca*.

This locality appeared to be only slightly polluted. Among the diatoms a number of marine species were present.

Locality 5: The dike of the Willem Adriaanpolder is a place with rather clean and transparent water. The substratum consists of small stones and a stony wall. At this place, *Chondrus crispus*, *Scytosiphon lomentaria* and *Petalonia fascia* were frequent among the spring vegetation, which consisted of *Enteromorpha linza*, *E. compressa*, *E. ahlnneriana*, *E. intestinalis*, *Ulothrix flacca*, *U. pseudoflacca*, *Ulva lactuca*, *Rhizoclonium riparium*, *Vaucheria* sp., *Cladophora glomerata*, *Monostroma grevillei*, *Urospora penicilliformis* and *U. wormskjoldii*.

In the autumn *Polysiphonia nigrescens* became dominant together with *Bryopsis plumosa*. *Cladophora glomerata* was replaced in the autumn by *Cladophora albida* and *Cl. rupestris*. Single specimens of *Fucus vesiculosus* were found here among the autumn vegetation.

In the spring *Licmophora gracilis* var. *anglica* formed luxuriant colonies, which were replaced by *Melosira moniliformis* colonies in the autumn.

Locality 6: Geersdijk. A sparse vegetation composed of *Enteromorpha intestinalis*, *E. ahlnneriana*, *E. compressa*, *E. clathrata*, *Ulva lactuca*, *Ulothrix flacca*, *Monostroma grevillei*, and *Chondrus crispus* was observed in the spring, while in the autumn *Cladophora albida*, *Bryopsis plumosa*, *Polysiphonia nigrescens*, *P. nigra*, *Scytosiphon lomentaria*, and *Chaetomorpha aerea* were added to the vegetation and *Monostroma grevillei* disappeared. As in most of the localities inside the Veerse Meer, the dominance of *Bryopsis plumosa* and *Polysiphonia nigrescens* was characteristic for the autumn vegetation.

It is further note-worthy that *Melosira moniliformis* covered *Cladophora albida* -- plants, while *Synedra tabulata* completely covered *Bryopsis plumosa* and *Rhoicosphaenia curvata* covered *Scytosiphon lomentaria*. *Amphipleura rutilans* on the other hand formed luxuriant colonies directly on the stones and the same was true for the spring-colonies of *Licmophora gracilis* var. *anglica*.

Locality 7: The dike of the Spieringpolder. A poor vegetation of higher benthic algae was found in this place, represented by *Ulva lactuca*, *Enteromorpha intestinalis*, *E. ahlnneriana*, *Ulothrix flacca* and *U. pseudoflacca* in May; and by the same species, together with *Bryopsis plumosa*, *Polysiphonia nigrescens*, *Cladophora albida* and *Enteromorpha linza* in October.

Locality 8: Landing-stage at Kamperland. The benthic vegetation was even more sparse in this place and was represented by the two *Ulothrix* species, mentioned above and by *Urospora penicilliformis* in May. In autumn, *Enteromorpha* species (*E. intestinalis*, *E. linza*, *E. ahlnneriana*), were found here as well, together with *Monostroma oxyspermum* and *Bryopsis plumosa*.

Locality 9: Inside the dam at Vrouwenpolder. This locality seems to be extremely polluted and appeared almost bare of any vegetation in the spring. Negligible amounts of *Enteromorpha clathrata*, *E. intestinalis*, *Percursaria percursa*, *Ulothrix flacca*, *U. subflaccida* and *Urospora penicilliformis* were found here, during the spring sampling, while in autumn *Ulva lactuca* and *Bryopsis plumosa* were dominant. Further *Enteromorpha linza*, *E. ahlnneriana* and two species of *Blidingia* (*B. minima*, *B. marginata*) occurred in the autumn vegetation here.

Locality 10: The Delta harbour near Veere seemed to be rather polluted at the time of sampling. In May, *Percursaria percursa* was dominant and was accompanied by *Ulothrix flacca*, *U. subflaccida* and by *Urospora penicilliformis*. In the autumn considerable quantities of *Bryopsis plumosa*, *Ulva lactuca*, *Cladophora rupestris* and of different *Enteromorpha* species (*E. intestinalis*, *E. clathrata*, *E. ahlnneriana*, *E. prolifera*) were found, as well as some *Blidingia minima*. *Percursaria percursa* had disappeared from the vegetation.

Locality 11: Veere. At Veere the water is clean and transparent and wooden pillars and larger stones offer a substratum for algal attachment. *Enteromorpha intestinalis*, *Ulothrix flacca*, *U. pseudoflacca*, *U. subflaccida*, *Monostroma grevillei*, *Capsosiphon fulvescens*, *Urospora penicilliformis* and *Ulva rigida* were found here in spring, while in the autumn vegetation *Bryopsis plumosa* and *Ulva lactuca* became dominant. *E. ahlnneriana* and *E. compressa* joined the vegetation while *Capsosiphon fulvescens* had disappeared together with *Monostroma grevillei*.

Locality 12: The dike west of Wolphaartsdijk. The spring vegetation here was relatively luxuriant, represented by *Petalonia fascia*, *Scytosiphon lomentaria*, *Cladophora rupestris*, *Monostroma grevillei*, *Capsosiphon fulvescens*, *Enteromorpha intestinalis*, *Enteromorpha compressa*, *Nostoc* sp. and *Oscillatoria limosa*.

In October no Cyanophyceae were observed. *Chaetomorpha aerea*, *Cladophora albida*, *Cladophora rupestris* and *Chondrus crispus* were found in the autumn vegetation, as well as single specimens of *Fucus serratus*.

Locality 13: Landing-stage at Wolphaartsdijk. At this place a *Protococcus* sp. was detected on the wooden construction together with *Ulothrix flacca* and *U. pseudoflacca*. *Enteromorpha intestinalis*, *E. clathrata*, *Capsosiphon fulvescens* and some *Scytosiphon lomentaria* were found attached to stones. In autumn *Cladophora albida*, *Enteromorpha prolifera*, *E. ahlnneriana* and *Ulva lactuca* were found on a stony substratum, while on the woodwork *Percursaria percursa* was additionally observed.

Locality 14: The dike of the Wilhelminapolder. In front of dike where it bends, considerable amounts of floating *Chaetomorpha aerea* were found. *Petalonia fascia* and *Scytosiphon lomentaria* seem to have their maximum abundance in this particular place. Further *Chondrus crispus*, *Ulva lactuca*, *Enteromorpha linza*, *E. clathrata*, *E. intestinalis*, *E. ahlnneriana* were found here in May. In October *Chaetomorpha aerea*, *Monostroma oxyspermum*, *Enteromorpha flexuosa*, *Bryopsis plumosa*, *Cladophora rupestris* and *Cladophora albida* were observed.

Locality 15: The dike of the Oranjepolder. Only *Percursaria percursa* and *Enteromorpha ablnneriana* were found here in May, while in October a rather luxuriant vegetation of green algae (*Ulva lactuca*, *Enteromorpha linza*, *E. ablnneriana*, *E. clathrata*, *E. prolifera*, *Bryopsis plumosa* and *Blidingia marginata*) was observed.

Locality 16: Noordsloe. This locality was visited in October only. The species *Ulva rigida*, *U. curvata*, *Enteromorpha linza*, *E. ablnneriana* and *Bryopsis plumosa* were found.

Locality 17: De Piet. The autumn vegetation of this place was very similar to the one in locality 16. *Cladophora albida* but not *Bryopsis plumosa* was found. The spring vegetation was on the other hand more luxuriant and was represented by *Percursaria percursa*, *Blidingia minima* and by *Enteromorpha* species (*E. intestinalis*, *E. compressa*, *E. ablnneriana*, *E. prolifera*, *E. torta*).

Locality 18: Middelplaten. On these flats similar conditions to those in locality 17 were found. Among the spring vegetation the same species had been observed, and additionally: *Enteromorpha radiata* and *E. ralfsii*. The autumn vegetation was on the other hand negligible, represented by *Enteromorpha flexuosa* and the three *Ulva* species (*U. lactuca*, *U. rigida*, *U. curvata*).

As already mentioned, the area between the Oranjepolder and Middelplaten presents special growing conditions, different from the rest of the localities in question. No red and brown algae were found here. However, in contrast to the rest of the area, it was the spring vegetation that was the more luxuriant here. In this area the species *Ulva rigida* and *U. curvata* had their maximum abundance.

Conditions in the investigated area before the closure

As mentioned above the Veerse Meer was a normal tidal area with an average chlorinity of about 17‰ before its complete closure. With regard to the algal vegetation, I refer firstly to the data obtained by Dr. C. DEN HARTOG.

There was the usual zonation of the littoral Fucaceae along the coast of the Veersche Gat and the Zandkreek, with *Pelvetia canaliculata* and *Fucus spiralis* and under them a zone of *Fucus vesiculosus* and *Ascophyllum nodosum*. Further down followed the zone of *Fucus serratus*. After the closure the littoral Fucaceae vegetation desiccated and died. Only single specimens of *Fucus vesiculosus* and *Fucus serratus* were found during my investigation.

Further the following species, found by DEN HARTOG (at Kortgene, Wolphaartsdijk, Spieringpolder, Willem Adriaanpolder) in the years before the closure, disappeared from the area: *Ectocarpus confervoides*, *Cladostephus spongiosus*, *Sphacelaria fusca*, *Ralfsia verrucosa*, *Rhodochorton floridulum*, *Dumontia incrassata*, *Hypoglossum woodwardii*, *Bangia fusco-purpurea*, *Porphyra umbilicalis*, *Polysiphonia violacea*, *Bostrychia scorpioides*, *Hildenbrandia prototypus* and *Codium fragile*.

The algal vegetation of the area under discussion could be also reconstructed by comparing the conditions in the lake with the neighbouring localities in the Oosterschelde.

In the Zandkreek*) (locality 20) close to the eastern dike, the algal growth is limited to the slopes of the dike. The following species were collected at this place, close to

*) The name Zandkreek here refers to that part of the former, larger Zandkreek which has not been closed off from the sea.

the Veerse Meer: *Pelvetia canaliculata*, *Fucus spiralis*, *F. vesiculosus*, *Ascophyllum nodosum*, *Fucus serratus*, *Laminaria saccharina*, *Porphyra umbilicalis*, *P. vulgaris*, *Ceramium rubrum*, *Hildenbrandia prototypus*, *Ulothrix flacca*, *U. pseudoflacca*, *Enteromorpha intestinalis*, *E. prolifera*, *E. clathrata*, *Blidingia minima*, *B. marginata*, *Ulva lactuca* and *Codium fragile*. In May *Pylaiella litoralis*, *Enteromorpha radiata* and *Urospora penicilliformis* were likewise observed. Outside the dike of Vrouwenpolder (locality 19) the vegetation was not essentially different from the Veerse Meer, as far as the algal vegetation is concerned. The slope of the dike is overgrown by *Ulothrix* species (*U. flacca*, *U. pseudoflacca*, *U. subflaccida*) together with *Urospora penicilliformis*, *Blidingia minima*, *B. marginata*, *Enteromorpha ahlnieriana*, *Percursaria percursa* and *Porphyra umbilicalis*.

At the dike of the Wilhelminapolder (locality 21) the algal vegetation is sparse and limited to smaller stones, lying on the sandy bottom. Masses of floating *Chaetomorpha aerea* were observed on the meadows of *Zostera noltii*. *Fucus vesiculosus*, *Ascophyllum nodosum*, *Enteromorpha ahlnieriana* and *E. intestinalis* were found attached to stones in the upper littoral. In the lower littoral *Zostera marina* appeared together with considerable quantities of *Ulva lactuca*. At the same level *Hypoglossum woodwardii*, *Polysiphonia nigrescens*, *Ceramium rubrum* and *Dumontia incrassata* were found.

On the border between the littoral and sublittoral diatom masses covered the sand in a thick layer. This layer was mainly formed by *Surirella gemma* and a number of marine species (see list of species) of diatoms.

In spring no drifting masses of *Chaetomorpha aerea* were found in this place. *Enteromorpha intestinalis*, *E. ahlnieriana*, *Hypoglossum woodwardii* and *Polysiphonia nigrescens* were also absent. Additionally, some *Ectocarpus confervoides*, *Pylaiella litoralis* and *Enteromorpha clathrata* were found.

At Kattendijke ca. 10 km east of the Veerse Meer, a relatively rich algal vegetation was found. The usual Fucaceae zonation was observed here, covering the dike (*Pelvetia canaliculata*, *Fucus spiralis*, *F. vesiculosus*, *Ascophyllum nodosum* and *Fucus serratus*). Lower down the Fucaceae zone is followed by beds of *Laminaria saccharina*.

Between the Fucaceae *Ralfsia verrucosa*, *Hildenbrandia prototypus*, *Rhodochorton purpureum*, *Lithothamnion lenormandii*, *Pylaiella litoralis*, *Ectocarpus confervoides*, *Callithamnion byssoides*, *Cladophora flexuosa*, *Monostroma grevillei*, *Percursaria percursa*, *Codium fragile*, *Chaetomorpha linum* and *Ch. aerea* were found in January. Above the Fucaceae as well as at the level of *Pelvetia canaliculata*, *Porphyra umbilicalis*, *P. leucosticta*, *Catenella repens* and *Rhizoclonium riparium* were found. During the summer-samplings, *Cladostephus spongiosus*, *Callithamnion roseum*, *Ceramium rubrum*, *C. deslongschampsii*, *Hypoglossum woodwardii*, *Sphacelaria fusca*, *Dumontia incrassata*, *Griffithsia devoniensis*, *Cladophora rupestris*, *Cl. utriculosa*, *Monostroma oxyspermum*, *Ulva lactuca*, and *Enteromorpha compressa* were observed together with the species, mentioned above. On isolated stones, lying on the sandy ground, *Enteromorpha* and *Ulothrix* species were found (*E. intestinalis*, *E. clathrata*, *E. ahlnieriana*, *Blidingia minima*, *Ulothrix flacca*).

Floristics

Only 7 species of red algae and 6 species of brown algae were found among the algae observed. The vegetation of the benthic algae in the Veerse Meer is dominated by

green algae, especially by Enteromorpha species. It has thus a brackish character. Out of the Chlorophyceae, the two species *Ulva rigida* and *U. curvata*, common around the Middelpaten, are new for the Deltaic area. The same is true for the species *Enteromorpha ramulosa*, *E. multiramosa*, *E. flexuosa*, *E. radiata* and *E. kylinii*. The flora of the diatoms shows still a heterogeneous picture, a mixture of marine, marine-brackish, brackish-marine and brackish water species. The brackish-fresh water character of the diatom flora, though expressed to a certain degree is not prevalent. The following species were observed in the lake:

Rhodophyceae:

Ceramium rubrum (Huds.) J. Ag.
C. areschongii Kylin
Callithamnion roseum (Roth) Harv.
C. scopulorum (C. Ag.) Traill.
Polysiphonia nigrescens (Huds.) Grev.
P. nigra (Huds.) Batt.
Chondrus crispus (L.) Lyngb.

Chlorophyceae:

Protococcus sp.
Ulothrix flacca (Dillw.) Thur.
U. pseudoflacca Wille
U. subflaccida Wille
Monostroma grevillei (Thur.) Wittr.
M. oxyspermum (Kütz.) Doty
Percursaria percurta (C. Ag.) Rosenv.
Capsosiphon fulvescens (C. Ag.) Setch. et Gardn.
Ulva lactuca L.
U. rigida (C. Ag.) Thur.
U. curvata J. Ag.
Enteromorpha linza (Linn.) J. Ag.
E. intestinalis (L.) Link.
E. compressa (L.) Grev.
E. ahlfneriana Bliding
E. clathrata (Roth) Grev.
E. prolifera (Müll.) J. Ag.
E. ramulosa (Smith) Hooker

Diatomeae:

I. marine species (M)
Rhabdonema minutum Kütz.
Pleurosigma affine Grun.
P. angulatum (Quekett) Smith
Actinopteryx splendens (Shadbolt) Ralfs
Auliscus sculptus (W. Smith) Ralfs

Phaeophyceae:

Petalonia fascia (Müll.) Kuntze
Scytosiphon lomentaria (Lyngb.) Endl.
Pylaiella littoralis (L.) Kjellm.
Ectocarpus confervoides (Roth) Le Jol.
Fucus vesiculosus L.
Fucus serratus L.

E. multiramosa Bliding
E. flexuosa (Wulfen ex Roth) J. Ag.
 subsp. *pilifera* (Kütz.) Bliding
E. radiata J. Ag.
E. kylinii Bliding
E. torta (Mertens) Reinbold
E. ralfsii Harvey
Blidingia minima (Nägeli ex Kütz.) Kylin
B. marginata (J. Ag.) Dang.
Urospora penicilliformis (Roth) Aresch.
U. wormskioldii (Mertens) Rosenv.
Chaetomorpha aerea (Dillw.) Kütz.
Cladophora glomerata (L.) Kütz.
Cl. albida (Huds.) Kütz.
Cl. rupestris (L.) Kütz.
Rhizoclonium riparium (Roth) Harv.
Vaucheria sp.
Bryopsis plumosa (Huds.) C. Ag.

Triceratium alternans Bailey
T. favus Ehrenberg
Podosira stelliger (Bailey) Mann.
Cymatosira belgica Grun.
Actinocyclus ehrenbergii Ralfs
Ampthora angustata Gregory

Diatomeae:

I *marine species* (M)

Aulacodiscus argus (Ehr.) A. Schmidt
Campylosira cymbelliformis (A. Schmidt) Grun.
Coscinodiscus radiatus Ehr.
Nitzschia panduriformis Gregory
Navicula sparsistriata Hustedt
Grammatophora marina (Lyngb.) Kütz.
G. oceanica (Ehr.) Grun.

Melosira sulcata (Ehr.) Kütz.
M. westii W. Smith
Cerataulus smithii Ralfs
Licmophora gracilis (Ehr.) Grun. var. *anglica* (Kütz.) Peragallo
L. paradoxa (Lyngb.) Ag.
Dimerogramma minor (Gregory) Ralfs
Denticulata sp.

II *marine-brackish species* (MB)

Diploneis smithii (de Bréb.) Cleve
D. didyma Ehr.
Actinoptychus undulatus (Bailey) Ralfs
Coscinodiscus excentricus Ehr.
Hyalodiscus scoticus (Kütz.) Grun.
Navicula humerosa De Bréb.
Navicula abrupta Gregory

N. flauaticum Grun.
N. forcipata Greville
Raphoneis amphiceros Ehr.
Achnanthes longipes Ag.
Cocconeis scutellum Ehr.
Navicula phyllepta Kütz.
Licmophora abbreviata Ag.
L. ehrenbergii (Kütz.) Grun.

III *brackish-marine species* (BM)

Pleurosigma elongatum W. Smith
Gyrosigma fasciola W. Smith
Diploneis estuarii Hustedt
Surirella ovalis de Bréb.
S. gemma Ehr.
Nitzschia punctata (W. Smith) Grun.

Melosira nummuloides (Dillw.) C. Ag.
M. moniliformis (Müll.) Ag.
Synedra tabulata (Ag.) Kütz.
Achnanthes brevipes Ag.
Scoliopleura tumida (de Bréb.) Rabenh.
Stauroneis gregori Ralfs

IV *brackish-water species* (B)

Gyrosigma balticum (Ehr.) Rabenh.
G. spenceri (W. Smith) Cleve
Diploneis interrupta (Kütz.) Cleve
Rhopalodia gibberula (Ehr.) Müll.
Cyclotella striata (Kütz.) Grun.
Amphipecten rutilans (Trentepohl) Cleve
Caloneis amphisbaena (Bory) Cleve
C. formosa (Gregory) Cleve
Amphora proteus Gregory
Nitzschia navicularis (de Bréb.) Grun.

Navicula peregrina (Ehr.) Kütz.
N. avenacea de Bréb.
N. plathii Brockmann
N. digitoradiata (Gregory) Schmidt
N. rostellata Kütz.
N. clementis Grun.
N. salinarum Grun.
Melosira jurgenssii Ag.
Achnanthes bauckiana Grun.
Rhopalodia musculus (Kütz.) O. Müll.
Synedra pulchella (Ralfs) Kütz.

V *brackish-fresh water species* (BF)

Nitzschia dubia W. Smith
N. sigma (Kütz.) W. Smith
N. hungarica Grun.

N. ignorata Krasske
Navicula mutica Kütz.
Amphora veneta Kütz.
Bacillaria paradoxa Gmelin

Diatomeae:

VI *fresh water-brackish species* (FB)
Nitzschia amphibia Grun.
Gyrosigma acuminatum (Kütz.) Rabenh.
Navicula rhynchocephala Kütz.
N. cryptocephala Kütz.
N. cincta (Ehr.) Kütz.
N. cuspidata Kütz.

N. menisculus Schum.
Synedra ulna (Nitzsch.) Ehr.
Fragilaria bidens Heiberg
Rhoicosphaenia curvata (Kütz.) Grun.
Achnanthes hungarica Grun.
Cocconeis placentula Ehr.
Hantzschia amphioxys (Ehr.) Grun.

VII *fresh water species* (F)
Navicula gracilis Ehr.

N. hungarica Grun.
N. sp.

Conclusions

The purpose of the algological investigations in the Veerse Meer was to study the changes in the submarine vegetation caused by shutting off this part of the Oosterschelde system from the sea.

The main effects of shutting off this part of the Oosterschelde were:

1. cessation of tidal movements.
2. dilution of the sea water, so that the previous marine area became brackish, with an average chlorinity of 10⁰/100.
3. less obvious salinity fluctuations, caused by the absence of currents and tidal streams.
4. stagnation of the water.
5. progressive eutrophication.
6. decreasing transparency of the water.

There are two levels maintained in the lake, a summer one, corresponding to NAP (Dutch standard level) and a 70 cm lower winter level.

All the changes in the ecology of the area in question exert their influence on the algal vegetation of the Veerse Meer.

While still an open part of the Oosterschelde, the littoral vegetation was dominated by Fucaceae (according to DEN HARTOG) in their usual zonation. Several species of red and brown algae were present, e. g. *Hildenbrandia prototypus*, *Dumontia incrassata*, *Rhodochorton purpureum*, *Hypoglossum woodwardii*, *Ralfsia verrucosa*, *Cladostephus spongiosus*, *Sphacelaria fusca*, etc.

These species disappeared after the closure together with the littoral vegetation of the Fucaceae. At the time of my observations no *Pelvetia canaliculata*, *Fucus spiralis* or *Ascophyllum nodosum* were found in the Veerse Meer.

The vegetation of the lake is characterised by the dominance of green algae, especially Enteromorpha species, among which *E. intestinalis*, *E. ahneriana*, *E. prolifera*, and *E. clathrata* were especially abundant.

The species *Ulva curvata* en *U. rigida*, new for the Deltaic area, were especially abundant between the Oranjepolder and the Middelplaten.

In characterising the vegetation of the Veerse Meer, the difference between the conditions at the summer and winter level should be stressed:

A) summer level, corresponding to NAP:

When sampling in the spring, the algal vegetation in the lake appeared extremely sparse. In some localities an Enteromorpha vegetation had developed, but in most places the vegetation mainly consisted of an Ulothrix-zone and of prolific diatom — colonies, mostly formed by *Licmophora gracilis* var. *anglica* and *Melosira nummuloides*. In some other places, single specimens of *Petalonia fasciata*, *Scytosiphon lomentaria*, *Chondrus crispus* and *Ulva lactuca* were found.

B) During the time when the 70 cm lower winter level is maintained, the vegetation of the lower levels can be reached, while that from the upper level desiccates.

The vegetation of the Veerse Meer appeared thus more luxuriant during the autumn sampling. The vegetation pattern is characterised, besides the pronounced dominance of Enteromorpha species, by considerable quantities of *Chondrus crispus*, *Petalonia fasciata*, *Scytosiphon lomentaria* and *Ulva lactuca*, as observed in several localities.

Furthermore, the appearance of *Bryopsis plumosa* and *Polysiphonia nigrescens* is characteristic for the autumn vegetation, forming a Polysiphonia-Bryopsis association and dominating the vegetation of several of the localities.

Single specimens of *Callithamnion* (*C. roseum*, *C. scopulorum*) and *Ceramium* (*C. rubrum*, *C. areschougii*) were found in the autumn vegetation.

The autumn vegetation was further characterised by prolific colonies of *Amphipleura rutilans*, *Achnanthes brevipes* and *Melosira moniliformis*. In spring *Licmophora gracilis* and *Melosira nummuloides* colonies were dominant.

The diatom flora in the Veerse Meer still shows a heterogeneous picture; a mixture of marine, marine-brackish, brackish and brackish-fresh-water species. Even fresh water species had been observed (*Navicula hungarica*, *N. gracilis*). The presence of some saprobic species (e. g. *Nitzschia dubia*) indicates the progressive pollution of the area. In general the diatom flora shows a prevalent brackish character.

Near the eastern dike, which by means of the sluice is in daily connection with the surrounding sea, more marine species were noticed.

It is further noteworthy that some of the diatom species seemed to prefer a certain species of a higher alga as substratum, e. g. *Synedra tabulata* was growing mostly on *Bryopsis plumosa*, *Melosira* species on *Cladophora albida*, *Cocconeis scutellum* on *Polysiphonia nigrescens*, *Rhoicospongia curvata* on *Scytosiphon lomentaria*, while *Achnanthes* species were mostly attached to Enteromorpha species.

In places with a greater degree of pollution less species were found than in cleaner places. The abundance of *Percursaria percurta* and absence of *Chondrus crispus* and *Polysiphonia* species was characteristic for such places.

Tables 1 to 5 show the chlorinity, the phosphorus content expressed as $\mu\text{g-at/L}$ in the water and the water temperatures at the time of samplings.

The changes in the algal vegetation of the Veerse Meer which occurred after the closure are the results of the interaction of several changing ecological factors, among which the cessation of tidal movements and progressive eutrophication may be responsible for the disappearance of the Fucaceae and a number of susceptible species. The lowered salinity, on the other hand, does not yet surpass the limit of the salinity

resistance of the main Fucaceae species involved, as far as I may judge from my previous experiences concerning the Fucaceae in estuaries (MUNDA, in print) and polluted land-locked fjords.

The exact cause of the changes in the vegetation pattern caused by the closure of certain tidal regions could be properly elucidated by studying the autecology of the main species involved and by metabolic experiments under conditions reproducing those in the fields.

Table 1
Veerse Meer. Chlorinity (‰)

Localities	25. 3. 1964 0—5 m	2. 4. 1964 0—5 m	6. 5. 1964 0—5 m	26/27. 10. 1964 0—5 m
3	9.87—9.72	10.44—12.06	10.84—10.89	10.79—10.90
3—4	9.70			
6		10.21—10.49		
7	10.18—10.59	10.15—12.77	10.89—10.69	10.84—11.52
8	10.20—10.27		10.54—10.54	11.69—11.72
9	10.21—10.22		10.48—10.44	11.74—11.73
9—10	10.27—10.17	10.26—10.24	10.49—10.55	11.64—11.70
10		10.28—10.25		
11				
12				
13				
12—13	9.76—9.73	10.19—10.66	10.84—10.94	11.01—11.23
14	9.86—9.86	10.30—12.51	10.74—10.94	10.62—11.15
15	10.18—10.19	10.01—10.80	10.64—10.64	11.03—11.42
17				

Table 2
Veerse Meer. Total Phosphorus content ($\mu\text{g-at/l.}$)

Localities	25. 3. 1964 0—5 m	2. 4. 1964 0—5 m	6. 5. 1964 0—5 m	26/27. 10. 1964 0—5 m
3	9.6—8.8	8.4—4.8	10.0—9.6	17.5—17.0
3—4	9.7			
6		7.2		
7	9.6—10.4	8.4—6.2	9.2—8.0	19.5—21.0
8	9.6—9.2		8.8—7.2	17.5—17.0
9	9.2—8.8		8.8	17.0—17.0
9—10	9.6—9.2	10.0—8.8	10.4—10.0	17.0—17.0
11		8.4—9.2		
12—13	8.4—8.8	8.4—6.4	9.4—14.4	19.5—18.0
15	9.6—9.6	9.2—8.0	8.0—9.2	18.0—17.0
17		8.8		

Table 3
Veerse Meer. Water temperatures (surface)

Localities	(T °C)		
	6. 5. 1964	21. 5. 1964	26/27. 10. 1964
3	12.2	17.3	8.2
4	12.5	17.3	8.4
7	12.3	16.5	9.0
8	13.0	17.2	9.0
9	12.3	16.5	9.3
9-10	12.3	16.5	9.5
14	12.5	17.5	8.1
15	12.2	16.8	8.2

Table 4
Veerse Meer. Chlorinity (surface)

Localities	(Chlorinity Cl ⁻ ‰)	
	4/5. 5. 1964	24/25. 10. 1964
1	10.12	11.01
2	10.12	11.01
2	10.05	10.48
3	10.15	11.05
5	10.11	10.98
6	10.30	11.00
7	10.09	11.21
10	10.32	11.07
11	10.17	11.55
12	10.25	11.18
14	10.12	10.75
15	10.84	8.63
16	10.75	6.74
17	7.03	2.06
18	1.16	0.45
20	15.66	16.03

Table 5
Veerse Meer. Total P in the water (surface) (µg-at/L)

Localities	24/25. 10. 1964
15	26.0
16	21.0
17	19.0
18	17.5



Plate 1: Fucaceae zone on the dike near Kattendijke



Plate 2: Fucaceae zone on the dike at the entrance to Veerse Meer (locality 20)

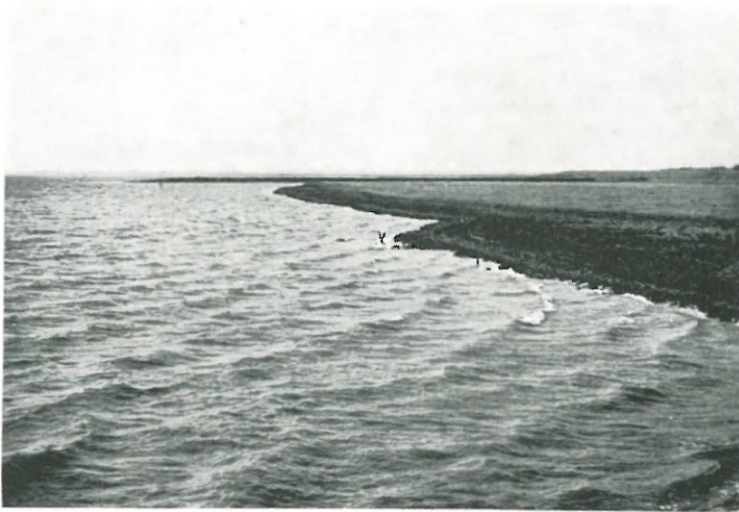


Plate 3: Banks of the Veerse Meer (neighbourhood of Kamperland) overgrown by *Enteromorpha* species



Plate 4: Area around Middelplaten

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Summary

The algal vegetation of the Veerse Meer in Southern Netherlands was investigated. This part of the Deltaic area was ultimately shut off in 1961.

After the closure this area became a brackish water lake. The cessation of tidal movements and other changing ecological factors caused pronounced changes in the algal vegetation.

The usual Fucaceae zonation disappeared together with a number of susceptible species. The vegetation of the benthic algae in the Veerse Meer is now dominated by green algae, especially by *Enteromorpha* species.

A survey of the algal vegetation along the banks of the Veerse Meer is given. Differences between the conditions in autumn and spring are stressed.

Zusammenfassung

Die Algenvegetation im Veerse Meer im südlichen Holland wurde von Verfasser untersucht.

Dieser Teil des Delta-Gebietes wurde im Jahre 1961 eingedämmt. Nach der Eindämmung verwandelte sich das Gebiet in ein brackisches Binnenwasser. Das Ausbleiben der Tidenbewegungen und andere veränderte ökologische Faktoren verursachten ausgeprägte Veränderungen der benthonischen Algenvegetation in diesem Gebiete.

Die übliche Zonierung der Fucaceen verschwand zusammen mit einigen empfindlicheren Arten. In der Vegetation der benthonischen Algen im Veerse Meer dominieren heute Grünalgen, besonders *Enteromorpha*-Arten.

Ein Überblick der Algenvegetation entlang des Strandes vom Veerse Meer wird gegeben. Unterschiede zwischen dem Zustande im Herbst und im Frühling wurden dabei berücksichtigt.

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