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ANALYSIS OF 1997 ZOOPLANKTON SAMPLES - LOCH LEVEN NNR

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SUMMARY

Zooplankton samples from Loch Leven were analysed for the period January to December, 1996. –These data were compared with zooplankton data from earlier years and related to changes in phytoplankton abundance.

Nine species of crustacea were found. These included *Cyclops vicinus* which had not been recorded here before. The crustacean zooplankton continued to be dominated by *Daphnia galeata* and *Cyclops abyssorum*, whose pattern of abundance was similar to that recorded in the early 1980s and in 1992, i.e. a spring/early summer maximum followed by an autumnal secondary peak. This contrasted with the much greater inter-annual variability of the intervening years (ie 1993-1995). In 1996, the crustacean zooplankton community population dynamics appeared to be related, primarily, to the prevailing algal conditions, rather than to any effect attributable to the recently introduced rainbow trout.

Seventeen species of rotifer were found. As in previous years, the dominant rotifer species in the loch were *Keratella cochlearis*, *Polyarthra dolichoptera*, *Keratella quadrata*, *Synchaeta oblonga* and *Pompholyx sulcata*. However, *Trichocerca pusilla*, which was previously considered a dominant species in the summer months, was almost completely absent. Most species continued to show a marked seasonality of occurrence. In the short term, rotifer abundance seemed to be inversely related to that of *Daphnia*. In the longer term, rotifer numbers seemed to be continuing the steady decline recorded in recent years.

The species composition of the zooplankton remains characteristic of an eutrophic waterbody. However, in general, the continuing decline in rotifer numbers seems to reflect the recent reductions in phosphorus load to the lake, suggesting that the loch becoming less productive.

CONTENTS

1. INTRODUCTION

For many years the eutrophic Loch Leven has been troubled by algal blooms, largely as a result of large amounts of phosphorus (P) entering the loch, combined with a relatively low flushing rate and a favourable light climate (Bailey-Watts *et al.*, 1994). Recent management of the loch has had the aim of reducing the risk of these algal blooms as well as improving the local fishery. This policy has resulted in inputs of P to the loch being reduced from 20.5 tonnes y^{-1} in 1985 to 10.5 tonnes y^{-1} in 1995 (Bailey-Watts and Kirika, 1997), and in the stocking of rainbow trout (Duncan, 1994).

Bailey-Watts (1978, 1982), Bailey-Watts *et al.* (1990) and May and Jones (1989) demonstrated that the overall abundance and species composition of the phytoplankton in Loch Leven is not only affected by the supply of nutrients (mainly P) but also by losses to the grazing activities of zooplankton, particularly the cladoceran *Daphnia*. Zooplankton are also important for providing a food source for fish such as brown and rainbow trout (Thorpe, 1974; Duncan, 1994) as well as being considered to be useful indicators of water quality, especially in relation to trophic status (Maitland *et al.*, 1981; Pejler, 1981; Jones, 1984; Bērziņš and Pejler, 1989; Pontin and Langley, 1993).

Routine monitoring of the zooplankton in Loch Leven began in the late 1960's (Johnson and Walker, 1974) as part of the International Biological Programme. However, sampling became more sporadic during the 1980's due to lack of suitable funding (May *et al.*, 1993). Regular sampling was not resumed until 1992, when public concern about the state of the loch was fuelled by the appearance of severe blue-green algal blooms during the summer months. Since then, the analysis of zooplankton samples collected at weekly or fortnightly intervals throughout the year has been funded on an annual basis by Scottish Natural Heritage. This has helped maintain the continuity of data needed to distinguish long-term changes in abundance and species composition from short-term temporal variation.

This report describes temporal variation in the species composition and abundance of the crustacean and rotifer zooplankton communities in Loch Leven during 1997. The data are compared with zooplankton data from earlier years and related to changes in phytoplankton abundance as well as the recent changes in the management of Loch Leven.

2. METHODS

2.1. Crustacean zooplankton

2.1.1. *Field sampling*

Samples of crustacean zooplankton were taken at the Sluices, South Deeps and Reed Bower sites during 1997 (**Figure 1**). These three sites were sampled throughout the year at fortnightly intervals from January to the beginning of June, weekly throughout the summer months and fortnightly again from the middle of October, onwards.

All open water samples were collected and concentrated with a plankton net (mesh size 118 μm), which was drawn slowly to the water's surface from a depth of 4.5 m at the South Deeps and from a depth of 4 m at the Reed Bower site. At the Sluices and the Public Pier, samples were normally taken with a bucket and, subsequently, concentrated by passing the sample through a zooplankton net (mesh size 118 μm). All of the samples were preserved with 4% formaldehyde.

2.1.2. *Laboratory analyses*

The samples were placed in a glass vessel and made up to a final volume of 250 ml with distilled water. Each sample was thoroughly mixed, to distribute the animals randomly, and then sub-sampled with a Stempel pipette (volume 5 ml). The animals present in each sub-sample were identified (Flößner and Kraus, 1986; Harding and Smith, 1974; Scourfield and Harding, 1966;) and counted under a low power binocular microscope. In most cases, three sub-samples were examined. The sub-sample counts were converted to numbers of individuals per litre using appropriate multiplication factors.

2.2. Rotifer zooplankton

2.2.1. *Field sampling*

Rotifer samples were collected at fortnightly intervals from January to the middle of April and from mid-October to December, and weekly during the summer months. On most occasions, samples were collected from both the Reed Bower and Sluices sampling sites (**Figure 1**) but, during bad weather, the Public Pier and Sluices sites were used instead.

The Reed Bower samples were taken with a 2 m Marley® plastic drainpipe, 5 cm in internal diameter, while those from the shallower Sluices and Public Pier sites were taken with a bucket from just below the water's surface. Each sample was mixed thoroughly and a 500-ml subsample was taken for counting. Sufficient procaine hydrochloride was then added to each sample to give a final concentration of approximately 0.04%. This relaxed the soft-bodied forms allowing preserved specimens to be identified more easily during the counting process (May, 1985). Each subsample was preserved with 4% formaldehyde approximately 12 h after collection.

2.2.2. *Laboratory analyses*

The rotifers were concentrated by sedimenting in glass measuring cylinders and siphoning off the water to give a final volume of 30 ml or 45 ml, depending on the density of material in the sample. In contrast to many other studies, plankton nets and sieves were not used to concentrate rotifer samples, as these can lead to significant under estimates of abundance (Bottrell *et al.*, 1976; Orcutt & Pace, 1984).

The rotifers were identified according to Koste (1978) and counted with an inverted microscope at x20 magnification. When rotifer numbers were high, the samples were randomly subsampled before counting. Several subsamples were examined in turn until either the entire sample had been enumerated or until at least 200 individuals had been counted.

3. RESULTS

3.1. Crustacean zooplankton

3.1.1. *Species list*

The list of seven crustacea species found in Loch Leven (**Table 1**) is basically similar to that recorded in earlier years (*cf.* May *et al.*, 1993; Gunn *et al.*, 1994; Gunn and May, 1995: Gunn and May, 1996: Gunn and May, 1997). One uncommon species recorded during 1997 was

Table 1. Crustacean zooplankton species recorded from Loch Leven during 1997.

Cladocera (Branchiopoda)

Anomopoda

Daphnia galeata Sars (formerly *D. hyalina* var *lacustris* Sars)*
Chydorus sphaericus (O. F. Müller)
Bosmina longirostris (O. F. Müller)

Haplopoda

Leptodora kindti (Focke)

Onychopoda

Bythotrephes longimanus Leydig

Copepoda

Calanoida

Eudiaptomus gracilis (Sars) (formerly *Diaptomus gracilis* Sars)

Cyclopoida

Cyclops abyssorum Sars (formerly *Cyclops strenuus abyssorum* Sars)

* see below

Bosmina longirostris. A single specimen of this planktonic species, typical of large alkaline water bodies (Fryer, 1993), was found in June. However, overall, there was a slight, but probably insignificant, decrease in species diversity from the nine species recorded in 1996 to seven in 1997. Those species which were recorded in 1996 but not 1997 were *Alona quadrangularis*, *Cyclops vicinus* and *Macrocyclops albidus*, All of these species have only been sporadically recorded in previous years.

There remains some uncertainty about the correct identification of the *Daphnia* species assigned to *D. galeata* in **Table 1.** This is because of the wide range of morphological variation that exists in the *D. hyalina-galeata* complex according to age, season and habitat (see Gunn and May, 1996).

3.1.2. *Abundance*

The population dynamics of the main crustacean zooplankton species are shown in **Figure 2.** The crustacean zooplankton community was co-dominated by *Daphnia galeata* and *Cyclops abyssorum*, while *Eudiaptomus gracilis* was found in smaller numbers. The large predatory cladocerans, *Leptodora kindti* and *Bythotrephes longimanus*, were relatively rare.

The main features of the population dynamics are as follows:

(a) Population densities of *Daphnia* were very low (<3 ind.l^{-1}) during the first four months of 1997. This was followed by a rapid increase in numbers during May which enabled the population to reach a peak of 23.9 ind. l^{-1} in late June. Numbers declined to relatively low densities of less than 9 ind.l^{-1} during July and early August before increasing again to an annual maximum of 34.7 ind. l^{-1} in early September. The *Daphnia* population then declined again and remained at low overwintering levels of about 2 ind.l^{-1} for the remainder of the year. The population dynamics of *Daphnia* were of a similar pattern to 1996 with the exception that the maximum peak in numbers occurred in the autumn rather than in the early summer.

(b) The concentrations of *Cyclops* nauplii, copepodites and adults were very low until the end of March when they began to increase, reaching a maximum of 89.4 ind.l^{-1} in mid -June. The *Cyclops* population declined rapidly after the beginning of June, thereafter maintaining concentrations of less than 7 ind.l^{-1} for the remainder of the year, apart from an increase in numbers to30.10 ind.l^{-1} in the beginning of November. This represents a marked increase in population density compared to 1996 although the seasonal pattern of occurrence of *Cyclops* was similar to previous years.

(c) *Eudiaptomus* densities remained at levels of less than 6 ind.l^{-1} for all of 1997, with numbers highest during the summer months. The population reached a maximum of 5.1 ind.l^{-1} in early July. After the beginning of August numbers remained at a level of less than 1 ind.l^{-1}.

(d) *Leptodora* and *Bythotrephes* occurred in extremely low numbers (<0.4 ind.l^{-1}) over the summer period.

Comparing the results from 1997 with previous years data (**Figure 3**) for the 3 main genera, *Cyclops*, *Daphnia* and *Eudiaptomus,* suggests that the relative abundance, absolute concentrations and seasonality of occurrence are broadly similar. However, there are some noticeable differences, particularly in relation to the 1996 data, in that *Cyclops* was found in greater densities than normal and *Daphnia*'s annual peak in numbers occurred in the autumn rather than the usual late spring/early summer.

3.2. Rotifer zooplankton

3.2.1. *Species list*

Seventeen rotifer species were found in Loch Leven during 1997 (**Table 2**). This represents a

Table 2. A list of rotifer species collected from Loch Leven during 1997.

Ploima	
Brachionidae	
	Keratella cochlearis (Gosse)
	Keratella tecta (Gosse)
	Keratella quadrata (Müller)
	Notholca squamula (Müller)
	Kellicottia longispina (Kellicott)
Colurellidae	
	Colurella adriatica Ehr.
Lecanidae	
	Lecane lunaris (Ehr.)
Trichocercidae	
	Trichocerca pusilla (Lauterborn)
	Trichocerca sp. Lamarck
Asplanchnidae	
	Asplanchna priodonta Gosse
Synchaetidae	
	Polyarthra dolichoptera Idelson
	Polyarthra major Burkhardt
	Synchaeta kitina Rousselet
Flosculariacea	
Testudinellidae	
	Pompholyx sulcata Hudson
	Filinia longiseta (Ehr.)
Conochilidae	
	Conochilus unicornis Rousselet
Collothecidae	
	Collotheca mutabilis (Hudson)

slight, but insignificant, decrease in species diversity compared to 1996. Those species that were recorded in 1996 but not in 1997 were *Brachionus angularis, Synchaeta grandis* and *Conochilus hippocrepis.* These species had only been recorded sporadically in previous years.

The most marked change within the rotifer community in 1997 was the almost complete absence of *Trichocerca pusilla*. In previous years, this species had often dominated the rotifer plankton in late summer/early autumn.

3.2.2. *Abundance*

The population dynamics of the five dominant rotifer species during 1997 are shown in

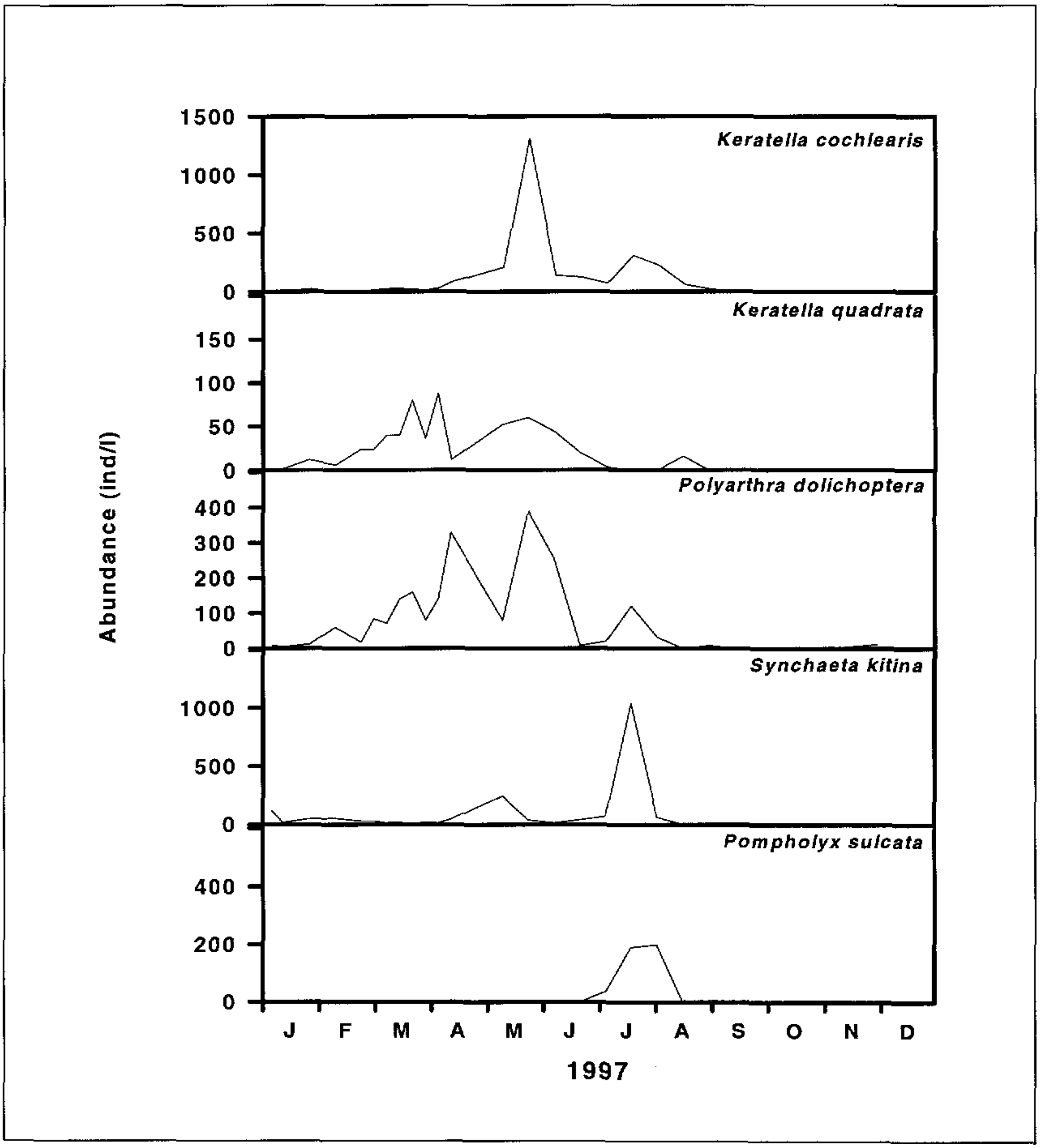

Figure 1 . Abundance of the five dominant rotifer species in Loch Leven, 1997.

Figure 1. *Keratella cochlearis* was present throughout the year, reaching a maximum population density of 1310 ind. l^{-1} in late May. This species was dominant in most of the samples collected from May to October. The next most abundant species was *Polyarthra dolichoptera*. This species also occurred throughout the year, but was most abundant during the spring (March to May) and reached a maximum abundance of almost 400 ind. l^{-1} in late May. In terms of mean annual abundance, the next most important species was *Synchaeta kitina*. Though a perennial species, *S. kitina* was recorded in much higher numbers in the summer months (July/August) than at other times of year. It reached its maximum abundance (1040 ind. l^{-1}) in late July.

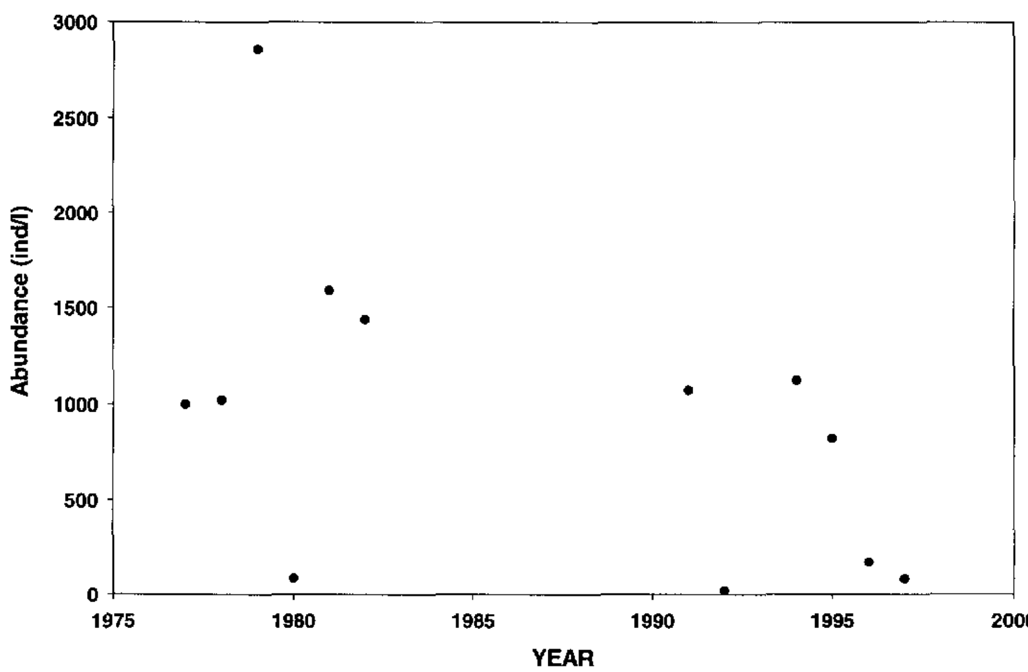

Figure 2. Annual maximum abundances of *Trichocerca pusilla* in Loch Leven, 1977-1997.

The remaining species were more seasonal in occurrence. *Keratella quadrata* tended to occur in late spring and early summer, reaching a maximum abundance of 88 ind. l^{-1} in early April. In contrast, *Pompholyx sulcata* was present only during the summer months, i.e. June to September, reaching maximum population densities of 200 ind. l^{-1} in early

August. In general, the seasonal pattern of occurrence of these species was similar to that found in previous years.

It is notable, however, that *Trichocerca pusilla* was almost completely absent from the plankton during 1997 (**Figure 2**). In the 1980s, this species had been dominant in the summer and early autumn, reaching densities of up to 2860 ind. l^{-1} in 1979. However, this species had shown a tendency towards a steady decline in abundance during the 1990s, culminating in its almost complete disappearance in 1997.

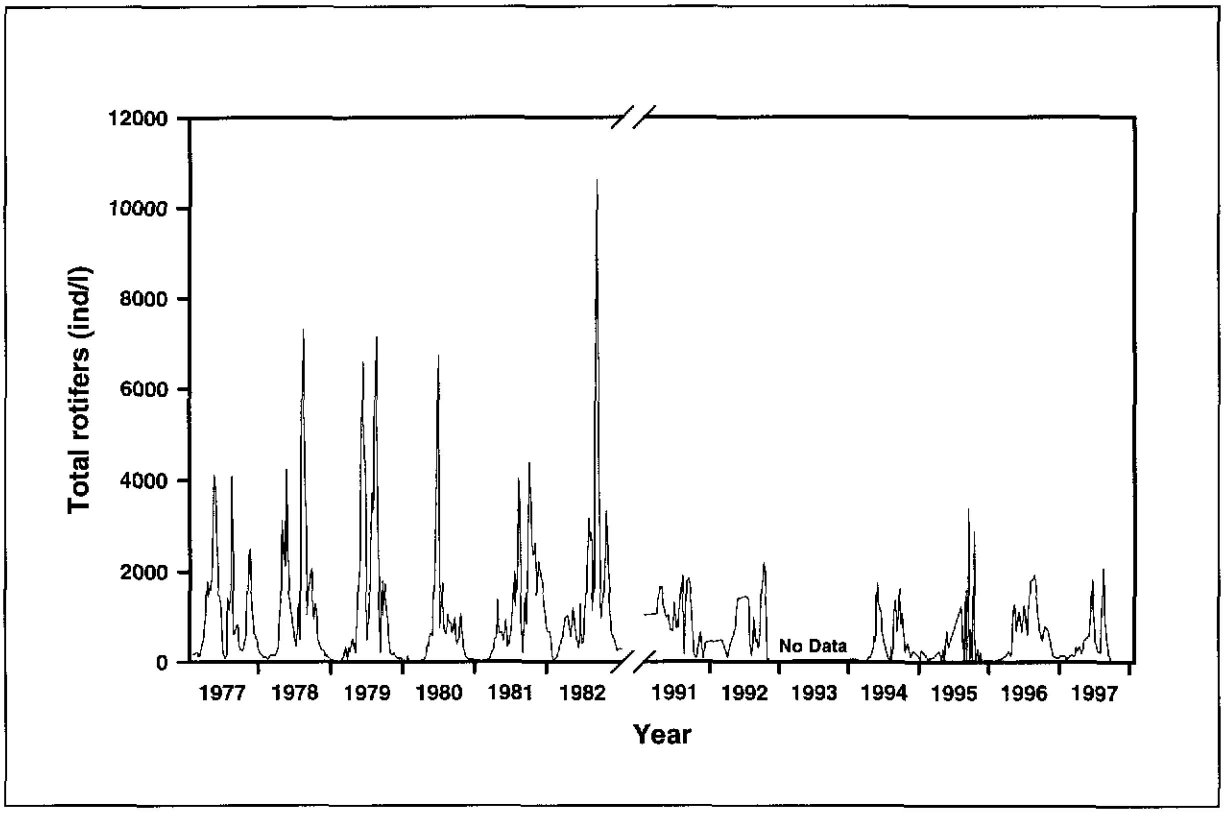

Figure 3. Long-term changes in total rotifer abundance in Loch Leven, 1977-1997.

Total rotifer abundance was, again, relatively low during 1997 compared to the period 1977-1982 (**Figure 3**). A maximum of only 2080 ind. l^{-1} was reached which contrasts markedly with the much larger annual maxima of up to 10,600 ind. l^{-1} recorded between 1977 and 1982. However, the 1997 value was similar to the lower annual maxima recorded between 1992 and 1996, which ranged between 1700 ind. l^{-1} and 3400 ind. l^{-1}. These figures probably reflect the recent reduction in P load and suggest that the loch is becoming less eutrophic.

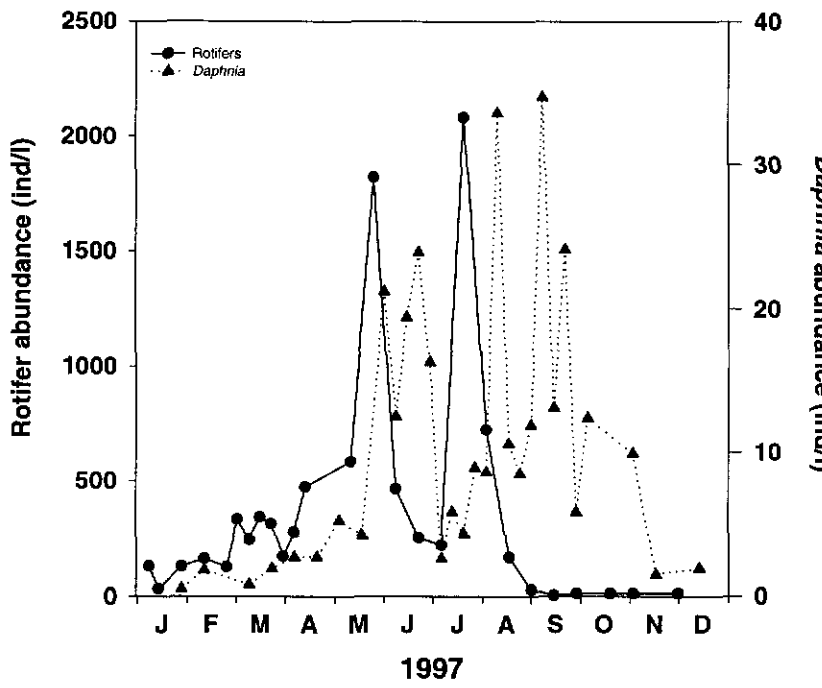

Figure 4. Abundances of *Daphnia* and total rotifer populations in Loch Leven, 1997.

As in previous years, short-term variations in total rotifer abundance appeared to be inversely related to *Daphnia* numbers (**Figure** 4). Rotifer abundances increased rapidly in early spring, reaching a maximum in late May. Numbers then declined dramatically in early June, as *Daphnia* became more abundant. Rotifer densities then remained low until the *Daphnia* population declined in late June. This was followed by a rapid increase in rotifer numbers, which reached their annual maximum (2080 ind. l^{-1}) in late July. In early August, *Daphnia* numbers increased again and appeared to suppress the development of the rotifer population for the remainder of the year.

4. DISCUSSION

Loch Leven is a shallow eutrophic loch which has been subject to recent changes in management policy aimed at reducing the risk of algal blooms and improving the local fishery. As a result, inputs of phosphorus (P) to the loch were reduced from 20.5 tonnes y^{-1} in 1985 to 10.5 tonnes y^{-1} in 1995 (Bailey-Watts and Kirika, 1997), and stocking with rainbow trout began in 1993 (Duncan, 1994). The effects of these changes on the structure and abundance of the zooplankton community are discussed below.

The ongoing programme of P-loading control is thought to have reduced algal productivity, and, thus, the amount of food available to the zooplankton. Although this seemed to have little effect on the crustacean population densities (*Cyclops*, *Daphnia* and *Eudiaptomus* in 1996 are either similar or slightly lower than were recorded between 1978 and 1982), a marked downward trend is more clearly demonstrated by the long-term changes in total rotifer abundance over the same period.

However, the crustacean zooplankton did exhibit marked changes in seasonal patterns of abundance between 1993 and 1995 (May *et al.*, 1993; Gunn *et al.*, 1994; Gunn and May 1995, 1996), in comparison with the earlier years. It seems likely that these was caused by instability within the plankton due to the changes outlined above. During 1996, the crustacean zooplankton community seems to have become more stable again, reverting back to the patterns of abundance observed prior to 1993, i.e. *Daphnia* and *Cyclops* co-dominant, with their main population peaks in late spring/early summer.

The changes in the structure and abundance of the crustacean zooplankton community in 1995, a year characterised by a weather conditions conducive to algal blooms (Bailey-Watts *et al.*, 1996), were primarily related to the availability of small 'edible' algae which *Daphnia* could readily exploit, rather than from the effects of trout predation (Gunn and May, 1996). In 1996, the pattern of phytoplankton dynamics was somewhat different in Loch Leven. A variety of larger diatoms (e.g. *Aulacoseira, Fragilaria, Synedra* spp.) dominated the phytoplankton, with moderate levels of blue-green species (*Anabaena* spp.) throughout most of the year (Bailey-Watts, *pers comm.*). In addition, a diverse background of smaller phytoplankton species were present, particularly in late July/early August - when blue-green blooms often occur (Bailey-Watts, *pers comm.*). Under these algal conditions, only moderate *Daphnia* levels would be expected, as was the case in 1996 (**Figure 7**). It also suggests that the introduction of rainbow trout from 1993 onwards has had no lasting effect on the zooplankton of the loch.

Despite the recent reductions in P load, the species composition of the zooplankton community remains characteristic of an eutrophic water body. During 1996, there was a slight increase in species diversity in both the crustacean and rotifer zooplankton communities with two species, *Cyclops vicinus* and *Conochilus hippocrepis,* recorded for the first time and one species, *Macrocyclops albidus*, re-appearing for the first time in many years. However, these 'new' species were relatively rare components of the zooplankton fauna and all of them are species which are commonly found in nutrient rich waters. As such, their appearance is unlikely to reflect a significant change in water quality within the loch.

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