Conference Paper

Changes in intertidal benthos communities after an increase in salinity

W. J. Wolff

Delta Institute for Hydrobiological Research, Yerseke, The Netherlands

The Krammer-Volkerak estuary, a typical salt-wedge estuary with a salinity gradient from 0.3 to 15‰ Cl', was dammed up in early 1969. This resulted in an increase of salinity seaward of the closing dam until a salinity of 9—15‰ Cl' had been reached everywhere.

The brackish-water fauna survived this environmental change, whereas a marine fauna immediately started the colonization of the new area. This resulted in an increase of the within-habitat as well as of the between-habitat diversity, still going on after 28 months.

INTRODUCTION

The Delta Plan aims at the closure of several estuaries in the southwestern part of The Netherlands. One of the projects of this scheme consisted of the damming up of the Krammer-Volkerak estuary, which formed a branch of the large Rhine-Meuse estuary. This resulted in a considerable increase of salinity in the part of the estuary seaward of the dam and offered an opportunity to investigate the reactions of the benthic communities after an important change of their environment.

Hydrographical changes

Before April 1969 the Krammer-Volkerak estuary was a typical salt-wedge estuary with salinities ranging from 0.3 to 15‰ Cl'. At some places maximal salinity differences of 7‰ Cl' and more could be observed during one tidal cycle.

The dam across the Volkerak (Fig. 1) was completed on April 28, 1969. After this closure fresh water did not reach the Krammer-Volkerak estuary any longer and salinity started to rise[1]. After one month salinity was over 10‰ Cl' everywhere and after three months over 14‰ Cl'. Since then salinity has fluctuated between 13 and 15‰ Cl' at transect A (Fig. 1), between 11 and 15‰ Cl' near transect B and between 9 and 13‰ Cl' near transect C. Once, during a short period, salinities about 2‰ Cl' lower than the minimal values recorded in Table I were registered. However, this situation proved to be an exception (pers. comm. R. Peelen).

Also the velocity of the tidal currents as well as the tidal amplitude changed[2]. The changes in the tidal currents occurred especially in the main tidal channels. The details are represented on Table I. On the tidal flats, however, no important changes in the current velocities were noted. Although no direct measurements have been carried out, the impression was obtained that near the transects sampled the changes were negligible.

Communication no. 103 of the Delta Institute.

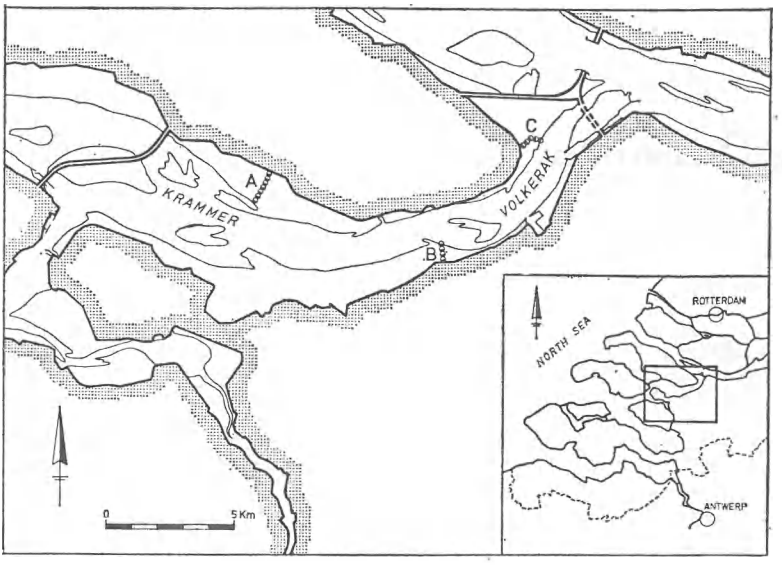

Fig. 1. Map of the Krammer-Volkerak area. The position of the transects A, B, and C is indicated by a dotted line.

The tidal amplitude increased as a result of the closure of the dam (Table I). Because these increases were caused by higher high tides as well as lower low tides, their effects on the sampling stations near mid-tide level may be neglected. The highest and the lowest stations, however, experienced prolonged immersion and emersion, respectively.

TABLE I

Environmental conditions near the three transects sampled before and after the closure of the Volkerakdam

Transect	A		B		C	
	before	after	before	after	before	after
salinity (‰ Cl')	10—15	13—15	5—12	11—15	0.3—5	9—13
maximal current velocity in the main channel (cm/sec)	120	120	110	50	120	25
mean tidal amplitude (cm)	275	350	255	380	230	390
range of median grain-sizes (phi-units)	3.03-3.25	3.03-3.27	2.83-3.53	2.77-3.50	3.05-3.35	3.10-3.37

Effects on the sediments

It might be expected that the changes in the hydrographical conditions induced changes in the nature of the sediments. Although locally in the estuary considerable changes in the grain-size distribution were observed, these changes were unimportant in the areas where the transects had been sampled (Table I). Perhaps the effects

of the decreasing current velocities in the main tidal channels were to some degree counteracted by an increased current velocity perpendicular to the former one owing to the increased tidal amplitude.

METHODS

The changes in the benthic fauna were studied by means of three transects across the tidal flats from high to low water mark (Fig. 1, Table I). The transects were located in areas with initially different salinities. Transects A and C counted ten sampling stations, transect B seven.

The samples had a surface area of 0.25 m^2 and were dug out till a depth of about 30 cm. All samples were washed through a 1 mm sieve and the residue was sorted by hand in the laboratory. All species in the samples have been identified to species level, except for the oligochaetes, the nemerteans, the insect larvae and the *Corophium*. All these groups, however, probably are represented by only one species.

All transects were sampled shortly before the closure of the dam in the first week of April 1969, and after the closure in the second week of November 1969 and of November 1970. Transect A was also sampled in October 1966 and November 1968, transects B and C also in the first week of August 1971.

After the closure of the dam the lower three sampling stations of the transects B and C were redistributed in order to adapt to the changes in the tidal range. The sediment composition of the new stations was comparable to that of the old stations, however. The uppermost stations remained located at the edge of the saltmarsh.

The macrobenthos before 1969

Before the closure of the dam the fauna of the Krammer-Volkerak area was characteristically estuarine with a fairly large brackish-water component. Species like *Nereis diversicolor*, *Macoma balthica* and *Heteromastus filiformis* occurred all over the estuary, but others like *Arenicola marina*, *Cardium edule*, *Anaitides maculata*, *Mytilus edulis*, and *Hydrobia ulvae* lived only at the seaward end. In the most brackish part of the estuary species like *Manayunkia aestuarina*, *Streblospio shrubsolii*, and *Assiminea grayana* were numerous. Table II enumerates the species

TABLE II

Species occurring on the tidal flats before the closure of the dam across the Volkerak

Transect	A	B	C
Average salinity	15‰ Cl'	10‰Cl'	3‰ Cl'
Sampling data	(3-IV-1969)	(2-IV-1969)	(1-IV-1969)
Hydrobia ulvae	+	−	−
Mytilus edulis	+	−	−
Cardium edule	+	−	−
Macoma balthica	+	+	−
Mya arenaria	+	+	−
Eteone longa	+	−	−
Nereis diversicolor	+	+	+
Nephtys hombergii	+	−	−
Scoloplos armiger	+	−	−
Polydora ligni	+	−	−
Pygospio elegans	+	+	−
Capitella capitata	+	−	−
Heteromastus filiformis	+	+	−
Manayunkia aestuarina	−	−	+
Crangon crangon	+	−	−
Schistomysis spiritus	+	−	−
Grammarus cf. *salinus*	+	−	−
Bathyporeia pilosa	+	+	−
Corophium cf. *volutator*	+	+	+

occuring in the three transects shortly before the closure of the dam. It shows a picture characteristic for all estuaries around the North Sea.

Changes in the benthic fauna

When after the closure of the dam salinity rose to a higher level, a large settlement of marine organisms took place. New species encountered in November 1969, six month after the closure, were, among others, *Lepidochitona cinerea*, *Anaitides maculata*, *Mysta picta*, *Nereis succinea*, *Spio martinensis*, *Magelona papillicornis*, *Tharyx marioni*, and *Eurydice pulchra*. Eighteen months after the closure also *Crepidula fornicata*, *Abra alba*, and *Cumopsis goodsiri* were found.

As had been expected, species with pelagic larvae or a free-swimming phase extended rapidly all over the estuary. Already after a few months, spat of *Cardium edule*, *Hydrobia ulvae*, and *Nephthys hombergii* was found at all transects. Species without pelagic larvae, however, obviously were hampered in their dispersal. After six months *Scoloplos armiger* and *Tharyx marioni*, both very common in the Delta area, had not yet reached the transects B and C. *Tharyx* was found after eighteen months in transect C, but *Scoloplos* did not reach B or C before 1971, when it was observed in transect B.

A remarkable phenomenon observed is the long survival of some brackish-water species. Six months after the closure of the dam the polychaete *Streblospio shrubsolii* was still found at transect B, whereas the isopod *Cyathura carinata* was found at the same transect even after 28 months. This clearly illustrates the euryhalinity of this faunal component.

Diversity

It was expected that this large-scale experiment would render interesting observations on the development of the diversity of the benthic communities.

Because all samples were of the same size, the number of species per unit of area, *i.e.* per sample, has been used as an index of diversity. It may be considered as a measurement of the "within-habitat" diversity. The number of species in the whole transect has been used as a second measurement of diversity, because it may supply information on the "between-habitat" diversity. The Shannon-Wiener formula and other indices of diversity combining species diversity and equitability diversity in one figure, have not been used, because many samples were dominated by enormous numbers of *Hydrobia ulvae*. Since, owing to its floating behaviour, the distribution and the abundance of this snail are strongly influenced by the weather, its inclusion in the calculations would lead to widely varying results.

The number of species per sample, *i.e.* the within-habitat diversity, increases after the increase in salinity (Fig. 2). The increase is observed at all transects, but transect A seems to have reached its maximum diversity already in the first autumn, whereas the transects B and C show a continuous increase of diversity. It seems that transect C lags one year behind transect B, but the difference also may be due to differences in salinity between both places.

The total number of species per transect is shown in Fig. 3. When this number increases more strongly than the number of species per sample, it is an argument in favour of an increase in the between-habitat diversity. Comparison of Figs. 2 and 3 shows that this is indeed happening, thus it may be concluded that after the increase of salinity the between-habitat diversity also shows a continuous increase.

Hence, the increase in salinity after the closure of the dam initiated a development which made the various communities richer in species, but also more different from one another.

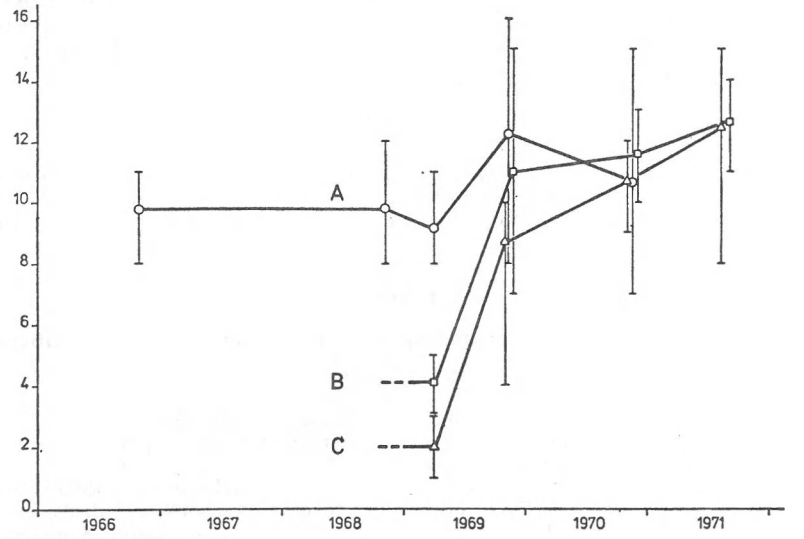

Fig. 2. Changes in the number of species per sample. The number of species is shown on the vertical axis and the time-scale on the horizontal one. For each time of sampling of each transect the average, the maximal and the minimal number of species per sample are shown.

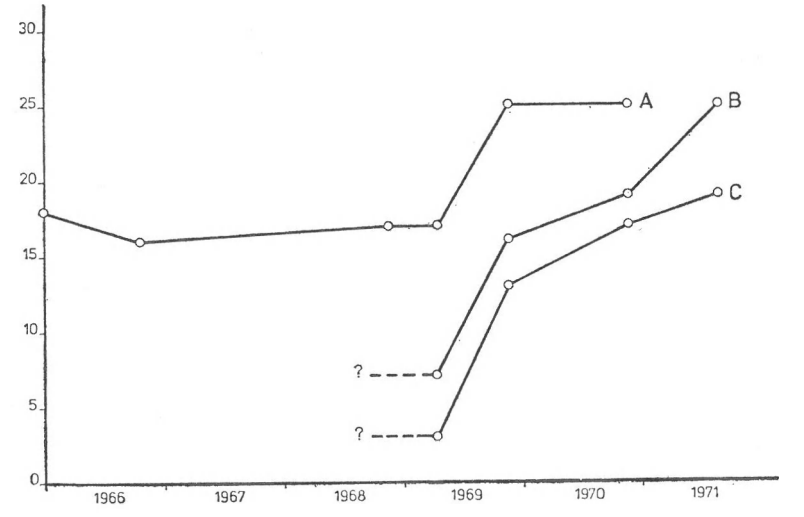

Fig. 3. Changes in the total number of species per transect. The number of species is shown on the vertical axis and the time-scale on the horizontal one.

DISCUSSION

It was expected that the sudden increase in salinity after the closure of the dam across the Volkerak would have a strongly negative influence upon the benthic fauna of the estuary, because this has been observed many times in terrestrial communities after comparable events. However, the original brackish-water com-

ponent of the fauna survived the drastic change of its environment, whereas the new component of marine origin began to colonize the new area at once. Logically, this resulted in an increase in diversity to be observed in the within-habitat as well as in the between-habitat diversity.

REFERENCES

1. R. Peelen, Changes in salinity in the Delta area of the rivers Rhine and Meuse resulting from the construction of a number of enclosing dams, *Neth. J. Sea Res.* **5** (1970) 1–19.
2. Veranderingen in de stroomsnelheden ten zuiden van de Volkerakdam, *Driemaandelijks Ber. Deltawerken* **51** (1970) 25–32.

IZVOD

Promjene u intertidalnoj bentoskoj zajednici nakon povišenja saliniteta

W. J. Wolff

Ušće Krammer – Volkerak sa salinitetnim gradijentom od 0.3–15 ‰ Cl' zatvoreno je je branom početkom 1969. godine. To je nizvodno od brane uzrokovalo povišenje saliniteta, dok čitavo područje nije doseglo klorinitet od 9–15 ‰.

Bočato vodna fauna preživjela je ove promjene sredine, a odmah je započelo i naseljavanje morske faune na novom području. To se odrazilo na povećanju raznolikosti jednako dobro u samim staništima, kao i između različitih staništa. Proces se nastavlja još i nakon 28 mjeseci.