GROWING DAPHNIA ON EFFLUENT TO IMPROVE THE FOOD SITUATION OF SPOONBILLS ON THE ISLAND OF TEXEL,

DO DAPHNIA REALLY EAT SEWAGE SLUDGE?

4th International Conference on Ecological Engineering for Wastewater Treatment, Ås, Norway, 7-11 June 1999

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SUMMARY

In the presettling basin of the constructed wetland Everstekoog the number of Daphnia spp. was high despite the low algae concentrations. How can these Daphnia survive? Can we use the effluent of a sewage treatment plant to grow Dapnia as food for sticklebacks, the main food of Spoonbills. Is it possible to use the effluent as a lure flow for a fish trap to syphon fish from the sea across a high Dutch dike? These are some of the questions we are trying to answer. This paper describes the results of preliminary tests in 1998 and plans for research in 1999.

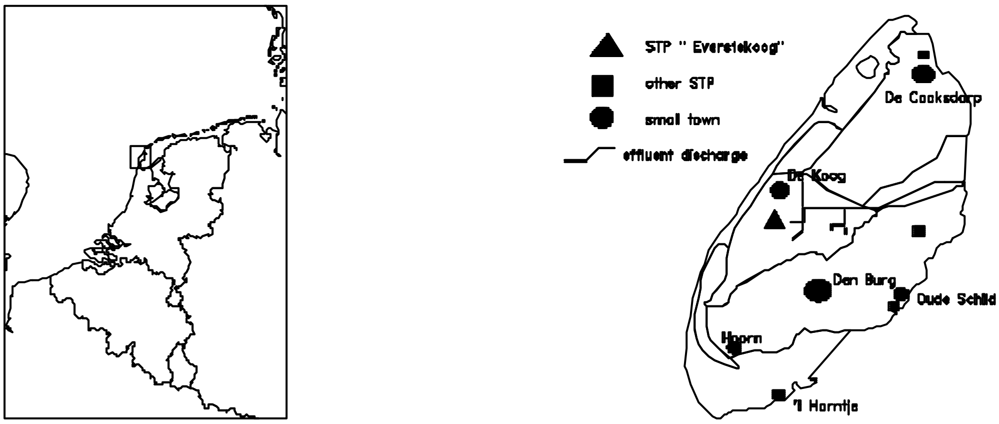
More about the project can be found at http:/www.rekel.nl/water

INTRODUCTION

Nature in The Netherlands is coping with many problems, but is still rich in diversity. The island Texel, situated in the northwestern part of the country is a famous tourist resort. Besides that, bird life on the island is rich: in 1998 110 breeding species. The number of breeding pairs of Eurasian Spoonbill (*Platalea leucordia*) on Texel was 214 in 1998 (Schutte et al, 1999). Total number of species observed on the island is 353 up to now. It is also a famous observation spot during bird migration, because its situation in the migration route along the north western coast of Europe. (Dijksen, 1996, 1999).

One of the problems on the island is that for defence against the sea high dikes have been built, this makes the island more difficult to reach for migrating fish from the sea. Three Spined Stickleback (*Gasterosteus acculeatus*) grow up at sea and migrate back to inland waters to spawn, like salmon. In contrary, Eel (*Anguila anguila*) come back from the ocean to grow up in inland waters. It is hardly a problem to migrate back to the sea. The fish is easily pumped or flushed out. The new and higher dikes resulted thus in lower number of fish on the island.

Together with other changes in landscape and land use, this resulted in a worsening of the food supply of fish eating birds on the island. Not only the number of Three Spined Stickleback got lower, but most the fish are smaller. A part of the population do not migrate anymore, these fish stay much smaller than the ones that grow up at open sea. One of the most striking birds of Texel, the Eurasian Spoonbill, feeds mainly on sticklebacks. It is a contrasting situation, the number of Spoonbills in The Netherlands have increased dramaticly the last years.



STP Everstekoog near De Koog and the STP and the fishladder near De Cocksdorp

Figure 1 The Island Of Texel In The Netherlands

Despite, or possibly because of the increasing numbers of Spoonbills the food situation of the Spoonbills becomes more vulnerable (Kemper, 1995, Wintermans in Schutte et al, 1999). To help fish passing the dikes a syphon fish ladder has been constructed near De Cocksdorp, on the northern tip of Texel (Figure 1). To lure the fish to the fish ladder a flow of 350 m^3/day fresh water is pumped in to the North Sea. When enough fish has gathered, the fish is transported by means of a siphon over the top of the dike into the surface waters of the island (Wintermans in Schutte et al, 1999). A couple of problems exists:

- A conflict with the farmers on the island: During drought the fresh water used for the lure flow is needed by the farmers;
- Water quality: The sewage treatment plant (STP) De Cocksdorp, which is overloaded in summer, discharges its effluent close to the point where the fish is released.

This brought us to the point why don't we combine the sewage treatment plant and the fishladder to improve the foodsituation for Spoonbills? The STP De Cocksdorp delivers up to 1000 m^3 treated waste water per day. From the research project on the constructed wetland Everstekoog (Kampf, 1999, this conference) we learned that in the presettling basin the water "turns red" of Daphnia (see also Moss, 1998). The basic idea is whether a surface constructed wetland can:

- improve the surface water quality near De Cocksdorp and;
- produce a water quality, good enough to be used as lure flow for the fish ladder and;
- be used to grow food for the Three Spined Sticklebacks that migrate to the island through the fishladder, thus improving the food situation of Spoonbills and other birds on the island.

The massive development of Daphnia and other zooplankton in the presettling basin of the Everstekoog constructed wetland (Kampf et al, 1999) during the summer had puzzled us first however. How could this zooplankton survive? The algae numbers in this basin (<10 µg/l chlorophyll-a) were very low, not enough to maintain this population. Most aquaculture systems have an algae module involved (See f.i. Proulx et al, 1985, Borowitzka et al, 1988, or Staudenmann et al, this conference, 1999). Therefore the hypothesis was that the zooplankton lived mainly of bacteria, on the so called “pin-point flocs” in the effluent.

RESEARCH

During a six-month period, the possibility of using effluent from a wastewater treatment plant for the improvement of the food situation of Sticklebacks and Spoonbills was studied on lab and pilot scale (Groot, 1998). Questions that were postulated were:

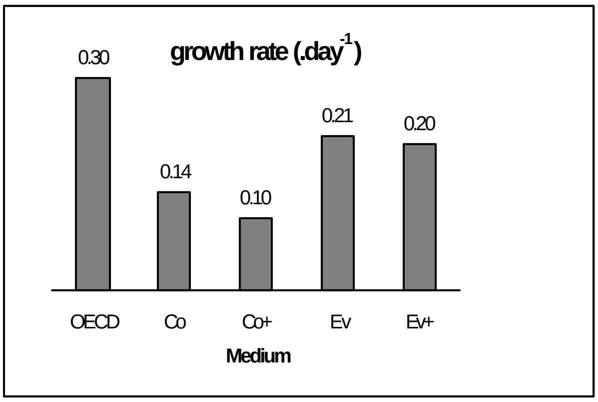
- Are there restrictions to cultivate algae and zooplankton on effluent due to water quality problems (e.g. oxygen levels, pH etc.)?
- Is it possible to breed zooplankton on organic matter from the STP (activated sludge)?
- Is it possible to maintain a breeding process in a surface flow system on effluent?
- What is the risk of biomagnification of copper and zinc in the food chain from zooplankton to Spoonbills?

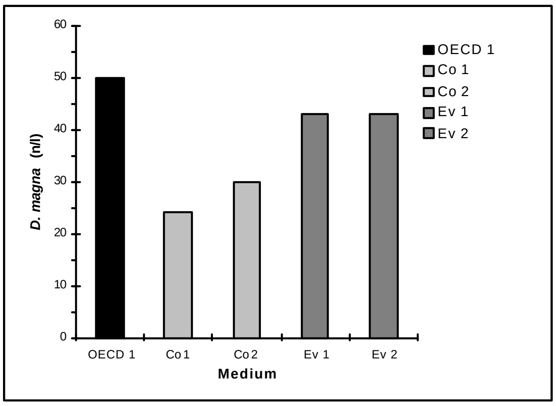
More on the experimental techniques can be found at the site http://www.tno.nl/er

Algae

The growth of *Chlorella pyrenoidosa* on effluent of STP De Cocksdorp and STP Everstekoog and OECD was followed for a 20 day period in duplicate systems. Nutrients were added to avoid nutrient limitation in order to allow for the assessment of toxic effects.

C. pyrenoidosa is able to grow on effluent, but the growth rate is lower than in the algal growth medium (OECD) (Figure 2). The inhibition of algal growth may result from unfavourable water quality conditions. Conclusion is therefore that low algal numbers in the presettling basin is not only due to grazing.





Co = De Cocksdorp, Ev = Everstekoog, + = nutrients added) and algal growth medium (OECD)

Figure 2 Growth Rate Of C. pyrenoidosa

Figure 3 Numbers Of D. magna After 23 Days

Daphnia

Daphnia magna was cultured on effluents from STP De Cocksdorp, STP Everstekoog and a growth medium (OECD) to compare its performance (determined by survival and reproduction). In most systems *D. magna* numbers increased (from the initial 20 individuals at the start) as a result of reproduction (Figure 3). Reproduction in the effluents was hampered in comparison with the standard medium. Growth on effluent of STP De Cocksdorp was more limited than growth on effluent of STP Everstekoog.

Phytoplankton and zooplankton in a flow-through system

When it became clear that phytoplankton and zooplankton were able to grow on effluent, the next step was to determine if it was possible to cultivate phytoplankton and zooplankton in a flow-through system (Figure 4): volume of the mesocosms 2 m^3 each, flow 0.4 m^3 per day.

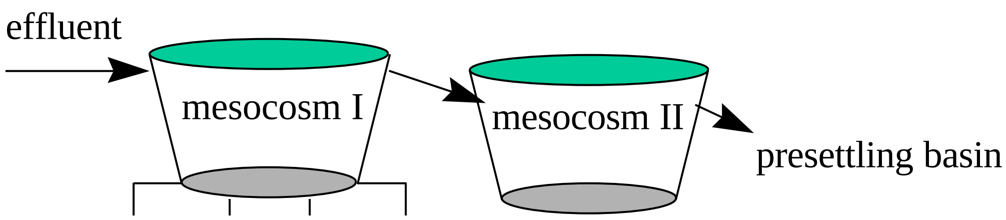


Figure 4 Set Up Of The Flow-through System

In mesocosm I *C. pyrenoidosa* was cultivated on effluent which flows to mesocosm II in which *D. magna* was grazing on *C.pyrenoidosa*. During 68 days, the density of *C. pyrenoidosa* and *D. magna* was followed. This experiment showed that the number of *D. magna* could reach a density of 1900 per litre as long as the concentration of algae in mesocosm I was 40 µg chlorophyll-a/l or more. In the field situation there was < 10 µg/l. The preliminary conclusion is that in effluent algae are not likely to be a good foodsource of zooplankton. However, bacteria on the "pin-point floc" in the effluent are probably a very good alternative.

Sludge As Food For Daphnia?

From an experiment with plankton enclosures (plastic bags) in the presettling basin, supplied with effluent it appeared that Daphnia grow faster when the concentration of activated sludge increased. Therefore, it can be concluded that *D. magna* is able to grow on sludge particles (activated sludge) in the effluent of the oxidation ditch. One of the tests to prove this, has been carried out in two times six microcosms filled with 80 l microcosms. One set was kept in the dark to prevent algal growth, the other set in light to stimulate growth. The dose of activated sludge was the main determent for growth of Daphnia. To assess the predation on sludge particles a calculation has been made, see Table 1. It pointed out that for the example of the presettling basin of the Everstekoog constructed wetland (Groot, 1998) the consumption of sludge particles by 1000 Daphnia per liter could well contribute in a sizable reduction of suspende solids in effluent from STP's.

Table 1 How Much Sludge Can Daphnia Eat?

DAPHNIA IN EVERSEKOOG PRESETTLING BASIN				
Volume basin	4400			m^3
Nr of daphnia	1000			number per l
Nr. of daphnia in pond	4.4e09			total number
Weight per daphnia	1.8			mg per daphnia
Mass of daphnia in pond	7920			kg fw
THEORETICAL CONSUMPTION OF SLUDGE BY DAPHNIA				
Sludge per daphnia per day	0.3			g sludge per g daphnia
Sludge daphnia in pond	2376			kg sludge per day
Suppose specific volume of sludge flocs:	0.016	0.05	0.1	kg per l
Consumption of sludge in pond per day	**38**	**119**	**238**	**kg sludge per day**
CALCULATION OF SLUDGE LOAD TO POND				
Flow to pond	3500			m^3 per day
Suppose suspended solids in effluent STP	1	5	10	g/m^3
Total load of pond	**3.5**	**17.5**	**35**	**kg sludge per day**

BIOMAGNIFICATION OF COPPER AND ZINC IN DAPHNIA AND STICKLEBACKS

Effluent can contain high copper and zinc concentrations from copper drinking water pipes and zinc gutters. Therefore, biomagnification of copper and zinc in the system may cause a risk. Both copper and zinc concentrations in Daphnia, grown in effluent were not higher than usual in Dutch surface water. The risk of biomagnification of copper and zinc was studied by feeding Three Spined Sticklebacks for a three week period with zooplankton caught from different locations; the presettling basin, a field location, and from a culture. After three weeks, the Sticklebacks were analysed on copper and zinc concentrations. The results indicate that bioaccumulation of these heavy metals does not cause a risk on Texel, since levels were in the range of those found in fish from natural surface waters in The Netherlands.

PRELIMINARY CONCLUSIONS

Cultivation of phytoplankton and zooplankton on effluent of STP De Cocksdorp en STP Everstekoog was possible at suboptimal rates. A difference in growth-rate between the STP effluents was observed.
Cultivation of zooplankton on algae in a flow-through system is possible as long as the algal concentration can be kept above 40 µg chlorophyll-a/l. Zooplankton can be cultivated on activated sludge instead of algae.

> Effluents from STP's have a high potential for reuse. The water originates from high quality sources (drinking water, rainwater) which are, in the case of household effluents, only slightly polluted. Furthermore, effluents from STP's contain nutrients with a high productive potential, but are considered as pollutants because this production occurs in natural surface waters which might result in eutrophication phenomena like high algal densities and related problems. Constructed wetland systems not only can reduce the loading with nutrients of receiving surface waters, the nutrients should be used in growing biomass with a positive value (Kampf, ed., 1998).

A combination of open ponds, helophytes and submerged aquatic plants is a cost-effective way to change sewage in to a "living" water suitable for various purposes. The use of the minerals in effluent of STP´s to "produce food" to improve the food situation on Texel of fish and subsequently birds, which feed on small zooplanktivorous fish, like Spoonbills seems feasible. A trapped ‘food-chain type’ system seems a promising option to increase the ecological value of effluents from oxidation ditches.

RESEARCH IN 1999

Current research focuses upon the factors that cause a suboptimal growth of Daphnia, and the quantification of the production of Daphnia with activated sludge as a food source. Therefore, a

combination of toxicity bioassays with Daphnia and chemical analyses, supplemented with biotic (zooplankton dynamics) and abiotic measurements (oxygen dynamics), will be performed in the presettling basin of the constructed wetland. Additional laboratory experiments will be set up to calculate the yield of zooplankton per quantity of sludge.
The results of this years research should indicate the quantitative production potential of biomass (zooplankton and stickleback), and a sketch of a trapped 'eco-production system' fed with STP effluent.

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[i] *4th International Conference on Ecological Engineering for Wastewater Treatment, Ås, Norway, 7-11 June 1999, paper_EcoEng99_daphnia_03.doc*