Offprint from

WETLANDS: Ecology and Management

(Proceedings of the First International Wetlands Conference)

New Delhi, India, 10–17 Sept. 1980

PART II

First published as
International Journal of Ecology and Environmental Sciences
Vol. 7 (1981)

Edited by

B. Gopal, R. E. Turner, R. G. Wetzel & D. F. Whigham

Published by

NATIONAL INSTITUTE OF ECOLOGY, JAIPUR

AND

INTERNATIONAL SCIENTIFIC PUBLICATIONS

C-70 A. L. Sethi Nagar, Jaipur 302 004, India

1982

THE CONTRIBUTION OF EXTENDED MUD-FLAT REGIONS TO THE SELF-CLEANSING POTENTIAL OF THE ELBE ESTUARY

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ABSTRACT

The paper describes the benthos associations of the freshwater and brackish regions in the Elbe Estuary ; the mud flats, uncovered at low tides are places of deposition for the organic compounds brought in by the tides. The benthos facilitates the intensive decomposition of the detritus from sewage outflows. This is a reason for preserving this habitat and limiting activities that destroy it.

INTRODUCTION

The mouth of the Elbe forms a funnel-shaped estuary into which the North Sea tides penetrate more than 100 km upstream. Because there is a 2.5 m difference between high and low tides, wide sections of the shore are exposed and re-flooded twice each day. They are examples of typical silt and mud-flats, similar to those found along the North Sea coast. According to the degree of dilution by fresh water, conditions range from polyhaline to oligohaline. The tidal movements occur upstream beyond the brackish water zone, so even in the freshwater region mud-flats are exposed each day. This phenomenon occurs only in such funnel estuaries.

The salinity in the brackish water region undergoes enormous fluctuations (Fig. 1). During periods of strong freshwater outflow due to rain or melting snow, mesohaline and oligohaline water masses are forced far toward the mouth of the estuary. On the other hand, salt water penetrates far up into the funnel during periods of dryness or prevailing northwest winds (Caspers 1948, 1959, 1968).

BENTHOS OF MUD-FLATS

The plankton structure varies with the change in the water mass, but the benthos must survive the astatic conditions. Consequently, only extremely euryhaline species can live in the brackish wazter zones. These migrate into the estuary from the sea. In general, the upper limit of their distribution is the transition zone to the freshwater region (Schulz 1961, Giere 1968).

In the freshwater mud-flats, a benthos very rich in individuals belonging mainly to endobiotic species is found. The fauna is composed chiefly of tubificids and chironomid larvae. Their massive populations are supported by the large amounts of detritus, which forms heavy deposits on the freshwater mud-flats. In the deep parts of these

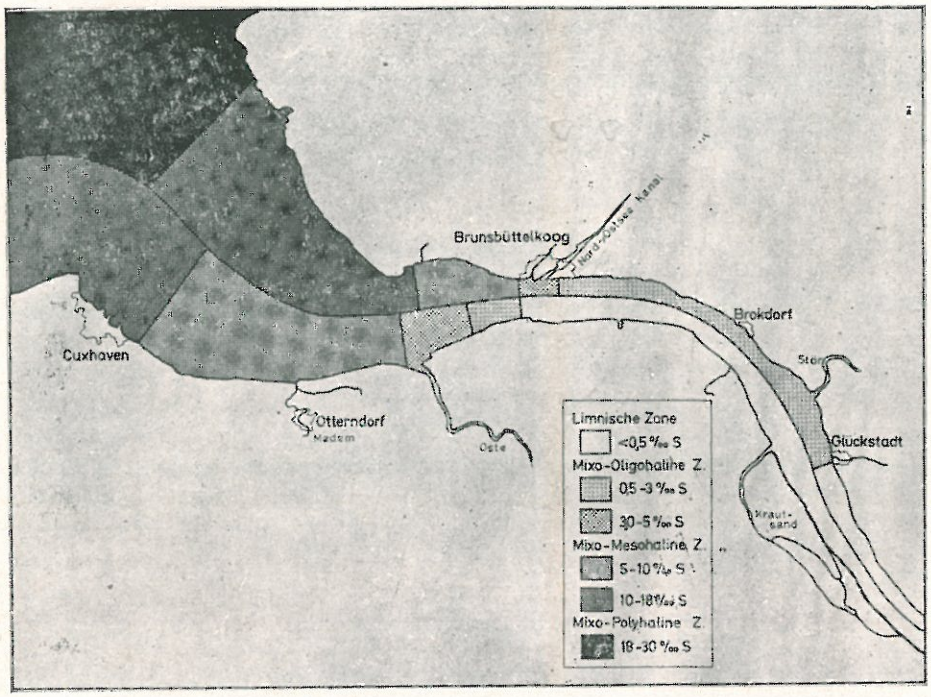

FIG. 1. Map of the Elbe Estuary showing the maximum (above) and minimum (below) extent of brackish water penetration (from Caspers 1968).

mud-flats, anaerobic decomposition takes place, producing large quantities of methane and hydrogen sulfide. Deep "craters" form in the sediment as a result of gas eruptions. Due to the periodic flooding, the surface of the mud-flats maintains aerobic conditions, providing a basis for the existence of the fauna. (Caspers 1949, Pfannkuche *et al.* 1975).

On or beneath 400 cm² of surface area in the central silty region of the Fährmannssand mud-flat, downstream from Hamburg (Figs. 2 and 3), the following specimens were found:

Endobiotic—2200 tubificids (*Limnodrilus hoffmeisteri*)
1080 chironomid larvae (*Pelopia* sp.)
11 chironomid pupae
110 bivalves (*Pisidium cineareum*, *P. subtruncatum*, and *P. nitidum*)
Epibiotic— 20 gastropods (*Valvata piscinalis*)

Isolated sections of the freshwater mud-flats are overgrown with monocots, forming an association designated as "*Scirpetum maritimi*" (Kötter, 1961), which consists of *Scirpus triqueter*, *S. americanus*, *S. duvalii*, and *S. tabernaemontani*. These rushes have long rhizomes in the sandy sediment. They are so firmly anchored that they can resist the pull of the current. The shores are bordered by *Phragmites communis* and *Typha latifolia*. Among the clumps of *Scirpus*, the zoobenthos is less rich. Beneath 400 cm² of surface

FIG. 2. Aerial view of a freshwater section of the Elbe downstream from Hamburg with extensive mud flats (Fährmannssand). (With permission of Wasser- und Schiffahrtsdrektion Nord).

area were found the following specimens:

520 tubificids (*Tubifex tubifex* and *Limnodrilus hoffmeisteri*)
12 chironomid larvae (*Tanypus* sp., *Pelopia* sp., and *Chironomus* sp.)
1 amphipod (*Gammarus zaddachi*)
35 bivalves (*Pisidium cineareum, P. subtruncatum,* and *P. nitidum*)

When the chironomid adult emerge, the water at flood tide is covered by masses of pupa exuvia. At ebb tide, the eggs can be found on the surface of the exposed sediment.

FIG. 3. Mud flat in the freshwater part of the Elbe Estuary (Fährmannssand) with a monocot association (*Scirpetum maritimi*).

From these hatch a large number of larvae.

Due to the rhythm of emergence, the population of chironomid larvae undergoes enormous fluctuations. Furthermore, the shifting of the sediment also causes great changes to occur in the abundance of the other zoobenthos elements. After a particularly cold winter during which the surfaces of the mud-flats froze at ebb tide and remained covered with large sheets of ice, the number of tubificids decreased sharply. During the spring, however, the population quickly regenerated itself.

The surface of the freshwater mud-flats is covered with a flora of diatoms composed of over 100 species. Among the diatoms live animals specialized to such habitats, including tardigrades and nematodes. During periods of sunshine, many bubbles of oxygen form in this lawn of algae, giving evidence for the high activity rates of the diatoms. The flood carries some of the algae away, and they live as a kind of pseudoplankton in the Elbe. In a few hours, the populations on the mud-flats are regenerated.

In the brackish water zones of the estuary (Fig. 4), the mud-flats contain a greater proportion of sand, but the sand is sometimes coated partially by a mud of fine particles. *Scirpus maritimus* grows on the shore. The detritus provides the nutritional basis for many species of zoobenthos, including polychaetes (*Nereis diversicolor*, etc.), marine molluscs (*Macoma balthica* and *Hydrobia ulvae*), and tubificids (*Limnodrilus hoffmeisteri* and *Tubifex barbatus*). Tube-building amphipods are very numerous, especially *Corophium volutator*. Marine decapods, such as *Crangon crangon*, occur regularly in the tidal gullys, and the catadromous Chinese full-hand crab, *Eriocheir sinensis*, spawns in this habitat. On solid bodies, thick crusts of barnacles, *Balanus improvisus*, and hydroid polyps, *Laomedea gelatinosa* and *Cordylophora lacustris*, are often observed. *C. lacustris*, as its name implies,

FIG. 4. Aerial view of a mud flat in the brackish section of the Elbe Estuary. The tributary in the picture is the Oste. (With permission of Wasser- und Schiffahrtsdirektion Nord.)

penetrates far into the freshwater region.

The brackish water region contains a mixed aggregation composed of both thalassogenic and limnogenic elements, together with genuine brackish water species. Corresponding to the large populations of individual species is the capability of the fauna to contribute to the self-cleansing of the Elbe, in which the brackish water mud-flats play an essential role, just as the freshwater ones do.

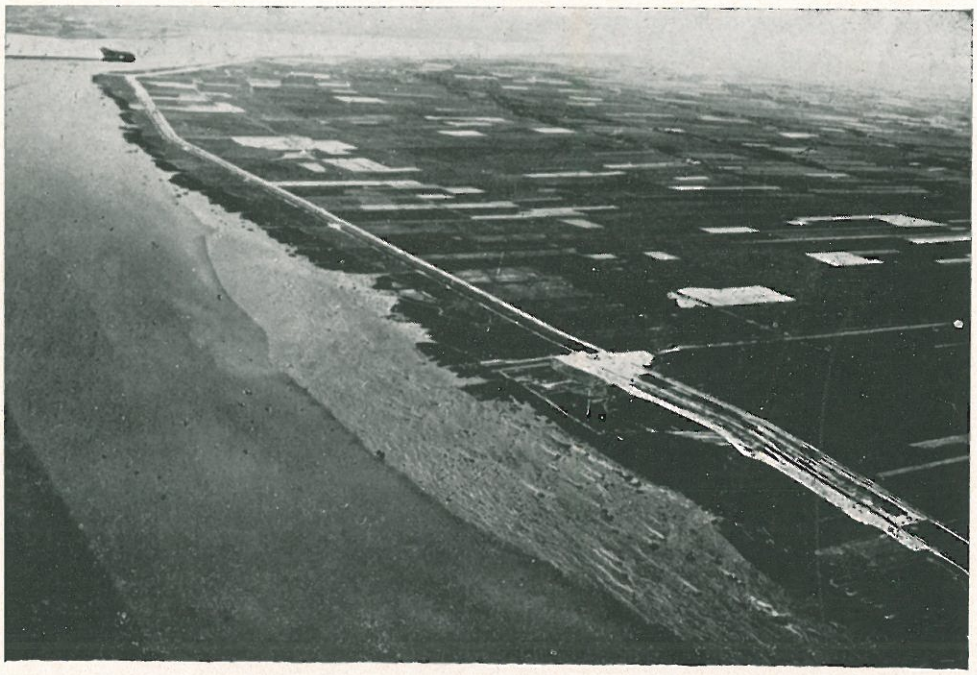

FIG. 5. Aerial view of a wetland ecosystem along the Elbe Estuary (brackish water section near Balje) that is transected by a new dike. (Phot. Doerffer).

HABITAT PROTECTION

Various mud-flat regions along the Elbe have been destroyed or greatly reduced in size during recent years; first to obtain land for industrial development. Later, dikes were constructed so close to the river that the connection between the mud-flats and adjacent marshlands was broken (Fig. 5). A few years ago, it was planned to deposit sand dredged from the Elbe channel during deepening operations directly on the mud-flats. This did not come about because the biological value of these shallow water habitats was demonstrated. Again and again, conflicts have arisen among the interest groups representing economic development plans, flood protection, and conservation of the mud-flats. Compromises are not always found.

From among the many grounds for conserving the mud-flats, including the arguments of ornithologists, the most important is perhaps the fact that these habitats play a vital role in the self-cleansing process of the estuary. The investigations on the distribution of the fauna and their importance in the decomposition of organic wastes were undertaken from a purely scientific point of view. As discussions with development planners and engineers began, a body of knowledge based on years of study was already available. The results provide a strong argument for the conservation of this special mud-flat habitat. Environmental protection can always be advocated best when the results of scientific research are available.

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