EFFECT OF DROUGHT ON THE FLORA AND FAUNA OF THE LUNDY QUARTERWALL POND

by
JENNIFER GEORGE
Sabella, Gays Lane, Holyport, Maidenhead, Berks., SL6 2HL
e-mail: georgej@wmin.ac.uk

ABSTRACT

The larger pond at Quarterwall, which has been studied since 1979, is subject to periods of desiccation. Opportunity arose after it dried up in September/October 2006 to monitor the effects on its flora and fauna. Physical and chemical measurements were taken and plankton collected immediately water returned to the pond in November 2006. Macroinvertebrates were monitored one year later and in the following two years.

Results showed that the three-week dry period had little overall effect on the composition of the flora and fauna. The seven plants found mainly in the shallows of the pond were unaffected and most of the planktonic organisms reappeared shortly after the pond regained water again. Many of the macroinvertebrates were present one year later, but some e.g. corixids, took longer to return.

Keywords: *Lundy, Quarterwall Pond, drought, aquatic plants, plankton, macroinvertebrates*

INTRODUCTION

The larger pond at the Quarterwall was probably excavated in the early 1860s during the time of the Lundy Granite Company. When the pond was dredged in 1995 various pieces of metalware such as hammers used by quarry workers were found (Lovell, pers. comm.) and more recently a piece of cast metal and a hand-forged strap have been found there by Roger Fursdon (Fursdon, pers. comm.). The pond which is 19m long (north to south) and 12m wide (west to east) maintains its shape although the water level varies according to weather conditions. It is situated at a high level on the island's eastern side and consequently receives little surface drainage; there is no outlet (Plate 1).

In very dry summers the pond dries up e.g. 1933 (Gade, 1978), 1976, 1981, and 1995 when part of the pond was dredged out (Parkes, 1996). In September 2006, the pond was completely dry for a period of three weeks from 18 September to 9 October (Saunders, pers. comm.) By 16 October approximately one third of the pond contained water and there was almost complete water coverage by early November although it was still very shallow with several bottom rocks exposed (Plates 2, 3 & 4).

Microorganisms, mainly Crustacea and Rotifera, occurring in the pond were first recorded by Galliford in 1953 (Galliford, 1954), but it was not until the summer of 1979 that the flora and fauna of the pond were fully surveyed (George & Stone, 1981).

Plate 1: The larger Quarterwall Pond in April 2005 (Photo © David George)

Plate 2: The Quarterwall Pond in August 2006 showing the effects of the drought (Photo © Alan Rowland)

Plate 3: Completely dry Quarterwall Pond in September 2006 (Photo © Judith Oakley)

Plate 4: Quarterwall Pond in November 2006 four weeks after the pond dried up (Photo © Jennifer George)

Plate 5: Fish, rudd, exposed in the drying up Quarterwall Pond in September 2006 (Photo © Roger Fursdon)

A further survey occurred in the summer of 1986 (George & Sheridan, 1987) and more recent surveys have taken place in October 2003 (George *et al*., 2004), April 2005 and January 2006 which documented the more recent flora and fauna as well as seasonal changes (George, 2007). In September 2006, as the pond was drying up, Roger Fursdon rescued a large number of fish of varying sizes (approximately 100), mainly rudd, and transferred them to the Rocket Pole Pond (Plate 5).

In early November 2006, four weeks after the three-week dry period occurred, depths, temperature and pH measurements were taken and plankton samples were collected. Full surveys of the pond were undertaken one year later in November 2007 followed by further surveys in November 2008 and 2009 (Plate 6). Data from these surveys were compared with results from the October 2003 and January 2006 monitoring as it is more feasible to compare the effects of the drying–up of the pond and its recolonisation at the

Plate 6: Quarterwall Pond in November 2008 showing the common spike rush, *Eleocharis palustris*, extending well into the pond (Photo © Jennifer George)

same time of the year (autumn/early winter) as seasonal differences in the flora and fauna occur in this pond with the most striking differences being in the spring and summer, particularly in the composition of the plankton.

METHODS

Physical and chemical measurements

The following parameters were measured: air and water temperatures, pH, oxygen content (October 2003, January 2006 and November 2007 only) and depth measurements taken at intervals across the pond.

Plants

Species of plants around the edges and within the pond were listed and the size and location of the main plant species were plotted on to an outline map of the pond.

Plankton

Plankton was collected with a FBA phytoplankton net (aperture 0.075mm) and two hauls were taken from north to south across the pond. Samples were fixed in 4% formaldehyde and transferred to ethanol for microscopic examination. An estimate of relative abundance of each taxon was made on a scale of 1-5:

1 One or two only of the taxon
2 3-25 of the taxon
3 26-100 of the taxon
4 101- 500 of the taxon
5 over 500

Macroinvertebrates

Macroinvertebrates were collected from the plant beds and open water using a standard FBA net (aperture 0.96mm) by sweeping for a five minute period.

RESULTS

Physical and chemical measurements (Table 1)

Quarterwall Pond is an acidic body of water with a pH varying from 5.5 to 6.0 in the different seasons. The water temperature is closely related to the ambient air temperature and there is little temperature stratification in this shallow pond. Surveys have shown the water to be well-oxygenated and in November 2007, one year after the drought occurred, oxygen levels were again high showing that oxygen is not a limiting factor in this shallow exposed pond, Water levels vary considerably depending on weather conditions, and in October 2003, following a very dry summer and early autumn, although the pond had full coverage, the maximum depth recorded was only 0.4m. Sampling in April 2005 and January 2006 recorded maximum depths of 0.75m. Four weeks after the pond was completely dry, several of the bottom rocks were still exposed and the depth in the deepest part was just 0.2m. In the following three years autumn water levels were again recorded with maximum depths ranging from 0.7 to 0.9m.

Table 1: Physical and chemical characteristics of the Quarterwall Pond before and after the pond dried up in September/October 2006

		January 2006	November 2006	November 2007	November 2008	November 2009
Max. depth (m)	0.40	0.75	Pools max. 0.2m	0.70	0.90	0.80
Air temp. ^{O}C	14.5	5	14	12	11	12
Water temp. °C						
Surface	14	6	11	10	10	10
Bottom	13.5	6	11	10	9.5	9.5
pH	5.5	5.8	6.0	6.0	6.0	6.0
Oxygen % sat.						
Surface	102	104	-	101	-	-
Bottom	98	99	-	98	-	-

Plants

Prior to the drying up of the pond seven species of plants had been recorded in the pond **(**Table 2). The soft rush *Juncus effusus* and the common spike rush *Eleocharis palustris* occur at the margins. Small patches of water forget-me-not *Myostis scorpioides,* bog pondweed *Potamogeton polygonifolius*, water purslane *Lythrum portula*, water starwort *Callitriche stagnalis* and marsh pennywort *Hydrocotyle vulgaris* are found in the shallower water near the edges of the pond.

All of the plants were present one year after the pond dried up and two years later (2008) *Eleocharis* had increased, encroaching further into the open water on the south side (Plate 6) and the beds of *Myosotis* had extended particularly in the SW and NW areas of the pond. Three years later (2009) the beds of *Callitriche* and *Potamogeton* had increased in size.

Plankton

Table 2 shows the species of planktonic organisms that have been found in the pond at various times of the year since monitoring began in 1979. Green algae include the colonial unicellular algae *Pediastrum boryanum* and *Desmodesmus* (*Scenedesmus*) *magnus*, the desmid *Closterium* and *Ulothrix*, a filamentous green alga.

The Cladocera (water fleas) are represented by *Daphnis obtusa*, *Bosmina longirostris* and *Chydorus sphaericus* which occur in the other larger Lundy water bodies. The cyclopid copepod, *Cyclops* (possibly, *C. vernalis*) and its juvenile forms, are abundant at all seasons of the year and the harpacticoid copepod, *Canthocamptus* sp., is also present. It is interesting that the other free-living group of copepods, the calanoids, e.g. *Diaptomus* sp. which is common in ponds on the mainland, appears to be absent from the Lundy freshwaters.

The Rotifera are represented by seven species with *Keratella vulga* and *Brachionus rubens* being particularly abundant in winter and spring. *Brachionus rubens* often occurs with *Daphnia obtusa* on which it is epizooic or commensal.

Chironomid (midge) larvae are common in the plankton at all times of the year, but the larva of the phantom midge, *Chaoborus crystallinus,* with its characteristic air sacs, appears usually in late summer/early autumn.

Table 2: Flora and fauna found in the Quarterwall Pond since 1979

FLORA

Hydrocotyle vulgaris Linnaeus
Marsh pennywort
Callitriche stagnalis Scopoli
Mud water starwort
Potamogeton polygonifolius Pourret
Bog pondweed
Myosotis scorpioides Linnaeus.
Creeping water forget-me-not
Lythrum portula Linnaeus.
Water purslane
Juncus effusus Linnaeus.
Soft rush
Eleocharis palustris Linnaeus.
Common spike-rush

PLANKTON

Chlorophyta (green algae)
Pediastrum boryanum (Turpin)
Desmodesmus (Scenedesmus) magnus Chodat
Closterium sp.
Ulothrix sp.

Crustacea: Cladocera (water fleas)
Daphnia obtusa Kurz
Bosmina longirostris (O.F. Müller)
Chydorus sphaericus (O.F. Müller)

Crustacea: Copepoda (copepods)
Cyclops sp. poss. *vernalis* (Fischer)
Immature cyclopids and nauplii
Canthocamptus sp, (Harpacticoid)

Crustacea:Ostracoda (ostracods)
Cypridid ostracod

Rotifera (rotifers)
Brachionus calyciflorus Pallas
Brachionus rubens Ehrenberg.
Keratella quadrata (O.F. Müller)
Keratella serrulata (Ehrenberg)
Keratella vulga (Ehrenberg)
Filinia longiseta (Ehrenberg)
Polyarthra minor Voigt

Insecta
Chaoborus crystallinus (Degeer) larva
Chironominae & *Corynoneura* larva

MACROINVERTEBRATES

Platyhelminthes (flatworms)
Polycelis nigra (O.F. Müller)

Oligochaeta (round worms)
Lumbriculus variegatus (O.F. Müller)

Hirudinea (leeches)
Helobdella stagnalis (Linnaeus)
Glossiphonia complanata (Linnaeus)
Haemopis sanguisuga (Linnaeus)
Theromyzon tessulatun (O.F. Müller)

Crustacea
Asellus meridianus Racovitza

Insecta: Ephemeroptera (may flies)
Cloëon dipterum (Linnaeus) larva

Insecta:Odonata (dragon/damsel flies)
Ischnura elegans (van der Linden) larva

Insects: Hemiptera (water bugs)
Notonecta marmorea viridis Delcourt
Immature notonectids
Corixa punctata (Illiger)
Callicorixa praeusta (Fieber)
Sigara dorsalis (Leach)
Immature corixids/sigarids

Insecta: Trichoptera (caddis flies)
Limnephilus vittatus (Fabricius) larva

Insecta:Coleoptera (water beetles)
Ilybius quadriguttatus Linnaeus adult
Dytiscid Colymbetinae larva
Noterus clavicornis (Degeer) adult

Insecta:Diptera (flies)
Chironomid larva and pupa
Chaoborus crystallinus (Degeer) larva
Eristalis sp. larva
Limnophora sp. larva

Mollusca:Bivalvia
Pisidium subtruncatum Malm

Table 3 shows the species and abundance of organisms occurring in the autumn 2003 and early winter 2006 before the drying-up of the pond in September/October 2006. Data are also shown for species and numbers four weeks after the dry period and in the following Novembers of 2007, 2008 and 2009. Members of the three major groups, Cladocera, Copepoda and Rotifera, returned quickly, with all species being present four weeks after water returned to the pond. Figure 1 shows that rotifers had the largest population in January 2006 with smaller numbers of cladocerans and copepods. The large rotifer population was due mainly to the high numbers of *Brachionus rubens* which dominated at this time. In November 2006, four weeks after the dry period, rotifers and cladocerans formed the greater part of the plankton population. In the following three years, 2007, 2008, 2009, cladocerans were the dominant organisms. This was mainly due to the very large numbers of *Daphnia obtusa* present in the samples.

Table 3: Planktonic organisms in the Quarterwall pond in autumn/early winter before the pond dried up in Sept./Oct. 2006 and when water returned in November 2006 and in the following Novembers of 2007, 2008 and 2009. Key: 1=less than 5 organisms; 2=5-25; 3=26-100; 4=101-500; 5= over 500; 5*=over 1000

Species	15 Oct 2003	23 Jan. 2006	6 Nov. 2006	6 Nov. 2007	4 Nov. 2008	10 Nov. 2009
Chlorophyta (algae)						
Pediastrum boryanum	2	2	-	2	-	1
Desmodesmus magnus.	2	-	2	-	2	2
Ulothrix sp.	2	-	-	2	2	2
Annelida: Oligochaeta						
Nais sp.	1	-	2	2	-	1
Crustacea: Cladocera						
Daphnia obtusa	3	3	4	5*	4	5*
Bosmina longirostris	2	2	3	2	2	3
Chydorus sphaericus	2	1	1	2	2	4
Crustacea: Copepoda						
Cyclops poss. *vernalis*	4	4	2	3	4	4
Cyclopid juveniles	3	3	2	3	3	3
Cyclopid nauplii	3	3	3	2	2	2
Canthocamptus sp.	3	3	2	2	2	2
Harpacticoid juveniles	2	1	1	2	2	2
Rotifera						
Brachionus rubens	2	5	3	2	2	2
Brachionus angularis	2	2	2	2	2	2
Keratella vulga	3	2	4	2	3	3
Keratella serrulata	2	1	2	2	2	2
Filinia longiseta	2	2	-	1	2	1
Insecta: Diptera						
Corynoneura sp. larva	-	-	-	-	-	2
Chironominae larvae	2	2	1	2	3	2
Chaoborus crystallinus larva	3	-	-	-	-	-

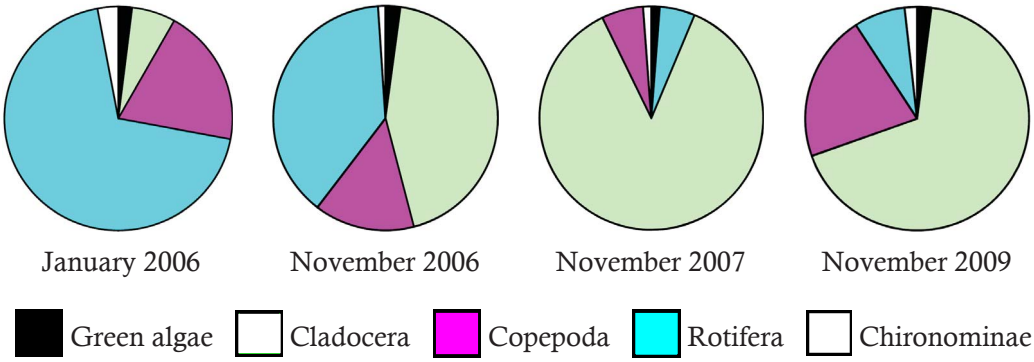

Figure 1: Composition of the main planktonic taxa in the pond in January 2006 prior to the three week dry period in September/October 2006, and in November 2006 immediately after the dry period and in two of the following years, 2007 and 2009

Macroinvertebrates

The pond has a fairly good diversity of macroinvertebrates with insect adults and larvae dominating in most seasons. Water boatmen (Hemiptera) are the most dominant group with four species occurring.

Table 2 shows the species of macroinvertebrates that have been found in the pond since 1979. The four species of leech that occur include the large horse leech *Haemopis sanguisuga* that occurs elsewhere in water bodies on the island. It is not an ectoparasite on horses as it is a macrophagous carnivore feeding on other invertebrates which it swallows whole and it also feeds on dead fish. This leech with its distinctive colouring has been the subject of DNA testing as it was first thought to be a different species. However the results showed that it is *Haemopis sanguisuga* with a different colouring to those on the mainland. The isopod *Asellus meridianus* which is present in all the other ponds on the island can be found at all seasons of the year in the Quarterwall pond.

Table 4 shows the composition of the macroinvertebrate fauna before and after the pond dried up. Although the diversity in January 2006 was similar to that in the October of 2003, fewer numbers of organisms were found, which was due to the much lower water temperatures at this time. One year after the pond was dry, most of the macroinvertebrates that were in the pond before the drought were present, except for the corixids. The smaller water boatmen, *Corixa punctata,* and a few immature forms were present in November 2008 and *Corixa punctata*, *Sigara dorsalis* and immature forms in November 2009, but they did not occur in such large numbers as were in the pond before the drought period. An interesting newcomer, one year after the pond dried up, was the black flatworm*, Polycelis nigra* which was present in the pond in large numbers.

DISCUSSION

Aquatic plants

All of the plants survived the three-week dry period, and several plant beds have increased in size over the last three years e.g. *Eleocharis*, *Potamogeton*, *Myosotis* and *Callitriche.*

Table 4: Macroinvertebrates in the Quarterwall Pond in autumn/early winter before and in autumn after the pond dried up in Sept/Oct. 2006. Numbers of individuals relate to the 5 minute net sweep

	15 Oct. 2003	23 Jan. 2006	6 Nov. 2007	4 Nov. 2008	10 Nov. 2009
Platyhelminthes					
Polycelis nigra	-	-	120	200	51
Oligochaeta					
Lumbriculus variegatus	6	3	3	10	5
Pristina sp. (Naididae) Family	-	-	-	- 4	2
Naididae	4	-	3		3
Hirudinea					
Helobdella stagnalis	7	3	2	6	5
Glossiphonia complanata	-	1	-	-	-
Theromyzon tessulatum	-	-	-	-	5
Crustacea					
Asellus meridianus	54	13	20	50	18
Insecta: Ephemeroptera					
Cloëon dipterum	3	1	2	3	4
Insecta: Odonata					
Ischnura elegans	10	2	3	4	3
Insecta: Hemiptera					
Notonecta marmorea viridis	6	2	8	4	9
Corixa punctata	10	3	-	1	2
Sigara dorsalis	19	3	-	-	1
Immature corixids/sigarids	10		-	3	9
Insecta: Trichoptera					
Holocentropus stagnalis	-	-	-	-	4
Limnephilus vittatus	-	2	-	-	-
Insecta: Coleoptera					
Ilybius quadriguttatus Dytiscid	-	-	-	1	-
Colymbetinae larva	4	-	-	3	1
Noterus clavicornus	-	-	6	-	-
Insecta: Diptera					
Chironomid larvae	15	6	6	20	15
Eristalis sp. larva	-	-	-	2	-
TOTAL TAXA	11	11	10	13	13
TOTAL NUMBERS	148	51	173	311	130

Plankton

The green alga *Desmodesmus (Scenedesmus)* reappeared in the pond three weeks after water returned. Many algae can produce special kinds of cells that can resist unfavourable conditions for a long time. Such resting spores, like seeds, will germinate when favourable conditions return which can be months or years later according to Canter-Lund & Lund, 1998.

Three of the zooplankton groups reappeared quickly - Cladocera, Rotifera and Copepoda. In the life cycle of Cladocera and Rotifera three types of eggs are produced; in good conditions they reproduce parthenogenetically and asexual eggs develop into females and this leads to the build up of large populations which are seen in the spring and summer. When environmental conditions deteriorate some of the eggs develop into males. Females then produce special eggs

requiring fertilisation. Fertilised eggs are usually darker and more opaque than the 'summer' eggs and they do not develop directly. They are referred to as 'resting' or 'winter' eggs. They can withstand drying or freezing and develop when suitable conditions return into parthenogenetic females. Resting eggs in the Cladocera are situated in the female's brood pouch whose wall thicken and darken. When the animal moults the brood pouch separates and closes over the eggs forming a protective covering called the 'ephippium'. In Rotifera the 'resting' eggs acquire a thick often spiny shell with a store of food, often oil droplets. Resting eggs from both groups can remain dormant for months and even years.

It is not thought that copepods produce resting eggs, but they can form cysts in unfavourable conditions. *Cyclops* appears resistant to desiccation and usually encysts in the juvenile copepodid stages rather than as the adult (Pennak, 1953). Both the cyclopids and harpacticoids were present four weeks after water reappeared in the pond.

One of the reasons for the fairly small numbers of cladocerans and rotifers in the autumn of 2003 was the presence of large numbers of the dipteran larva *Chaoborus crystallinus* (Phantom Midge) which is an active predator on both groups. This larva uses a large prehensile antenna to catch its prey and the small fast-moving copepods are probably more difficult to catch. *Chaoborus* was not found in the November of the years following the drying up of the pond. The composition of the plankton community changes very quickly in a small pond throughout the year and monthly samples are required to fully understand these changes.

The same species of planktonic Cladocera, Rotifera and Copepoda were found in the pond in 2003, 2006, 2007, 2008 and 2009. They seem to be long-standing members of the Lundy plankton fauna as Galliford recorded them in 1953, over fifty eight years ago, and are obviously well-adapted to survive drought conditions (Galliford, 1954).

Chironomid larvae (midge) were found in the plankton before and after the drying up of the pond. Eggs are often laid by the adult midges in water plants and these could have survived in the damp plant stems on the exposed mud.

Macroinvertebrates

Corixids and notonectids (Water boatmen) were abundant in the pond before it dried up in September/October 2006. Both are fairly strong fliers and could move to other water bodies when the pond was drying up. The greater water boatman *Notonecta marmorea viridis* was present in the pond one year after the drying up of the pond and in the following two years. However the two species of smaller water boatmen, *Corixa punctaa* and *Sigara dorsalis,* that occurred in the autumn/early winter before the pond dried up were not found in autumn 2007 and only occurred in very small numbers in 2008 and 2009. Both *Corixa punctata* and *Sigara dorsalia* and immature forms were found in Pondsbury in November 2007 and also in the small pond near the Quarters.

The ubiquitous water slater *Asellus meridianus* that is found in many of Lundy's freshwater bodies can burrow into moist sediments during times of drought and survive for several weeks (Pennak, 1953). It has been found that the closely related species *Asellus aquaticus* can survive in water-saturated air for a considerable period and moves into the substratum to avoid desiccation (Moth Iversen *et al.*, 1978). *Asellus meridianus* probably remained in the damp roots of plants such as *Myosotis* that was present in several parts of the pond. This species that commonly occurs on offshore islands rather

than the common mainland species *Asellus aquaticus* (Williams, 1979) has two generations per year. Fertilisation is internal with mating occurring in the spring and autumn and it is the autumn cohort that was likely to have been affected by the pond drying up in September/October 2006. However one year later, reasonable numbers of *Asellus* were found and they obviously survived the three weeks of the 'dry' pond.

Some leeches can also withstand dry conditions by burrowing into damp sediments, often forming mucus cocoons e.g. *Helobdella stagnalis* (Elliott & Mann, 1979) and this leech was found one year after the drought in reasonable numbers. The large horse leech *Haemopis sanguisuga* was seen in a pool in the main track by the Quarterwall Pond in May 2008 (Lundy Log Book) and swimming in the pond in the summer of 2009 (Rowland, pers. comm.) *Haemopis* often leaves the water to forage for food and can often be seen in temporary pools on the island.

Aquatic beetles (Coleoptera) are usually strong fliers and it is common for them to move from pond to pond on the island. It is interesting that the small black beetle *Noterus clavicornis* that was found in the Quarterwall pond one year after the pond dried up also occurred at the same time in Pondsbury and in the pond near the Quarters.

The mayfly larva *Cloeon dipterum* which occurred in the pond before it dried up was again found in the following year 2007 and in 2008 and 2009. This species has a wide range of life cycles but always has a slow growing winter larval generation followed by one or more rapidly growing summer generations so that adults can be found from May to October (Nagell, 1980, 1981). This species in Europe is known to be oviviparous (Degrange, 1959). The female rests for 10-14 days after copulation and then lays her eggs on the water surface, where they hatch immediately and the larvae swim away. September/October 2006 was a warm period and adult mayflies could still be flying and mating with the females laying their eggs as soon as the water returned in the pond.

A damselfly larva occurs in the Quarterwall Pond, *Ischnura elegans.* Adults lay their eggs in the stems of water plants and the warm late summer and autumn of 2006 probably allowed adults still to be flying and mating at that time. (It is interesting to note that two species of the related adult dragonflies were recorded in the 2006 Lundy Logbook as late as 18/19 October in that year). Eggs would have survived in the damp tissues of the water plants and then develop into larvae when sufficient water was available.

It is interesting that the black flatworm *Polycelis nigra* was present in the pond in large numbers the year after the drought occurred and in the years following. It was not recorded in the earlier surveys of this pond. This species is very abundant in Pondsbury and was found also in the nearby smaller pond at Quarterwall in April 2005. Ponies drink from Pondsbury as well as the Quarterwall ponds and these flatworms could easily have been transferred by them on their legs into the larger Quarterwall pond.

CONCLUSION

The three-week dry period of the pond appeared to have had little effect overall on its flora and fauna. The aquatic plants which were situated in the shallow water areas were unaffected. Many of the planktonic organisms which can withstand drought conditions were present within four weeks of the water reappearing in the pond. Most of the macroinvertebrates were present one year later, but the smaller water boatmen (corixids) took longer to return.

ACKNOWLEDGEMENTS

The author would like to thank David George and Barry Mapstone for collecting the plankton samples in November 2006 and David George and John Hedger for collecting plankton samples and taking depth measurements in January 2006, November 2007, 2008 and 2009. David John identified the species of the algae *Desmodesmus* and *Pediastrum* (Reference, John *et al.*, 2011). Alan Rowland ably assisted with the five-minute sweep samples and sorting of macroinvertebrates in November 2008 and 2009. Information from Nicola Saunders and Roger Fursdon on the drying-up of the pond in September 2006 was much appreciated.

REFERENCES

Canter-Lund, H. & Lund, J.W.G., 1998. *Freshwater Algae Their microscopic world explored*. Bristol: Biopress Ltd.

Degrange, C. 1959. L'ovolarviparitié de *Cloëon dipterum* (L.) (Ephemeroptera: Baetidae) *Bulletin de la Société entomologique de France*, 64, 94-100.

Elliott, J.M. & Mann, K.H. 1979. *A key to the British freshwater leeches*. Freshwater Biological Association Scientific Publication no. 40. Cumbria: FBA.

Gade, F.W. 1978. *My Life on Lundy*. Privately printed.

Galliford, A.L. 1954. Notes on the freshwater organisms of Lundy with especial reference to the Crustacea and Rotifera. *Annual Report of the Lundy Field Society 1953*, 7, 29-35.

George, J. 2007. Lundy's lentic waters:their biology and ecology. In J. George (ed). *Lundy Studies: Proceedings of the 60th Anniversary Symposium of the Lundy Field Society 2006*, 103-128. Bideford :The Lundy Field Society.

George, J.J., McHardy (Stone) B.M. & George, J.D. 2004. Further investigations of the flora and fauna of the Lundy lentic freshwaters. *Annual Report of the Lundy Field Society 2003,* 53, 110-130.

George, J.J. & Sheridan, S.P. 1987. Further investigations of the Lundy freshwater habitats. *Annual Report of the Lundy Field Society 1986 ,* 37, 35-46.

George, J.J. & Stone, B.M. 1981. A comparative investigation of the flora and fauna of the Lundy ponds. *Annual Report of the Lundy Field Society* 1980, 31, 19-34.

John, D.M., Whitton, B.A. & Brook, A.J.(eds). 2011. *The Freshwater Algal Flora of the British Isles*. 2nd edition. Cambridge: Cambridge University Press.

Nagell, B.H. 1980. Overwintering strategy of *Cloëon dipterum* L. larvae. *Advances in Ephemeroptera Biology* (eds. J.F. Flanagan & K.E. Marshall), 259-64. New York: Plenum Press.

Moth Iversen,T., Wiberg-Larsen, P., Birkholm Hansen, S. & Hansen, F.S. 1978. The effect of partial and total drought on the macroinvertebrate communities of three small Danish streams. *Hydrobiologia*, 60(3), 235-242.

Nagell, B.H. 1981. Overwintering strategy of two closely related forms of *Cloëon* (*dipterum*?) (Ephemeroptera) from Sweden and England. *Freshwater Biology*,11, 237-44.

Parkes, E. 1996. Warden's Report for 1995. *Annual Report of the Lundy Field Society 1995*, 46, 6-7.

Pennak, R.W. 1953. *Freshwater Invertebrates of the United* States. New York: The Ronald Press Company.

Williams, W.D. 1979. The distribution of *Asellus aquaticus* and *A. meridianus*. (Crustacea: Isopoda) in Britain. *Freshwater Biology*, 9, 491-501.