Changes in the littoral macroinvertebrate assemblages of Oak Mere from 1980 to 1998

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Abstract
Data on the macroinvertebrate assemblages of Oak Mere, England are presented for the period 1980 to 1998. There was a marked fall in species richness and numbers of individuals associated with a fall in surface level. Correlations between surface level, areas of vegetation and aspects of the macroinvertebrate assemblages are demonstrated.

Keywords: Macroinvertebrates, Oak Mere, species richness

Introduction
A series of groups of lakes associated with the terminal moraines of the last glaciation stretch across the north temperate zone. Most of these lakes lie in lowland glacial drift plains and are eutrophic. Oak Mere (grid reference SJ 575677) is one of a total of approximately 60 lakes (meres) lying in the lowland glacial drift plain of the north-west Midlands, England (Reynolds 1979). These meres comprise a series of groups of small lakes with areas of 1–51 ha (mean 11.7 ha) lying at altitudes ranging from 16 to 122 m above sea level (mean 75 m). Their geographical positions are associated with the terminal moraine of the Weichselian (Devensian) glaciation (Reynolds 1979; Savage et al. 1992). The great majority of the meres contain alkaline water with relatively high concentrations of calcium ions, bicarbonate ions and nutrients. They have stable surface levels and are at least partially bordered by emergent marginal vegetation which has a characteristic macroinvertebrate fauna. They are naturally base-rich eutrophic lakes. Oak Mere is unique among the meres owing to its acid water containing very low concentrations of calcium and bicarbonate ions but moderate amounts of nutrients (Swale 1968; Reynolds 1978). However, in the present context, an important characteristic of Oak Mere is its naturally fluctuating surface level. Emergent marginal vegetation has only been observed in quantity when surface levels were high and submerged vegetation intermittently (A. A. Savage, personal observations, 1970–1998). The macroinvertebrate fauna is different from other lakes of the north-west Midlands. Thus, it may be described as a base-poor mesotrophic lake.
Observations on regulated natural lakes and artificial reservoirs show that changes in water level are associated with changes in the macroinvertebrate fauna (e.g. Macan 1970; Hynes and Yadov 1985). These changes are probably mediated by changes in vegetation. Emergent and submerged macrophytes have long been recognized as refuges for aquatic animals (e.g. Krecker 1939). Other authors have emphasized the importance of the density and species composition of macrophytes on the quantitative and qualitative nature of the macroinvertebrate fauna (e.g. Dvorak and Best 1982; Parsons and Matthews 1995).

Oak Mere, with its naturally fluctuating surface level and unstable emergent and submerged macrophytes, provides a natural, if uncontrolled, experiment on the effect of these factors on the macroinvertebrate assemblages (Savage and Beaumont 1997; Savage et al. 1998).

The aim of the present paper is to summarize the changes in macroinvertebrate assemblages from 1980 to 1998. Detailed descriptions of Oak Mere may be found in three earlier papers (Lind 1951; Savage 1986; Savage et al. 1992).

**Methods**

Qualitative and quantitative collections of vegetation and macroinvertebrates were made in the littoral zone in October 1980, 1994, 1996, 1997 and 1998. The marginal vegetation was mapped continuously along 100 m of shore. The macroinvertebrates were collected by 10–30 standard samples although there were slight variations according to the nature of the substrata. The lake was briefly sampled in 1983, 1986 and 1989 to check whether any changes had occurred. For full details see Savage and Beaumont (1997) and Savage et al. (1998).

**Results and discussion**

**Lake morphometry**

Oak Mere stands at approximately 73 m above sea level, occupies an area varying from 15.5 to 23 ha and the depth varied by approximately 1.5 m during the period 1977 to 1998. The available records for lake area and surface level show a highly significant linear correlation in the littoral zone ($y = 22.9 - 5.3x$, $r = 0.997$, $P < 0.001$, $n = 7$). The lake surface level increased steadily from 1977 to 1981 and reached a maximum in 1986 and fell steadily until 1991. Between 1992 and 1994 there was a rapid fall in level (reported to us by the owner, Mr W. Fergusson). The lake then remained at a low level until 1997 followed by a rapid rise in 1998. There was a Spearman Rank correlation ($r_s$) of 1 ($P = 0.01$, $n = 5$) between lake level and number of macroinvertebrates (Table I).

**Vegetation**

Former studies of Oak Mere when water levels were high have indicated that the macrophyte vegetation was usually divisible into an emergent marginal zone, composed principally of *Juncus effusus* L., *Juncus bulbosus* L. and *Carex rostrata* Stokes, and a submerged zone either contiguous with the marginal zone or some 5 m off-shore composed almost exclusively of *Littorella uniflora* (L.) Aschers. (Savage 1986; Savage and Beaumont 1997; Savage et al. 1998). This was the situation in 1980 and inspections showed that it remained so until 1992. In 1994, after the fall in surface level, marginal and submerged...
vegetation was virtually absent. Recolonization soon began and from 1996 to 1998 the marginal vegetation zone consisted mainly of *J. effusus* and *J. bulbosus* with just a few plants of *L. uniflora*. The distribution of plants was sparse in 1996 and 1997 but many times more extensive in 1998 owing to the rise in water level. The areas of emergent vegetation were large in 1980 and 1998 but small in the other three years (Table I).

There was a Spearman Rank correlation ($r_s$) of 0.9 ($P=0.05$, $n=5$) between area of vegetation and number of macroinvertebrates (Table I).

**Macroinvertebrates**

A total of 76 macroinvertebrate taxa was recorded over the 18-year period (Table II). Of the 64 taxa (species richness) in 1980, 50 were not recorded again in future years although 12 new taxa were found. In later years species richness varied between 9 and 17. Thus the most notable event was the very large fall in species richness associated with the fall in surface level during the early years of the study.

In 1990 the commonest invertebrates were insects with 55 taxa present (Table II). All groups were reduced markedly but, proportionately, they continued to form an important part of species richness with nine new species. In contrast molluscs, leeches (Hirudinea), Crustaceans and stone flies (Plecoptera) were not found after 1980.

Only three taxa were found in all years of the survey, namely *Leptophlebia vespertina*, Chironomidae and Leptoceridae, all insects. Again only three taxa were found in four years, namely *Polycelis nigra*, *Coenagrion puella* and *Hygrotus inaequalis*. Thus five of the six most frequently occurring taxa were insects. All six taxa were present in the 1980 collections.

There was no correlation between species richness and either surface level or area of vegetation in contrast with number of individuals (Table I). Even here the relationship was largely owing to the numbers of *Leptophlebia vespertina*.

Water chemistry may be divided into two main aspects, namely nutrient ions (resources) and major ions (conditions). Examples of the former are silicate, phosphate and nitrate while examples of the latter are sodium, potassium, calcium, magnesium, sulphate, chloride and bicarbonate. The resources have varied in Oak Mere, mainly seasonally, but there have been no major changes or trends in conditions over the past half century, including 1980 to 1998 (Lind 1951; Reynolds 1979; Savage et al. 1992, 1998). We are aware that the north-west Midlands meres in general have been subject to slight eutrophication in recent decades but Oak Mere appears to be an exception to this trend. Thus, it is extremely unlikely that conditions have affected the macroinvertebrate fauna.

In contrast, the presence of emergent and submerged macrophytes has long been recognized as a refuge for aquatic animals (e.g. Krecker 1939). Dvorak and Best (1982) found that the density of macrophytes on a lake substratum had a profound effect on the
Table II. The benthic macroinvertebrate taxa recorded (X) in Oak Mere from 1980 to 1998.

| Species                         | 1980 | 1994 | 1996 | 1997 | 1998 | 1980–1998 |
|---------------------------------|------|------|------|------|------|-----------|
|                                 | Lost | Gained |      |      |      |           |
| Coelenterata                    |      |       |      |      |      |           |
| Hydra spp.                      | X    | 0     | X    | X    | 0    | 0         |
| Platyhelminthes                 |      |       |      |      |      |           |
| *Polycladus nigra* (Müller)     | X    | X     | X    | X    | 0    | 0         |
| Mollusca                        |      |       |      |      |      |           |
| *Lymnaea peregra* (Müller)      | X    | 0     | 0    | 0    | 0    | 1         |
| *Planorbis albus* (Müller)      | X    | 0     | 0    | 0    | 0    | 0         |
| *Pisidium obtusale* (Lamarck)   | X    | 0     | 0    | 0    | 0    | 0         |
| Annelida                        |      |       |      |      |      |           |
| *Haemopis sanguisuga* (L.)      | X    | 0     | 0    | 0    | 0    | 1         |
| *Theromyzon tessulatum* (Müller)| X    | 0     | 0    | 0    | 0    | 0         |
| Oligochaeta                     | 0    | X     | X    | X    | 0    | 1         |
| Hydracarina                     |      |       |      |      |      |           |
| Hydrachnidae                    | 0    | 0     | X    | X    | X    | 1         |
| Araneae                         |      |       |      |      |      |           |
| *Agyroneta aquatica* (Clerck)   | 0    | 0     | X    | X    | 0    | 0         |
| Crustacea                       |      |       |      |      |      |           |
| *Asellus meridians* (Racovitza)| X    | 0     | 0    | 0    | 0    | 0         |
| Insecta                         |      |       |      |      |      |           |
| Ephemeroptera                   |      |       |      |      |      |           |
| *Cloeon dipterum* (L.)          | X    | 0     | 0    | 0    | 0    | 2         |
| *Cloeon similis* (Eaton)        | X    | 0     | 0    | 0    | 0    | 0         |
| *Leptophlebia vespertina* (L.)  | X    | X     | X    | X    | X    | 9         |
| Odonata                         |      |       |      |      |      |           |
| *Pyrrhosoma nymphula* (Sulzer)  | X    | 0     | 0    | 0    | 0    | 0         |
| *Ishmore elegans* (van der Linden)| X    | 0     | 0    | 0    | 0    | 0         |
| *Enallagma cyathigerum* (Charpentier)| X    | 0     | 0    | 0    | 0    | 0         |
| *Coenagrion puella* (L.)        | X    | 0     | X    | X    | X    | 0         |
| *Lestes sponsa* (Hansemann)     | X    | 0     | 0    | 0    | 0    | 0         |
| *Aeshna cyanea* (Müller)        | X    | 0     | 0    | 0    | 0    | 0         |
| *Aeshna grandis* (L.)           | X    | 0     | 0    | 0    | 0    | 0         |
| *Libellula quadrimaculata* (L.) | X    | 0     | 0    | 0    | 0    | 0         |
| *Symptetrum danas* (Sulzer)     | X    | 0     | 0    | 0    | 0    | 0         |
| *Symptetrum striolatum* (Charpentier)| X    | 0     | 0    | 0    | 0    | 0         |
| Plecoptera                      |      |       |      |      |      |           |
| *Nemoura cinerea* (Retzius)     | X    | 0     | 0    | 0    | 0    | 2         |
| *Perlodoides microcephala* (Pictet)| X    | 0     | 0    | 0    | 0    | 0         |
| Hemiptera                       |      |       |      |      |      |           |
| *Nepa cinerea* L.               | X    | 0     | X    | 0    | 0    | 7         |
| *Notonecta glauca* L.           | X    | 0     | X    | 0    | 0    | 1         |
| *Corixa punctata* (Illiger)     | X    | 0     | 0    | 0    | 0    | 0         |
| *Hesperocorixa limnai* (Fieber) | X    | 0     | 0    | 0    | 0    | 0         |
| *Sigara falleni* (Fieber)       | X    | 0     | 0    | 0    | 0    | 0         |
| *Sigara scotti* (Fieber)        | X    | 0     | 0    | 0    | X    | 0         |
| *Sigara semistriata* (Fieber)   | X    | 0     | 0    | 0    | 0    | 0         |
| *Sigara dorsalis* (Leach)       | X    | X     | X    | 0    | 0    | 0         |
| *Gallicorixa praestata* (Fieber)| 0    | X     | X    | 0    | 0    | 0         |
| Trichoptera                     |      |       |      |      |      |           |
| *Holocentropus dubius* (Rambur) | 0    | 0     | 0    | X    | 0    | 10        |
| *Holocentropus stagnalis* (Albarda)| X    | 0     | 0    | 0    | X    | 2         |
| *Agrypnia varia* (Fabricius)    | 0    | 0     | 0    | 0    | X    | 0         |
| *Agrypnia pagetana* (Curtis)    | X    | 0     | 0    | 0    | 0    | 0         |
| *Cyrnus flavidus* (McLachlan)   | X    | 0     | 0    | 0    | X    | 0         |
densities of macroinvertebrate communities. In their study of a eutrophic pond, Parsons and Matthews (1995) concluded that at least some macroinvertebrates depend on the stability and persistence of vegetative structures throughout the year for the direct and indirect provision of food and refuge. Hanson (1990) noted the importance of the species composition of aquatic macrophyte beds in influencing the quality and quantity of littoral zone macroinvertebrates and concludes that a change in species composition of macrophytes will alter the species composition of the macroinvertebrate assemblages. There is, then, ample evidence in the literature to support the hypothesis that the qualitative and quantitative nature of macrophytes in the littoral zone, here affected by surface level, has an effect on the benthic macroinvertebrate assemblages.

Table II. Continued.

| Species                        | 1980 | 1994 | 1996 | 1997 | 1998 | 1980–1998 | Lost | Gained |
|-------------------------------|------|------|------|------|------|-----------|------|--------|
| *Limnephilus griseus* (L.)    | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Limnephilus politus* (McLachlan) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Mystacides longicornis* (L.) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Triaenodes bicolor* (Curtis) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Oecetis lacustris* (Picot)   | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Molanna angustata* (Curtis)  | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Phryganea striata* (L.)      | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Phryganea* sp.               | X    | X    | 0    | X    | 0    | X         | 0    | 0      |
| *Leptoceridae*                | X    | X    | X    | X    | X    | X         | 0    | 0      |
| *Coleoptera*                  |      |      |      |      |      | 17        | 5    |        |
| *Haliplus confinis* (Stephens) | 0    | 0    | X    | 0    | 0    | X         | 0    | 0      |
| *Haliplus fluviatilis* (Aube) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Haliplus ruficollis* (Degeer) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Hygrobia hermanni* (Fabricius) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Noterus crassicornis* (Müller) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Lacophilus minutus* (L.)     | X    | 0    | 0    | 0    | X    | X         | 0    | 0      |
| *Hydroporus erythrecephalus* (L.) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Hydroporus palustris* (L.)   | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Hydroporus striola* (Gyllenhal) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Agabus sturni* (Gyllenhal)   | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Ilybius fenestratus* (Fabricius) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Ilybius fuliginosus* (Fabricius) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Ilybius subaeneus* (Erichson) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Rhantus exsoletus* (Forster) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Colybnetes fuscus* (L.)      | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Helochares lividus* (Forster) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Enochrus affinis* (Thunberg) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Enochrus testaceus* (Fabricius) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Oulimnius tuberculatus* (Müller) | X    | 0    | 0    | 0    | 0    | X         | 0    | 0      |
| *Oulimnius trogloides* (Gyllenhal) | 0    | X    | X    | X    | 0    | X         | 0    | 0      |
| *Hygrothus inaequalis* (Fabricius) | X    | X    | X    | X    | 0    | X         | 0    | 0      |
| *Potamonectes assimilis* (Paykull) | X    | X    | 0    | 0    | 0    | X         | 0    | 0      |
| *P. depressus depressus* (Fabricius) | 0    | X    | 0    | 0    | 0    | X         | 0    | 0      |
| *P. depressus elegans* (Panzer) | 0    | X    | 0    | 0    | 0    | X         | 0    | 0      |
| *Cercyon marinus* (Thompson)  | 0    | X    | X    | X    | 0    | X         | 0    | 0      |
| *Dytiscidae larvae*           | 0    | 0    | X    | 0    | X    | 0         | 0    | 1      |
| *Chironomidae*                | X    | X    | X    | X    | X    | X         | 0    | 1      |
| *Ceratopogonidae*             | 0    | 0    | X    | X    | 0    | 0         | 1    |        |
| Species richness              | 64   | 14   | 19   | 16   | 10   |           |      |        |
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