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Biological Research Ems–Dollart Estuary. Some aspects of an estuarine ecosystem in a series of ten poster summaries

1 Introduction

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The Ems-Dollart estuary is situated on the Dutch-German frontier, in the north eastern part of the Netherlands. The estuary has an area of approx. 500 km², and is vertically well-mixed and very turbid.

The primary production in the estuary is not limited as to phosphorus and nitrogen, and only locally and temporarily as to silicon.

The estuary receives from the river Ems approx. 4×10^9 m³ water and 117.000 tons of sediment. Of this amount of sediment 7.300 tons are organic carbon.

From the North Sea the estuary receives a tidal volume of $1,1 \times 10^9$ m³ seawater per tide.

From a small river, the Westerwoldsche Aa, a small amount of fresh water (4×10^8 m³) with a heavy load of potato-waste ($17 - 25 \times 10^3$ tons organic carbon) reaches the estuary.

Due to the great waste load the estuary is an area where there are many conflicts of interest.

The aims of the Biological Research Ems-Dollart Estuary Project are:

1. A qualitative and quantitative description of the estuary and a study of factors which determine structure and function of the ecosystem.
2. A study of changes and the prediction of changes as a result of human influences, if possible by the use of mathematical models.
3. The supply of data for the management of the estuary as to waste water, dredging, harbour building, industries and others.

During the period 1972 – 1980 a great amount of data has been collected; an ecosystem scheme was developed. In 1979 and 1980 work on a mathematical model, or mathematical models, for the estuary was begun.

2 Influence of turbidity on primary production of phytoplankton

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Phytoplankton was sampled during 1979 at 8 different stations in the Ems estuary. The samples were incubated in a laboratory incubator at 8 different light intensities. From these incubations P versus L curves were calculated.

Simultaneous measurements of day-time irradiance and light attenuation at the 8 stations were made. A calculation model was made to convert these incubator data, light attenuation data and irradiance data to daily and annual primary production estimates.

The results showed that the annual primary production values ranged from over 400 g $C \cdot m^{-2}$ in the seaward part of the estuary to 60 g $C \cdot m^{-2}$ in the turbid inner part of the estuary. Primary production was correlated with the vertical attenuation coefficient of the water which ranged from ca. 1.2 to over 7 in the inner part of the estuary.

The range in vertical attenuation coefficients itself was caused by the turbidity gradient in the estuary, and closely related to the amount of suspended matter in the water.

It was concluded that the primary production in the estuary was limited by light and that planned dredging for harbour facilities would increase this light limitation, especially in the most seaward part of the estuary.

3 Mobilization of benthic diatom populations from tidal flats

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Hydrographic surveys in 1975 and 1976 showed relatively high chlorophyll a values, as well as a high turbidity in the inner part of the estuary. This seems to be in contradiction with the conclusion of COLIJN, that primary production is strongly light-limited. A possible explanation for these high Chl a values is: "High flat-gully surface ratios lead to an important Chl a contribution to the water due to suspension of benthic diatoms".

This hypothesis was examined in field observations as well as in laboratory experiments. Laboratory experiments with natural flat sediments over which a water current was established, showed a current-dependent increase in suspended matter as well as in Chl a, suggesting a positive correlation between Chl a and suspended matter. The critical current velocity interval, above which the sediment and Chl a came into suspension, ranged from 10 – 20 cm $\cdot$ $sec.^{-1}$. Current velocities found during float experiments in the field were mostly higher than the critical values given above.

The tide, which is the main generating factor for this current, leads in the inner parts of the estuary to a positive correlation between suspended matter and Chl a during ebb, while during flood the Chl a values were suspended matter independent. Moreover, the mean Chl a value during ebb was higher than during flood.

Float experiments carried out above a flat system during two subsequent tides showed the strong influence of wave/wind action on the suspension of benthic diatoms.

From these experiments it may be concluded that due to tidal currents as well as wind/wave action, benthic diatoms go into suspension. Consequently they might play an important role as an additional food source for the pelagic system, especially in the inner, shallow and turbid parts of the estuary.

4 Population dynamics, productivity and competition in mudflat diatoms

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Populations of benthic diatoms cover the large surface areas of intertidal flats in the estuary. The ecology of these populations is analysed by experiments and field observations. Natural diatom populations on a nutrient-rich mudflat, as well as laboratory cultures, showed exponential population growth at low densities and retarded growth at densities equalling $> 10^6$ cells $\cdot$ cm^{-2} or > 50 mg chl a $\cdot$ m^{-2}. This phenomenon is explained by the observation that levels of photosynthetic oxygen production by diatom films is limited to ~ 500 mg $O_2 \cdot m^{-2} \cdot h^{-1}$ by the diffusion of bicarbonate into the populations.

The dominance of two abundant species in natural populations in the exponential growth phase is determined by their maximum cell division rates. At high population density in the cultures the competition for bicarbonate is severe; in densely mixed cultures only one species reached numerical dominance.

It is concluded that primary production, population dynamics and interspecific competition in benthic diatom populations are highly interwoven processes.

5 Meiofauna grazing in tidal flats

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Investigations on meiofauna grazing are complicated by the diversity of this fauna of which dozens of species normally occur in different locations of estuarine tidal flats. In the oligohaline part of the Ems estuary, in the Dollart near the freshwater inlet at Nieuwe Statenzijl, the meiofauna consists mainly of two nematode species and (temporarily) of a few oligochaeta species. These two nematode species are: *Eudiplogaster pararmatus* W. Schneider 1937 and *Dichromadora geophila* de Man 1876.

Maximum densities of 10^7 specimens · m^{-2} have been observed in this area. Both nematode species feed primarily on diatoms though grazing on diatoms is to a certain extent selective. For example: the nematode species *E. pararmatus* penetrates frustules of the diatom species *Navicula salinarum*, *Gyrosigma spenceri*, *Nitzschia sigma* and *Surirella ovata* easily but often does not succeed in penetrating *Navicula pygmea*. The nematode species can be cultivated under experimental conditions in agar, mixed with living diatoms. This cultivation however is not as easy as cultivations of bacteria-feeding nematodes.

For growth of populations of the species *E. pararmatus* diatom densities must exceed 10^6 cells · cm^{-2}. Experiments with grazing of *E. pararmatus* on ^{14}C-labelled cells of *Navicula salinarum* indicated a consumption of several hundreds of cells/nematode/day.

6 Carbon flux through the tidal flats sediment of the Ems–Dollart Estuary

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Parts of the carbon flux within intertidal estuarine sediments were quantified by measuring on six stations the annual cycles of *in situ* benthic primary production and community respiration as well as algal biomass and organic carbon content of the sediment. Recently fixed organic carbon was rapidly remineralized, whereas the bulk of organic matter within the top 10 cm of the sediment had a turnover of many years. It was concluded that the rates of primary production and community respiration showed only moderate gradients along the main axis of the estuary, although there were strong gradients in physical and chemical parameters.

7 Composition and distribution of macrobenthic fauna

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The biomass of the fauna is expressed in grams ash-free dry weight per m^2. The mean biomass values for the tidal flats range from 2 to 19, for the channels from 0 to 4 g ADW/m^2. Common species on the tidal flats are: *Nereis diversicolor*, *Macoma balthica*, *Eteone longa* (whole area), *Nephtys hombergii*, *Scoloplos armiger*, *Cerastoderma edule*, *Arenicola marina*, *Hydrobia ulvae* (more saline part), *Heteromastus filiformis*, *Mya arenaria* and *Corophium volutator* (more brackish part).

Regarding their way of feeding, the biomass of the fauna is composed of filter-feeders (25 – 85 %), deposit-feeders (4 – 45 %) and carnivores (2 – 32 %).

In the Dollart (inner part of the estuary) 85 % of the total biomass is available for birds and 40 % of it is available for fishes.

8 Population dynamics of the copepod Eurytemora affinis

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A method is given to estimate mortality in a field population from the relative densities of the successive developmental stages in a sample, by curve fitting. The usefulness of this approach, and the conditions under which it is valid, are discussed.

An example on its use is given in the form of a time series of field samples, together with the fitted curves.

9 The food of the pelagic fishes of the Dollart

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Total stock of 4 species of pelagic fish in the Dollart (a 89 km^2 part of the Ems-Dollart estuary) was determined by a passive fishing method, using the tidal currents.

The species were: young herring (*Clupea harengus*), sprat (*Sprattus sprattus*), smelt (*Osmerus eperlanus*) and three-spined stickleback (*Gasterosteus aculeatus*). Variations of numbers of fish present were measured also.

Herring numbers ranged from $< 10^6$ in July to 18×10^6 in March, sprat from 1 1/2 $\times 10^6$ in autumn to 54×10^6 in mid winter, smelt from 2×10^6 in mid winter to 80×10^6 in summer and sticklebacks from 19×10^6 in winter and early spring to 2×10^6 in summer and autumn.

Analysis of stomach contents gave a crude estimate of total amounts of *Corophium* and copepods eaten by these species: viz. 300 tons of *Corophium* and 400 tons of copepods.

10 Simulation of zooplankton and pelagic predator biomass

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The results of a model simulation of the water column and field observations are compared.

In the model the following groups are incorporated: phytoplankton, zooplankton and detritus. All stages of zooplankton copepods are distinguished in the model. The biomass of zooplankton, which eats phytoplankton, is controlled in part by pelagic fish and jellyfish; these predators enter the estuary, from the sea, in the spring when the zooplankton biomass is rapidly growing.

Because of the last statement, in the model the relative predation is made linearly dependent on the zooplankton biomass.

Comparison of the simulations for different relative predation rates on zooplankton with field observations lead to the following conclusions:

1. The biomass of zooplankton in all simulations is much higher than in the field.
2. A decrease of the zooplankton biomass in the field, although there is a sufficiency of phytoplankton.

From these two points it follows that the amount of phytoplankton is controlled in a different way, and not through grazing by zooplankton.

It is concluded that models can be used: firstly to check whether biomass of groups of organisms fit, and secondly to test the influences of changing conditions (e. g. a changing predation pressure on zooplankton).