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ANALYSIS OF 1996 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.

Twenty species of rotifer were found, including *Conochilus hippocrepis* which had not been recorded here before. This species seemed to 'replace' *Conochilus unicornis* in the plankton in early summer when the latter species fell victim of a parasite infection. As in previous years, the dominant rotifer species in the loch were *Keratella cochlearis*, *Polyarthra dolichoptera*, *Keratella quadrata*, *Synchaeta oblonga*, *Pompholyx sulcata* and *Trichocerca pusilla*. Most of these species continued to show a marked seasonality of occurrence. In the short term, rotifer abundance seemed to be inversely related to the abundance of *Daphnia*.

The species composition of the zooplankton remains characteristic of an eutrophic waterbody. However, in general, rotifer abundance has declined since the recent reductions in phosphorus load to the lake, probably as a result of the loch becoming less productive.

CONTENTS

1. INTRODUCTION

Bailey-Watts (1978, 1982), Bailey-Watts *et al.* (1990) and May and Jones (1989) showed that the grazing activities of zooplankton, particularly the cladoceran *Daphnia*, play an important role in determining the overall abundance and species composition of the phytoplankton in Loch Leven.

Zooplankton also provide an important food source for fish such as brown and rainbow trout (Thorpe, 1974; Duncan, 1994) and are 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 1996. The data are compared with zooplankton data from earlier years and related to changes in phytoplankton abundance. The results are discussed in relation to the recent reductions in phosphorus (P) inputs to the loch (Bailey-Watts and Kirika, 1997) and the stocking with rainbow trout which began in March 1993.

2. METHODS

2.1. Crustacean zooplankton

2.1.1. *Field sampling*

Samples of crustacean zooplankton were taken at 5 sites during 1996 (**Figure 1**). The Sluices, South Deeps and Reed Bower sites were sampled throughout the year at fortnightly intervals from January to mid-April, weekly throughout the summer months and fortnightly again from the middle of October, onwards. When bad weather conditions prevented open water samples being taken, samples were collected from an alternative site at the Public Pier. In addition to this regular sampling programme, samples were collected occasionally from the North Deeps.

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). Occasionally, these samples were collected and concentrated by a 2-m plankton net haul. 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.

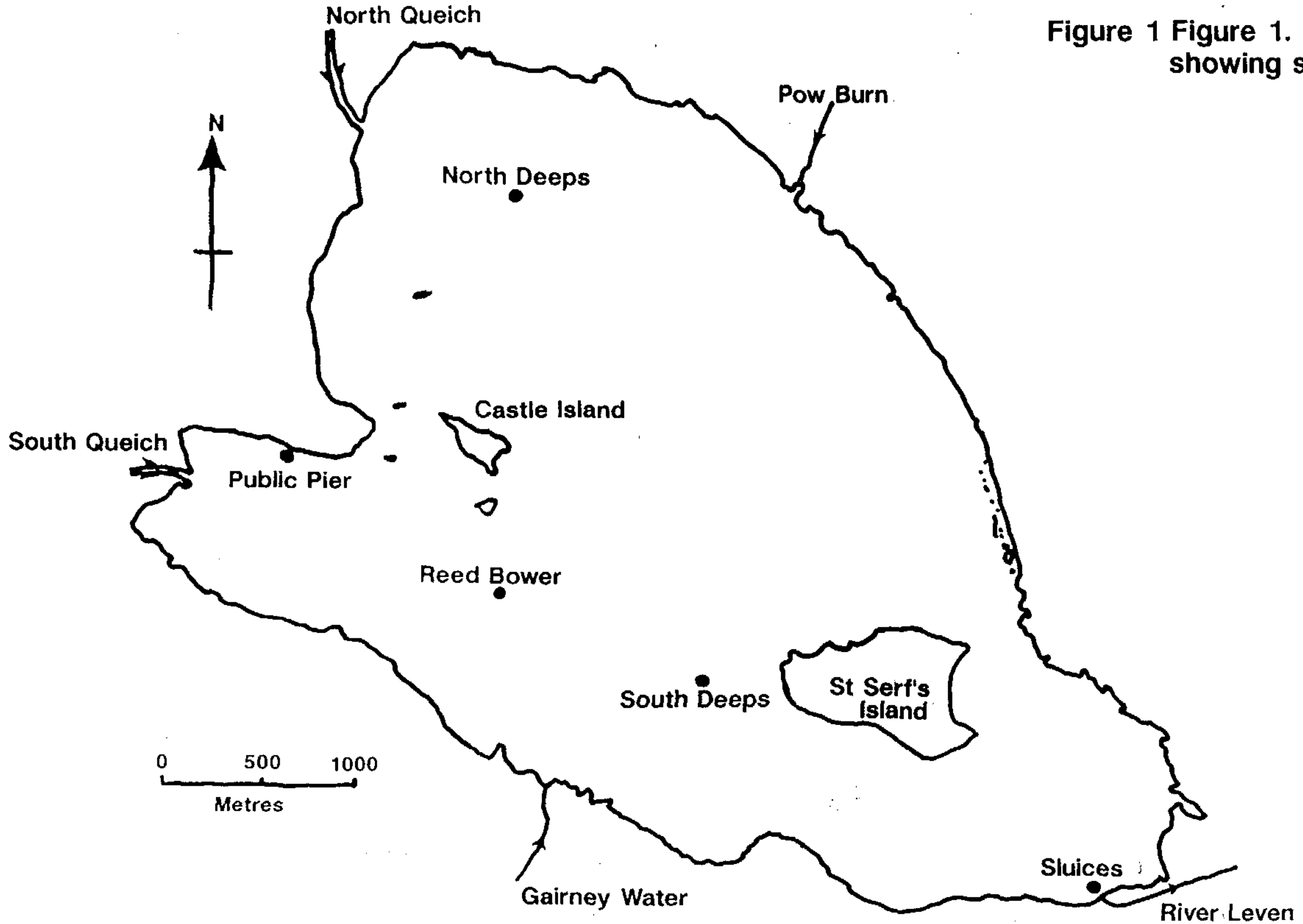

Figure 1 Figure 1. Map of Loch Leven showing sampling sites (•).

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 sedimentating 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 species of crustacean zooplankton found in Loch Leven during 1996 are shown in **Table 1**.

Table 1. Crustacean zooplankton species recorded from Loch Leven during 1996.

Branchiopoda: Anomopoda	
	Daphnia galeata Sars (formerly *D. hyalina* var *lacustris* Sars)*
	Alona quadrangularis (O. F. Müller)
	Chydorus sphaericus (O. F. Müller)
Branchiopoda: Haplopoda	
	Leptodora kindti (Focke)
Branchiopoda: Onychopoda	
	Bythotrephes longimanus Leydig
Copepoda: Calanoida	
	Eudiaptomus gracilis (Sars) (formerly *Diaptomus gracilis* Sars)
Copepoda: Cyclopoida	
	Cyclops abyssorum Sars (formerly *Cyclops strenuus abyssorum* Sars)
	Cyclops vicinus Uljanin
	Macrocyclops albidus (Jurine)
	* see below

The species composition was similar to that recorded in earlier years (*cf.* May *et al.*, 1993; Gunn *et al.*, 1994; Gunn and May, 1995: Gunn and May, 1996), apart from a number of specimens of *Cyclops vicinus* which were collected in April/May and a single *Macrocyclops albidus* found in September. Although *Macrocyclops albidus,* a benthic species typically found in of large water bodies (Fryer, 1993), has been recorded in Loch Leven before (Johnson and Walker, 1974), the occurrence of *Cyclops vicinus*, an open water species characteristic of large lowland water bodies (Fryer, 1993), has not previously been documented.

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**. As in previous years, 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 (<1 ind.l^{-1}) during the first four months of 1996. This was followed by a rapid increase in numbers during May which enabled the population to reach a maximum of 38.5 ind. l^{-1} in early June. Numbers declined to relatively low densities of less than 4 ind.l^{-1} during July and early August before increasing again to a second peak of 24 ind. l^{-1} in early October. The *Daphnia* population then declined again and remained at low overwintering levels of about 2 ind.l^{-1} for the remainder of the year.

(b) The concentrations of *Cyclops* nauplii, copepodites and adults were very low until mid-April when they began to increase, reaching a maximum of 43 ind.l^{-1} in late May. The *Cyclops* population declined rapidly after the middle of June, thereafter maintaining concentrations of less than 6 ind.l^{-1} for the remainder of the year, apart from a small

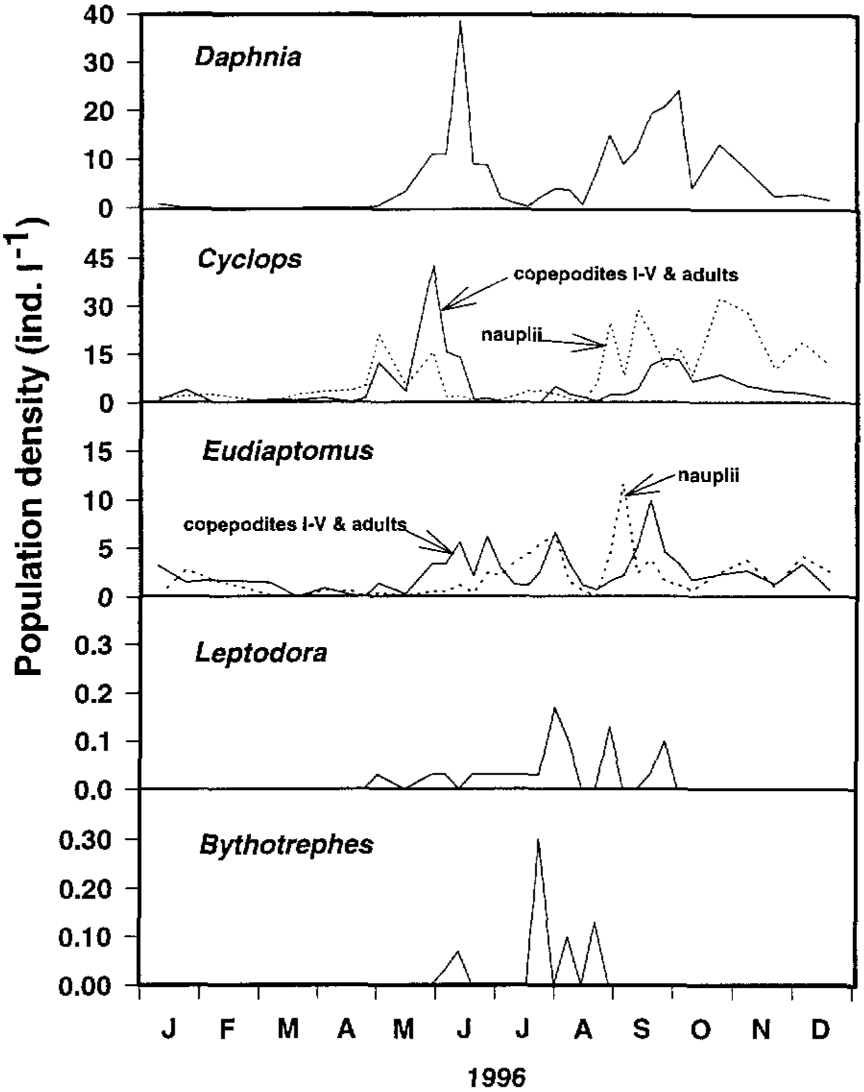

Figure 2. Mean population densities of crustacean zooplankton species in Loch Leven, 1996.

increase to 14 ind.l^{-1} in October.

(c) *Eudiaptomus* densities remained at levels of less than 6 ind.l^{-1} for most of 1996, fluctuating more noticeably during the summer months. The population reached a maximum of 10 ind.l^{-1} in mid-September, but declined to less than 3 ind. l^{1} shortly afterwards.

(d) *Leptodora* and *Bythotrephes* occurred in extremely low numbers (<0.3 ind.l^{-1}) over the summer period. While the former was found from July until late September, the latter

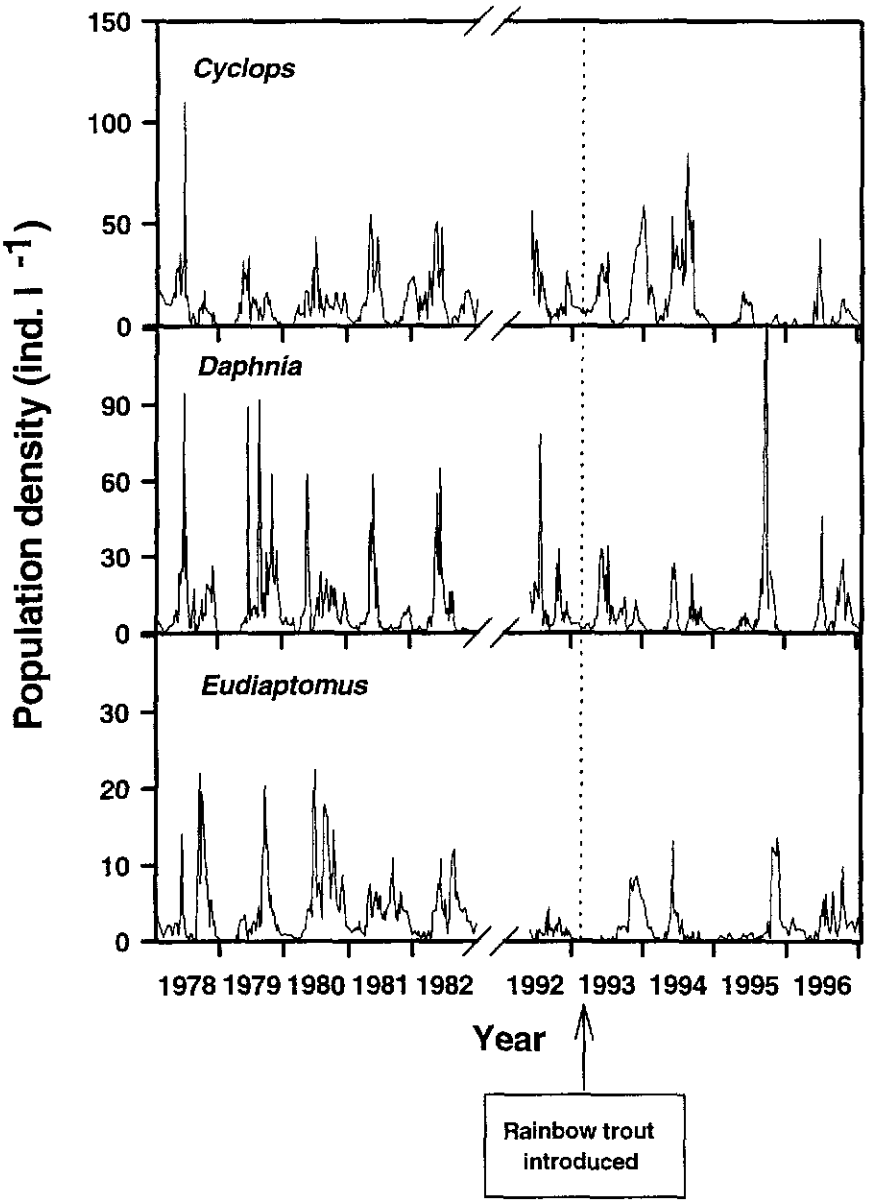

Figure 3. Long-term changes in abundance of *Cyclops*, *Daphnia* and *Eudiaptomus* in Loch Leven, 1978-1996

was recorded from June to August, only.

Figure 3 suggests that the relative abundance, absolute concentrations and seasonality of occurrence of each of the 3 main genera (*Cyclops*, *Daphnia* and *Eudiaptomus*) in 1996 are similar to those last recorded in 1992 and during the early 1980s. These years were characterised by spring or early summer maxima in both *Cyclops* and *Daphnia* numbers followed by smaller, secondary peaks in the autumn. This contrasts with the intervening years (1993-1995 inclusive) which exhibited much greater inter-annual variability.

3.2. Rotifer zooplankton

3.2.1. *Species list*

Twenty rotifer species were found in Loch Leven during 1996 (**Table 2**). This represents a

Table 2. A list of rotifers species collected from Loch Leven during 1996.

	Ploima
Brachionidae	
	Brachionus angularis Gosse
	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
	Synchaeta grandis Zacharias
	Flosculariacea
Testudinellidae	
	Pompholyx sulcata Hudson
	Filinia longiseta (Ehr.)
Conochilidae	
	Conochilus unicornis Rousselet
	Conochilus hippocrepis (Schrank)
Collothecidae	
	Collotheca mutabilis (Hudson)

slight increase in species diversity over that recorded in 1995 (i.e. 17 species). *Synchaeta oblonga* was not recorded at all in 1996, although it had been recorded occasionally in

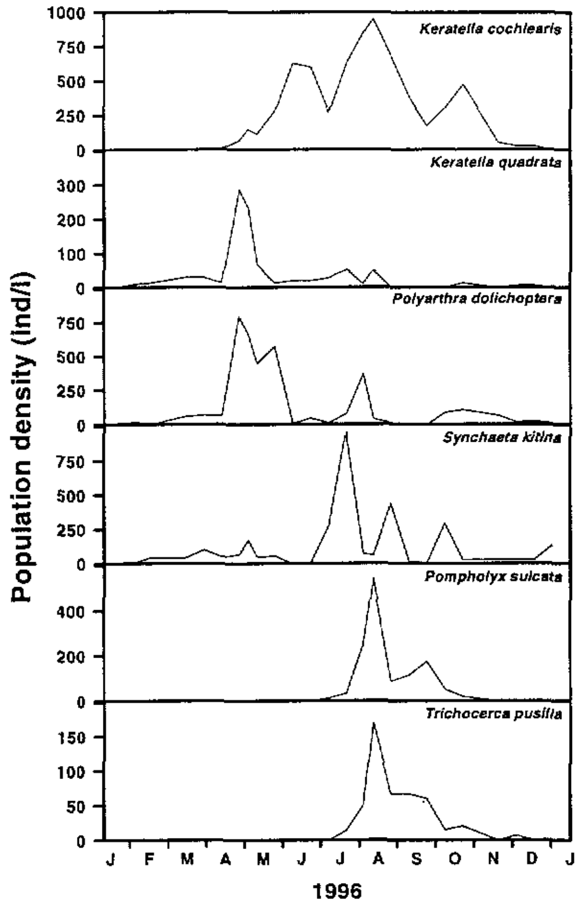

Figure 4. Abundance of the 6 dominant rotifer species in Loch Leven, 1996.

previous years. *Brachionus angularis, Kellicottia longispina* and *Colurella adriatica* were recorded in 1996, but were not observed at all in the 1995 samples. The most marked change within the rotifer community concerned the appearance of Conochilus hippocrepis for the first time, in June 1996. Previously, a closely related species, *Conochilus unicornis*, had been found in May and June of each year. However, in 1996, the *C. unicornis* population appeared, as usual, in early May, but was decimated by a parasite infection in mid May. Its disappearance from the plankton was followed by the rather sudden and unusual appearance of *C. hippocrepis* in early June.

3.2.2. *Abundance*

The population dynamics of the 6 dominant rotifer species during 1996 are shown in **Figure 4**. *Keratella cochlearis* occurred throughout the year, reaching a maximum population density of 950 ind. l^{-1} in late July. This species was dominant in most of the samples collected between May and October. The next most abundant species was *Polyarthra dolichoptera* which, again,

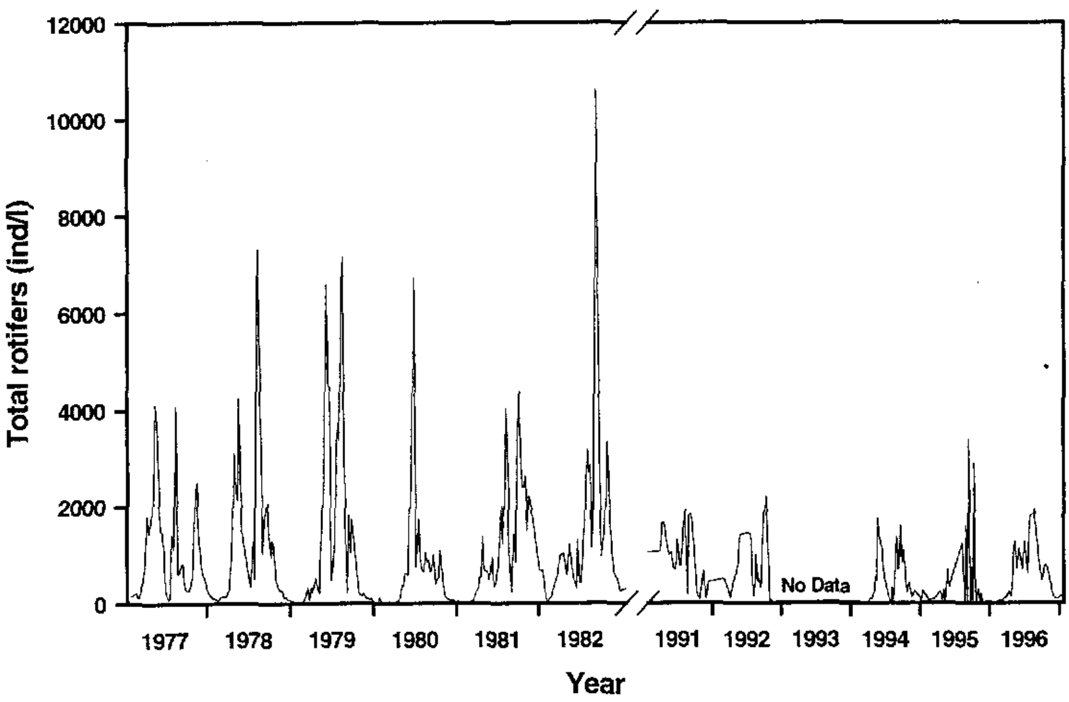

Figure 5. Long-term changes in total rotifer abundance in Loch Leven, 1977-1996.

occurred throughout the year, but was most abundant during the spring. This species reached a maximum abundance of almost 800 ind. l^{-1} in mid April. 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 than at other times of year, and reached its maximum abundance of 960 ind. l^{-1} in early July.

Of the remaining species, *Keratella quadrata* was most commonly found in late spring and early summer, reaching a maximum abundance of 290 ind. l^{-1} in mid April. In contrast, *Pompholyx sulcata* and *Trichocerca pusilla* were present only during the summer months, i.e. June to September, reaching maximum population densities of 540 ind. l^{-1} and 170 ind. l^{-1}, respectively, in late July. In general, the seasonal pattern of occurrence of these species was similar to that found in previous years.

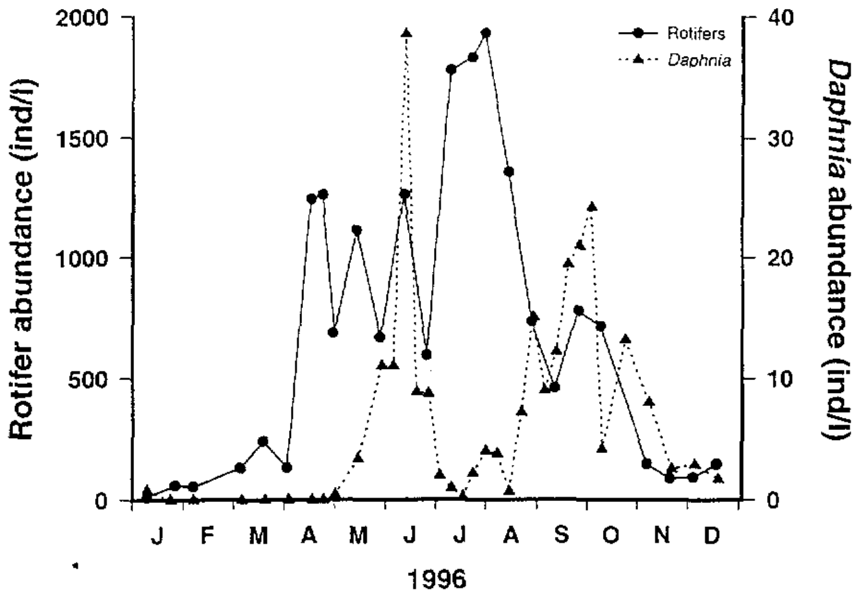

Figure 6. Total rotifer and *Daphnia* abundance in Loch Leven, 1996.

Total rotifer abundance was relatively low during 1996 in comparison with the numbers recorded between 1977-1982 (**Figure 5**), but was similar to the values recorded between 1992 and 1996. In the short-term, rotifer abundance appeared to be inversely related to the size of the *Daphnia* population (**Figure 6**). However, in the longer term, the overall reduction in rotifer abundance since 1991 seems to reflect the recent reduction in P load, suggesting that the loch is becoming less productive than it was.

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

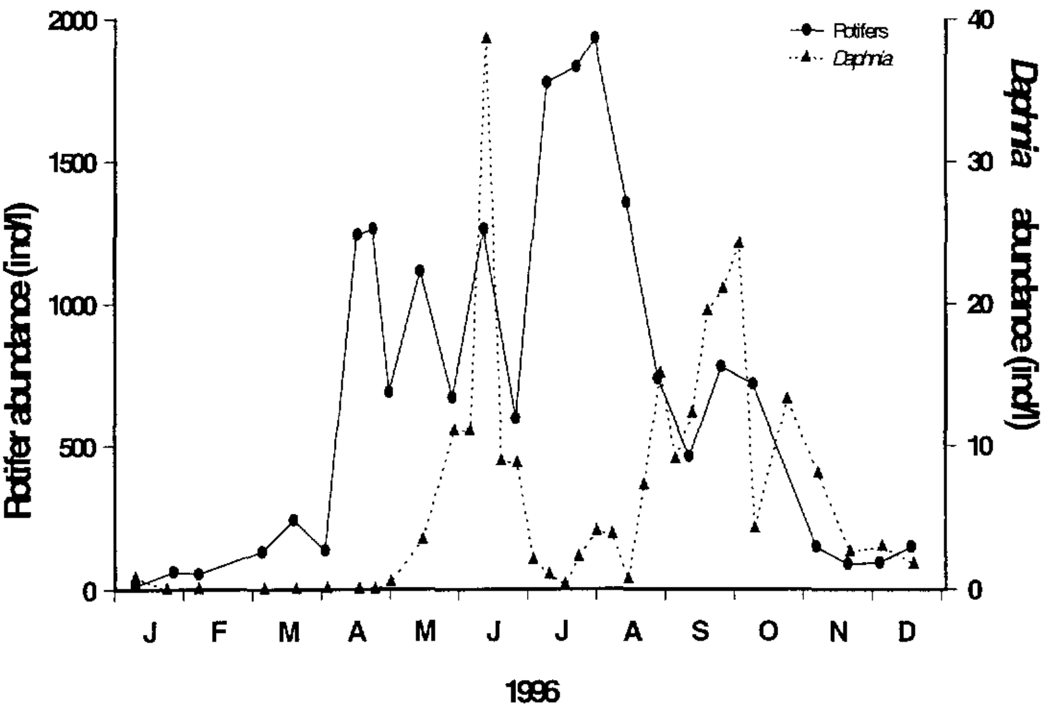

Figure 7. Chlorophyll$_a$ concentration and *Daphnia* abundance in LochLeven, 1996.

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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