THE "DREISSENA-MONITOR" – FIRST RESULTS ON THE APPLICATION OF THIS BIOLOGICAL EARLY WARNING SYSTEM IN THE CONTINUOUS MONITORING OF WATER QUALITY

Jost Borcherding* and Markus Volpers**

* Zoologisches Institut der Universität Köln, Physiologische Ökologie, Weyertal 119, W-5000 Köln 41, Germany
** Borcherding & Volpers GbR, ENVICONTROL, Lindenbornstraße 5, W-5000 Köln 30, Germany

ABSTRACT

The "Dreissen-Monitor" is a biological early warning system used in the continuous monitoring of water quality. The system is based on a computer assessment of valve movements in two groups of up to 42 zebra mussels (Dreissena polymorpha). Every 5 minutes, the percentage of open mussels and the average number of valve movements per mussel are calculated to describe the activity behaviour of the mussels. Rapid changes in both parameters normally reflect the onset of stress. More than 5½ years of experience in the continuous monitoring of water quality have revealed (1) that the "Dreissen-Monitor" is suited to large rivers like the Rhine as well as small rivers like the Erft or Ruhr, (2) that a lack of technical interruptions guarantees reliable, unattended operation, (3) that normally less than 3 hours of weekly maintenance are required, (4) that the validity check of the primary measurements was capable of identifying dead mussels and poorly aligned measurement components, (5) that the system can operate under unfavourable conditions (e.g. temperatures below 5°C), (6) that mortality rates were low and correlated positively with temperature, and (7) that the alarm thresholds provided a high degree of statistical security.

KEYWORDS

Biomonitoring; early warning system; Dreissena polymorpha; valve movements; Dreissena-Monitor

INTRODUCTION

In recent years, the physico-chemical techniques used to monitor water quality have been supplemented increasingly by biological early warning systems such as the "Kerren-Fischtest" (e.g. LWA, 1991). An important feature of these systems is their required ability to distinguish an alarm situation reliably from the background of normal (variable) behaviour (Caspers, 1988). Further requirements are (1) reliable, unattended operation, (2) ease of handling and low maintenance, and (3) automatic detection of alarm situations (Jenner et al., 1989). The "Dreissen-Monitor" reported by Borcherding (1992, in press) is an early warning system that fulfils these requirements, and is based on a computer assessment of valve movements in the zebra mussel Dreissena polymorpha. This organism is native to control Middle European aquatic environments, which often require a continuous assessment of their water quality.
The valve movements of mussels in the "Dreissena-Monitor" are measured using a reed switch associated with a small magnet glued to the top of one of the valves of each of the 42 mussels exposed in each of two experimental channels (only one is shown in Fig. 1). At intervals of 1 second, a computer registers the number of mussels with their valves open or closed. Activity behaviour of the mussels is determined from computations made every five minutes of the percentage of open mussels and the mean number of valve movements per mussel. Previous knowledge of the mussels' normal behaviour and their reactions to toxicants were used to define alarm thresholds for the detection of a threatening situation (Borcherding, submitted). In addition to these primary measurements and the automatic alarm detection, the computer also conducts a number of ancillary functions necessary for the early warning system, e.g. storage and documentation of all data, validity check of the primary measurements, and graphic presentation of all results.

RESULTS AND DISCUSSION

Since installation of the first "Dreissena-Monitor" in December 1990 in the River Rhine at the Bad Honnef control station, further systems have been put into operation at a number of water analysis stations: Bergheim on the River Erft in April 1991 (Mader, 1993), Fröndenberg on the River Ruhr in June 1992, Karlsruhe on the River Rhine in July 1992, Frankfurt on the River Main in April 1992 for 5 months, and Koblenz on the River Rhine in October 1992 for nearly 2 months. During this total of more than 5½ years of operation, the "Dreissena-Monitor" functioned without any technical problems in unattended analysis containers (with once-weekly maintenance) as well as in continuously-supervised analysis stations. The maintenance time ranged between 1 and 4 hours per week, depending on the fouling intensity in summer, and the mortality rate of Dreissena which increased proportionally with temperature (Fig. 2). A validity check incorporated into the "Dreissena-Monitor" notifies the operator of potential mussel mortality. This function checks whether (1) the mussel can be expected to be dead (their valves remain open), (2) the magnet has become detached from the valve, or (3) the reed switch is poorly aligned in relation to the magnet. If any of these situations arise, the mussel is excluded from further measurements and this is indicated to the operator. In this way the "Dreissena-Monitor" is capable of identifying the mussels which can be assumed to be providing false information. In practice, during the continuous monitoring of water quality, the dead mussels were normally all identified. Along with those mussels where the reed switch had come out of alignment, around 10 of the 42 individuals in each experimental channel...
had been excluded by the end of a given week. Thus there was always an adequate safety margin above the minimum registration of 24 active mussels needed for reliable operation (Borcherding, 1992).

The avoidance of false alarms is of prime importance when designing the automatic alarm detection of an early warning system (Caspers, 1988). Borcherding (submitted) used a novel approach for assessing the automatic alarm criteria in the "Dreissena-Monitor". This was based on extensive experience gained on both the normal mussel behaviour and their reactions to toxicants. The "Dreissena-Monitor" calculates dynamic limits for both activity parameters and combines them to yield various levels of alarm criteria. Additionally, the final alarm criterium, the so-called water alarm, reflects the combined evaluation of both experimental channels. Thus, the statistical probability of a false alarm is about once in 2½ years (Borcherding, submitted). This theoretical calculation was verified during the last 1½ years in the River Rhine at the Bad Honnef control station, where no false alarms were given. Regarding the sensitivity of the system, results of a toxicity test with pentachlorophenol in the River Rhine demonstrated that the "Dreissena-Monitor" could detect this toxicant at a comparatively low level, even at temperatures below 3° C (Borcherding, 1992). Alarm situations that arose during the continuous monitoring of water quality in the rivers Erft and Ruhr were sometimes detected by the "Dreissena-Monitor". These water alarms were undoubtedly the result of stress situations for the mussels, although the causal connection to specific toxicants has yet to be established (e.g. Mader 1993).

CONCLUSIONS

Its application in the continuous monitoring of water quality has demonstrated that the "Dreissena-Monitor" complies with the main functional requirements outlined by Jenner et al. (1989): (1) reliable, unattended operation for at least one week, (2) ease of handling, (3) an average of less than three hours of maintenance per week, and (4) automatic detection of alarm situations. In particular, the alarm functions achieve a good balance between a high level of sensitivity and the necessary avoidance of false alarms. Thus the "Dreissena-Monitor" offers the high degree of reliability strived for in the continuous monitoring of water quality.

ACKNOWLEDGEMENT

Our thanks are due to Prof. Dr. D. Neumann for his support of this work. The support given by the LWA NW is gratefully acknowledged. We thank Dr. D. Fiebig for improving the English text. This study was supported by a grant from the "Umweltbu.desamt Berlin" to Prof. Neumann (F+E Vorhaben 108 02 088).

REFERENCES


