BEAUFORTIA

SERIES OF MISCELLANEOUS PUBLICATIONS

ZOOLOGICAL MUSEUM - AMSTERDAM

No. 73 Volume 6 January 20, 1958

Observations on the plankton of some inland waters, especially "wielen", in the Netherlands*)

by

P. LEENTVAAR

R.I.V.O.N., Staatsbosbeheer, Utrecht

(Institute for Nature Conservation Research).

Communication R.I.V.O.N. nr. 14

INTRODUCTION.

In August 1941, the Municipal Waterworks of Amsterdam started an investigation on the biological an hydrographical conditions of the water in some "wielen". "Wielen" are exceptionally deep pools. They originate from old dikebursts caused by high floods of the river. The new dike has been constructed around the "wiel" which had been formed behind the breach by the whirling water (see figure A).

The drinking water supply from the dunes of the Westcoast of Holland, which, owing to a rise of the salty groundwater level is running short, is a serious problem. New sources of fresh water must be found and a plan has been made for the construction of some deep basins for the storage of river water.

The biologist of the Municipal Waterworks, Dr. G. P. H. VAN HEUSDEN, was charged with studying the questions concerning the future biological conditions in the basins. Especially the activity of the plankton and the rooting waterplants should be studied in relation to the decalcification of the water in summer and the anaerobical conditions which arise when the organisms die in autumn.

For this study, it was necessary to find some waters with comparable conditions. So Dr. VAN HEUSDEN started an investigation on several deep

old "wielen" behind the dikes of the great rivers in August 1941 and the results of the chemical, physical and hydrographical data were published by him in „Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap", nr. 52, 2, 1945.

The data on the plankton of the "wielen", especially the data on the vertical distribution of the plankton as found in 1941, are investigated by me and given here, completed with some data found in 1955 (research for the R.I.V.O.N.).

The reader of this publication possibly will ask the reason to publish this work as a R.I.V.O.N. communication. It may be said here, that the contents act on descriptions of planktoncommunities and shorevegetations of "wielen" investigated in 1941. This is already sufficient for the purposes of the R.I.V.O.N. Inventarisation of plant- and animalcommunities living in natural resources is of basic importance. As will been shown, "wielen" are interesting biotops for hydrobiological studies. Moreover most "wielen" are worth to protect for landscape gardening. Another important reason in publishing the results is the fact, that most waters in the Netherlands like canals, rivers and rivulets, are seriously polluted or menaced by pollution. The "wielen" are isolated waters and therefore we may expect, that the biocommunity in the water in most cases will not been influenced by human activities. The biocommunity will live in natural circumstances and this is interesting for the purpose of Nature Conservation.

It will be clear, that the "wielen" are important for Nature Conservation and all facts about it must be collected and published in order to be able to protect these waters.

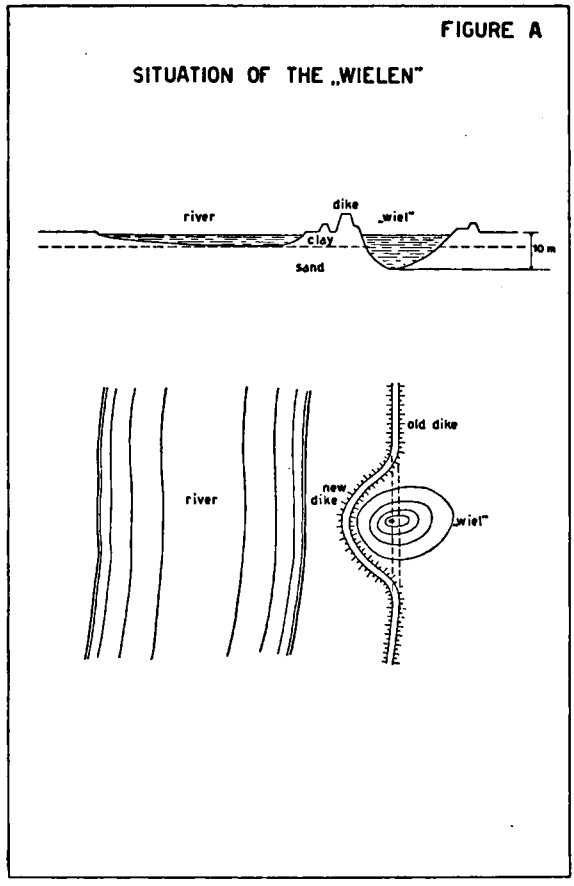
In connection with this we must warn here against the use of "wielen" as a basin for purification of polluted water. In some cases one is intended to drain off the effluent of sewage purification systems into a "wiel", motiviting that it is a large body of water with a great depth. The sewage effluent will be diluted and the biological purification of the water will be easier. As will be shown in this paper the water in the "wielen" is stratified and oxygenless layers exist. If a sewage effluent is mixed in it, the water will not be purified, by lack of circulation. As a result the pollution remains unaltered and some time this will be perceptible at the surface, causing the death of many animals and plants. Even it will be a danger for human sanity. This phenomen of stratification in a deep water and its consequences is not always known by engineers in waterpurification.

Not only pollution menaces the biocommunities in a "wiel", also eutrophication (without pollution) changes the biocommunity. Fertilizers used in the surrounding cultivated land change the chemical composition of the water. The biocommunity will bechanged and the extent is of interest fot the reseach of Nature Protection.

So the facts in this paper, collected in 1941 will be of much value for detailed conclusions and further researches.

METHODS.

The plankton samples were collected by pumping up 25 liters of water from different depths on the deepest spot. The water was sieved through a plankton-net and the sample preserved in a 3% formalin solution. In each "wiel" two or more samples were taken at different depths on each day of visiting.



The plankton in the samples was counted under the microscope in a so-called „Planktonkammer von Kolkwitz". According to this method, 1½ cc of the homogeneously distributed plankton-sample was brought under the microscope and the number of individuals of each species, that after settling in the planktonkammer appears in one view was counted. From the average of the numbers of three countings, the total number of each species in the whole sample was calculated.

The method of catching plankters by pumping water, is subject to some failings. Motile plankters, like copepods and other crustaceans, often are able to resist currents caused by the sucking of the pump and will flee before being caught. As a result they are lacking or may be represented in the counts, by figures which are too low. I do not believe, that this affects the results.

LIST OF "WIELEN" INVESTIGATED.

(cf map fig. c, p. 179)

No.	Date	Municipality	surface area (acres)	max. depth (meters)	chlorine (mg/l)
1	12-8-'41	Everdingen	3,3	15	37
2	14-8-'41	Schoonrewoerd	13,3	10	17
3	15-8-'41	Leerdam	2,0	7	39
4	16-8-'41	Asperen	6,6	5½	30
5	19-8-'41	Kedichem	1,9	12	29
6	19-8-'41	Kedichem	2,0	10	29
7	20-8-'41	Kedichem	1,2	13	22
8	21-8-'41	Vuren	1,4	11	47
9	21-8-'41	Vuren	1,1	11	50
10	26-8-'41	Zaltbommel	4,2	6½	29
11	28-8-'41	Echteld	0,8	6½	37
12	28-8-'41	Echteld	2,0	11	36
13	29-8-'41	Echteld	2,1	15	31
14	2-9-'41	Elst	3,1	11	10
15	4-9-'41	Lienden	1,9	12	23
16	5-9-'41	Wijk bij Duurstede	0,9	8	24

ENVIRONMENTAL CONDITIONS IN THE "WIELEN".

It is known, that in deep lakes the vertical distribution of plankton is not homogeneous, owing to different environmental conditions in the different water layers. During summer a stratification of the water in epi-, meta- and hypolimnion exists. It disappears in autumn when the whole waterbody from top to bottom is mixed as a consequence of the decreasing temperature at the surface and the action of the wind. Properties of water at different temperatures, radiation of the sun and action of the wind, give rise to a new thermocline in spring. So in summer the surface layer (epilimnion) has an equally high temperature and circulates independently from the transitional deeper layer (metalimnion), where the temperature decreases abruptly. Near the bottom, in the hypolimnion, the temperature is uniformly low. The same is found for the amount of oxygen in the different water layers. The epilimnion is saturated with oxygen, in the metalimnion the oxygen concentration decreases suddenly and in the hypolimnion oxygen concentration is low. In eutrophic lakes oxygen may be absent in the hypolomnion (see WELCH, 1935, BAAS BECKING, 1934).

In our "wielen" too, nearly always epi-, meta- and hypolimnion could be distinguished. The water in the "wielen" was eutrophic. The hypolimnion contained no oxygen at all. In some of the "wielen" sulfate reducing bacteria in the hypolimnion even gave rise to the presence of H_2S.

In comparison with temperate lakes in other countries, the thermocline is situated higher (at ± 5 m in "wielen", in lakes at ± 10 m and lower. See THOMAS, 1943). This is caused by the sheltered situation of the "wielen". The action of the wind is but slight and cannot cause deep circulating currents. The depth of the "wielen" investigated was sufficient for the formation of a thermocline. A thermocline was found if the water

was deeper than 5 to 6 m. The temperature in the hypolimnion was high (10°C) as compared to lakes.

It is obvious, that the different environmental circumstances in the different water layers of the "wiel" are important for the vertical distribution of the plankters. Some organisms prefer the epilimnion saturated with oxygen, others prefer the lower water poor in oxygen. The overturn in autumn causes great changes in the environment and the vertical distribution of the plankters is totally changed.

In addition to the differences and changes of the vertical distribution of the plankton caused by the yearly stratification, differences caused by diurnal migrations of the plankters are found.

Chemical analyses show, that the water in the "wielen" has a different composition from river-water. The amount of Cl and SO_4 is lower, the HCO_3 higher. Chemically the water closely resembles the groundwater in the surrounding area.

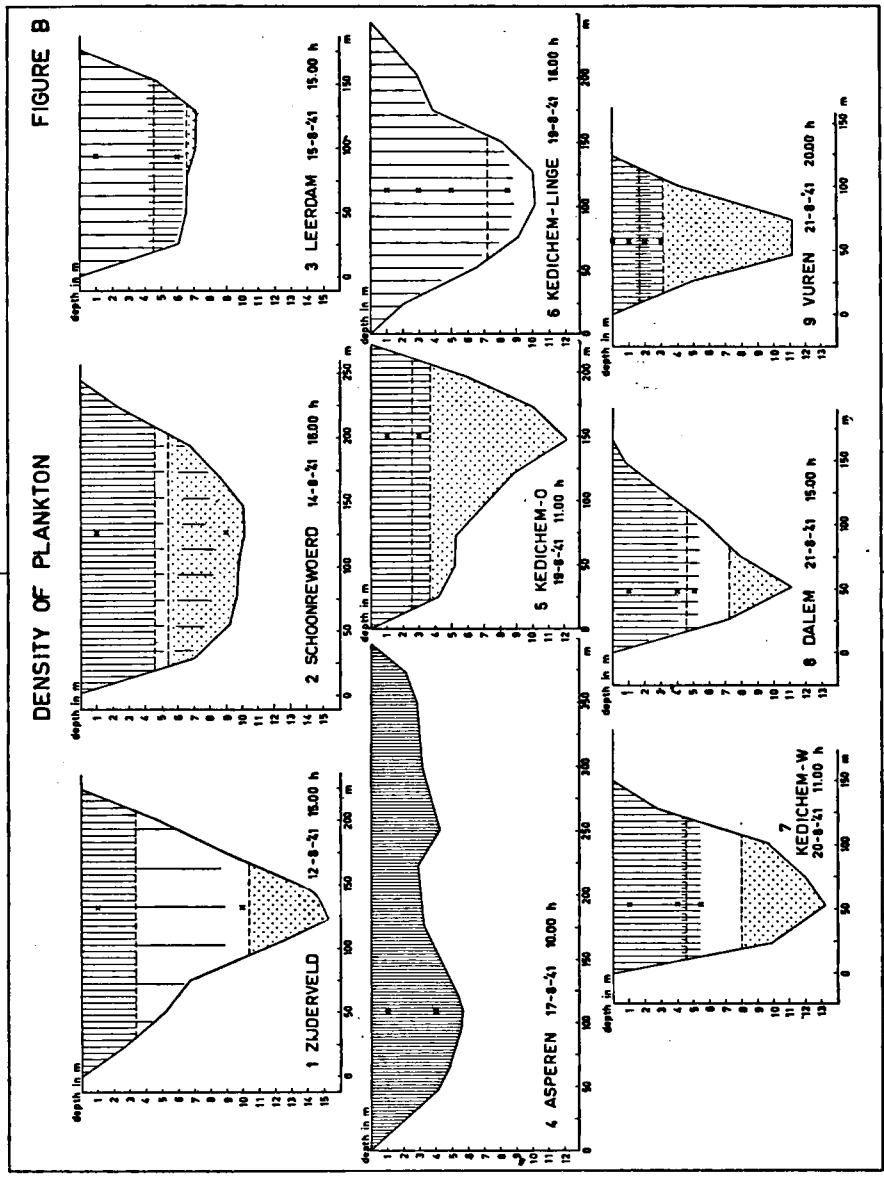
In the "wielen" on the lower western part of the river, i.e. nearer to the sea, the amount of chlorine is higher, showing the influence of the brackish groundwater in the lower estuary (cf. map. fig. c, p. 179, and p. 174).

The composition of the subsoil greatly affects the chemical composition of the water. In this connection, we note that all "wielen" are situated in riverclay soils. The bottom is rich in black mud, with organic substances and much FeS. Only the "wiel" near Asperen no. 4 has a sandy subsoil and as a consequence aerobic conditions from top to bottom.

"Wielen" of great depth are unfavourable for pond plankton (Heleoplankton). The shores of most "wielen" are very steep on almost all sides. The growth of rooting and floating waterplants is in most cases scarce and consist of a narrow zone only. The conditions therefore, will be most favourable for lake plankton (Limnoplankton), which is adapted to floating in open water. A special analysis of the plankton in the "wielen" has been made with regard to this point.

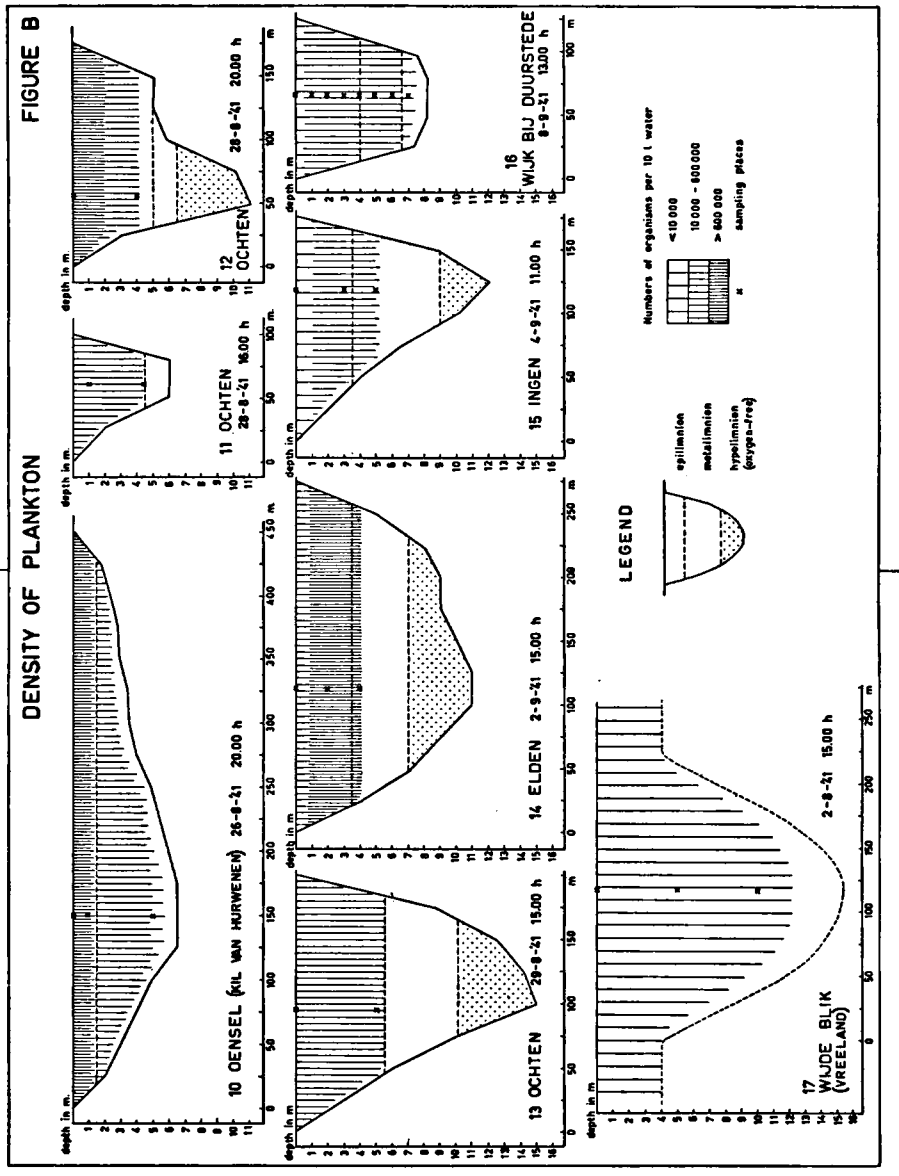
Proof of the suitability of "wielen" as an environment for typical limnoplankters was given in 1955, by my researches on the plankton of these waters for the Department of Nature Protection. In a deep "wiel" I found rather big numbers of the diatom *Centronella reichelti,* which had not yet been found in the Netherlands and only occurs in the deep Baltic sens (cf. LEENTVAAR, 1955). We may expect to find more of these typical lake plankters in "wielen". The species of plankton most commonly found in the "wielen" are the following: *Cyclops oithonoides, Diaptomus gracilis, Daphnia longispina, Diaphanosoma brachyurum, Keratella cochlearis, Keratella quadrata, Polyarthra trigla, Filinia longiseta, Gastropus stylifer, Pompholyx complanata, Ceratium hirundinella, Peridinium* sp., *Mallomonas* sp., *Staurastrum paradoxum, Asterionella* sp., *Synedra acus.* Species such as *Alona rectangula, Rattulus* spp., *Synura uvella, Volvox aureus, Surirella* sp., *Cymbella* sp., also occur in small numbers however. The last mentioned species are bottom-dwellers or shallow-water dwellers. So our conclusion is that the environmental conditions in the "wielen" are more favourable for limnoplankton than for heleoplankton. From the Limnologists point of view the "wielen" are the only real "lakes" in the Netherlands.

(For the species found im the "wielen" see table 2, p. 194).



A COMPARISON OF THE TOTAL AMOUNT OF PLANKTON IN DIFFERENT "WIELEN".

The observations on the total amount of plankton in the old "wielen" need further explanation. In table 1 (p. 178) we see, that the total amount of phytoplankton is larger than that of the zooplankton. This was not the case in nr. 11 and the deeper layers of nr. 15. The relations between zooplankton and phytoplankton, e.g. food relations, are not easily explained.



The largest amount of plankton was found in the nrs. 4, 10, 12 and 14. (see table 1 and figure B). We may suggest an explanation. The first two "wielen" are relatively shallow. In shallow waters the whole column of water, from top to bottom, is mixed by the action of the wind, so a thermocline does not exist, higher temperature, oxygen and nutrients are present in all waterlayers and much plakton will develop. Nr. 12 however, is a deep water with a thermocline. Here possibly the communication with other water, rich in food, gives rise to a rich plankton development.

TABLE 1. Total numbers of plankton per 10 liters of water.

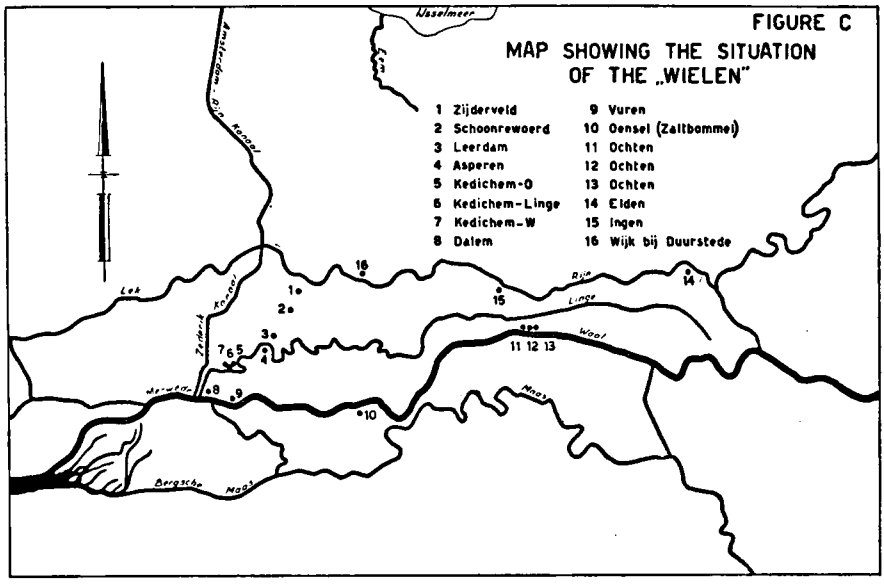
"Wiel" nr :	depth :	phytoplankton	zooplankton	total
1	1 m	276500	750	277000
	10	40	10	50
2	1	49400	2600	50000
	9	300	—	300
3	1	3000	750	4000
	6	38100	1140	40000
4	1	868000	8735	877000
	4	679650	6050	686000
5	1	19550	7430	27000
	3	118200	6550	12500
6	1	2430	1160	3600
	3	1910	1550	3500
	5	3375	365	3700
	8½	2600	1080	3700
7	1	49800	1980	52000
	4	91700	510	92000
	5½	297600	1390	299000
8	1	394000	14100	408000
	4	245100	8560	254000
	5	53400	3320	57000
9	0	76400	3550	80000
	1	57500	4480	62000
	2	abundant	1200	abundant
	3	200800	13685	215000
10	0	1226150	20540	1247000
	1	518600	19200	538000
	5	180960	5990	187000
11	1	13100	19885	33000
	4½	4400	8250	14000
12	0	1904500	8500	1913000
	4	441600	5300	447000
13	0	181300	2400	184000
	5	15900	1600	175000
14	0	265000	1800	267000
	2	1118900	8600	1128000
	4	739800	39300	779000
15	0	2000	1180	3000
	3	3100	7680	11000
	5	4300	6800	11000
16	0	1530	120	1650
	1	47750	2990	50000
	2	27250	2190	30000
	3	21650	1530	23000
	4	20030	990	21000
	5	138000	920	139000
	6	75300	1660	77000
	7	100000	60	100000

Nr. 14 has been used as a fishpond and fertilizers have been added for stimulating plankton growth.

If we may go by the small number of observations made in each "wiel", a difference in density of plankton in different water layers occurs. For example in nrs. 10 and 12 most plankton is concentrated near the surface. In nearly all cases most plankton occurs in the epilimnion only. In nr 9 most plankton occurs in countless quantities in the metalimnion, in nr 3 in the hypolimnion.

Small amounts of plankton were found in the "Buitenwiel" near Kedichem (nr 6). This "wiel" is a part of the former river Linge. We may expect, that the same plankton is found in the river as in the "Buitenwiel". This has not been investigated. A thermocline was absent, possibly due to communication with the river Linge. Chemically, the water in the river Linge was polluted, but in the plankton of the "Buitenwiel", no indicators of polluted water were found. In comparison with the other "wielen" investigated, the plankton was scarce.

Sections through the "wielen", derived from the data of VAN HEUSDEN and a picture of the density of plankton is given in figure B.



THE VERTICAL DISTRIBUTION OF THE SPECIES OF PLANKTERS.

The vertical distribution of the species of plankters found in sufficient numbers is given in 16 figures in the present paper. In most "wielen", the plankton was pumped up from two or three different depths. Lack of time was the reason that no more samples could be taken. Therefore the figures give an incomplete picture of the vertical distribution of the species. The two er three samples were taken in both epilimnioni and thermocline, after determination of the level of these waterlayers.

We will first give a view of each "wiel" separately.

1. *Zijderveld.* ("Waai", Municipality: Everdingen).

The "wiel" has a large area of open water and a scarce vegetation near the shore. The water contained a narrow zone of *Nymphoides peltata, Nuphar luteum, Polygonum amphibium, Ceratophyllum demersum* and *Potamogeton lucens* and some *Phragmites communis* and *Schoenoplectus lacustris* along the margin shore.

In open water plankton was caught at a depth of one meter and just below the thermocline. Near the surface, plankters were found in considerable numbers; filamental *Cyanophycea* were abundant. At a depth of 10 meters only a few individuals of copepods and *Ceratium hirundinella* were found, which may have strayed from upper waterlayers. Other plankton lacked in this oxygen-free water.

This "wiel" is a nice and quiet place, little influenced for human activity.

2. *Schoonrewoerd.* ("de Kruithof", Municipality: Schoonrewoerd).

This is the largest "wiel" studied. Its beautiful borders are planted with fruit trees on the slopes of the dike. Some houses and a farm are built along the sides. It is a property of the Stichting „Het Zuid-Hollands Landschap" and kept as a nature reserve since 1955.

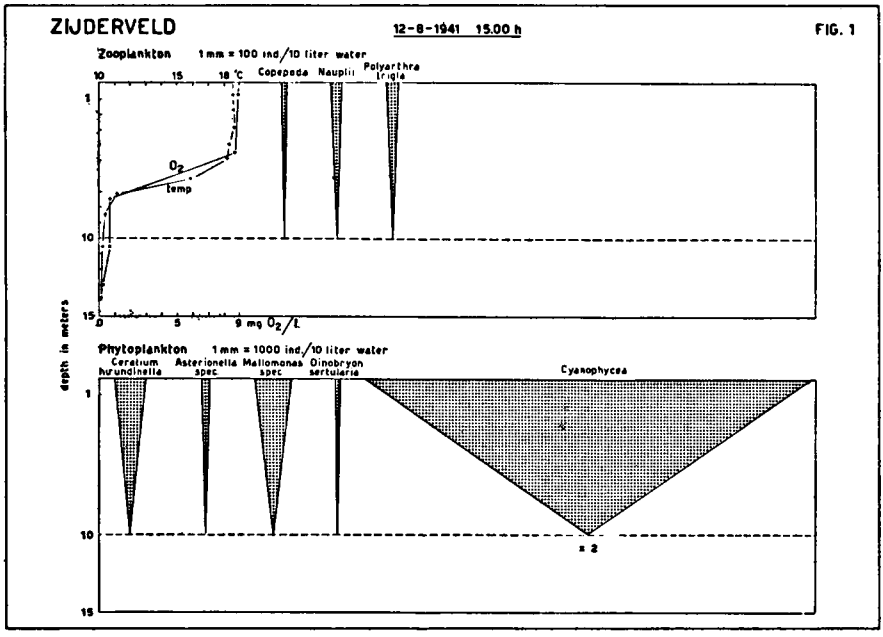
Along the shores, narrow zones of *Phragmites communis* and *Schoenoplectus lacustris* are found. Particularly on the western side, where the water is shallow, fields of floating waterplants are present: *Nuphar luteum, Polygonum amphibium* and the submersed *Myriophyllum spicatum, Cerathophyllum demersum* and *Potamogeton lucens.*

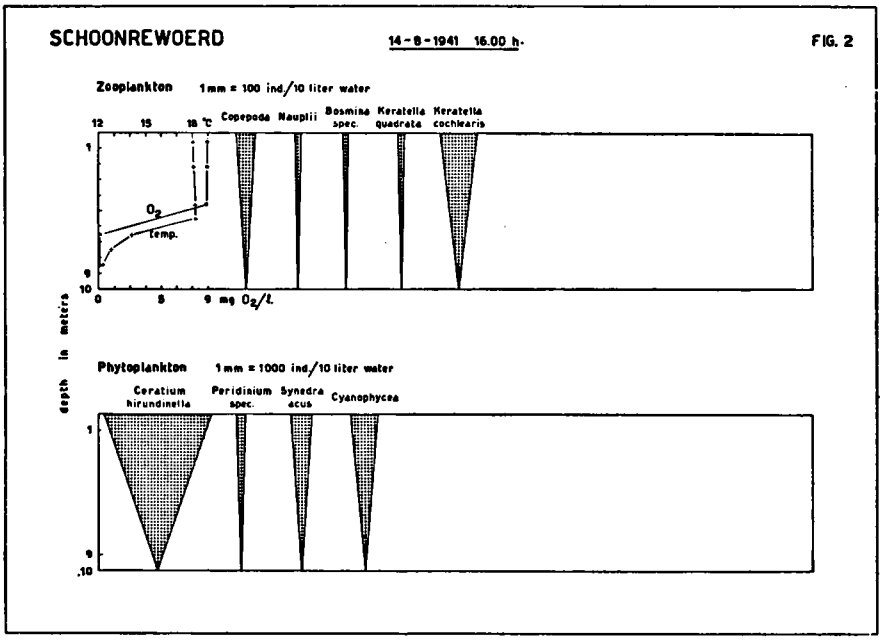
In the large open area of water, plankton was caught at depths of 1 and 9 meter. As in the preceding "wiel", no plankton was found in the oxygen-free zone at 10 meter, except for a few individuals of *Ceratium hirundinella, Peridinium* sp. and filamental *Cyanophycea.*

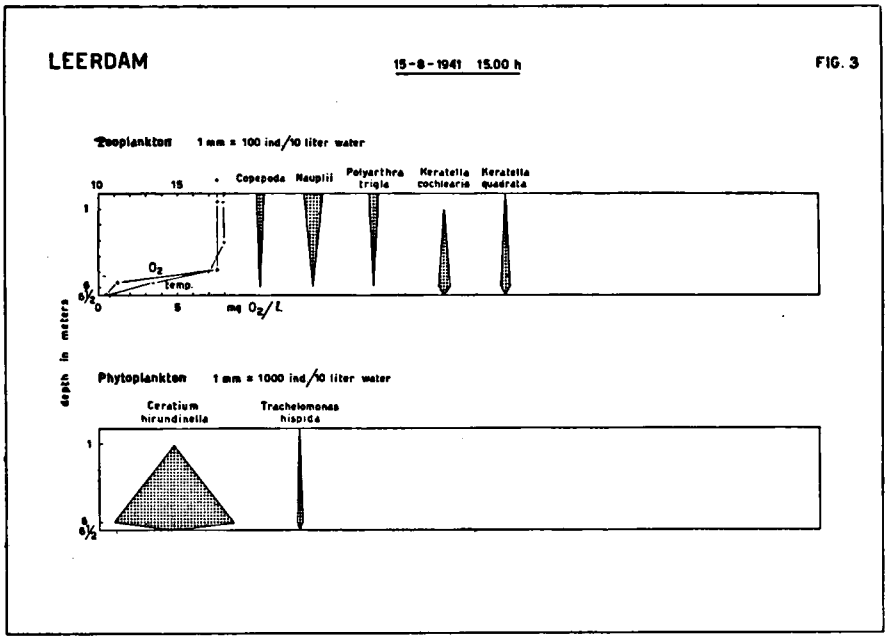
3. *Leerdam.* ("Wiel aan de Spoordijk", Municipality: Leerdam).

This "wiel" has communication with water of the polder, which carries the sewage of the town Culemborg, situated at a distance of 10 kilometers. The pollution of the water shows itself in a strong colour; the water contains high amounts of nitrates and organic matter. A slight streaming of the water is caused by the draining of the polder canals. The shallowness allows the waterplants to cover a larger area than in the deep "wielen". The following waterplants were found: *Azolla caroliniana, Ceratophyllum demersum, Elodea canadensis, Hydrocharis morsus ranae, Iris pseudacorus, Lemna trisulca, Myriophyllum spicatum, Nymphoides peltata, Nuphar luteum, Phragmites communis, Ranunculus circinatus, Schoenoplectus lacustris, Sparganium erectum, Lemna polyrrhiza* and *Typha angustifolia.*

The pollution of the water was not noticed to influence the composition of the plankton community. Only large numbers of *Trachelomonas hispida,* which concentrates at a depth of 6 meters, were an indication of slightly polluted water. *Trachelomonas hispida* prefers mesosaprobic water. Among the other plankters we see a concentration of the rotifers *Keratella cochlearis* and *Keratella quadrata* and the peridinian *Ceratium hirundinella* at 6 meter. The amount of oxygen was very low here.


ZIJDERVELD
12-8-1941 15.00 h
FIG. 1
Zooplankton 1 mm = 100 ind./10 liter water
10 15 18 °C
Copepoda Nauplii Polyarthra trigla
O_2
temp
0 5 9 mg O_2/L
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Asterionella spec.
Mallomonas spec.
Dinobryon sertularia
Cyanophycea
= 2


SCHOONREWOERD
14-8-1941 16.00 h.
FIG. 2
Zooplankton 1 mm = 100 ind./10 liter water
12 15 18 °C
Copepoda Nauplii Bosmina spec. Keratella quadrata Keratella cochlearis
O_2
temp.
0 5 9 mg O_2/L
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Peridinium spec.
Synedra acus
Cyanophycea



4. *Asperen.* ("Galgewiel", Municipality: Asperen).

The water is very shallow (5½ m) and has a sandy bottom. On one side the shores are planted with poplars. The growth of the waterplants along the shore is more extensive than in deeper "wielen", especially in the wind-sheltered corner. *Hydrocharis morsus ranae, Nymphoides peltata. Phragmites communis, Potamogeton lucens, Schoenoplectus lacustris, Sparganium erectum* and *Typha angustifolia* were found. A large area of open water exists.

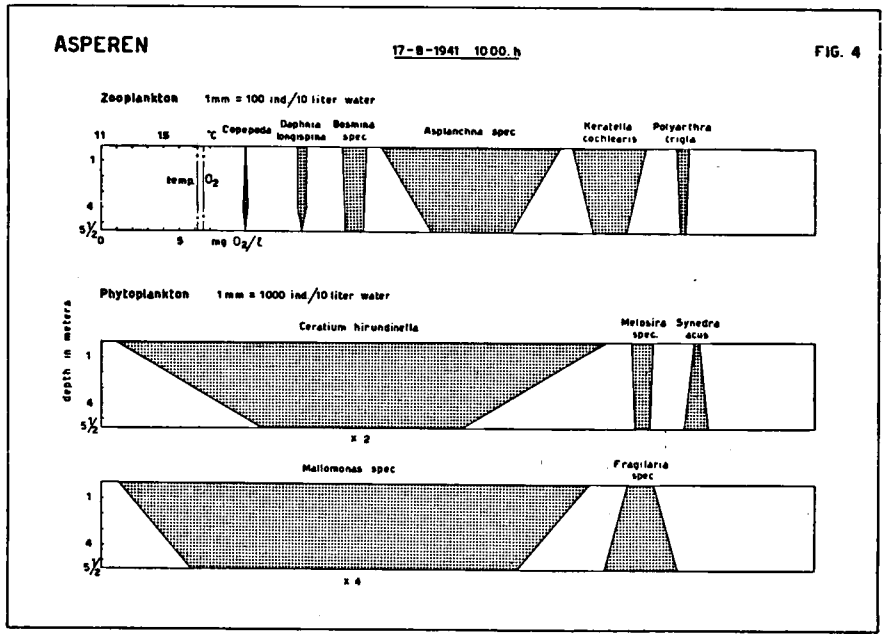
A thermocline was absent. The water was saturated with oxygen from top to bottom. On 1 and 4 meter depth, plankton was caught. *Ceratium hirundinella, Mallomonas* sp. *Asplanchna* sp., and *Keratella cochlearis* were more abundant at 1 meter depth, possibly owing to the greater light-intensity. The development of total plankton was considerable.

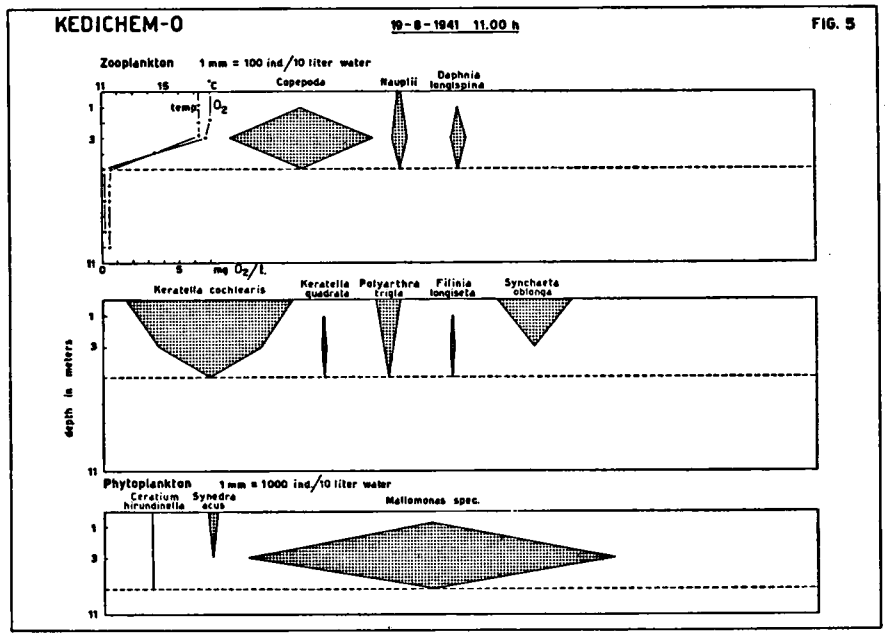
5. *Kedichem* ("Oude wiel", Municipality: Kedichem)

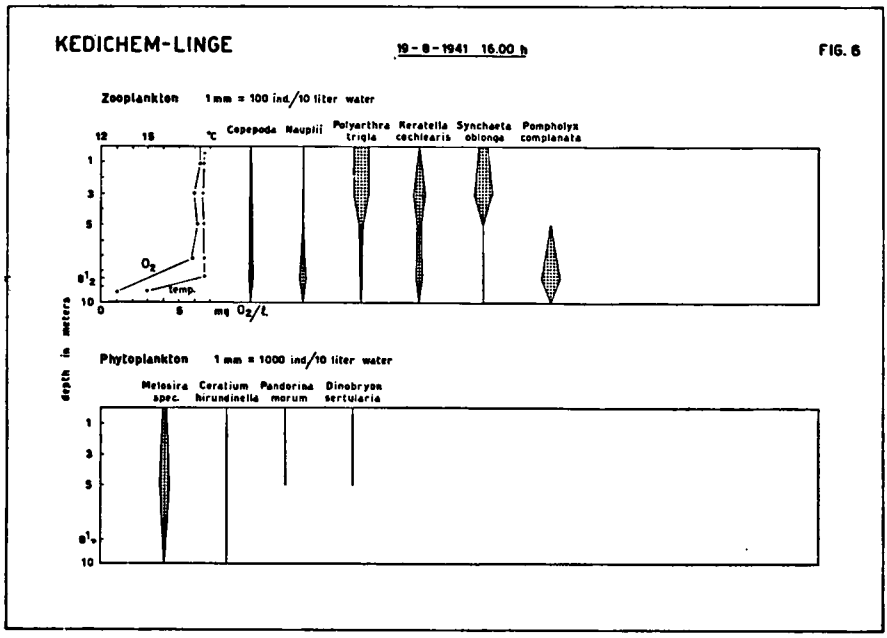
This is a long-drawn "wiel" with poplars and willows along the side of the dike. Waterplants border the shores in a narrow zone of open water, viz. *Hydrocharis morsus ranae, Iris pseudacorus, Nymphoides peltata, Nuphar luteum, Phragmites communis, Polygonum amphibium, Potamogeton lucens, Sagittaria sagittifolia, Schoenoplectus lacustris* and *Sparganium erectum.*

Plankton was pumped up from a depth of 1 and 3 meter in the epilimnion. At 5 meter depth no sample has been taken, for as we have seen in the preceding "wielen", no plankton is present in oxygen-free water.

At 1 meter depth copepods, *nauplii, Daphnia longispina, Keratella quadrata, Filinia longiseta* and *Mallomonas* sp. were present in smaller numbers than at a depth of three meter. *Keratella cochlearis, Polyarthra trigla* and *Synedra acus* frequented the surface layers of the epilimnion.


ASPEREN
17-8-1941 10.00 h
FIG. 4
Zooplankton 1mm = 100 ind./10 liter water
11 15 °C
Copepoda
Daphnia longispina
Bosmina spec
Asplanchna spec
Keratella cochlearis
Polyarthra trigla
temp.
O2
1
4
5½
0 5 mg O2/l
Phytoplankton 1 mm = 1000 ind./10 liter water
depth in meters
Ceratium hirundinella
Melosira spec.
Synedra acus
x 2
Mallomonas spec
Fragilaria spec
x 4


KEDICHEM-O
19-8-1941 11.00 h
FIG. 5
Zooplankton 1 mm = 100 ind./10 liter water
11 15 °C
Copepoda
Nauplii
Daphnia longispina
temp.
O2
1
3
11
0 5 mg O2/l
Keratella cochlearis
Keratella quadrata
Polyarthra trigla
Filinia longiseta
Synchaeta oblonga
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Synedra acus
Mallomonas spec.



6. *Kedichem — Linge* ("Buitenwiel", Municipality: Kedichem)

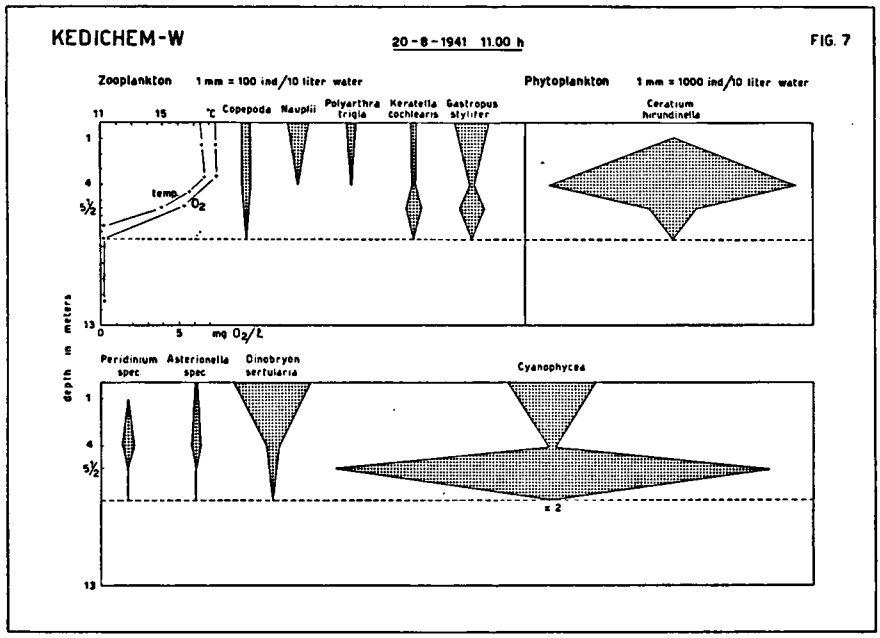
This is near the preceding "wiel" and in former years it was united with "wiel" nr. 7. Now the dike divides these "wielen". Nr. 6 is the outer part, which communicates with the river Linge. The communication is formed by a large open area. The river Linge is regulated and as a result has no current water. It is polluted by sewage water of the town Leerdam. The vegetation on the shore along the dike is nearly the same as in nr. 5.

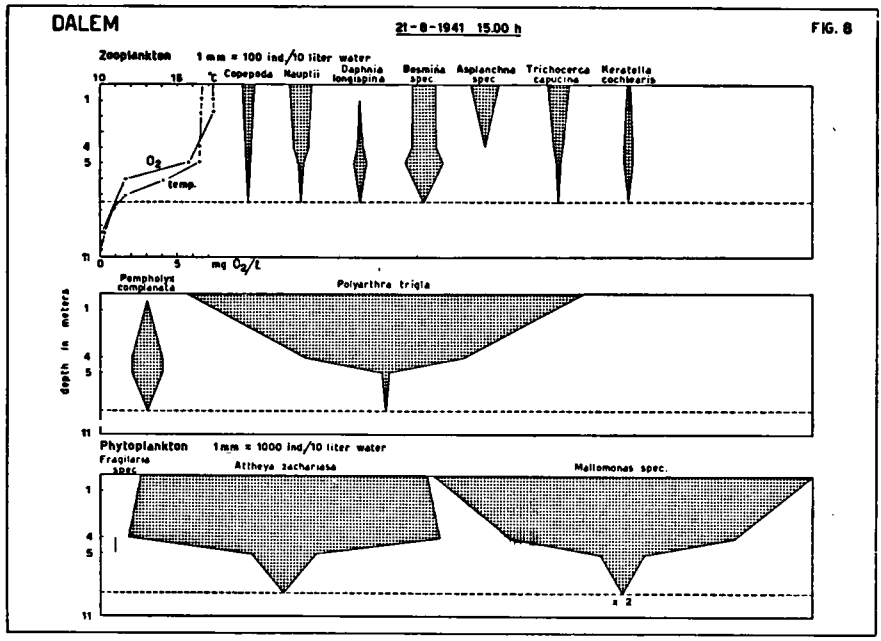
The total number of plankton was very small. Plankton samples were taken at 1, 3, 5 and 6½ meter at 8½ meter dept oxygen was very low. *Pompholyx complanata* concentrated in the thermocline. It is known that this species prefers dwelling in the thermocline. Pollution of the water was not indicated by the composition of the plankton. For other considerations see p. 9.

7. *Kedichem W.* ("Nieuwe wiel", Municipality: Kedichem)

The water is situated on the inner side of the dike near no. 6. It is isolated and wind sheltered and has no houses around it. The shores on the western side are very steep and without vegetation. In the water near the shore *Ceratophyllum demersum, Iris pseudacorus, Nuphar luteum, Phragmites communis, Polygonum amphibium, Schoenoplectus lacustris* and *Sparganium erectum* were found.

Plankton was sampled at 1, 4 and 5½ meter. The filamental *Cyanophycea* (perhaps in two species) and the rotifer *Gastropus stylifer* had unfavourable conditions at 4 meter. It may be, that the factors causing concentration at 1 meter and at 5½ meter differ. Such factors may be light intensity, amount of oxygen temperature and food. Ceratium hirundinella preferred the deeper water layers as we saw already in no. 3.


KEDICHEM-W
20-8-1941 11.00 h
FIG. 7
Zooplankton 1 mm = 100 ind/10 liter water
Phytoplankton 1 mm = 1000 ind/10 liter water
Copepoda Nauplii Polyarthra trigla Keratella cochlearis Gastropus stylifer
Ceratium hirundinella
temp.
O2
mg O2/l
depth in meters
Peridinium spec Asterionella spec Dinobryon sertularia
Cyanophycea
x 2


DALEM
21-8-1941 15.00 h
FIG. 8
Zooplankton 1 mm = 100 ind/10 liter water
Copepoda Nauplii Daphnia longispina Bosmina spec Asplanchna spec Trichocerca capucina Keratella cochlearis
O2
temp.
mg O2/l
depth in meters
Pompholyx complanata
Polyarthra trigla
Phytoplankton 1 mm = 1000 ind/10 liter water
Fragilaria spec
Attheya zacharias
Mallomonas spec.
x 2

8. *Dalem.* ("Grote wiel", Municipality : Vuren)

This water has a very narrow zone of waterplants along the shore. The whole surface of water is free from floating waterplants. The species present were : *Butomus umbellatus, Glyceria aquatica, Hydrocharis morsus ranae, Iris pseudacorus Nuphar luteum, Polygonum amphibium, Potamogeton lucens* and *Schoenoplectus lacustris.*

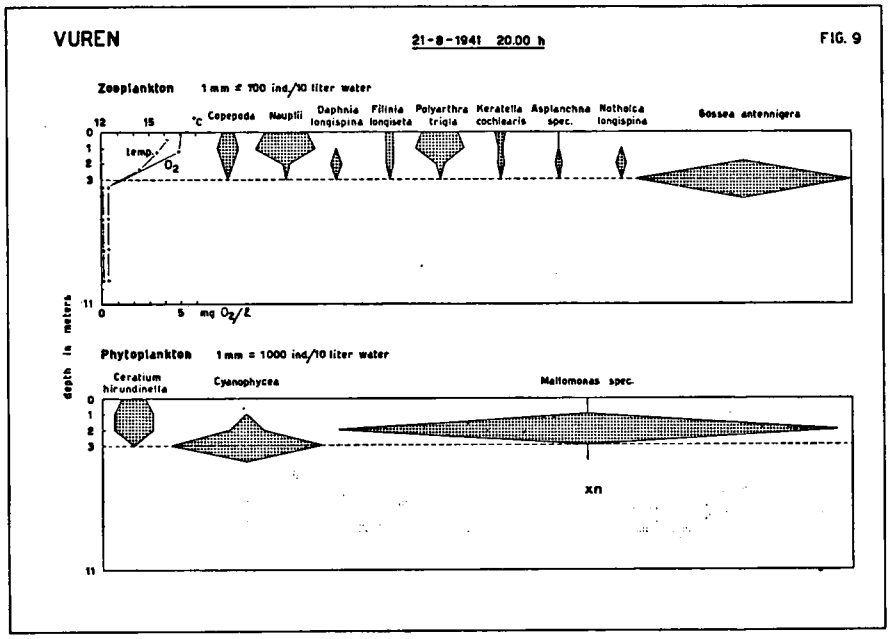
Plankton was sampled at 1, 4 and 5 meter. The cladocerian *Daphnia longispina* and the rotatorian *Pompholyx complanata* were concentrated at 5 meter. *Pompholyx complanata* again preferred the water layers near the thermocline, but possibly *Daphnia longispina* was only found here in relation to the high light intensity at that time of the day, and will be found in upper water layers at night.

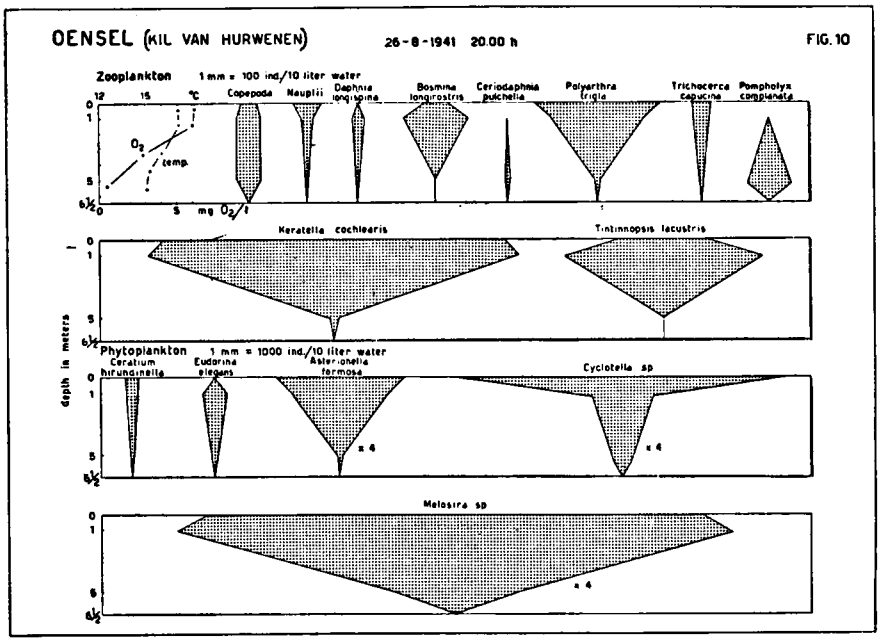
We were struck by the great amount of the very transparant diatom *Attheya zachariasae.*

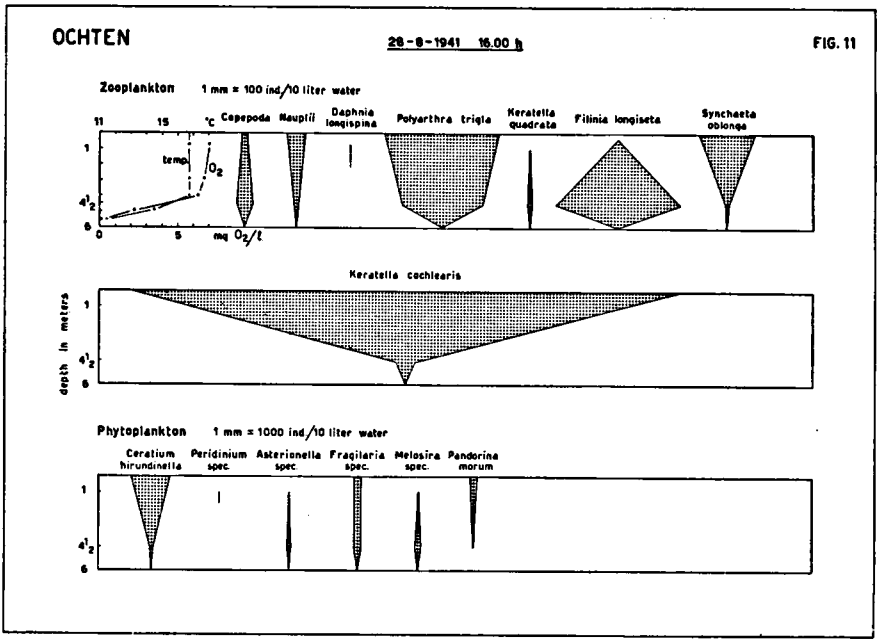
9. *Vuren.* ("Wiel van de Waal", Municipality : Vuren)

A thermocline at a remarkably high-level and very steep slopes are found in this wind sheltered "wiel". The vegetation near the shores was limited to a verv narrow zone : *Ceratophyllum demersum, Glyceria aquatica, Myriophyllum spicatum, Nymphoides peltata, Phragmites communis, Polygonum amphibium, Potamogeton lucens, Schoenoplectus lacustris* and *Sparganium erectum* were found.

In the very narrow epilimnion (0—1 meter !) an abundant development of *Mallomonas* sp. was found. At 3 meter depth (oxygen-free !) the concentration of this species was so strong, that the meshes were clogged. At this depth, filamental *Cyanophycea* were present too in large numbers. The rare species *Gossea antennigera,* a *Gasterotricha,* concentrated in large numbers feeding on decaying plankters.




OENSEL (KIL VAN HURWENEN)
26-8-1941 20.00 h
FIG. 10
Zooplankton 1 mm = 100 ind./10 liter water
Copepoda
Nauplii
Daphnia longispina
Bosmina longirostris
Ceriodaphnia pulchella
Polyarthra trigla
Trichocerca capucina
Pompholyx complanata
temp.
mg O2/l
Keratella cochlearis
Tintinnopsis lacustris
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Eudorina elegans
Asterionella formosa
Cyclotella sp
Melosira sp


OCHTEN
28-8-1941 16.00 h
FIG. 11
Zooplankton 1 mm = 100 ind./10 liter water
Copepoda
Nauplii
Daphnia longispina
Polyarthra trigla
Keratella quadrata
Filinia longiseta
Synchaeta oblonga
temp.
mg O2/l
Keratella cochlearis
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Peridinium spec.
Asterionella spec.
Fragilaria spec.
Melosira spec.
Pandorina morum

This "wiel" is very interesting for its remarkable vertical stratification and its consequences there on the plankton community.

10. *Oensel.* ("Kil van Hurwenen", Municipality: Zaltbommel)

The Kil van Hurwenen is an old branch of the river Waal, cut off in 1639. The large area of the branch is chiefly occupied by large fields of *Phragmites communis* and *Schoenoplectus lacustris.* Most of the water is shallow; only in the southern part deeper water (6 meter) without floating vegetation exists. On the southern side the vegetation consisted of *Butomus umbellatus, Hydrocharis morsus ranae, Lemna trisulca, Nymphaea alba, Nymphoides peltata, Nuphar luteum, Phragmites communis, Potamogeton lucens, Sagittaria sagittifolia, Schoenoplectus lacustris, Lemna polyrrhiza, Typha angustifolia* and *Utricularia vulgaris.*

The plankton community differed from the true "wielen" by its richness and variety of plankton.

The species *Eudorina elegans, Melosira granulata* and *Cyclotella* sp. are not common in "wielen"; they usually evolve large numbers in old river branches. Most organisms concentrated near the surface. Possibly they had moved there by the end of the day (20 h). Only *Pompholyx complanata* again, concentrated near or in the thermocline.

The Kil van Hurwenen is one of the prettiest old branches along the great rivers in our country.

In 1954 and 1955 an extensive research has been made on the vegetation and the micro-organisms. The result has been published in Beaufortia 5 (64) 1957.

11. *Ochten.* (Municipality: Echteld)

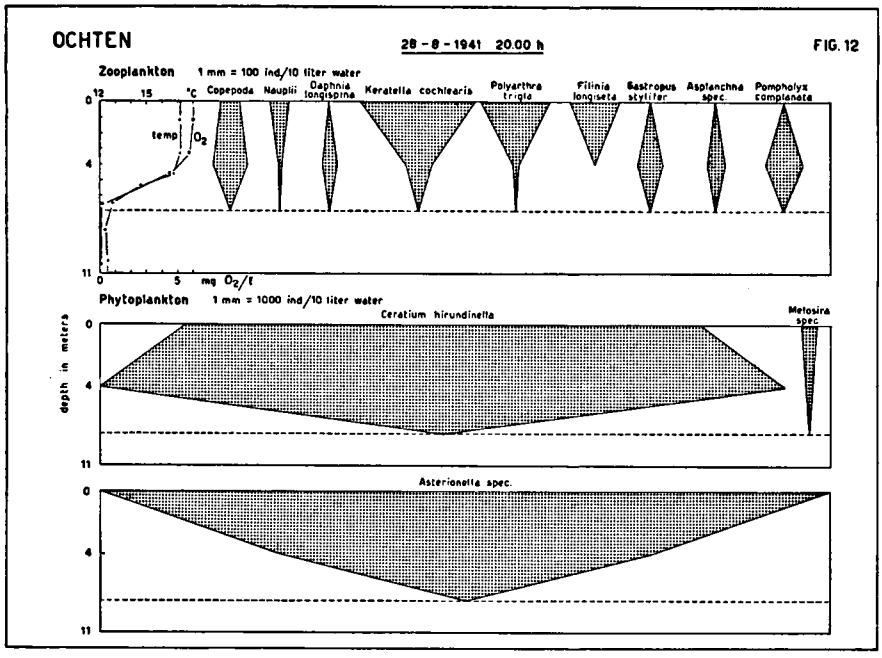
Near the village Ochten, going east, a number of "wielen" is situated along the inner side of the dike. These waters may be relics of a former branch of the river Waal. The large of these remainders were investigated. The first (nr. 11) nearest to Ochten, is surrounded by an area rather densely built an. The vegetation near the shore was composed of the species *Nymphoides peltata, Nuphar luteum, Phragmites communis* and *Polygonum amphibium.*

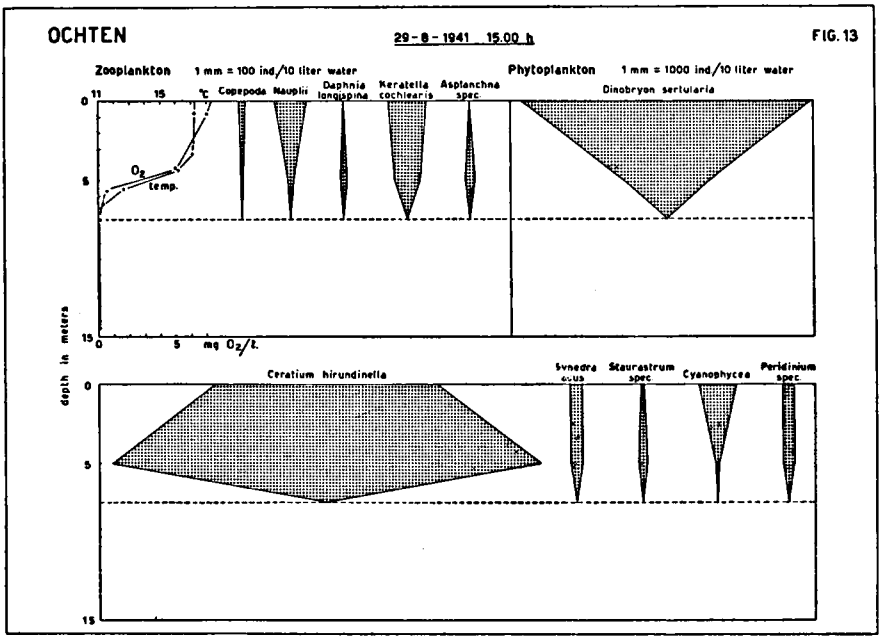
The water is shallow and the plankton at 1 and 4½ meter was mainly composed of zooplankton with *Keratella cochlearis* as a dominant. *Filinia longiseta* and *Keratella quadrata* were the only plankters that concentrate at the low oxygen tension at 4½ meter.

12. *Ochten.* (Municipality: Echteld)

The next "wiel" is wider and deeper. It has bushes of willows and some poplars along the shores. Shore vegetation: *Ceratophyllum demersum, Iris pseudacorus, Nymphoides peltata, Nuphar luteum, Phragmites communis, Polygonum amphibium, Potamogeton lucens, Sagittaria sagittifolia, Schoenoplectus lacustris.*

Plankton was caught at the surface and at 4 meter. The amount of total plankton is large. In the zooplankton many species are developed in rather large numbers. The diatom *Asterionella* and the peridinian *Ceratium hirundinella* were abundant. Some species, e.g. *Daphnia longispina, Gastropus stylifer, Asplanchna, Pompholyx complanata* and *Ceratium hirundinella, preferred* the deeper, the others the upper water layers. It is not possible to give any reason for this behaviour of the plankters.

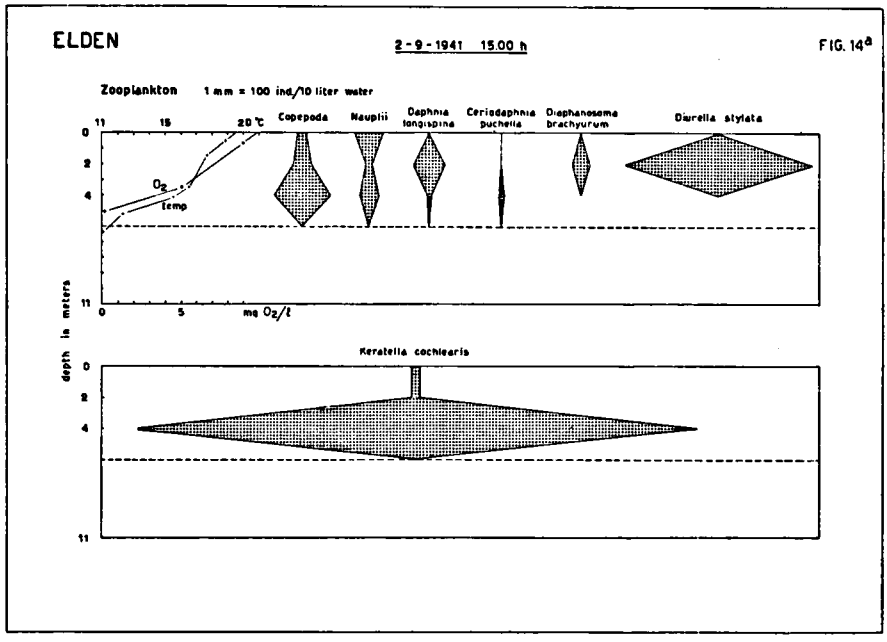

OCHTEN
28 - 8 - 1941 20.00 h
FIG. 12
Zooplankton 1 mm = 100 ind./10 liter water
°C
Copepoda
Nauplii
Daphnia longispina
Keratella cochlearis
Polyarthra trigla
Filinia longiseta
Gastropus stylifer
Asplanchna spec.
Pompholyx complanata
temp
O_2
mg O_2/l
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Melosira spec.
Asterionella spec.
depth in meters


OCHTEN
29 - 8 - 1941 15.00 h
FIG. 13
Zooplankton 1 mm = 100 ind./10 liter water
Phytoplankton 1 mm = 1000 ind./10 liter water
°C
Copepoda
Nauplii
Daphnia longispina
Keratella cochlearis
Asplanchna spec.
Dinobryon sertularia
O_2
temp.
mg O_2/l.
Ceratium hirundinella
Synedra acus
Staurastrum spec.
Cyanophycea
Peridinium spec.
depth in meters

13. *Ochten.* (Municipality: Echteld)

The deepest "wiel" of the three near Ochten. It had no houses around it. The scarce shore vegetation was composed of *Butomus umbellatus, Iris pseudacorus, Nuphar luteum, Phragmites communis, Polygonum amphibium, Schoenoplectus lacustris* and *Sparganium erectum.*

Plankton was caught at the surface and at about 5 meter. *Ceratium hirundinella* concentrates at 5 meter and together with *Dinobryon sertularia,* it is the most abundant plankter.



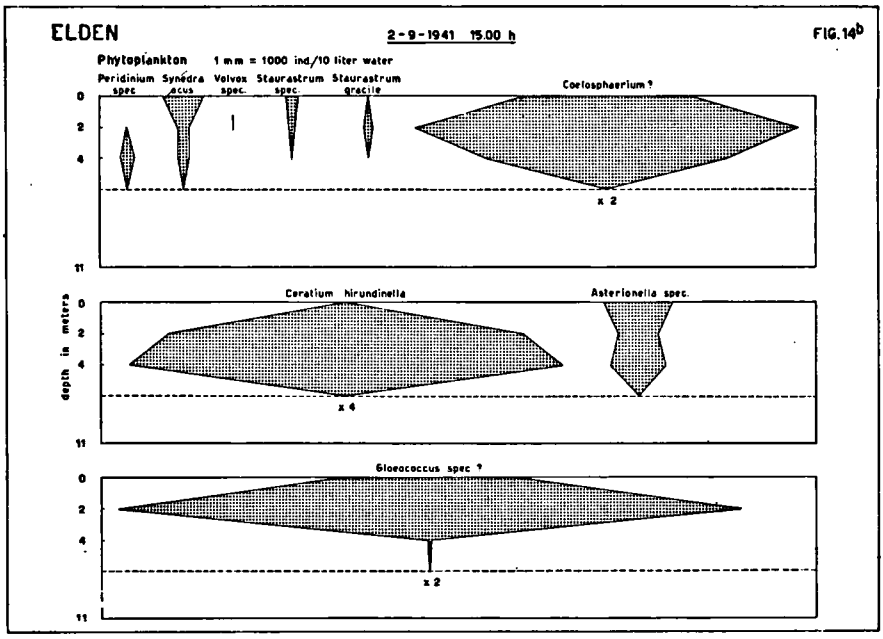
14. *Elden.* („Huize Westerveld", near Arnhem, Municipality: Elst)

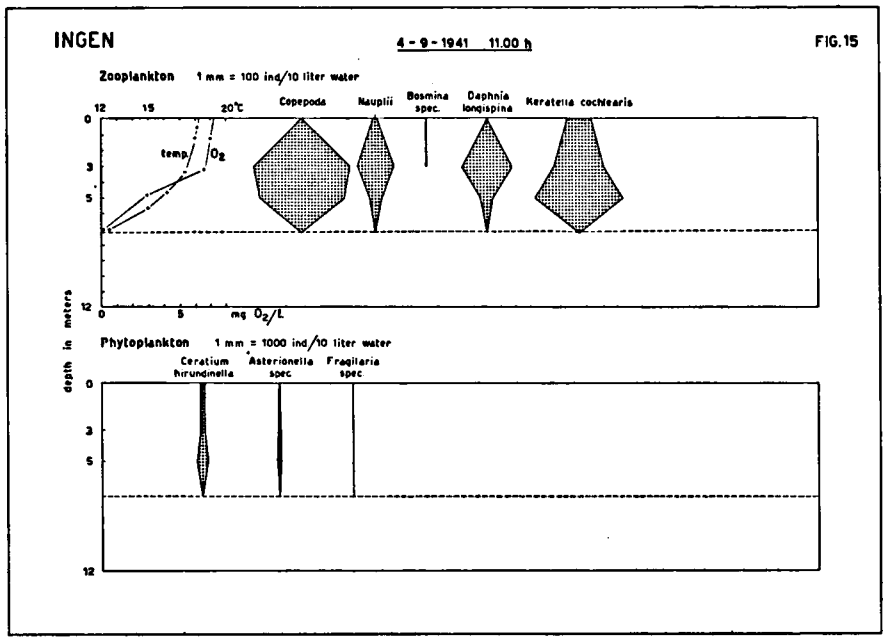
The "wiel" was situated in a forest near the country-house „Huize Westerveld". In this respect it differs from the other "wielen", which are situated among meadows. Moreover it has been used as a fish pond and therefore fertilizers have been added to the water. As a consequence the plankton is very rich.

Along the shore a scarce vegetation was found: *Acorus calamus, Glyceria aquatica, Iris pseudacorus, Myriophyllum spicatum, Nuphar luteum, Phragmites communis, Potamogeton lucens* and *Schoenoplectus lacustris.* High trees directly border the shore.

The abundant plankton was chiefly composed of phytoplankton with the species *Ceratium hirundinella* and representatives of the genera *Gloeococcus* and *Coelosphaerium,* which could not be identified with certainty. The rotifer *Keratella cochlearis* developed great numbers too.

The plankton was pumped from the surface and from 2 and 4 meters.

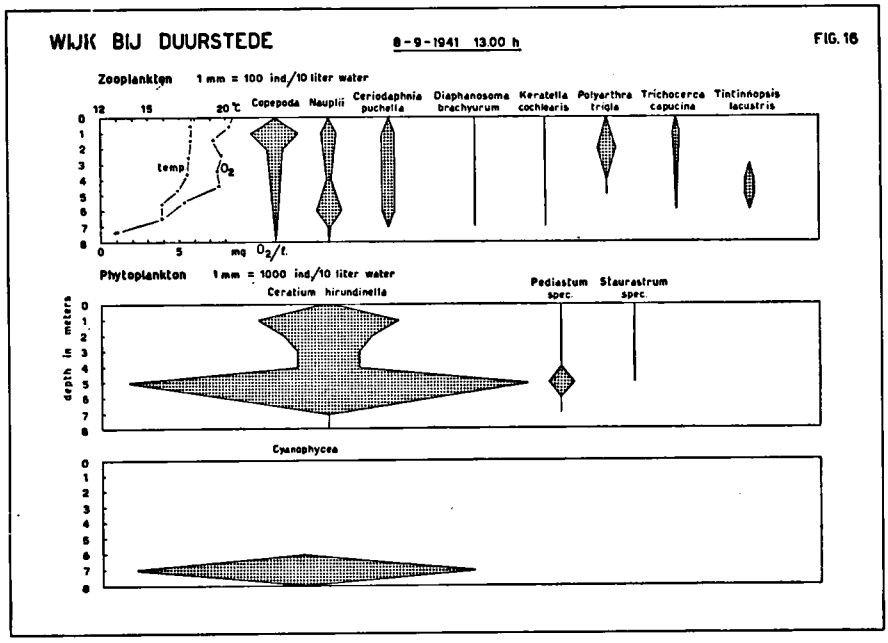

ELDEN
2-9-1941 15.00 h
FIG. 14b
Phytoplankton 1 mm = 1000 ind./10 liter water
Peridinium spec.
Synedra acus
Volvox spec.
Staurastrum spec.
Staurastrum gracile
Coelosphaerium?
x 2
depth in meters
Ceratium hirundinella
Asterionella spec.
x 4
Gloeococcus spec ?
x 2


INGEN
4-9-1941 11.00 h
FIG. 15
Zooplankton 1 mm = 100 ind./10 liter water
temp.
O2
Copepoda
Nauplii
Bosmina spec.
Daphnia longispina
Keratella cochlearis
mg O2/L
depth in meters
Phytoplankton 1 mm = 1000 ind./10 liter water
Ceratium hirundinella
Asterionella spec.
Fragilaria spec.

15. *Ingen.* („Vredenburg", near Ingense Veer, Municipality: Lienden)

As the former "wiel", this water is situated along the river Rhine. On one side high trees are planted around it. The shore vegetation was composed of *Butomus umbellatus, Ceratophyllum demersum, Lemna trisulca, Nuphar luteaum, Phragmites communis, Polygonum amphibium, Potamogeton perfoliatus, Ranunculus circinatus, Schoenoplectus lacustris, Sparganium erectum* and *Typha angustifolium.*

Plankton was caught at the surface and at 3 and 5 meters. It was chiefly composed of zooplankton and it was not abundant. *Keratella cochlearis* preferred the deeper water layers. All species decreased near the surface, probably in consequence of the high light intensity at that time of the day.



16. *Wijk bij Duurstede* ("Gat van de Dijk", Municipality: Wijk bij Duurstede)

In the preceding 15 "wielen" the vertical distibution of the species of plankton differs in every "wiel", as we have seen.

While in most 'wielen" plankton was pumped up from two or three depths. Only in this one samples have been taken from every one meter. Moreover chemical analyses of the water were also carried out at every meter. As a consequence, the environmental conditions of the plankters and their distribution in the different water layers were better known than in the preceding "wielen". Conclusions therefore are more valuable.

The "wiel" is situated in flat meadows. The shore vegetation is negligable. The open water of the "wiel" borders the flat grassland. As is shown in figure 16, temperature and amount of oxygen is the same from the surface to a depth of 4½ meter.

The thermocline ranges from 4½ to 7 meters. The hypolimnion, where oxygen is nearly absent, forms a layer of about one meter only over the bottom.

Chemical data show, that the concentration of electrolytes is stratified. Near the bottom, in the hypolimnion, the amount of sulfate decreases; the amount of H_2S increases, by the reduction of sulfate by anaerobic bacteria. As a result of the mineralisation, by bacteria, from decaying dead plankters and organic matter which sink down to the bottom, the concentration of NO_3, NO_2 HCO_3, NH_4, Fe, Mn, Ca and PO_4 is higher near the bottom than near the surface.

One species of *Cyanophycea* occurs in large numbers near the bottom only where conditions are favourable for just this plankton species. (*Oscillatoria* sp.). Such filamental blue-green Algae are able to live in conditions with low light intensity and low oxygen tension, when nutrient salts are abundant. We have seen that such are the conditions in the hypolimnion. It is quite possible that in other "wielen" also *Cyanophycea* occur near the bottom. This has not been investigated and the occurrence of *Cyanophycea* above the bottom only, in this "wiel", shows the necessity of sampling at all depths. In the "wielen" 1, 7 and 9 we found filamental blue-green Algae in the upper water layers. It may be that these are other species. As to the other plankters in "wiel" 16, some organisms concentrate in the upper water, (*Copepoda, Polyarthra trigla*), some near the bottom or in the thermocline (*Tintinnopsis lacustris, Pediastrum duplex*) and others in both layers (*Nauplii* and *Ceratium hirundinella*). We do not know what causes the different species to behave in this way, for there are many environmental factors, which influence them. Therefore, we only give a summary of the data of the species as found in "wiel" 16.

The copepods (*Cyclops oithonoides, Diaptomus gracilis*) preferred the upper water layers. The largest numbers were found at the depth of 1 meter. We may suppose, that they flee the uppermost water layers owing to the high light intensity at that time of the day (cf. nrs. 5, 11, 14 and 15). Probably they show a diurnal migration as it can be obseved in other plankters too in this "wiel". However, not all species concentrate at the same depth, for their light optima differ. Moreover, some zooplankters will migrate in search of food and thus reach not their own light optimum, but that of their prey.

Nauplii, the larvae of copepods are concentrated at one meter and at a depth of 6 meter. Probably two species of *nauplii* occur, the *nauplii* of *Cyclops oithonoides* may be present at the surface and the *nauplii* of *Diaptomus gracilis* at the thermocline, or just the reverse. The species of *nauplius* had not been determined. In any case there is a difference in vertical distribution of adult and juvenile copepods.

This is also stated by other investigators (see WELCH). The different behaviour is a result of a different reaction to light intensity of youngs and adults. A different behaviour is found in the same species in different lakes even.

From the other crustaceans in "wiel" 6, *Ceriodaphnia pulchella* is present in equal numbers at nearly all depths. This cladocerian was scarce in deep "wielen". It prefers shallow waters. Because of absence of oxygen this species lacks near the bottom. Another cladocerian, *Dia-*

phanosoma brachyurum, is present in very low numbers at all depths.

The rotifer *Polyarthra trigla* only lived in the epilimnion, where oxygen is sufficient. This was also found in other "wielen" (see nrs. 5, 6, 7, 8, 9, 10 and 12). The same applies for *Trichocerca capucna,* as far as we may conclude from the number present. *Keratella cochlearis* was present in very small numbers at all depths in this "wiel". In most of the others it occurred in large numbers.

The protozo *Tintinnopsis lacustris* concentrates in the thermocline only. Possibly this is caused by the food viz. dead decaying plankters. In "wiel" 10 it shows the same behaviour. In other "wielen" it was not present in large amounts.

The most abundant plankter in "wiel" 16 was the motile peridinian *Ceratium hirundinella.* It is the most common plankter in "wielen" in summertime and has a preference for living at the thermocline. In "wiel" 16 concentrations occurred at two depths. Possibly in the higher water layer, light intensity was favourable.

Green Algae are not very common in "wielen". So it is remarkable, that in "wiel" 16 the species *Pediastrum duplex* occurred in large numbers at a depth of 5 meters. At a depth of 5 meters, the light intensity may be too low for its assimilatory function. So the occurrence in such large numbers is rather strange. Probably this phenomenon caused by *Pediastrum* in a "wiel" is an exception.

Of the other phytoplankters, *Staurastrum* sp. was found, though in small numbers. This desmid never develops in great numbers in "wielen".

Not all plankton organisms can be caught with a planktonnet. The nannoplankton (bacteria, flagellates) occurs in far greater numbers than the netplankton. Its presence can be deduced from the chemical processes in the different water layers. The species of nanno-plankton present in the "wielen" have not been determined.

In conclusion we see how each "wiel" is to be considered as an independent biocommunity with its own character which differs from each other "wiel". Each "wiel" is different from the others by its geographical situation, the manner in which the thermocline seasonally develops and in general by its conditions influencing the biocommunity.

TABLE 2. Species of Plankters found in the "wielen".

Nr. of "wiel":	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cyclops oithonoides SARS	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Cyclops leuckarti CLAUS		+						+						+		
Diaptomus gracilis G. O. SARS	+	+					+	+	+		+	+		+		+
Nauplii	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
Daphnia longispina O.F.M.	+	+		+	+			+	+	+	+	+	+	+	+	
Bosmina longirostris LEYD.						+	+	+		+		+				
Bosmina coregoni BAIRD.		+	+	+											+	
Bosmina sp.									+							
Diaphanosoma brachyurum (LÉVIN)		+		+		+	+	+	+			+	+	+	+	+
Ceriodaphnia pulchella G. O. SARS		+						+	+	+		+	+	+		+
Alona rectangula SARS							+									
Leptodora kindti FOCKE									+							
Brachionus angularis GOSSE																+
Asplanchna sp.				+	+			+	+		+	+	+		+	+
Keratella cochlearis (GOSSE)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Keratella quadrata (O.F.M.)		+	+		+	+	+	+		+	+	+	+		+	+

Nr. of "wiel":	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Polyarthra trigla EHRB.	+		+	+	+	+	+	+	+	+	+	+	+		+	+
Trichocerca capucina (W. etz.)	+			+	+	+		+	+	+						
Synchaeta oblonga EHRB.				+	+	+					+					
Filinia longiseta (EHRB.)	+		+		+	+	+	+	+		+	+			+	+
Diurella stylata EYF.	+	+	+			+					+	+	+	+		+
Notholca longispina KELLIC.	+	+					+		+	+	+				+	
Gastropus stylifer IMHOF		+	+				+	+	+		+	+	+			+
Pompholyx complanata GOSSE		+	+		+	+		+	+	+	+	+	+			
Pterodina patina O.F.M.									+	+	+	+			+	
Rattulus gracilis (TESSIN)												+				
Rattulus cylindricus (IMHOF)														+		
Noteus quadricornis EHRB.												+				
Cathypna luna (O.F.M.)																+
Gossea antennigera (COSSE)									+		+					
Tintinnopsis lacustris ENTZ.				+						+	+					+
Epistylis sp.				+									+			
Tintinnidium fluviatile (ST.)											+					
Phacus sp.			+			+	+			+	+			+		
Dreissena polymorpha (PALLAS) *larvae*	+					+										
Ceratium hirundinella O.F.M.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ceratium cornutum CL. et L.		+	+							+						
Peridinium sp.		+	+	+			+		+	+	+	+	+	+		
Trachelomonas hispida STEIN.		+	+	+		+				+		+	+		+	
Mallomonas sp.	+	+		+	+	+	+	+	+			+		+	+	
Dinobryon sp.				+		+		+						+		
Dinobryon sertularia EHRB.	+										+	+	+			
Dinabryon cylindricum IMHOF							+									
Pandorina morum (O.F.M.)				+	+	+					+					
Eudorina elegans EHRB.	+									+		+	+			
Synura uvella EHRB.						+										
Volvox aureus EHRB.														+		+
Staurastrum paradoxum MEYEN		+	+	+	+		+	+	+			+	+	+		+
Staurastrum sp.														+		
Closterium sp.		+									+					
Pediastrum sp.		+		+		+		+			+			+	+	
Pediastrum duplex MEYEN	+									+						+
Pediastrum boryanum MENEGH.			+				+									
Scenedesmus caudatus												+				
Scenedesmus quadricauda BRÉB.										+						
Scenedesmus sp.					+											
Mougeotia sp.																
Microcystis aeruginosa KUETZ.						+										
Gloeococcus sp.?														+		
Coelosphaerium sp.?		+						+					+	+		
Anabaena flos-aquae BRÉB.	+															
Anabaena sp.												+		+		
Merismopedium elegans A. BR.			+													
Filamental Cyanophycea	+	+	+				+		+				+	+		+
Asterionella sp.	+	+		+				+	+		+	+	+	+	+	+
Fragilaria crotonensis KITTON	+	+		+	+		+		+		+	+				
Fragilaria sp.			+			+		+		+			+	+	+	+
Synedra acus KÜTZ.		+	+	+	+		+	+	+	+	+	+	+	+	+	
Diatoma sp.				+												
Surirella sp.			+	+		+	+			+	+					
Pleurosigma acuminatum W. SW.	+			+		+	+			+	+		+			+
Attheya zachariasa J. BRUN.	+			+	+			+		+				+		
Melosira sp.			+	+		+				+	+	+			+	
Cymbella sp.							+									
Cyclotella sp.		+					+		+	+	+	+		+	+	

LITERATURE.

BAAS BECKING, L. G. M.
1934 Geobiologie. — Den Haag.

BUDDE, H.
1943 Die benthale Algenflora, die Entwicklungsgeschichte der Gewässer und die Seentypen im Naturschutzgebiet „Heiliges Meer". — Archiv für Hydrobiologie, 39.

CLASON, E. W.
1929 Over de plantengroei van het Zuidlaardermeer en omgeving. — „De Levende Natuur", 33.

GOOR, A. C. J.
1925 Enige typische verschillen in het phytoplankton van de Maas en de Rijn in Nederland. — Nuova Notarisia, 36.

HAVINGA, B.
1919 Studies over de Flora en Fauna van het Zuidlaarder meer. — Diss. Groningen.

HEUSDEN, G. P. H. VAN
1945 Waarnemingen in enige „wielen" in de Betuwe. — Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap, 62 (2).

HEYMANN, J. A. — REDEKE, WIBAUT.
1931a. Hydrobiologische onderzoekingen in het Abcoudemeer en zijn omgeving. Commissie voor het botanisch onderzoek van de Zuiderzee en omgeving. — Ned. Kruidk. Archief 1931, 2.
1931b. De Rijn als toekomstige bron der drinkwatervoorziening van Amsterdam. — „Water", 12, 14 and 15.

KROON, J. H.
1930 Het Brasemermeer. — „De Levende Natuur", 34.

KOLKWITZ, R. and MARSSON.
1908 Oekologie der Pflanzlichen Saprobien. — Berichte der Deutsche Botanische Gesellschaft, 26.
1909 Oekologie der Tierischen Saprobien. — Revue International der Gesamte Hydrobiologie und Hydrografie, 2.

LAUTERBORN, R.
1918 Die Geografische und Biologische Gliederung des Rheinstroms. — Sitzungsberichte der Akademie von Wissenschaften, Heidelberg (B).

LEENTVAAR, P.
1955 Een diatomee nieuw voor Nederland. — „De Levende Natuur", 57, (7).
1956a. Voorjaarsplankton van enige Nederlandse meren. — „De Levende Natuur", 59 (6).
1956b. De betekenis van onze wielen voor mens, dier en plant. — „De Levende Natuur", 59, (5).

LIST.
1920 Das Plankton einiger Kolke des Altrheines bei Erfelde und ein Vergleich des Kolkplanktons mit dem einiger Teiche in der Umgebung von Darmstadt. — Archiv für Hydrobiologie, XII.

OTTO, J. P.
1927 Een oecologische studie van de Kagerplassen. — Leiden. (diss.)

REDEKE, H. C.
1903 Plankton onderzoekingen in het Zwanenwater bij Callantsoog. — Natuurwetenschappeijke verhandelingen van de Hollandse Mij. voor Wetenschappen, Haarlem, 5.
1935 Synopsis van het Nederlandse zoet- en brakwaterplankton. — Verhandelingen der Hydrobiologische Club, 2.

and A. P. C. DE VOS.
1932 Beiträge zurKenntnis der Fauna Niederländischer oligotropher Gewässer, — Int. Rev. der Gesamte Hydrografie und Hydrobiologie, 28.
1948 Hydrobiologie van Nederland. — Amsterdam.

ROMIJN, G.
1918 Verslag van het biologisch onderzoek van de Maas en haar oevers. — Jaarboek 1918 van het Natuurhistorisch Genootschap Limburg.

RUTTNER, F.
1938 Grundriss der Limnologie. — Berlin.

THIENEMANN, A.
1938 Die Binnengewässer. — Stuttgart, 16 Editions.
THOMAS, E. A.
1949 Regionallimnologische Studien an 25 Seen der Nordschweiz. — Verh. Int. Ver. f. Theor. u. Angew. Limnologie, 10.
VINK, T.
1926 De Lekstreek. — Utrecht. (diss.)
VLEESCHHOUWER, J. J.
1932 Onderzoek naar de toestand van de Vecht en van de openbare wateren in de Gemeente Utrecht. — Utrecht. (diss.)
VORSTMAN, A. C.
1939 Een overzicht van het plankton van het Kinselmeer 1938—1939. — Handelingen van de Hydrobiologische Club, (2).
VOS, A. P. C. DE
1939 Over de oever- en bodemfauna der binnendijkse kolken langs de kust van het IJsselmeer. — Handelingen der Hydrobiologische Club, (2).
WEIMANN, R.
1942 Zur Gliederung und Dynamiek der Flachgewässer. — Archiv für Hydrobiologie, bd. 38.
WELCH, P. S.
1935 Limnology. — New York and London.
WIBAUT-ISEBREE MOENS, N. L.
1919 Mededeling van het resultaat van 3 jaar planktononderzoek van de Amsterdamse grachten. — Tijdschrift van de Nederlandse Dierkundige Vereniging, (2): XVII, versl. p. XVII.
ZACHARIAS, O.
1896 Quantitatieve Untersuchungen über das Limnoplankton. — Forschungsberichte Plön, (IV).
ZINDEREN BAKKER, E. M.
1947 De West-Nederlandse veenplassen. — Amsterdam.
AUT, Dlv.
1954 Veranderingen in de Flora en Fauna van de Zuiderzee (thans IJsselmeer) na de afsluiting in 1932. — Edit. Nederlands Dierkundige Vereniging, Den Helder.