MÝVATN-LAXÁ RAMSAR SITE - A CASE OF INTEGRATED MONITORING

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Abstract

Waterfowl populations at Lake Mývatn and River Laxá, Iceland, have been monitored since 1975. A hypothesis that the local populations of breeding waterfowl are determined by the food supply on the breeding grounds stimulated monitoring of the most abundant food species. Chironomid midges have been monitored since 1977. The record of two duck species, the Wigeon (*Anas penelope*) and Common Scoter (*Melanitta nigra*) and a critical food, chironomid midges, is used to illustrate how analyses of time lags can generate hypotheses about the causes of population changes in waterfowl. The records of waterfowl numbers, and also the catch of Brown Trout (*Salmo trutta*), suggest a close relationship with food conditions. A record of egg harvesting, going back to 1901, also indicates a close link with food conditions on the breeding grounds. By employing palaeolimnological methods it has been possible to gain a better historical perspective and assess the stability of the ecosystem.

Einarsson, Á.: **Mývatn-Laxá RAMSAR Gebiet - ein Fallbeispiel für integriertes Monitoring**

Monitoring von Wasservogelpopulationen wird am Mývatn-See und am Laxá-Fluß seit 1975 durchgeführt. Aufgrund der Hypothese, daß die lokale Brutpopulation der Wasservögel vom Nahrungsangebot an den Brutplätzen bestimmt wird, begann man mit Monitoringstudien an den abundanten Nahrungsarten. Seit 1977 findet Monitoring an Chironomiden statt. Daten über zwei Entenarten, Pfeifente (*Anas penelope*) und Trauerente (*Melanitta nigra*) und über Chironomiden als Nahrung, sollen illustrieren wie die Analyse von Zeitverschiebungen zu Hypothesen über die Ursachen von Populationsschwankungen bei Wasservögeln führt. Angaben über Wasservogelbestände und Forellenfangergebnisse (*Salmo trutta*) lassen einen engen Zusammenhang zu den Nahrungsbedingungen vermuten. Daten über die Ernte von Eiern, die bis 1901 zurückreichen, zeigen ebenfalls enge Beziehungen zu den Nahrungsgrundlagen an den Brutplätzen. Durch palaeolimnologische Methoden wurde es möglich, eine bessere historische Einsicht zu gewinnen und die Stabilität des Ökosystems zu erfassen.

Einarsson, Á.: **Ramsarská lokalita Mývatn-Laxá - příklad integrovaného monitorování**

Populace vodního ptactva na jezeře Mývatn a řece Laxá na Islandu jsou monitorovány od roku 1975. Hypotéza, že místní populace hnízdícího vodního ptactva jsou závislé na zdroji potravy na hnízdištích, byla podnětem k monitorování nejrozšířenějších druhů potravy. Populace pakomárů jsou monitorovány od roku 1977. Analýzy populačních dat dvou druhů kachen hvízdáka (*Anas penelope*) a turpana černého (*Melanitta nigra*) a jejich základní potravy larev pakomárů jsou základem hypotéz o příčinách populačních změn vodního ptactva. Počty vodních ptáků i úlovky pstruha (*Salmo trutta*) ukázaly těsnou závislost na potravě, stejně jako údaje o sběru vajec, které se datují od roku 1901. Paleolimnologické analýzy poskytly přesnější historické údaje a tak umožnily zhodnocení stability ekosystému.

INTRODUCTION

Lake Mývatn is a large (37 km^2), shallow, eutrophic lake in a region of active volcanism in Iceland. The landscape is shaped by volcanism and the present lake was created only about 2300 years ago by a volcanic eruption which poured large volumes of lava over the district. The lake rests in a shallow depression in the lava-field. The lake and its outflowing river - the Laxá - have a worldwide reputation as a breeding and moulting place for waterfowl, especially ducks. Iceland is situated on biogeographical crossroads, between North America and Eurasia, and the Arctic and the Boreal regions. This results in a unique species composition of waterfowl at Mývatn. Larvae of Diptera constitute the most important food for the ducks and the local fish populations. In the lake chironomids dominate, but in the river *Simulium* is the dominant food species. The name "Mývatn" literally means "lake of midges" and reflects the large amounts of these flies on the banks (see JÓNASSON, ed., 1979).

The lake and the river were protected by law in 1974, and in 1978 designated on the RAMSAR list of wetlands of international importance. Large changes had been observed in populations of both the vertebrates and the invertebrates in the preceding years, and there were fears that recent industrial development (mining of the lake sediment for diatomite production, commencing in 1967) was harming the ecosystem. A research station was established in 1974 and among its earliest aims was to monitor the animal populations. The current monitoring programme started with bird censuses in 1975, but more animal populations were included later. The programme developed hand in hand with our knowledge of the ecosystem which increased considerably during the first years. Academic interest in the lake is high and interaction between the monitoring and academic research activities has played a crucial role in the development of the monitoring. At the same time, all the now familiar questions about the purpose and limitations of monitoring have emerged, - if not in the beginning then in retrospect. In this paper I should like to use examples from our monitoring programme and related research to illustrate how monitoring data can be used to gain insight into the processes at work within the ecosystem.

AIMS AND PRINCIPLES

Monitoring has been defined in various ways (cf. GOLDSMITH, 1991 and SPELLERBERG, 1991) but here I shall use a definition which suits the Mývatn situation: "Monitoring is a long-sighted, systematic and repeated documentation of populations and their habitats." This definition is population oriented, rather than focusing on environmental quality as displayed by chemical and physical parameters.

There are two main aims of monitoring. One is to aid conservation, the other to promote understanding of the ecosystem. These two aims interact: better understanding of the ecosystem helps conservation. Collection of data may, however, be done purely out of academic interest. The aims of monitoring can be defined further:

a. To be an alarm bell, i.e. to give early notice that unwanted changes may be taking place.
b. To provide information on base line variation in the ecosystem.
c. To observe how perturbations travel through the ecosystem in order to highlight hypotheses about causal links.
d. To assess the efficiency of management measures.

The aims may vary from place to place, depending on the characteristics of the ecosystem, the type of threat, if any, and the political environment. The usefulness and limitations of monitoring for detecting environmental stress in natural populations has been discussed by UNDERWOOD (1989); see also CARPENTER (1988) for discussions about temporal variability in freshwater ecosystems.

EXAMPLES OF MONITORING

When monitoring of animal populations started in 1975 there were clear signs of a poor situation in the waterfowl populations. Waterfowl has a relatively high conservation value, and seems suitable as an indicator of the general situation of the area because there are many species with different requirements. Also, waterfowl can be counted rather easily. So when comparing cost and efficiency, waterfowl was the obvious choice for starting a monitoring programme. As examples I should like to take the Common Scoter (*Melanitta nigra*) and the Wigeon (*Anas penelope*), a diving duck and a dabbling duck (Fig. 1). The numbers in spring of these two species vary about 2-3 fold. Periods of increase may last 6-8 years, decreases seem to take a shorter time. The variation is large enough to conceal a long term trend, if it exists.

Why do these changes occur? At the outset there were indications that recent changes in the duck populations were linked with food abundance in the lake. Older historical data suggested that this might be the rule. Chironomid midges were known to be the most important food (BENGTSON 1971, GARDARSSON 1979). The Common Scoter, like most other diving ducks, takes the chironomid larvae on the bottom of the lake or picks the flies from the surface when they emerge. The Wigeon has to rely on flies on the water surface or larvae washed up on the shore with vegetation. Although the Wigeon is to a large extent a herbivore, midges comprise an important source of protein for the laying female and small young. Midge larvae in Mývatn can be divided into two groups. There is a group of infaunal species, with larvae living in the bottom mud. These are the most abundant ones, represented by *Tanytarsus* and *Chironomus* species. The other group of species has epifaunal larvae, crawling upon the bottom and moving about in vegetation. The epifaunal larvae are preferred by the diving ducks, probably because of greater accessibility.

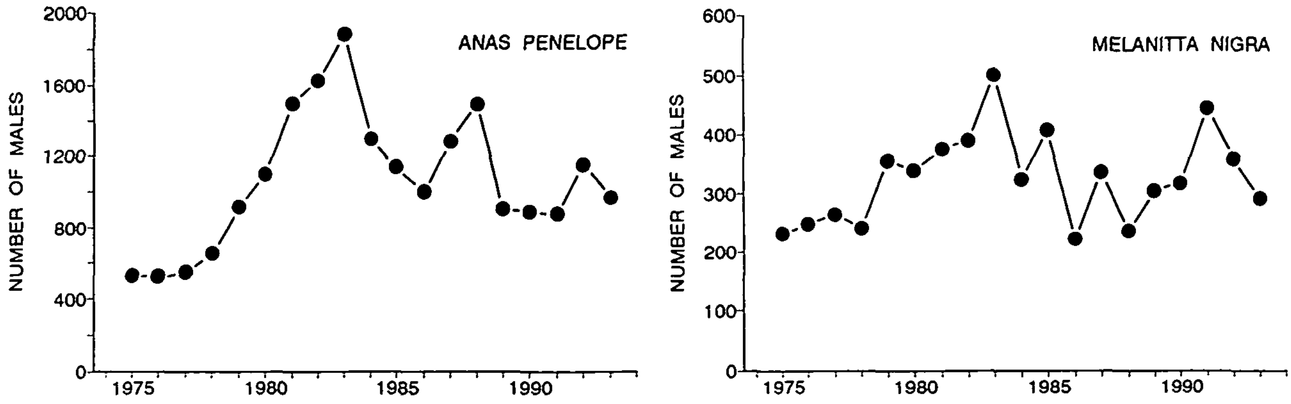

Fig. 1.: Numbers of male Wigeon (*Anas penelope*) and Common Scoter (*Melanitta nigra*) in spring in the Lake Mývatn area.

Monitoring of midges started in 1977. Specially designed window traps have been employed to catch flying insects (JONSSON et al. 1978). The traps are emptied at 7-10 day intervals in the summertime. About 50 different species of chironomid midges have been recorded, about 10 of which play a significant role in terms of abundance. The total catch of chironomid midges (Fig. 2) in 1977-89 shows fluctuations which suggest a link between the food supply and the duck populations (GARDARSSON & EINARSSON, in press).

We wanted to consider the question whether the duck numbers respond directly to the food situation or whether the response is through the production of young. In other words: do duck numbers increase because adults become attracted to richer food supplies or because they produce more young? By analysing time lags between changes in the food situation and changes in the duck populations we may learn which process is the more important. If the response is slow (long time lags) it becomes more likely that the population is reacting by increased production. Multiple regression analysis makes it possible to analyze the importance of several independent variables simultaneously.

As a dependent variable, we use the change that had occurred in duck numbers since the previous year. As independent variables, we use the catch of chironomid midges in the year (t) and the production of young in the previous year (t-1), two years earlier (t-2) and three years earlier (t-3). Analyzing longer time lags is hardly worth while in this case because too many data points will be lost.

The duck populations studied did not show significant correlations with the numbers of chironomid midges in the same year. This means that in spring the ducks do not react directly to the food supply. Both the Common Scoter and Wigeon numbers correlated with the number of young produced the year before. In the case of the Wigeon this is understandable because yearlings return to the breeding grounds. The response of the Common Scoter is more surprising because their young do not return to the breeding grounds until later. The one- year lag suggests that the adult birds "remember" the situation from last year. Good food conditions the previous summer may encourage the birds to return to Mývatn rather than going somewhere else. Perhaps they simply survive better.

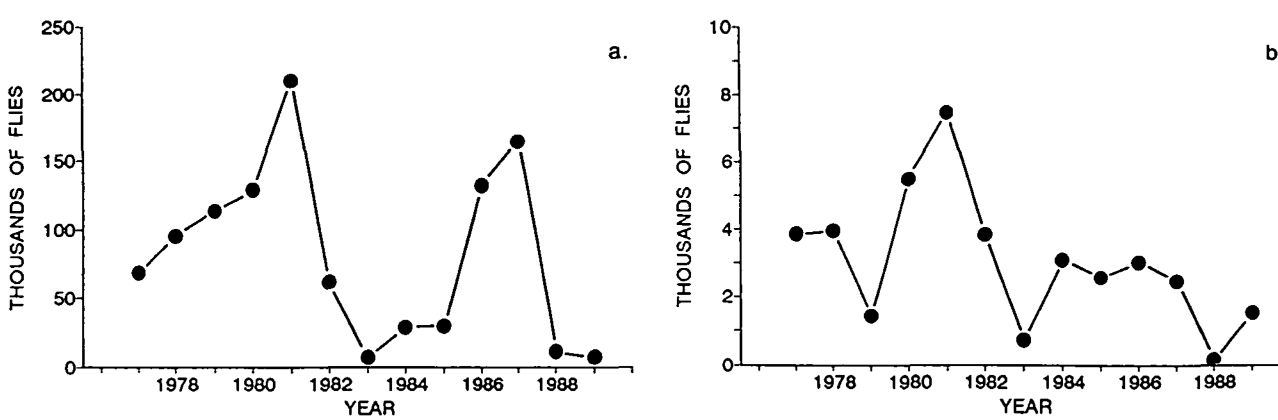

Fig. 2: Catches of adult chironomid midges in flytraps at Lake Mývatn. A: all chironomids; B: chironomid midges whose larvae are epifaunal. (Data from GARDARSSON & EINARSSON, in press)

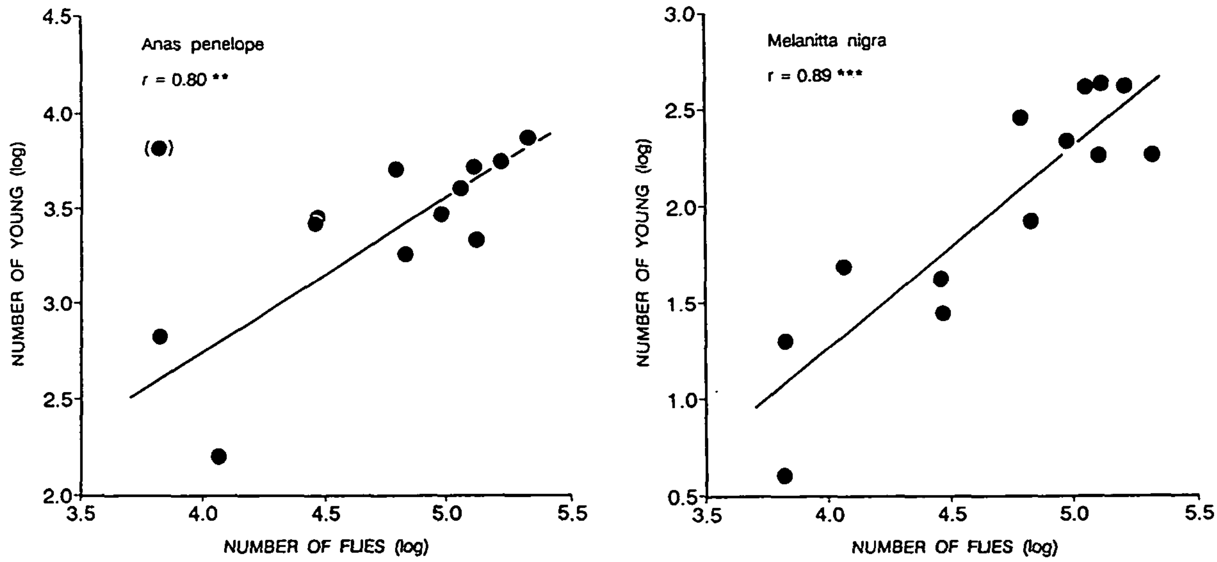

Fig. 3. Production of Wigeon (*Anas penelope*) and Common Scoter (*Melanitta nigra*) young in relation to the total catch of chironomid midges in fly traps. The data point in parentheses is excluded from the analysis. It is from 1983, when counting methods differed and resulted in an overestimation of production. (Data from GARDARSSON & EINARSSON, in press)

The young of the Common Scoter do return later, and a significant correlation occurs between the change in spring numbers and the production of young three years earlier (GARDARSSON & EINARSSON, in press).

We are aware of the pitfalls involved in correlating time series and also in relying too heavily on the results of multiple regression analyses. Our intention is to sort out the relationships which seem to be the most significant in order to get a better focus for future research.

The link with food can be further clarified by analyzing the relationship between the food situation and the production of young. The relationship is statistically significant for both species (Fig. 3).

The Brown Trout (*Salmo trutta*) in the River Laxá is another example of how monitoring of different trophic levels can be useful. Catch statistics (from angling) are available from 1976 onwards. The main food of the Brown Trout, the blackfly (*Simulium vittatum*), has been monitored with fly traps since 1977. A regression of the catch of trout on the food situation in the previous year indicates a significant relationship (Fig. 4) (GÍSLASON, in press).

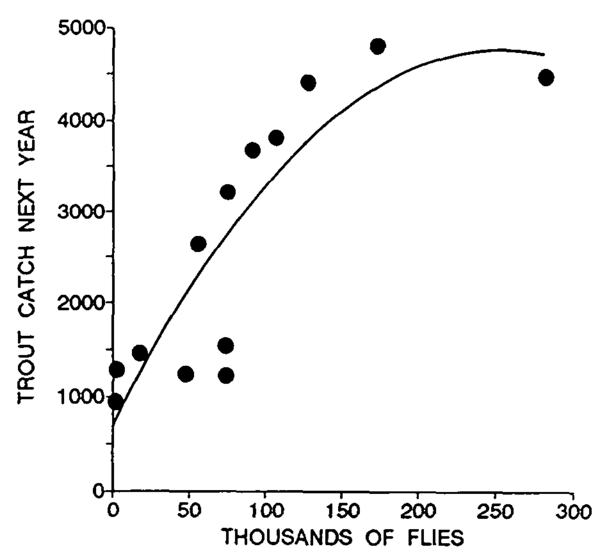

Fig. 4.: Catch by rod fishing of Brown Trout (*Salmo trutta*) in the River Laxá in relation to the previous year's catch of blackflies (*Simulium*) in flytraps. (Redrawn from GÍSLASON, in press).

The relationship is curvilinear: the total catch of Brown Trout seldom exceeds 4500 fishes. This is probably because of catch

restrictions, or alternatively, because at high food levels other environmental factors than food may become limiting.
In this example we can go further down the food chain. The blackfly larvae are filter feeders and planktonic algae (mostly *Anabaena flos-aquae*) and detritus drifting from the lake comprise their main food. The drift of algae varies considerably between years. A multiple regression analysis reveals a significant relationship between blackfly numbers and both drift of *Anabaena* and water temperature (GÍSLASON, in press).

HISTORICAL PERSPECTIVE

Very few biological monitoring programmes have been running for more than twenty years. This number of data points is minimal if we want to detect long term-trends, given the variation in the data. A search for historical data may be fruitful. Most often such information is based on harvest figures: fishing or hunting, and can be difficult to interpret because of varying and often unknown intensity of harvesting. At Mývatn we have fishing data from 1900 to the present day, also figures about harvesting of duck eggs from 1901 to 1957 (GUDMUNDSSON, 1979). The similarity of the harvest figures of Common Scoter (*Melanitta nigra*) and Long-tailed Duck (*Clangula hyemalis*) eggs is interesting (Fig. 5) (see GARDARSSON et al. 1988).
The similarity cannot be explained by changes in harvesting practice. The two duck populations have different wintering grounds, and these data indicate that changes in duck numbers at Mývatn are primarily governed by local processes rather than processes operating on the wintering grounds (GARDARSSON, 1979).
The historical perspective can be improved considerably by employing palaeolimnological methods. A number of techniques are available, which allow tracing the history of, e.g., chironomids, cladocerans, diatoms, chrysophyceans as well as plant pigments (e.g. HAWORTH & LUND, 1984; GRAY, 1988). This kind of information is useful in revealing the conditions in a wetland before, e.g. the industrial revolution or forest clearance, and also gives an indication of the long term stability of the ecosystem. Some of the microfossils in the sediment are derived from species which are important in the food web, such as the chironomid midge *Psectrocladius barbimanus* and the cladoceran *Eurycercus lamellatus* (Fig. 6). In Lake Mývatn, both species are associated with filamentous, mat-forming green algae (*Cladophora aegagropila*) on the bottom of the lake. Palaeolimnological studies indicate that in Lake Mývatn these species have been more common in the last 270 years than earlier in the history of the lake, which spans about 2300 years. This has been linked with a corresponding increase in *Cladophora* (EINARSSON & HAFLIDASON, 1988; EINARSSON et al., 1993).

DISCUSSION

Monitoring is, strictly speaking, an endless process and because of financial constraints we have to be selective about what to monitor and about the methods employed. We have to make efforts to combine low cost and high efficiency, and have to be certain that our methods will be valid for a long time. At the same time, we should make efforts to identify the most important factors in the ecosystem, and I have demonstrated how a monitoring programme may be useful in this process, although by no means sufficient. I would like to stress the importance of having well formulated hypotheses, preferably more than one, about the crucial factors determining the populations in question, be it animals or plants. Equally important is to formulate hypotheses about the impact of man-induced changes.

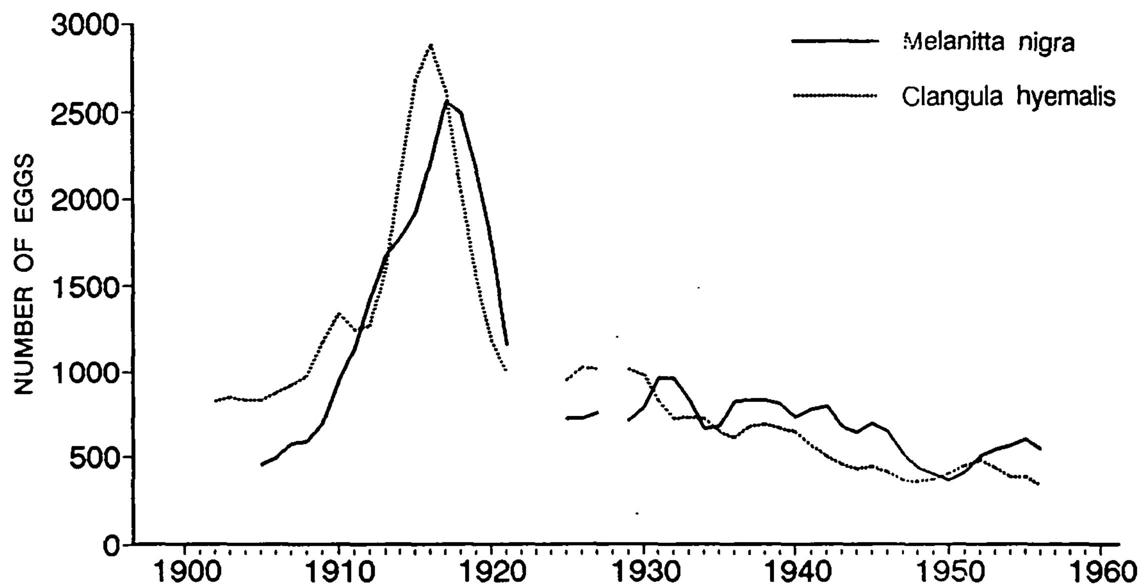

Fig. 5. Harvest of eggs of Long-tailed Duck (*Clangula hyemalis*) and Common Scoter (*Melanitta nigra*) at Mývatn 1901-1957. Three years running averages. (Data from GUDMUNDSSON, 1979).

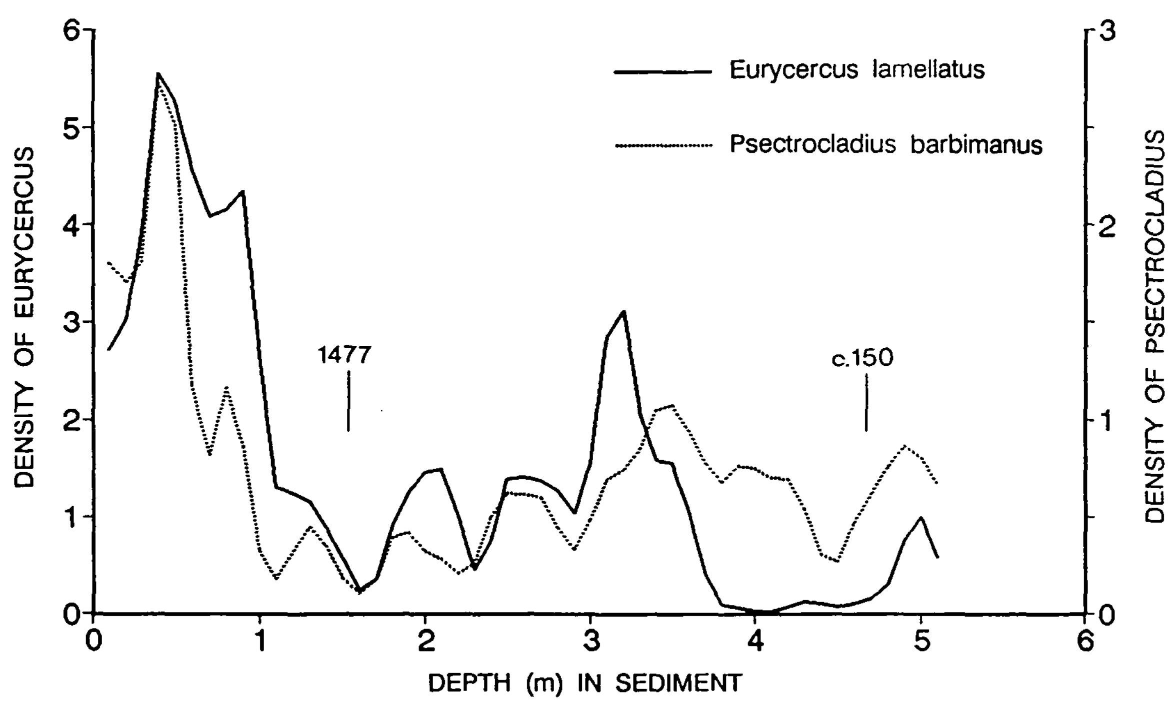

Fig. 6.: A palaeolimnological record of 2300 years of the chironomid *Psectrocladius* and the cladoceran *Eurycercus* from the Lake Mývatn sediment. The location of two dated volcanic ash layers (A.D. 1477 and A.D. 150) is also shown. The densities are thousands of fragments per g organic sediment. Redrawn from EINARSSON & HAFLIDASON (1988).

The problem most of us are faced with is the lack of baseline data. The need for monitoring a piece of wetland does not become generally recognized until after the threat is there and after symptoms have emerged. We normally do not know the so-called natural variation in the ecosystem or the variation that existed before the most recent threat was realized. The frequent lack of control is also frustrating: quite often we are dealing with some precious piece of wetland, and there is no other Lake Mývatn to compare with. And even though there was a similar lake, because of cost considerations we have to choose whether to spread the effort and run a parallel monitoring programme in the control lake or whether we should concentrate on our own lake that we know so much about already. There is no golden rule. Each case is in some way special and what we do depends on the local situation and the hypotheses posed.

Each wetland has its characteristics and ecological principles can only be applied in a rather general way. Therefore we must formulate hypotheses about the dynamics of the specific wetland we are interested in. Hypotheses, as a tool of science, have an important property: they have to be falsifiable, and furthermore, every effort should be made to prove them wrong. What then is the value of letting hypotheses govern our choice about what to monitor if we run the risk of spending time and money for years in watching a parameter which may prove unimportant? The answer lies in the long-term objective. Only by understanding the functioning of the ecosystem can we hope to be able to deal properly with future threats. Only by rejecting hypotheses can we drop some parameters from our monitoring programme and make it cheaper. All hypotheses about function have to take into account the long term variation, or stability, of the parameters involved, and this is one reason why monitoring becomes an important practice. This process may take a while and needs constant attendance by interested scientists, carrying out well designed research projects.

The food web is a fundamental feature of the ecosystem. When unexpected changes occur in an animal population, changes in the food situation should be suspected. Monitoring different trophic levels at Lake Mývatn and River Laxá has been especially rewarding in this respect. Statistically significant relationships within the food web, like the ones I have presented here, are stimulating, because they suggest that we might be on the right track. But the lack of significant relationship between two time series is equally important, especially in the light of hypothesis testing. Food web studies are gaining more attention because of recent crystallization of theories about the controlling factors of lake communities ("top down" and "bottom up") (see KERFOOT & SIH, 1987; MCQUEEN et al., 1989). I would not like to say that we should concentrate all our effort on food webs. By doing so we may miss other important parameters. But omitting the study of the food web seems to be unwise.

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